



# **Agilent EasyEXPERT**

## **Application Library Reference**



**Agilent Technologies**

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## In This Document

Agilent EasyEXPERT software contains the application library which supports the characteristic measurements of CMOS devices, TFT, BJT, diode, resistor, capacitor, varactor, memory, nanotechnology devices such as CNT FET, and so on. The application library includes more than one hundred test definitions. And they are classified into the following categories.

This document consists of the chapters corresponding to the categories. And each chapter lists and describes all test definitions belonging to the category.

1. BJT
2. CMOS
3. Discrete
4. Generic Test
5. Memory
6. Mixed Signal
7. Nano Tech
8. Power Device
9. Reliability
10. Structure
11. TFT
12. Utility

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### NOTE

#### Application Library

The application library is a set of test definitions effective for the EasyEXPERT application test execution mode. The application test can be performed by selecting a test definition and setting the test condition for the actual DUT (device under test). And the setup can be saved as the dedicated test setup for the DUT.

All test definitions are just sample. If the samples damage your devices, Agilent Technologies is NOT LIABLE for the damage.

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## What is described in the reference sections

Reference section contains detailed description of test definitions. The test definitions are listed in alphabetical order. Each entry explains one test definition and provides the information following to the next terms. Some sections may not follow to some terms and may follow to the terms not in this table.

| Term                                | Description  |
|-------------------------------------|--|
| Description                         | Brief explanation of the test definition.  |
| Device Under Test                   | DUT name. The number of terminals, the connection information, and the other information may be included.  |
| Required Modules and Accessories    | Lists the required accessories, modules, and/or equipment. The connection information may be included.   |
| Required Test Definition            | Lists the test definitions if they are used in this test definition.   |
| Device Parameters                   | Lists the parameters changeable in the Device Parameters area of the EasyEXPERT Application Test screen.   |
| Test Parameters                     | Lists the parameters changeable in the Test Parameters area of the EasyEXPERT Application Test screen.   |
| Extended Test Parameters            | Lists the parameters changeable in the dialog box opened by clicking the Extended Setup button.  |
| Measurement Parameters              | Lists the parameters measured by this test definition.   |
| User Function and Analysis Function | Lists the parameters used for the user function or the analysis function.  |
| X-Y Plot or X-Y Graph               | Lists the parameters to be displayed in the X-Y Graph Plot area, List Display area, or Parameters area on the Data Display window.   |
| List Display                        |  |
| Parameters Display Area             |  |
| Auto Analysis                       | Lists the parameters used for the auto analysis function.  |
| Test Output: X-Y Graph              | Lists the parameters defined in the Test Output tab screen of the Test Definition window. The parameters will be displayed in the X-Y Graph Plot area, List Display area, or Parameters area on the Data Display window. |
| Test Output: List Display           |  |
| Test Output: Parameters             |  |

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## Revision number

The test definitions are managed by using the revision number shown below.

| Revision Number | Description   |
|-----------------|---|
| A.01.xx         | Test definitions supported by EasyEXPERT A.01.xx and later.                         |
| A.01.20         | Test definitions updated from A.01.xx or supported by EasyEXPERT A.02.00 and later. |
| A.02.00         | This number is used by the Subsite move test definition only.                       |
| A.03.00         | Test definitions supported by EasyEXPERT A.03.00 and later.                         |
| A.03.10         | Test definitions supported by EasyEXPERT A.03.10 and later.                         |

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## Supported Analyzer and Required Equipment

Each test definition (Library) supports the following analyzer, and requires the following accessories, modules, and/or equipment.

| Category | Library                  | Supported analyzer     | Required equipment and quantity |
|----------|--------------------------|------------------------|---------------------------------|
| BJT      | BC Diode Fwd             | B1500A,4155B/C,4156B/C | SMU 2                           |
|          | BC Diode Rev             | B1500A,4155B/C,4156B/C | SMU 2                           |
|          | BVcbo                    | B1500A,4155B/C,4156B/C | SMU 2                           |
|          | BVcei                    | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | BVceo                    | B1500A,4155B/C,4156B/C | SMU 2                           |
|          | BVebo                    | B1500A,4155B/C,4156B/C | SMU 2                           |
|          | CS Diode Fwd             | B1500A,4155B/C,4156B/C | SMU 2                           |
|          | CS Diode Rev             | B1500A,4155B/C,4156B/C | SMU 2                           |
|          | Ctc-Freq Log             | B1500A                 | MFCMU 1                         |
|          | Ctc-Vc                   | B1500A                 | MFCMU 1                         |
|          | Cte-Ve                   | B1500A                 | MFCMU 1                         |
|          | Cts                      | B1500A                 | MFCMU 1                         |
|          | EB Diode Fwd             | B1500A,4155B/C,4156B/C | SMU 2                           |
|          | EB Diode Rev             | B1500A,4155B/C,4156B/C | SMU 2                           |
|          | G-Plot ConstVce Pulse    | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | G-Plot ConstVce Pulse[3] | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | G-Plot ConstVce          | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | G-Plot ConstVce[3]       | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | G-Plot Vbc=0V Pulse      | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | G-Plot Vbc=0V Pulse[3]   | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | G-Plot Vbc=0V            | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | G-Plot Vbc=0V[3]         | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | hfe-Vbe ConstVce         | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | hfe-Vbe Vbc=0V           | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | Ic-Vc Ib                 | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | Ic-Vc Ib[3]              | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | Ic-Vc Pulse Ib           | B1500A,4155B/C,4156B/C | SMU 4                           |

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| Category | Library            | Supported analyzer     | Required equipment and quantity |
|----------|--------------------|------------------------|---------------------------------|
| BJT      | Ic-Vc Pulse Ib[3]  | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | Ic-Vc Pulse Vb     | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | Ic-Vc Pulse Vb[3]  | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | Ic-Vc Vb           | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | Ic-Vc Vb[3]        | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | Rb                 | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | Re+Rc              | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | Re                 | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | Simple Gummel Plot | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | Vbe-Le             | B1500A                 | SMU 4, B2200A/B2201A 1          |
|          | Vbe-We             | B1500A                 | SMU 4, B2200A/B2201A 1          |
| CMOS     | BVdss              | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | BVgso              | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | Cgb-AC Level       | B1500A                 | MFCMU 1, SMU 1                  |
|          | Cgb-Freq Log       | B1500A                 | MFCMU 1, SMU 1                  |
|          | Cgb-Vg HighVoltage | B1500A                 | MFCMU 1, SMU 3, SCUU 1, GSWU 1  |
|          | Cgb-Vg             | B1500A                 | MFCMU 1, SMU 1                  |
|          | Cgc-Freq Log       | B1500A                 | MFCMU 1, SMU 1                  |
|          | Cgc-Vg             | B1500A                 | MFCMU 1, SMU 1                  |
|          | Cgg-Freq Linear    | B1500A                 | MFCMU 1                         |
|          | Cgg-Freq Log       | B1500A                 | MFCMU 1                         |
|          | Cgg-Vg 2Freq       | B1500A                 | MFCMU 1                         |
|          | Cgg-Vg             | B1500A                 | MFCMU 1                         |
|          | IdRdsGds           | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | Id-Vd pulse        | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | Id-Vd pulse[3]     | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | Id-Vd              | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | Id-Vd[3]           | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | Id-Vg pulse        | B1500A,4155B/C,4156B/C | SMU 4                           |
|          | Id-Vg Vpulse[3]    | B1500A,4155B/C,4156B/C | SMU 3                           |
|          | Id-Vg              | B1500A,4155B/C,4156B/C | SMU 4                           |

| Category    | Library                          | Supported analyzer     | Required equipment and quantity              |
|-------------|----------------------------------|------------------------|--|
| CMOS        | Id-Vg[3]                         | B1500A,4155B/C,4156B/C | SMU 3  |
|             | IonIoffSlope                     | B1500A,4155B/C,4156B/C | SMU 4  |
|             | Isub-Vg                          | B1500A,4155B/C,4156B/C | SMU 4  |
|             | QSCV[4]                          | B1500A                 | SMU 5  |
|             | QSCV C Offset Meas               | B1500A                 | SMU 2  |
|             | Simple Cgb                       | B1500A                 | MFCMU 1                                      |
|             | Simple Vth                       | B1500A,4155B/C,4156B/C | SMU 4  |
|             | Vth Const Id                     | B1500A,4155B/C,4156B/C | SMU 4  |
|             | Vth gmMax                        | B1500A,4155B/C,4156B/C | SMU 4  |
|             | VthAndCgg-Vg ASU                 | B1500A                 | MFCMU 1, SMU 1, HRSMU/ASU 2                  |
|             | VthAndCgg-Vg SCUU                | B1500A                 | MFCMU 1, SMU 3, SCUU 1, GSWU 1               |
|             | Vth-Lg                           | B1500A                 | SMU 4, B2200A/B2201A 1                       |
|             | Vth-Wg                           | B1500A                 | SMU 4, B2200A/B2201A 1                       |
| Discrete    | BJT GummelPlot                   | B1500A,4155B/C,4156B/C | SMU 3  |
|             | BJT Ic-Vc Ib                     | B1500A,4155B/C,4156B/C | SMU 3  |
|             | Diode IV Fwd                     | B1500A,4155B/C,4156B/C | SMU 2  |
|             | Diode IV Rev                     | B1500A,4155B/C,4156B/C | SMU 2  |
|             | FET Id-Vd                        | B1500A,4155B/C,4156B/C | SMU 3  |
|             | FET Id-Vg                        | B1500A,4155B/C,4156B/C | SMU 3  |
| GenericTest | Generic C-f                      | B1500A                 | MFCMU 1                                      |
|             | Generic C-t                      | B1500A                 | MFCMU 1                                      |
| Memory      | Flash Ccf-V                      | B1500A                 | MFCMU 1                                      |
|             | Flash Cfb-V                      | B1500A                 | MFCMU 1                                      |
|             | Flash Cgg-Vcg                    | B1500A                 | MFCMU 1                                      |
|             | NandFlash2 Endurance 3devices    | B1500A                 | SMU 3, B2200A/B2201A 1, 81110A (2 outputs) 1 |
|             | NandFlash2 Endurance             | B1500A                 | HRSMU/ASU 3, 81110A (2 outputs) 1            |
|             | NandFlash2 IV-Erase-IV           | B1500A                 | SMU 1, HRSMU/ASU 2, 81110A (2 outputs) 1     |
|             | NandFlash2 IV-Write-IV           | B1500A                 | SMU 2, HRSMU/ASU 1, 81110A (2 outputs) 1     |
|             | NandFlash2 Retention(ErasedCell) | B1500A                 | SMU 1, HRSMU/ASU 2, 81110A (2 outputs) 1     |



| Category | Library                               | Supported analyzer | Required equipment and quantity                                  |
|----------|---------------------------------------|--------------------|--|
| Memory   | NandFlash2 Retention(WrittenCell)     | B1500A             | SMU 2, HRSMU/ASU 1, 81110A (2 outputs) 1                         |
|          | NandFlash2 Vth(ErasingTimeDependence) | B1500A             | SMU 1, HRSMU/ASU 2, 81110A (2 outputs) 1                         |
|          | NandFlash2 Vth(WritingTimeDependence) | B1500A             | SMU 2, HRSMU/ASU 1, 81110A (2 outputs) 1                         |
|          | NandFlash2 WordDisturb(ErasedCell)    | B1500A             | HRSMU/ASU 3, 81110A (2 outputs) 1                                |
|          | NandFlash2 WordDisturb(WrittenCell)   | B1500A             | SMU 2, HRSMU/ASU 1, 81110A (2 outputs) 1                         |
|          | NandFlash3 Endurance                  | B1500A             | [SPGU 1, HRSMU/ASU 3] or [SPGU 1, SMU 3, 16440A/16445A 2]        |
|          | NandFlash3 IV-Erase-IV                | B1500A             | [SPGU 1, SMU 1, HRSMU/ASU 2] or [SPGU 1, SMU 3, 16440A/16445A 1] |
|          | NandFlash3 IV-Write-IV                | B1500A             | [SPGU 1, SMU 2, HRSMU/ASU 1] or [SPGU 1, SMU 3, 16440A/16445A 1] |
|          | NandFlash3 Retention(ErasedCell)      | B1500A             | [SPGU 1, SMU 1, HRSMU/ASU 2] or [SPGU 1, SMU 3, 16440A/16445A 1] |
|          | NandFlash3 Retention(WrittenCell)     | B1500A             | [SPGU 1, SMU 2, HRSMU/ASU 1] or [SPGU 1, SMU 3, 16440A/16445A 1] |
|          | NandFlash3 Vth(ErasingTimeDependence) | B1500A             | [SPGU 1, SMU 1, HRSMU/ASU 2] or [SPGU 1, SMU 3, 16440A/16445A 1] |
|          | NandFlash3 Vth(WritingTimeDependence) | B1500A             | [SPGU 1, SMU 2, HRSMU/ASU 1] or [SPGU 1, SMU 3, 16440A/16445A 1] |
|          | NandFlash3 WordDisturb(ErasedCell)    | B1500A             | [SPGU 1, HRSMU/ASU 3] or [SPGU 1, SMU 3, 16440A/16445A 2]        |
|          | NandFlash3 WordDisturb(WrittenCell)   | B1500A             | [SPGU 1, SMU 2, HRSMU/ASU 1] or [SPGU 1, SMU 3, 16440A/16445A 1] |
|          | NorFlash Endurance                    | B1500A             | [SPGU 2, SMU 1, HRSMU/ASU 3] or [SPGU 2, SMU 4, 16440A/16445A 2] |
|          | NorFlash IV-Erase-IV                  | B1500A             | [SPGU 1, SMU 2, HRSMU/ASU 2] or [SPGU 1, SMU 4, 16440A/16445A 1] |
|          | NorFlash IV-Write-IV                  | B1500A             | [SPGU 1, SMU 2, HRSMU/ASU 2] or [SPGU 1, SMU 4, 16440A/16445A 1] |
|          | NorFlash Retention(ErasedCell)        | B1500A             | [SPGU 1, SMU 2, HRSMU/ASU 2] or [SPGU 1, SMU 4, 16440A/16445A 1] |
|          | NorFlash Retention(WrittenCell)       | B1500A             | [SPGU 1, SMU 2, HRSMU/ASU 2] or [SPGU 1, SMU 4, 16440A/16445A 1] |

| Category    | Library                                | Supported analyzer     | Required equipment and quantity                                     |
|-------------|--|------------------------|---|
| Memory      | NorFlash<br>Vth(ErasingTimeDependence) | B1500A                 | [SPGU 1, SMU 2, HRSMU/ASU 2] or<br>[SPGU 1, SMU 4, 16440A/16445A 1] |
|             | NorFlash<br>Vth(WritingTimeDependence) | B1500A                 | [SPGU 1, SMU 2, HRSMU/ASU 2] or<br>[SPGU 1, SMU 4, 16440A/16445A 1] |
|             | NorFlash<br>WordDisturb(ErasedCell)    | B1500A                 | [SPGU 1, SMU 2, HRSMU/ASU 2] or<br>[SPGU 1, SMU 4, 16440A/16445A 1] |
|             | NorFlash<br>WordDisturb(WrittenCell)   | B1500A                 | [SPGU 1, SMU 2, HRSMU/ASU 2] or<br>[SPGU 1, SMU 4, 16440A/16445A 1] |
|             | NorFlash<br>DataDisturb(ErasedCell)    | B1500A                 | [SPGU 2, SMU 1, HRSMU/ASU 3] or<br>[SPGU 2, SMU 4, 16440A/16445A 2] |
|             | NorFlash<br>DataDisturb(WrittenCell)   | B1500A                 | [SPGU 1, SMU 2, HRSMU/ASU 2] or<br>[SPGU 1, SMU 4, 16440A/16445A 1] |
| MixedSignal | BJT Varactor CV Mismatch               | B1500A                 | MFCMU 1   |
|             | Diff-R Mismatch                        | B1500A                 | SMU 8   |
|             | Diode IV Fwd Mismatch                  | B1500A                 | SMU 3   |
|             | Diode IV Rev Mismatch                  | B1500A                 | SMU 3   |
|             | G-Plot ConstVce Mismatch               | B1500A                 | SMU 6   |
|             | G-Plot ConstVce Mismatch[3]            | B1500A                 | SMU 5   |
|             | G-Plot Vbc=0V Mismatch                 | B1500A                 | SMU 6   |
|             | G-Plot Vbc=0V Mismatch[3]              | B1500A                 | SMU 5   |
|             | Ic-Vc Ib Mismatch                      | B1500A                 | SMU 6   |
|             | Ic-Vc Ib Mismatch[3]                   | B1500A                 | SMU 5   |
|             | Ic-Vc Vb Mismatch                      | B1500A                 | SMU 6   |
|             | Ic-Vc Vb Mismatch[3]                   | B1500A                 | SMU 5   |
|             | Id-Vd Mismatch                         | B1500A                 | SMU 5   |
|             | Id-Vd Mismatch[3]                      | B1500A                 | SMU 4   |
|             | Id-Vg Mismatch                         | B1500A                 | SMU 5   |
|             | Id-Vd Mismatch[3]                      | B1500A                 | SMU 4   |
|             | MIM CV Mismatch                        | B1500A                 | MFCMU 1   |
|             | MOS Varactor CV Mismatch               | B1500A                 | MFCMU 1   |
|             | Poly-R Mismatch                        | B1500A                 | SMU 7   |
| NanoTech    | CNT Differential R[AC]                 | B1500A                 | MFCMU 1   |
|             | CNT Gate Leak                          | B1500A,4155B/C,4156B/C | SMU 2   |
|             | CNT Id-Time                            | B1500A,4156B/C         | SMU 4   |

| Category    | Library                      | Supported analyzer     | Required equipment and quantity |
|-------------|------------------------------|------------------------|---------------------------------|
| NanoTech    | CNT Id-Vd                    | B1500A,4155B/C,4156B/C | SMU 4                           |
|             | CNT Id-Vg                    | B1500A,4155B/C,4156B/C | SMU 4                           |
|             | CNT Id-Vg-Time               | B1500A,4156B/C         | SMU 4                           |
|             | CNT IV Sweep                 | B1500A,4155B/C,4156B/C | SMU 2                           |
|             | CNT R-I Kelvin 2SMU          | B1500A,4155B/C,4156B/C | SMU 2                           |
|             | CNT R-V Kelvin 2SMU          | B1500A,4155B/C,4156B/C | SMU 2                           |
|             | CNT Vth gmMax                | B1500A,4155B/C,4156B/C | SMU 4                           |
| PwrDevice   | BVdss[3] PwrDevice           | B1500A                 | SMU 3                           |
|             | BVgso[3] PwrDevice           | B1500A                 | SMU 2                           |
|             | Id-Vd pulse[3] PwrDevice     | B1500A                 | SMU 3                           |
|             | Id-Vd[3] PwrDevice           | B1500A                 | SMU 3                           |
|             | Id-Vg pulse[3] PwrDevice     | B1500A                 | SMU 3                           |
|             | Id-Vg[3] PwrDevice           | B1500A                 | SMU 3                           |
|             | Vth Const Id[3] PwrDevice    | B1500A                 | SMU 3                           |
|             | Vth gmMax[3] PwrDevice       | B1500A                 | SMU 3                           |
| Reliability | BJT EB RevStress 3devices    | B1500A                 | SMU 6, B2200A/B2201A 1          |
|             | BJT EB RevStress 3devices[3] | B1500A                 | SMU 5, B2200A/B2201A 1          |
|             | BJT EB RevStress             | B1500A                 | SMU 4                           |
|             | BJT EB RevStress2            | B1500A                 | SMU 4                           |
|             | BJT EB RevStress[3]          | B1500A                 | SMU 3                           |
|             | BJT EB RevStress2[3]         | B1500A                 | SMU 3                           |
|             | BTI 3devices                 | B1500A                 | SMU 5, B2200A/B2201A 1          |
|             | BTI 3devices[3]              | B1500A                 | SMU 5, B2200A/B2201A 1          |
|             | BTI                          | B1500A                 | SMU 4                           |
|             | BTI2                         | B1500A                 | SMU 4                           |
|             | BTI[3]                       | B1500A                 | SMU 3                           |
|             | BTI2[3]                      | B1500A                 | SMU 3                           |
|             | Charge Pumping               | B1500A                 | SMU 2, 81110A (2 outputs) 1     |
|             | Charge Pumping2              | B1500A                 | SMU 2, SPGU 1                   |
|             | EM Istress                   | B1500A                 | SMU 4                           |
|             | EM Istress2                  | B1500A                 | SMU 4                           |

| Category    | Library                | Supported analyzer     | Required equipment and quantity |
|-------------|------------------------|------------------------|---------------------------------|
| Reliability | EM Istress[2]          | B1500A                 | SMU 2                           |
|             | EM Istress2[2]         | B1500A                 | SMU 2                           |
|             | EM Istress[6]          | B1500A                 | SMU 6                           |
|             | EM Istress2[6]         | B1500A                 | SMU 6                           |
|             | EM Vstress             | B1500A                 | SMU 4                           |
|             | EM Vstress2            | B1500A                 | SMU 4                           |
|             | EM Vstress[2]          | B1500A                 | SMU 2                           |
|             | EM Vstress2[2]         | B1500A                 | SMU 2                           |
|             | EM Vstress[6]          | B1500A                 | SMU 6                           |
|             | EM Vstress2[6]         | B1500A                 | SMU 6                           |
|             | HCI 3devices           | B1500A                 | SMU 8                           |
|             | HCI                    | B1500A                 | SMU 4                           |
|             | HCI2                   | B1500A                 | SMU 4                           |
|             | J-Ramp                 | B1500A                 | SMU 2                           |
|             | TDDB Istress 3devices  | B1500A                 | SMU 4                           |
|             | TDDB Istress2 3devices | B1500A                 | SMU 4                           |
|             | TDDB Istress           | B1500A                 | SMU 2                           |
|             | TDDB Istress2          | B1500A                 | SMU 2                           |
|             | TDDB Vstress 3devices  | B1500A                 | SMU 4                           |
|             | TDDB Vstress2 3devices | B1500A                 | SMU 4                           |
|             | TDDB Vstress           | B1500A                 | SMU 2                           |
|             | TDDB Vstress2          | B1500A                 | SMU 2                           |
|             | TZDB                   | B1500A                 | SMU 2                           |
|             | V-Ramp                 | B1500A                 | SMU 2                           |
| Structure   | BVgb ThinOx            | B1500A,4155B/C,4156B/C | SMU 2                           |
|             | BVgb                   | B1500A,4155B/C,4156B/C | SMU 2                           |
|             | Cgb-Freq[2] Log        | B1500A                 | MFCMU 1                         |
|             | Cgb-Vg 2Freq           | B1500A                 | MFCMU 1                         |
|             | Cgb-Vg[2]              | B1500A                 | MFCMU 1                         |
|             | Cj-Freq Log            | B1500A                 | MFCMU 1                         |
|             | Cj-V                   | B1500A                 | MFCMU 1                         |

| Category  | Library                  | Supported analyzer     | Required equipment and quantity |
|-----------|--------------------------|------------------------|---------------------------------|
| Structure | Diode BVAndCj-V ASU      | B1500A                 | MFCMU 1, HRSMU/ASU 2            |
|           | Diode BVAndCj-V SCUU     | B1500A                 | MFCMU 1, SMU 2, SCUU 1, GSWU 1  |
|           | Ig-Vg Iforce             | B1500A,4155B/C,4156B/C | SMU 2                           |
|           | Ig-Vg Vforce             | B1500A,4155B/C,4156B/C | SMU 2                           |
|           | Interconnect CouplingCap | B1500A                 | MFCMU 1                         |
|           | Interconnect OverlapCap  | B1500A                 | MFCMU 1                         |
|           | Junction BV              | B1500A,4155B/C,4156B/C | SMU 2                           |
|           | Junction DcParam         | B1500A,4155B/C,4156B/C | SMU 2                           |
|           | Junction IV Fwd          | B1500A,4155B/C,4156B/C | SMU 2                           |
|           | Junction IV Rev          | B1500A,4155B/C,4156B/C | SMU 2                           |
|           | QSCV[2]                  | B1500A                 | SMU 3                           |
|           | QSCV C Offset Meas       | B1500A                 | SMU 2                           |
|           | Rdiff-I kelvin           | B1500A                 | SMU 5                           |
|           | Rdiff-I                  | B1500A,4155B/C,4156B/C | SMU 3                           |
|           | Rdiff-V kelvin           | B1500A                 | SMU 5                           |
|           | Rdiff-V                  | B1500A,4155B/C,4156B/C | SMU 3                           |
|           | R-I DVM                  | B1500A                 | SMU 2, 3458A 1                  |
|           | R-I kelvin               | B1500A,4155B/C,4156B/C | SMU 4                           |
|           | R-I                      | B1500A,4155B/C,4156B/C | SMU 2                           |
|           | R-V DVM                  | B1500A                 | SMU 2, 3458A 1                  |
|           | R-V kelvin               | B1500A,4155B/C,4156B/C | SMU 4                           |
|           | R-V                      | B1500A,4155B/C,4156B/C | SMU 2                           |
|           | VanDerPauw Square        | B1500A,4155B/C,4156B/C | SMU 4                           |
| TFT       | TFT Id-Vd                | B1500A,4155B/C,4156B/C | SMU 3                           |
|           | TFT Id-Vg                | B1500A,4155B/C,4156B/C | SMU 3                           |
| Utility   | ForcePG1                 | B1500A                 | 81110A (2 outputs) 1            |
|           | ForcePG2                 | B1500A                 | 81110A (2 outputs) 1            |
|           | ForcePG2P                | B1500A                 | 81110A (2 outputs) 1            |
|           | ForcePG12                | B1500A                 | 81110A (2 outputs) 1            |
|           | ForcePG                  | B1500A                 | 81110A (2 outputs) 1            |
|           | ForcePGC                 | B1500A                 | 81110A (2 outputs) 1            |

| Category | Library            | Supported analyzer | Required equipment and quantity |
|----------|--------------------|--------------------|---------------------------------|
| Utility  | Measure Diff-V     | B1500A             | 3458A 1                         |
|          | QSCV C Offset Meas | B1500A             | SMU 2                           |
|          | ResetPG            | B1500A             | 81110A (2 outputs) 1            |
|          | Subsite move       | B1500A             | Wafer prober 1                  |
|          | CVSweep4284_a      | B1500A             | 4284A 1 or E4980A 1             |

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## NOTE

### If you delete a test definition

Application library should be recovered. Import the test definition by using the Import Test Definition... function of the Library button. The original test definitions are stored in the following folder.

C:\Program Files\Agilent\B1500\EasyEXPERT\Application Tests

---

# 1 BJT

|                               |   |
|-------------------------------|---|
| 1. BC Diode Fwd:              | Base-Collector junction forward characteristics (A.01.20)                                 |
| 2. BC Diode Reverse:          | Base-Collector junction reverse characteristics (A.01.20)                                 |
| 3. BVcbo:                     | Base-Collector junction breakdown voltage (A.01.20)                                       |
| 4. BVcei:                     | Emitter-Collector breakdown voltage (A.01.20)   |
| 5. BVceo:                     | Emitter-Collector breakdown voltage, opened base (A.01.20)                                |
| 6. BVebo:                     | Emitter-Base breakdown voltage (A.01.20)  |
| 7. CS Diode Fwd:              | Collector-Substrate junction forward characteristics (A.01.20)                            |
| 8. CS Diode Reverse:          | Collector-Substrate junction reverse characteristics (A.01.20)                            |
| 9. Ctc-Freq Log:              | Ctc-f characteristics (A.01.20)   |
| 10. Ctc-Vc:                   | Ctc-Vcb characteristics (A.01.20)   |
| 11. Cte-Ve:                   | Cte-Veb characteristics (A.01.20)   |
| 12. Cts:                      | Cts-Vsc characteristics (A.01.20)   |
| 13. EB Diode Fwd:             | Emitter-Base junction forward characteristics (A.01.20)                                   |
| 14. EB Diode Rev:             | Emitter-Base junction reverse characteristics (A.01.20)                                   |
| 15. G-Plot ConstVce Pulse:    | Ic-Vb characteristics, Vce=const, SMU Pulse (A.01.11)                                     |
| 16. G-Plot ConstVce Pulse[3]: | Ic-Vb characteristics, Vce=const, 3-terminal, SMU Pulse (A.01.11)                         |
| 17. G-Plot ConstVce:          | Gummel characteristics, Vce=constant (A.01.20)  |
| 18. G-Plot ConstVce[3]:       | Gummel characteristics, Vce=constant, 3-terminal (A.01.20)                                |
| 19. G-Plot Vbc=0V Pulse:      | Ic-Ve characteristics, Vbc=0, SMU Pulse (A.01.11)   |
| 20. G-Plot Vbc=0V Pulse[3]:   | Ic-Ve characteristics, Vbc=0, 3-terminal, SMU Pulse (A.01.11)                             |
| 21. G-Plot Vbc=0V:            | Gummel characteristics, Vbc=0 (A.01.20)   |
| 22. G-Plot Vbc=0V[3]:         | Gummel characteristics, Vbc=0, 3-terminal (A.01.20)                                       |
| 23. hfe-Vbe ConstVce:         | hfe-Ic characteristics, Vce=constant (A.01.20)  |
| 24. hfe-Vbe Vbc=0V:           | hfe-Ic characteristics, Vbc=0 (A.01.20)   |
| 25. Ic-Vc Ib:                 | Ic-Vc characteristics, Ib sweep (A.01.20)   |
| 26. Ic-Vc Ib[3]:              | Ic-Vc characteristics, 3-terminal, Ib sweep (A.01.20)                                     |
| 27. Ic-Vc Pulse Ib:           | Ic-Vc characteristics, Ib sweep, SMU Pulse (A.01.11)                                      |
| 28. Ic-Vc Pulse Ib[3]:        | Ic-Vc characteristics, 3-terminal, Ib sweep, SMU Pulse (A.01.11)                          |
| 29. Ic-Vc Pulse Vb:           | Ic-Vc characteristics, Vb sweep, SMU Pulse (A.01.11)                                      |
| 30. Ic-Vc Pulse Vb[3]:        | Ic-Vc characteristics, 3-terminal, Vb sweep, SMU Pulse (A.01.11)                          |
| 31. Ic-Vc Vb:                 | Ic-Vc characteristics, Vb sweep (A.01.20)   |
| 32. Ic-Vc Vb[3]:              | Ic-Vc characteristics, 3-terminal, Vb sweep (A.01.20)                                     |
| 33. Rb:                       | Base resistance (flyback method, 4-terminal) (A.01.20)                                    |
| 34. Re+Rc:                    | Collector resistance (including Emitter resistance, flyback method, 4-terminal) (A.01.20) |
| 35. Re:                       | Emitter resistance (flyback method, 4-terminal) (A.01.20)                                 |
| 36. Simple Gummel Plot:       | Evaluation of Gummel characteristics (Vce=const) (A.01.10)                                |
| 37. Vbe-Le:                   | hfe,Vbe-Le characteristics (A.01.20)  |
| 38. Vbe-We:                   | hfe,Vbe-Le characteristics (A.01.20)  |

## 2 CMOS

|                        |  |
|------------------------|--|
| 1. BVdss:              | Breakdown voltage between source and drain (A.01.20)                   |
| 2. BVgso:              | Breakdown voltage between gate and source (A.01.20)                    |
| 3. Cgb-AC Level:       | Cgb-Vosc characteristics (A.01.11)                                     |
| 4. Cgb-Freq Log:       | Cgb-f characteristics (A.01.20)  |
| 5. Cgb-Vg HighVoltage: | Cgb-Vg characteristics using SCUU (A.01.11)                            |
| 6. Cgb-Vg:             | Cgb-Vg characteristics (A.01.11)                                       |
| 7. Cgc-Freq Log:       | Cgc-f characteristics (A.01.20)  |
| 8. Cgc-Vg:             | Cgc-Vg characteristics (A.01.11)                                       |
| 9. Cgg-Freq Linear:    | Cgg-f characteristics (A.01.20)  |
| 10. Cgg-Freq Log:      | Cgg-f characteristics (A.01.20)  |
| 11. Cgg-Vg 2Freq:      | Cgg-Vg characteristics, 2-frequency method (A.01.11)                   |
| 12. Cgg-Vg:            | Cgg-Vg characteristics (A.01.11)                                       |
| 13. IdRdsGds:          | Drain resistance/conductance (A.01.20)                                 |
| 14. Id-Vd pulse:       | Id-Vd characteristics, SMU Pulse (A.01.11)                             |
| 15. Id-Vd pulse[3] :   | Id-Vd characteristics (3-terminal), SMU Pulse (A.01.11)                |
| 16. Id-Vd:             | Id-Vd Characteristics (A.01.20)  |
| 17. Id-Vd[3]:          | Id-Vd Characteristics (3-terminal) (A.01.20)                           |
| 18. Id-Vg pulse:       | Id-Vg characteristics, SMU Pulse (A.01.12)                             |
| 19. Id-Vg Vpulse[3]:   | Id-Vg characteristics (3-terminal), SMU Pulse (A.01.11)                |
| 20. Id-Vg:             | Id-Vg Characteristics (A.01.20)  |
| 21. Id-Vg[3]:          | Id-Vg Characteristics (3-terminal) (A.01.20)                           |
| 22. IonIoffSlope:      | On current, off current, and subthreshold slope (A.01.20)              |
| 23. Isub-Vg:           | Isub-Lg characteristics (A.01.20)                                      |
| 24. QSCV[4]            | C-Vg, Ig-Vg (4-terminal) (A.03.00)                                     |
| 25. QSCV C Offset Meas | Offset capacitance measurement   |
| 26. Simple Cgb :       | Evaluation of gate-substrate capacitance versus gate voltage (A.01.10) |
| 27. Simple Vth :       | Evaluation of Threshold Voltage (Vth) (A.01.10)                        |
| 28. Vth Const Id:      | Constant current Vth (A.01.20)   |
| 29. Vth gmMax :        | Linear region Vth (A.01.20)  |
| 30. VthAndCgg-Vg ASU:  | Cgg-Vg, Id-Vg, using ASU (A.01.20)                                     |
| 31. VthAndCgg-Vg SCUU: | Cgg-Vg, Id-Vg, using SCUU (A.01.20)                                    |
| 32. Vth-Lg:            | Vth-Lg characteristics (A.01.20)                                       |
| 33. Vth-Wg:            | Vth-Wg characteristics (A.01.20)                                       |



### 3 Discrete

- |                    |   |
|--------------------|---|
| 1. BJT GummelPlot: | Bipolar transistor gummel characteristics (A.01.20) |
| 2. BJT Ic-Vc Ib :  | Bipolar transistor Ic-Vc characteristics (A.01.20)  |
| 3. Diode IV Fwd:   | Diode forward bias characteristics (A.01.20)        |
| 4. Diode IV Rev:   | Diode reverse bias characteristics (A.01.20)        |
| 5. FET Id-Vd:      | MOSFET Id-Vd characteristics (A.01.20)              |
| 6. FET Id-Vg :     | MOSFET Id-Vg characteristics (A.01.20)              |

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### 4 Generic Test

1. C-f C-f characteristics of condenser (2 terminals) (A.03.00)
2. C-t C-t characteristics of condenser (2 terminals) (A.03.00)

## 5 Memory

1. Flash Ccf-V: Flash memory cell Control Gate to Floating Gate capacitance (A.01.11)
2. Flash Cfb-V: Flash memory cell Floating Gate-Substrate capacitance (A.01.11)
3. Flash Cgg-Vcg: Flash memory cell Gate capacitance (A.01.11)
4. NandFlash2 Endurance 3devices: Repeatedly tests write/erase on a NAND-type flash memory cell, simultaneously using three devices (A.01.20).
5. NandFlash2 Endurance: NAND flash memory cell endurance test (A.01.20)
6. NandFlash2 IV-Erase-IV: NAND flash memory cell Id-Vg, Erase, Id-Vg (A.01.20)
7. NandFlash2 IV-Write-IV: NAND flash memory cell Id-Vg, Write, Id-Vg (A.01.20)
8. NandFlash2 Retention(ErasedCell): NAND flash memory cell Data retention test after Erase (A.01.20)
9. NandFlash2 Retention(WrittenCell): NAND flash memory cell Data retention test after Write (A.01.20)
10. NandFlash2 Vth(ErasingTimeDependence): NAND flash memory cell erasing time dependence test (A.01.20)
11. NandFlash2 Vth(WritingTimeDependence): NAND flash memory cell writing time dependence test (A.01.20)
12. NandFlash2 WordDisturb(ErasedCell): NAND flash memory cell erase-disturb test (A.01.20)
13. NandFlash2 WordDisturb(WrittenCell): NAND flash memory cell read-disturb test (A.01.20)
14. NandFlash3 Endurance: NAND flash memory cell endurance test (A.03.10)
15. NandFlash3 IV-Erase-IV: NAND flash memory cell Id-Vg, Erase, Id-Vg (A.03.10)
16. NandFlash3 IV-Write-IV: NAND flash memory cell Id-Vg, Write, Id-Vg (A.03.10)
17. NandFlash3 Retention(ErasedCell): NAND flash memory cell Data retention test after Erase (A.03.10)
18. NandFlash3 Retention(WrittenCell): NAND flash memory cell Data retention test after Write (A.03.10)
19. NandFlash3 Vth(ErasingTimeDependence): NAND flash memory cell erasing time dependence test (A.03.10)
20. NandFlash3 Vth(WritingTimeDependence): NAND flash memory cell writing time dependence test (A.03.10)
21. NandFlash3 WordDisturb(ErasedCell): NAND flash memory cell erase-disturb test (A.03.10)
22. NandFlash3 WordDisturb(WrittenCell): NAND flash memory cell read-disturb test (A.03.10)
23. NorFlash Endurance: NOR flash memory cell endurance test (A.03.10)
24. NorFlash IV-Erase-IV: NOR flash memory cell Id-Vg, Erase, Id-Vg (A.03.10)
25. NorFlash IV-Write-IV: NOR flash memory cell Id-Vg, Write, Id-Vg (A.03.10)
26. NorFlash Retention(ErasedCell): NOR flash memory cell Data retention test after Erase (A.03.10)
27. NorFlash Retention(WrittenCell): NOR flash memory cell Data retention test after Write (A.03.10)
28. NorFlash Vth(ErasingTimeDependence): NOR flash memory cell erasing time dependence test (A.03.10)
29. NorFlash Vth(WritingTimeDependence): NOR flash memory cell writing time dependence test (A.03.10)
30. NorFlash WordDisturb(ErasedCell): NOR flash memory cell word disturb test after Erase (A.03.10)
31. NorFlash WordDisturb(WrittenCell): NOR flash memory cell word disturb test after Write (A.03.10)

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- 32. NorFlash DataDisturb(ErasedCell):  
NOR flash memory cell data disturb test after Erase (A.03.10)
- 33. NorFlash DataDisturb(WrittenCell):  
NOR flash memory cell data disturb test after Write (A.03.10)

## 6 Mixed Signal

1. BJT Varactor CV Mismatch: BJT Varactor capacitance CV characteristics mismatch (A.01.11)
2. Diff-R Mismatch: Diffusion resistor R-I characteristics mismatch, Kelvin conneciton (A.01.11)
3. Diode IV Fwd Mismatch: Diode forward bias characteristics mismatch (A.01.20)
4. Diode IV Rev Mismatch: Diode reverse bias characteristics mismatch (A.01.20)
5. G-Plot ConstVce Mismatch: Gummel characteristics mismatch, Vce=Const (A.01.20)
6. G-Plot ConstVce Mismatch[3]: Gummel characteristics mismatch, Vce=Const, 3-terminal (A.01.20)
7. G-Plot Vbc=0V Mismatch: Gummel characteristics mismatch, Vbc=0 V (A.01.20)
8. G-Plot Vbc=0V Mismatch[3]: Gummel characteristics mismatch, Vbc=0, 3-terminal (A.01.20)
9. Ic-Vc Ib Mismatch: Ic-Vce characteristics mismatch, Ib sweep (A.01.20)
10. Ic-Vc Ib Mismatch[3]: Ic-Vce characteristics mismatch, Ib sweep, 3-terminal (A.01.20)
11. Ic-Vc Vb Mismatch: Ic-Vce characteristics mismatch, Vb sweep (A.01.20)
12. Ic-Vc Vb Mismatch[3]: Ic-Vce characteristics mismatch, Vb sweep, 3-terminal (A.01.20)
13. Id-Vd Mismatch: Id-Vd characteristics mismatch (A.01.20)
14. Id-Vd Mismatch[3]: Id-Vd characteristics mismatch, 3-terminal (A.01.20)
15. Id-Vg Mismatch: Id-Vg characteristics mismatch (A.01.20)
16. Id-Vd Mismatch[3]: Id-Vd characteristics mismatch, 3-terminal (A.01.20)
17. MIM CV Mismatch: MIM capacitor C-V characteristics mismatch (A.01.11)
18. MOS Varactor CV Mismatch: MOS Varactor capacitance CV characteristics mismatch (A.01.11)
19. Poly-R Mismatch: Resistor R-I characteristics mismatch, Kelvin connection (A.01.11)

## 7 NanoTech

1. CNT Differential R[AC]: CNT Differential R-V characteristics (A.01.20)
2. CNT Gate Leak: CNT FET Ig-Vg characteristics (A.01.20)
3. CNT Id-Time: CNT FET Id-Time Characteristic (A.01.20)
4. CNT Id-Vd: CNT FET Id-Vd characteristics (A.01.20)
5. CNT Id-Vg: Carbon Nano Tube FET Id-Vg characteristics (A.01.20)
6. CNT Id-Vg-Time: CNT FET Ig-Vg characteristics (A.01.20)
7. CNT IV Sweep: CNT Differential I-V characteristics (A.01.20)
8. CNT R-I Kelvin 2SMU: CNT R-I characteristics, Kelvin connection (A.01.20)
9. CNT R-V Kelvin 2SMU: CNT R-V characteristics, Kelvin connection (A.01.20)
10. CNT Vth gmMax: CNT FET linear region Vth (A.01.20)

## 8 Power Device

1. BVdss[3] PwrDevice: Breakdown voltage between source and drain (A.01.20)
2. BVgso[3] PwrDevice: Breakdown voltage between gate and source (A.01.20)
3. Id-Vd pulse[3] PwrDevice: Id-Vd characteristics (3-terminal), SMU Pulse (A.01.20)
4. Id-Vd[3] PwrDevice: Id-Vd Characteristics (3-terminal) (A.01.20)
5. Id-Vg pulse[3] PwrDevice: Id-Vg characteristics (3-terminal), SMU Pulse (A.01.20)
6. Id-Vg[3] PwrDevice: Id-Vg Characteristics (3-terminal) (A.01.20)
7. Vth Const Id[3] PwrDevice:  
Constant current Vth (A.01.20)
8. Vth gmMax[3] PwrDevice: Linear region Vth (A.01.20)

## 9 Reliability

1. BJT EB RevStress 3devices: Emitter-Base junction Reverse bias Stress test, 4 terminals, 3 devices (A.01.20)
2. BJT EB RevStress 3devices[3]: Emitter-Base junction Reverse bias Stress test, 3 terminals, 3 devices (A.01.20)
3. BJT EB RevStress: Emitter-Base junction Reverse bias Stress test, 4 terminals (A.01.20)
4. BJT EB RevStress2: Emitter-Base junction Reverse bias Stress test, 4 terminals (A.03.10)
5. BJT EB RevStress[3]: Emitter-Base junction Reverse bias Stress test, 3 terminals (A.01.20)
6. BJT EB RevStress2[3]: Emitter-Base junction Reverse bias Stress test, 3 terminals (A.03.10)
7. BTI 3devices: Bias Temperature Instability test, 4 terminals, 3 devices (A.01.20)
8. BTI 3devices[3]: Bias Temperature Instability test, 3 terminals, 3 devices (A.01.20)
9. BTI: Bias Temperature Instability test, 4 terminals (A.01.20)
10. BTI2: Bias Temperature Instability test, 4 terminals (A.03.10)
11. BTI[3]: Bias Temperature Instability test, 3 terminals (A.01.20)
12. BTI2[3]: Bias Temperature Instability test, 3 terminals (A.03.10)
13. Charge Pumping: Evaluation of the interface state using charge pumping method (A.01.20)
14. Charge Pumping2: Evaluation of the interface state using charge pumping method (A.03.10)
15. EM Istress: Electromigration test, current stressed, 4 SMUs (A.01.20)
16. EM Istress2: Electromigration test, current stressed, 4 SMUs (A.03.10)
17. EM Istress[2]: Electromigration test, current stressed, 2 SMUs (A.01.20)
18. EM Istress2[2]: Electromigration test, current stressed, 2 SMUs (A.03.10)
19. EM Istress[6]: Electromigration test, current stressed, 6 SMUs (A.01.20)
20. EM Istress2[6]: Electromigration test, current stressed, 6 SMUs (A.03.10)
21. EM Vstress: Electromigration test, voltage stressed, 4 SMUs (A.01.20)
22. EM Vstress2: Electromigration test, voltage stressed, 4 SMUs (A.03.10)
23. EM Vstress[2]: Electromigration test, voltage stressed, 2 SMUs (A.01.20)
24. EM Vstress2[2]: Electromigration test, voltage stressed, 2 SMUs (A.03.10)
25. EM Vstress[6]: Electromigration test, voltage stressed, 6 SMUs (A.01.20)
26. EM Vstress2[6]: Electromigration test, voltage stressed, 6 SMUs (A.03.10)
27. HCI 3devices: Hot Carrier Injection test, 4 terminals, 3 devices (A.01.20)
28. HCI: Hot Carrier Injection test, 4 terminals (A.01.20)
29. HCI2: Hot Carrier Injection test, 4 terminals (A.03.10)
30. J-Ramp: Insulator lifetime evaluation, current stressed (A.01.20)
31. TDDB Istress 3devices: TDDB Test, current stressed, 3 devices (A.01.20)
32. TDDB Istress2 3devices: TDDB Test, current stressed, 3 devices (A.03.10)
33. TDDB Istress: TDDB Test, current stressed (A.01.20)
34. TDDB Istress2: TDDB Test, current stressed (A.03.10)
35. TDDB Vstress 3devices: TDDB Test, voltage stressed, 3 devices (A.01.20)
36. TDDB Vstress2 3devices: TDDB Test, voltage stressed, 3 devices (A.03.10)
37. TDDB Vstress: TDDB Test, voltage stressed (A.01.20)
38. TDDB Vstress2: TDDB Test, voltage stressed (A.03.10)
39. TZDB: TZDB Test of oxide layer (A.01.20)
40. V-Ramp: Insulator lifetime evaluation, voltage stressed (A.01.20)



## 10 Structure

1. BVgb ThinOx: MOS capacitor Ig-Vg characteristics (A.01.20)
2. BVgb: MOS capacitor Gate-Substrate breakdown voltage (A.01.20)
3. Cgb-Freq[2] Log: Cgb-f characteristics, 2 terminals (A.01.20)
4. Cgb-Vg 2Freq: MOS capacitor Cgb-Vg characteristics, 2-frequency method (A.01.11)
5. Cgb-Vg[2]: MOS capacitor Cgb-Vg characteristics (A.01.11)
6. Cj-Freq Log: Cj-f characteristics, junction device (A.01.20)
7. Cj-V: Junction capacitance Cj-V characteristics (A.01.11)
8. Diode BVAndCj-V ASU: Diode junction capacitance and breakdown voltage measurement using ASUs (A.01.20)
9. Diode BVAndCj-V SCUU: Diode junction capacitance and breakdown voltage measurement using SCUU (A.01.20)
10. Ig-Vg Iforce: MOS capacitor Ig-Vg characteristics, current sweep (A.01.20)
11. Ig-Vg Vforce: MOS capacitor Ig-Vg characteristics, voltage sweep (A.01.20)
12. Interconnect CouplingCap: Interconnection capacitance (A.01.11)
13. Interconnect OverlapCap: Layer to layer film capacitance (A.01.11)
14. Junction BV: Junction device breakdown voltage (A.01.20)
15. Junction DcParam: Junction device DC parameters (Is,N,Rs) (A.01.20)
16. Junction IV Fwd: Diode forward bias characteristics (A.01.20)
17. Junction IV Rev: Diode reverse bias characteristics (A.01.20)
18. QSCV[2] C-Vg, Ig-Vg (2-terminal) (A.03.00)
19. QSCV C Offset Meas: Offset capacitance measurement
20. Rdiff-I kelvin: Diffusion resistor R-I characteristics, Kelvin connection (A.01.11)
21. Rdiff-I: Diffusion resistor R-I characteristics (A.01.11)
22. Rdiff-V kelvin: Diffusion resistor R-V characteristics, Kelvin connection (A.01.20)
23. Rdiff-V: Diffusion resistor R-V characteristics (A.01.20)
24. R-I DVM: Low resistance measurement using 3458A, current force (A.01.20)
25. R-I kelvin: Resistor R-I characteristics, Kelvin connection (A.01.11)
26. R-I: Resistor R-I characteristics (A.01.11)
27. R-V DVM: Low resistance measurement using 3458A, voltage force (A.01.20)
28. R-V kelvin: Resistor R-V characteristics, Kelvin connection (A.01.20)
29. R-V: Resistor R-V characteristics (A.01.20)
30. VanDerPauw Square: Van Der Pauw pattern sheet resistance (A.01.11)

## Contents

# 11 TFT

- |               |                                     |
|---------------|-------------------------------------|
| 1. TFT Id-Vd: | TFT Id-Vd characteristics (A.01.20) |
| 2. TFT Id-Vg: | TFT Id-Vg characteristics (A.01.20) |

## 12 Utility

- |                       |  |
|-----------------------|--|
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## ***1.1 BC Diode Fwd: Base-Collector junction forward characteristics (A.01.20)***

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the Base-Collector junction forward characteristics of BJT. Emitter and Substrate are opened.

### [Device Under Test]

Bipolar transistor

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Lb: Base length

Wb: Base width

Temp: Temperature

Imax: Current compliance

### [Test Parameters]

IntegTime: Integration time

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

Base: SMU connected to Base terminal, constant voltage output

### [Extended Test Parameters]

Vb: Base voltage

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng: Minimum range for the base current measurement

CollectorMinRng: Minimum range for the collector current measurement

### [Measurement Parameters]

Collector current Icollector

Base current Ibase

### [User Function]

$I_{cPerArea} = I_{collector} / L_b / W_b$

$I_{bPerArea} = I_{base} / L_b / W_b$

### [X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

Y1 axis: Collector current Icollector (LOG)

Y2 axis: Collector current Icollector (LINEAR)

Y3 axis: Base current Ibase (LOG)

Y4 axis: Base current Ibase (LINEAR)

## 1 BJT

### ***1.2 BC Diode Reverse: Base-Collector junction reverse characteristics (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the Base-Collector junction reverse characteristics of BJT. Emitter and Substrate are opened.

[Device Under Test]

Bipolar transistor

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Lb: Base length

Wb: Base width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

IcLimit: Collector current compliance

Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]

Vb: Base voltage

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng: Minimum range for the base current measurement

CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]

Collector current Icollector

Base current Ibase

[User Function]

$IcPerArea = I_{collector} / Lb / Wb$

$IbPerArea = I_{base} / Lb / Wb$

[X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

Y1 axis: Collector current Icollector (LOG)

Y2 axis: Base current Ibase (LOG)



### 1.3 *BVcbo: Base-Collector junction breakdown voltage (A.01.20)*

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector current vs collector voltage characteristics, and extracts the Base-Collector junction breakdown voltage (BVcbo). Emitter and Substrate are opened.

[Device Under Test]

Bipolar transistor

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Lb: Base length

Wb: Base width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Ic@BVcbo: Collector current to decide the breakdown

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]

Vb: Base voltage

HoldTime: Hold time

DelayTime: Delay time

CollectorMinRng: Minimum range for the collector current measurement

BaseMinRng: Minimum range for the base current measurement

[Measurement Parameters]

Collector current Icollector

Base current Ibase

For the all terminals, the SMU current compliance is set to Ic@BVcbo\*1.1.

[User Function]

IcPerArea=Icollector/Lb/Wb

IbPerArea=Ibase/Lb/Wb

[Analysis Function]

BVcbo=@L1X (X interrupt of Line1)

[X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

Y1 axis: Collector current Icollector (LOG)

Y2 axis: Base current Ibase (LOG)

[Parameters Display Area]

Base-Collector junction breakdown voltage BVcbo

## **1 BJT**

[Auto Analysis]

Line1: Vertical line through Y1 data at  $I_{\text{collector}}=I_c@BV_{\text{cbo}}$

## 1.4 *BV<sub>cei</sub>: Emitter-Collector breakdown voltage (A.01.20)*

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the collector current vs collector voltage characteristics, and extracts the Emitter-Collector junction breakdown voltage (BV<sub>cei</sub>). Substrate is opened.

### [Device Under Test]

Bipolar transistor

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Ic@BV<sub>cei</sub>: Collector current to decide the breakdown

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

Base: SMU connected to Base terminal, constant current output

Ib: Base current

VbLimit: Base voltage compliance

Emitter: SMU connected to Emitter terminal, constant voltage output

### [Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

CollectorMinRng: Minimum range for the collector current measurement

### [Measurement Parameters]

Collector current Icollector

Emitter current Iemitter

Base voltage Vbase

For the all terminals, the SMU current compliance is set to Ic@BV<sub>cei</sub>\*1.1.

### [User Function]

IcPerArea=Icollector/Le/We

IePerArea=Iemitter/Le/We

### [Analysis Function]

BV<sub>cei</sub>=@L1X (X interrupt of Line1)

### [X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

Y1 axis: Collector current Icollector (LOG)

Y2 axis: Emitter current Iemitter (LOG)

## **1 BJT**

[Parameters Display Area]

Emitter-Collector junction breakdown voltage  $BV_{cei}$

[Auto Analysis]

Line1: Vertical line through Y1 data at  $I_{collector}=I_c@BV_{cei}$

## 1.5 *BV<sub>ceo</sub>: Emitter-Collector breakdown voltage, opened base (A.01.20)*

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the collector current vs collector voltage characteristics, and extracts the Emitter-Collector junction breakdown voltage (BV<sub>ceo</sub>). Base and Substrate are opened.

### [Device Under Test]

Bipolar transistor

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Ic@BV<sub>ceo</sub>: Collector current to decide the breakdown

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

Emitter: SMU connected to Emitter terminal, constant voltage output

### [Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

CollectorMinRng: Minimum range for the collector current measurement

### [Measurement Parameters]

Collector current Icollector

Emitter current Iemitter

For the all terminals, the SMU current compliance is set to Ic@BV<sub>ceo</sub>\*1.1.

### [User Function]

IcPerArea=Icollector/Le/We

IePerArea=Iemitter/Le/We

### [Analysis Function]

BV<sub>ceo</sub>=@L1X (X interrupt of Line1)

### [X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

Y1 axis: Collector current Icollector (LOG)

Y2 axis: Emitter current Iemitter (LOG)

### [Parameters Display Area]

Emitter-Collector junction breakdown voltage BV<sub>ceo</sub>

### [Auto Analysis]

## 1 BJT

Line1: Vertical line through Y1 data at  $I_{\text{collector}}=I_c@BV_{\text{ceo}}$

## 1.6 *BVebo: Emitter-Base breakdown voltage (A.01.20)*

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the emitter current vs emitter voltage characteristics, and extracts the Emitter-Base junction breakdown voltage (BV<sub>ebo</sub>). Collector and Substrate are opened.

### [Device Under Test]

Bipolar transistor

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Ie@BV<sub>ebo</sub>: Emitter current to decide the breakdown

Emitter: SMU connected to Emitter terminal, primary sweep voltage output

VeStart: Sweep start voltage for Emitter terminal

VeStop: Sweep stop voltage for Emitter terminal

VeStep: Sweep step voltage for Emitter terminal

Base: SMU connected to Base terminal, constant voltage output

### [Extended Test Parameters]

Vb: Base voltage

HoldTime: Hold time

DelayTime: Delay time

EmitterMinRng: Minimum range for the emitter current measurement

BaseMinRng: Minimum range for the base current measurement

### [Measurement Parameters]

Emitter current I<sub>emitter</sub>

Base current I<sub>base</sub>

For the all terminals, the SMU current compliance is set to Ie@BV<sub>ebo</sub>\*1.1.

### [User Function]

IePerArea=I<sub>emitter</sub>/Le/We

IbPerArea=I<sub>base</sub>/Le/We

### [Analysis Function]

BV<sub>ebo</sub>=@L1X (X interrupt of Line1)

### [X-Y Plot]

X axis: Emitter voltage V<sub>emitter</sub> (LINEAR)

Y1 axis: Emitter current I<sub>emitter</sub> (LOG)

Y2 axis: Base current I<sub>base</sub> (LOG)

### [Parameters Display Area]

Emitter-Base junction breakdown voltage BV<sub>ebo</sub>

## 1 BJT

[Auto Analysis]

Line1: Vertical line through Y1 data at  $I_{emitter}=I_e@BVebo$



## ***1.7 CS Diode Fwd: Collector-Substrate junction forward characteristics (A.01.20)***

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the Collector-Substrate junction forward characteristics of BJT. Base and Emitter are opened.

### [Device Under Test]

Bipolar transistor, 4 terminals

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Lc: Collector length

Wc: Collector width

Temp: Temperature

Imax: Current compliance

### [Test Parameters]

IntegTime: Integration time

Subs: SMU connected to Substrate, primary sweep voltage output

VsubsStart: Sweep start voltage for Substrate

VsubsStop: Sweep stop voltage for Substrate

VsubsStep: Sweep step voltage for Substrate

Collector: SMU connected to Collector terminal, constant voltage output

### [Extended Test Parameters]

Vc: Collector voltage

HoldTime: Hold time

DelayTime: Delay time

CollectorMinRng: Minimum range for the collector current measurement

SubsMinRng: Minimum range for the substrate current measurement

### [Measurement Parameters]

Substrate current Isubs

Collector current Icollector

### [User Function]

$IcPerArea = I_{collector} / Lc / Wc$

$IsubsPerArea = I_{subs} / Lc / Wc$

### [X-Y Plot]

X axis: Substrate voltage Vsubs (LINEAR)

Y1 axis: Substrate current Isubs (LINEAR)

Y2 axis: Substrate current Isubs (LOG)

Y3 axis: Collector current Icollector (LINEAR)

Y4 axis: Collector current Icollector (LOG)

## 1 BJT

### ***1.8 CS Diode Reverse: Collector-Substrate junction reverse characteristics (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the Collector-Substrate junction reverse characteristics of BJT. Base and Emitter are opened.

[Device Under Test]

Bipolar transistor, 4 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Lc: Collector length

Wc: Collector width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Subs: SMU connected to Substrate, primary sweep voltage output

VsubsStart: Sweep start voltage for Substrate

VsubsStop: Sweep stop voltage for Substrate

VsubsStep: Sweep step voltage for Substrate

IsubsLimit: Substrate current compliance

Collector: SMU connected to Collector terminal, constant voltage output

[Extended Test Parameters]

Vc: Collector voltage

HoldTime: Hold time

DelayTime: Delay time

CollectorMinRng: Minimum range for the collector current measurement

SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]

Substrate current Isubs

Collector current Icollector

[User Function]

$IcPerArea = I_{collector} / Lc / Wc$

$IsubsPerArea = Isubs / Lc / Wc$

[X-Y Plot]

X axis: Substrate voltage Vsubs (LINEAR)

Y1 axis: Substrate current Isubs (LOG)

Y2 axis: Collector current Icollector (LOG)

## 1.9 Ctc-Freq Log: Ctc-f characteristics (A.01.20)

### [Supported Analyzer]

B1500A

### [Description]

Measures BJT's characteristics of base-to-collector capacitance (Ctc, linear) vs frequency (f, log). The measurement frequency is 10 points per decade.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

Bipolar transistor, 4 terminals

Connect CMU High and CMU Low to the collector terminal and base terminal respectively. For the emitter and substrate, connect GNDU.

### [Required Modules and Accessories]

Agilent B1520A MFCMU 1 unit

### [Device Parameters]

Polarity: NPN (CMU forces the specified value) or PNP (CMU forces the negative specified value)

Le: Emitter length

We: Emitter width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Base: CMU connected between Base and Collector

FreqStart: Sweep start frequency

NoOfDecade: Number of decades for data collection

OscLevel: Measurement signal level

Vcb: Collector-Base voltage, constant voltage output

### [Extended Test Parameters]

G\_Min: Minimum transconductance value for graph

G\_Max: Maximum transconductance value for graph

Cp\_Min: Minimum capacitance value for graph

Cp\_Max: Maximum capacitance value for graph

### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

### [User Function]

Circular constant  $PI=3.141592653589$

Frequency  $Frequency=Freq$

Dissipation factor  $D=G/(2*PI*Freq*Cp)$

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Parallel resistance  $R_p=1/G$   
Series capacitance  $C_s=(1+D^2)*C_p$   
Reactance  $X=-1/(2*PI*Freq*C_s)$   
Series resistance  $R_s=D*abs(X)$   
Impedance  $Z=sqrt(R_s^2+X^2)$   
Phase Theta= $atan(X/R_s)$

### [X-Y Plot]

X axis: Frequency Freq (LOG)  
Y1 axis: Base-Collector capacitance (parallel capacitance)  $C_p$  (LINEAR)  
Y2 axis: Conductance G (LINEAR)

### [List Display]

Frequency Freq  
Base-Collector capacitance (parallel capacitance)  $C_p$   
Conductance G  
Series capacitance  $C_s$   
Series resistance  $R_s$   
Parallel resistance  $R_p$   
Dissipation factor D  
Reactance X  
Impedance Z  
Phase Theta  
Collector voltage  $V_{collector}$

### [Test Output: X-Y Graph]

X axis: Frequency FreqList (LOG)  
Y1 axis: Base-Collector capacitance (parallel capacitance)  $C_pList$  (LINEAR)  
Y2 axis: Conductance GList (LINEAR)

### [Test Output: List Display]

Frequency FreqList  
Base-Collector capacitance (parallel capacitance)  $C_pList$   
Conductance GList  
Series capacitance  $C_sList$   
Series resistance  $R_sList$   
Parallel resistance  $R_pList$   
Dissipation factor DList  
Reactance XList  
Impedance ZList  
Phase ThetaList  
Collector voltage  $V_{cList}$

## 1.10 Ctc-Vc: Ctc-Vcb characteristics (A.01.20)

### [Supported Analyzer]

B1500A

### [Description]

Measures the Base-Collector capacitance (Ctc), and plots the Ctc-Vcb characteristics.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

Bipolar transistor

Connect Base to the CMU Low, Collector to the CMU High, and the other terminals to the GNDU.

### [Device Parameters]

Polarity: NPN (CMU forces the specified value) or PNP (CMU forces the negative specified value).

Le: Emitter length

We: Emitter width

Lb: Base length

Wb: Base width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

Base: CMU connected between Base and Collector (CV sweep measurement)

VcbStart: DC bias start voltage

VcbStop: DC bias stop voltage

VcbStep: DC bias step voltage

### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

### [User Function]

$PI=3.141592653589$

$D=G/(2*PI*FREQ*Cp)$

$Rp=1/G$

$Cs=(1+D^2)*Cp$

$X=-1/(2*PI*FREQ*Cs)$

$Rs=D*abs(X)$

$Z=sqrt(Rs^2+X^2)$

## 1 BJT

Theta=atan(X/Rs)  
Vcb=Vcollector  
CtcPerArea=Cp/Lb/Wb

[Analysis Function]  
Cj0=@L1Y1 (Y interrupt of Line1)

[X-Y Graph]  
X axis: Base-Collector voltage Vcb (LINEAR)  
Y1 axis: Base-Collector capacitance (parallel capacitance) Cp (LINEAR)  
Y2 axis: Conductance G (LINEAR)

[List Display]  
Base-Collector voltage Vcb  
Base-Collector capacitance (parallel capacitance) Cp  
Conductance G  
Series capacitance Cs  
Series resistance Rs  
Parallel resistance Rp  
Dissipation factor D  
Reactance X  
Impedance Z  
Phase Theta

[Parameter Display Area]  
Zero bias capacitance Cj0

[Auto Analysis]  
Line1: Horizontal line through Y1 data at Vcb=0

## 1.11 Cte-Ve: Cte-Veb characteristics (A.01.20)

### [Supported Analyzer]

B1500A

### [Description]

Measures the Base-Emitter capacitance (Cte), and plots the Cte-Veb characteristics.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

Bipolar transistor

Connect Base to the CMU Low, Emitter to the CMU High, and the other terminals to the GNDU.

### [Device Parameters]

Polarity: NPN (CMU forces the specified value) or PNP (CMU forces the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

### [Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

Base: CMU connected between Base and Emitter (CV sweep measurement)

VebStart: DC bias start voltage

VebStop: DC bias stop voltage

VebStep: DC bias step voltage

### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

### [User Function]

$PI=3.141592653589$

$D=G/(2*PI*FREQ*Cp)$

$Rp=1/G$

$Cs=(1+D^2)*Cp$

$X=-1/(2*PI*FREQ*Cs)$

$Rs=D*abs(X)$

$Z=sqrt(Rs^2+X^2)$

$Theta=atan(X/Rs)$

$Veb=Vemitter$

$CtePerArea=Cp/Le/We$

## 1 BJT

### [Analysis Function]

Cj0=@L1Y1 (Y interrupt of Line1)

### [X-Y Graph]

X axis: Base-Emitter voltage Veb (LINEAR)

Y1 axis: Base-Emitter capacitance (parallel capacitance) Cp (LINEAR)

Y2 axis: Conductance G (LINEAR)

### [List Display]

Base-Emitter voltage Veb

Base-Emitter capacitance (parallel capacitance) Cp

Conductance G

Series capacitance Cs

Series resistance Rs

Parallel resistance Rp

Dissipation factor D

Reactance X

Impedance Z

Phase Theta

### [Parameter Display Area]

Zero bias capacitance Cj0

### [Auto Analysis]

Line1: Horizontal line through Y1 data at Veb=0



## 1.12 Cts: Cts-Vsc characteristics (A.01.20)

### [Supported Analyzer]

B1500A

### [Description]

Measures the Collector-Substrate capacitance (Cts), and plots the Cts-Vsc characteristics.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

Bipolar transistor

Connect Collector to the CMU Low, Substrate to the CMU High, and the other terminals to the GNDU.

### [Device Parameters]

Polarity: NPN (CMU forces the specified value) or PNP (CMU forces the negative specified value).

Le: Emitter length

We: Emitter width

Lc: Collector length

Wc: Collector width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

Subs: CMU connected between Collector and Substrate (CV sweep measurement)

VscStart: DC bias start voltage

VscStop: DC bias stop voltage

VscStep: DC bias step voltage

### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

### [User Function]

$PI=3.141592653589$

$D=G/(2*PI*FREQ*Cp)$

$Rp=1/G$

$Cs=(1+D^2)*Cp$

$X=-1/(2*PI*FREQ*Cs)$

$Rs=D*abs(X)$

$Z=sqrt(Rs^2+X^2)$

## 1 BJT

Theta=atan(X/Rs)  
Vsc=Vsubs  
CtsPerArea=Cp/Lc/Wc

[Analysis Function]  
Cj0=@L1Y1 (Y interrupt of Line1)

[X-Y Graph]  
X axis: Collector-Substrate voltage Vsc (LINEAR)  
Y1 axis: Collector-Substrate capacitance (parallel capacitance) Cp (LINEAR)  
Y2 axis: Conductance G (LINEAR)

[List Display]  
Collector-Substrate voltage Vsc  
Collector-Substrate capacitance (parallel capacitance) Cp  
Conductance G  
Series capacitance Cs  
Series resistance Rs  
Parallel resistance Rp  
Dissipation factor D  
Reactance X  
Impedance Z  
Phase Theta

[Parameter Display Area]  
Zero bias capacitance Cj0

[Auto Analysis]  
Line1: Horizontal line through Y1 data at Vsub(=Vsc)=0

### ***1.13 EB Diode Fwd: Emitter-Base junction forward characteristics (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the Emitter-Base junction forward characteristics of BJT. Collector and Substrate are opened.

[Device Under Test]

Bipolar transistor

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

Imax: Current compliance

[Test Parameters]

IntegTime: Integration time

Emitter: SMU connected to Emitter terminal, primary sweep voltage output

VeStart: Sweep start voltage for Emitter terminal

VeStop: Sweep stop voltage for Emitter terminal

VeStep: Sweep step voltage for Emitter terminal

Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]

Vb: Base voltage

HoldTime: Hold time

DelayTime: Delay time

EmitterMinRng: Minimum range for the emitter current measurement

BaseMinRng: Minimum range for the base current measurement

[Measurement Parameters]

Emitter current Iemitter

Base current Ibase

[User Function]

$I_{ePerArea} = I_{emitter} / Le / We$

$I_{bPerArea} = I_{base} / Le / We$

[X-Y Plot]

X axis: Emitter voltage Vemitter (LINEAR)

Y1 axis: Emitter current Iemitter (LINEAR)

Y2 axis: Emitter current Iemitter (LOG)

Y3 axis: Base current Ibase (LINEAR)

Y4 axis: Base current Ibase (LOG)

## 1 BJT

### ***1.14 EB Diode Rev: Emitter-Base junction reverse characteristics (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the Emitter-Base junction reverse characteristics of BJT. Collector and Substrate are opened.

[Device Under Test]

Bipolar transistor

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Emitter: SMU connected to Emitter terminal, primary sweep voltage output

VeStart: Sweep start voltage for Emitter terminal

VeStop: Sweep stop voltage for Emitter terminal

VeStep: Sweep step voltage for Emitter terminal

IeLimit: Emitter current compliance

Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]

Vb: Base voltage

HoldTime: Hold time

DelayTime: Delay time

EmitterMinRng: Minimum range for the emitter current measurement

BaseMinRng: Minimum range for the base current measurement

[Measurement Parameters]

Emitter current Iemitter

Base current Ibase

[User Function]

$I_{ePerArea} = I_{emitter} / Le / We$

$I_{bPerArea} = I_{base} / Le / We$

[X-Y Plot]

X axis: Emitter voltage Vemitter (LINEAR)

Y1 axis: Emitter current Iemitter (LOG)

Y2 axis: Base current Ibase (LOG)

### ***1.15 G-Plot ConstVce Pulse: Ic-Vb characteristics, Vce=const, SMU Pulse (A.01.11)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector current vs base voltage characteristics. The SMU pulse is used for the Collector voltage output.

[Device Under Test]

Bipolar transistor, 4 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

[Test Parameters]

Base: SMU connected to Base terminal, primary sweep voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Collector: SMU connected to Collector terminal, constant voltage output

Vc: Collector voltage

PulsePeriod: Pulse period

PulseWidth: Pulse width

BaseValue: Pulse base value

Emitter: SMU connected to Emitter terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

[Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Collector current Icollector

[User Function]

IcPerArea=Icollector/Le/We

[X-Y Plot]

X axis: Base voltage Vbase (LINEAR)

Y1 axis: Collector current Icollector (LINEAR)

## 1 BJT

### ***1.16 G-Plot ConstVce Pulse[3]: Ic-Vb characteristics, Vce=const, 3-terminal, SMU Pulse (A.01.11)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector current vs base voltage characteristics. The SMU pulse is used for the Collector voltage output.

[Device Under Test]

Bipolar transistor, 3 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

[Test Parameters]

Base: SMU connected to Base terminal, primary sweep voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Collector: SMU connected to Collector terminal, constant voltage output

Vc: Collector voltage

PulsePeriod: Pulse period

PulseWidth: Pulse width

BaseValue: Pulse base value

Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Collector current Icollector

[User Function]

IcPerArea=Icollector/Le/We

[X-Y Plot]

X axis: Base voltage Vbase (LINEAR)

Y1 axis: Collector current Icollector (LINEAR)

### ***1.17 G-Plot ConstVce: Gummel characteristics, Vce=constant (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector current vs base voltage characteristics and the base current vs base voltage characteristics, extracts the current amplification factor hfe, and plots the gummel characteristics.

[Device Under Test]

Bipolar transistor, 4 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

[Test Parameters]

IntegTime: Integration time

Base: SMU connected to Base terminal, primary sweep voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Collector: SMU connected to Collector terminal, constant voltage output

Vc: Collector voltage

Emitter: SMU connected to Emitter terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

[Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng: Minimum range for the base current measurement

CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]

Collector current Icollector

Base current Ibase

[User Function]

IbPerArea=Ibase/Le/We

IcPerArea=Icollector/Le/We

hfe=Icollector/Ibase

hfeMax=max(hfe)

[X-Y Plot]

X axis: Base voltage Vbase (LINEAR)

Y1 axis: Base current Ibase (LOG)

Y2 axis: Collector current Icollector (LOG)

Y3 axis: Current amplification factor hfe (LINEAR)

## 1 BJT

[Parameters Display Area]

Current amplification factor maximum value hfeMax



### ***1.18 G-Plot ConstVce[3]: Gummel characteristics, Vce=constant, 3-terminal (A.01.20)***

**[Supported Analyzer]**

B1500A, 4155B, 4155C, 4156B, 4156C

**[Description]**

Measures the collector current vs base voltage characteristics and the base current vs base voltage characteristics, extracts the current amplification factor hfe, and plots the gummel characteristics.

**[Device Under Test]**

Bipolar transistor, 3 terminals

**[Device Parameters]**

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

**[Test Parameters]**

IntegTime: Integration time

Base: SMU connected to Base terminal, primary sweep voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Collector: SMU connected to Collector terminal, constant voltage output

Vc: Collector voltage

Emitter: SMU connected to Emitter terminal, constant voltage output

**[Extended Test Parameters]**

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng: Minimum range for the base current measurement

CollectorMinRng: Minimum range for the collector current measurement

**[Measurement Parameters]**

Collector current Icollector

Base current Ibase

**[User Function]**

$IbPerArea = Ibase / Le / We$

$IcPerArea = Icollector / Le / We$

$hfe = Icollector / Ibase$

$hfeMax = \max(hfe)$

**[X-Y Plot]**

X axis: Base voltage Vbase (LINEAR)

Y1 axis: Base current Ibase (LOG)

Y2 axis: Collector current Icollector (LOG)

Y3 axis: Current amplification factor hfe (LINEAR)

## 1 BJT

[Parameters Display Area]

Current amplification factor maximum value hfeMax

***1.19 G-Plot  $V_{bc}=0V$  Pulse:  $I_c$ - $V_e$  characteristics,  $V_{bc}=0$ , SMU Pulse (A.01.11)*****[Supported Analyzer]**

B1500A, 4155B, 4155C, 4156B, 4156C

**[Description]**

Measures the collector current vs emitter voltage characteristics. The SMU pulse is used for the Emitter voltage output.

**[Device Under Test]**

Bipolar transistor, 4 terminals

**[Device Parameters]**

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

**[Test Parameters]**

Base: SMU connected to Base terminal, constant voltage output

Collector: SMU connected to Collector terminal, constant voltage output

Emitter: SMU connected to Emitter terminal, primary sweep voltage output

VeStart: Sweep start voltage for Emitter terminal

VeStop: Sweep stop voltage for Emitter terminal

VeStep: Sweep step voltage for Emitter terminal

PulsePeriod: Pulse period

PulseWidth: Pulse width

Subs: SMU connected to Substrate terminal, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

**[Extended Test Parameters]**

BaseValue: Pulse base value

Vb: Base voltage

Vc: Collector voltage

HoldTime: Hold time

DelayTime: Delay time

**[Measurement Parameters]**

Collector current Icollector

**[User Function]**

IcPerArea=Icollector/Le/We

**[X-Y Plot]**

X axis: Emitter voltage Vemitter (LINEAR)

Y1 axis: Collector current Icollector (LINEAR)

## 1 BJT

### ***1.20 G-Plot Vbc=0V Pulse[3]: Ic-Ve characteristics, Vbc=0, 3-terminal, SMU Pulse (A.01.11)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector current vs emitter voltage characteristics. The SMU pulse is used for the Emitter voltage output.

[Device Under Test]

Bipolar transistor, 3 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

[Test Parameters]

Base: SMU connected to Base terminal, constant voltage output

Collector: SMU connected to Collector terminal, constant voltage output

Emitter: SMU connected to Emitter terminal, primary sweep voltage output

VeStart: Sweep start voltage for Emitter terminal

VeStop: Sweep stop voltage for Emitter terminal

VeStep: Sweep step voltage for Emitter terminal

PulsePeriod: Pulse period

PulseWidth: Pulse width

[Extended Test Parameters]

BaseValue: Pulse base value

Vb: Base voltage

Vc: Collector voltage

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Collector current Icollector

[User Function]

IcPerArea=Icollector/Le/We

[X-Y Plot]

X axis: Emitter voltage Vemitter (LINEAR)

Y1 axis: Collector current Icollector (LINEAR)

## 1.21 G-Plot $V_{bc}=0V$ : Gummel characteristics, $V_{bc}=0$ (A.01.20)

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the collector current vs emitter voltage characteristics and the base current vs emitter voltage characteristics, extracts the current amplification factor  $h_{fe}$ , and plots the gummel characteristics.

### [Device Under Test]

Bipolar transistor, 4 terminals

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

### [Test Parameters]

IntegTime: Integration time

Base: SMU connected to Base terminal, constant voltage output

Collector: SMU connected to Collector terminal, constant voltage output

Emitter: SMU connected to Emitter terminal, primary sweep voltage output

VeStart: Sweep start voltage for Emitter terminal

VeStop: Sweep stop voltage for Emitter terminal

VeStep: Sweep step voltage for Emitter terminal

Subs: SMU connected to Substrate terminal, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

### [Extended Test Parameters]

Vb: Base voltage

Vc: Collector voltage

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng: Minimum range for the base current measurement

CollectorMinRng: Minimum range for the collector current measurement

### [Measurement Parameters]

Collector current Icollector

Base current Ibase

### [User Function]

IbPerArea=Ibase/Le/We

IcPerArea=Icollector/Le/We

$h_{fe}$ =Icollector/Ibase

$h_{feMax}$ =max( $h_{fe}$ )

### [X-Y Plot]

X axis: Emitter voltage Vemitter (LINEAR)

Y1 axis: Base current Ibase (LOG)

Y2 axis: Collector current Icollector (LOG)

Y3 axis: Current amplification factor  $h_{fe}$  (LINEAR)

## 1 BJT

[Parameters Display Area]

Current amplification factor maximum value hfeMax

## 1.22 G-Plot $V_{bc}=0V[3]$ : Gummel characteristics, $V_{bc}=0$ , 3-terminal (A.01.20)

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the collector current vs emitter voltage characteristics and the base current vs emitter voltage characteristics, extracts the current amplification factor  $h_{fe}$ , and plots the gummel characteristics.

### [Device Under Test]

Bipolar transistor, 3 terminals

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

### [Test Parameters]

IntegTime: Integration time

Base: SMU connected to Base terminal, constant voltage output

Collector: SMU connected to Collector terminal, constant voltage output

Emitter: SMU connected to Emitter terminal, primary sweep voltage output

VeStart: Sweep start voltage for Emitter terminal

VeStop: Sweep stop voltage for Emitter terminal

VeStep: Sweep step voltage for Emitter terminal

### [Extended Test Parameters]

Vb: Base voltage

Vc: Collector voltage

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng: Minimum range for the base current measurement

CollectorMinRng: Minimum range for the collector current measurement

### [Measurement Parameters]

Collector current Icollector

Base current Ibase

Emitter current Iemitter

### [User Function]

IbPerArea=Ibase/Le/We

IcPerArea=Icollector/Le/We

hfe=Icollector/Ibase

hfeMax=max(hfe)

### [X-Y Plot]

X axis: Emitter voltage Vemitter (LINEAR)

Y1 axis: Base current Ibase (LOG)

Y2 axis: Collector current Icollector (LOG)

Y3 axis: Current amplification factor hfe (LINEAR)

### [Parameters Display Area]

## **1 BJT**

Current amplification factor maximum value hfeMax



### ***1.23 hfe-Vbe ConstVce: hfe-Ic characteristics, Vce=constant (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector current vs base voltage characteristics and the base current vs base voltage characteristics, extracts the current amplification factor hfe, and plots the hfe-Ic characteristics.

[Device Under Test]

Bipolar transistor, 4 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

[Test Parameters]

IntegTime: Integration time

Base: SMU connected to Base terminal, primary sweep voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Collector: SMU connected to Collector terminal, constant voltage output

Vc: Collector voltage

Emitter: SMU connected to Emitter terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

[Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng: Minimum range for the base current measurement

CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]

Collector current Icollector

Base current Ibase

[User Function]

IbPerArea=Ibase/Le/We

IcPerArea=Icollector/Le/We

hfe=Icollector/Ibase

hfeMax=max(hfe)

[Analysis Function]

Ic@hfeMax=@L1X (X intercept of Line1)

[X-Y Plot]

X axis: Collector current Icollector (LOG)

## 1 BJT

Y1 axis: Current amplification factor hfe (LINEAR)

[Parameters Display Area]

Current amplification factor maximum value hfeMax

Collector current at hfeMax Ic@hfeMax

[Auto Analysis]

Line1: Vertical line through Y1 data at hfe=hfeMax

## 1.24 *hfe-Vbe Vbc=0V: hfe-Ic characteristics, Vbc=0 (A.01.20)*

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the collector current vs emitter voltage characteristics and the base current vs emitter voltage characteristics, extracts the current amplification factor  $h_{fe}$ , and plots the  $h_{fe}$ - $I_c$  characteristics.

### [Device Under Test]

Bipolar transistor, 4 terminals

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

### [Test Parameters]

IntegTime: Integration time

Base: SMU connected to Base terminal, constant voltage output

Collector: SMU connected to Collector terminal, constant voltage output

Emitter: SMU connected to Emitter terminal, primary sweep voltage output

VeStart: Sweep start voltage for Emitter terminal

VeStop: Sweep stop voltage for Emitter terminal

VeStep: Sweep step voltage for Emitter terminal

Subs: SMU connected to Substrate terminal, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

### [Extended Test Parameters]

Vb: Base voltage

Vc: Collector voltage

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng: Minimum range for the base current measurement

CollectorMinRng: Minimum range for the collector current measurement

### [Measurement Parameters]

Collector current Icollector

Base current Ibase

### [User Function]

IbPerArea=Ibase/Le/We

IcPerArea=Icollector/Le/We

$h_{fe}$ =Icollector/Ibase

$h_{feMax}$ =max( $h_{fe}$ )

### [Analysis Function]

Ic@ $h_{feMax}$ =@L1X (X intercept of Line1)

### [X-Y Plot]

X axis: Collector current Icollector (LOG)

## 1 BJT

Y1 axis: Current amplification factor hfe (LINEAR)

[Parameters Display Area]

Current amplification factor maximum value hfeMax

Collector current at hfeMax Ic@hfeMax

[Auto Analysis]

Line1: Vertical line through Y1 data at hfe=hfeMax

## 1.25 *Ic-Vc Ib: Ic-Vc characteristics, Ib sweep (A.01.20)*

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the collector current vs collector voltage characteristics.

### [Device Under Test]

Bipolar transistor, 4 terminals

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

### [Test Parameters]

IntegTime: Integration time

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

Base: SMU connected to Base terminal, secondary sweep voltage output

IbStart: Sweep start current for Base terminal

IbStop: Sweep stop current for Base terminal

IbStep: Sweep step current for Base terminal

Emitter: SMU connected to Emitter terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

### [Extended Test Parameters]

Ve: Emitter voltage

VbLimit: Base voltage compliance

HoldTime: Hold time

DelayTime: Delay time

CollectorMinRng: Minimum range for the collector current measurement

SubsMinRng: Minimum range for the substrate current measurement

### [Measurement Parameters]

Collector current Icollector

Base voltage Vbase

Substrate current Isubs

### [User Function]

$IbPerArea = I_{base}/Le/We$

$IcPerArea = I_{collector}/Le/We$

$hfe = I_{collector}/I_{base}$

$VA = I_{collector} * diff(V_{collector}, I_{collector}) - V_{collector}$

### [X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

## 1 BJT

Y1 axis: Collector current  $I_{\text{collector}}$  (LINEAR)

## ***1.26 Ic-Vc Ib[3]: Ic-Vc characteristics, 3-terminal, Ib sweep (A.01.20)***

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the collector current vs collector voltage characteristics.

### [Device Under Test]

Bipolar transistor, 3 terminals

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

### [Test Parameters]

IntegTime: Integration time

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

Base: SMU connected to Base terminal, secondary sweep voltage output

IbStart: Sweep start current for Base terminal

IbStop: Sweep stop current for Base terminal

IbStep: Sweep step current for Base terminal

Emitter: SMU connected to Emitter terminal, constant voltage output

### [Extended Test Parameters]

Ve: Emitter voltage

VbLimit: Base voltage compliance

HoldTime: Hold time

DelayTime: Delay time

CollectorMinRng: Minimum range for the collector current measurement

### [Measurement Parameters]

Collector current Icollector

Base voltage Vbase

### [User Function]

$IbPerArea = I_{base}/Le/We$

$IcPerArea = I_{collector}/Le/We$

$hfe = I_{collector}/I_{base}$

$VA = I_{collector} * \text{diff}(V_{collector}, I_{collector}) - V_{collector}$

### [X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

Y1 axis: Collector current Icollector (LINEAR)

## 1 BJT

### ***1.27 Ic-Vc Pulse Ib: Ic-Vc characteristics, Ib sweep, SMU Pulse (A.01.11)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector current vs collector voltage characteristics. The SMU pulse is used for the collector voltage output.

[Device Under Test]

Bipolar transistor, 4 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

[Test Parameters]

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

PulsePeriod: Pulse period

PulseWidth: Pulse width

Base: SMU connected to Base terminal, secondary sweep voltage output

IbStart: Sweep start current for Base terminal

IbStop: Sweep stop current for Base terminal

IbStep: Sweep step current for Base terminal

Emitter: SMU connected to Emitter terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

[Extended Test Parameters]

Ve: Emitter voltage

BaseValue: Pulse base value

VbLimit: Base voltage compliance

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Collector current Icollector

[User Function]

$IcPerArea = I_{collector} / Le / We$

$VA = I_{collector} * diff(V_{collector}, I_{collector}) - V_{collector}$

[X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

Y1 axis: Collector current Icollector (LINEAR)



## ***1.28 Ic-Vc Pulse Ib[3]: Ic-Vc characteristics, 3-terminal, Ib sweep, SMU Pulse (A.01.11)***

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the collector current vs collector voltage characteristics. The SMU pulse is used for the collector voltage output.

### [Device Under Test]

Bipolar transistor, 3 terminals

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

### [Test Parameters]

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

PulsePeriod: Pulse period

PulseWidth: Pulse width

Base: SMU connected to Base terminal, secondary sweep voltage output

IbStart: Sweep start current for Base terminal

IbStop: Sweep stop current for Base terminal

IbStep: Sweep step current for Base terminal

Emitter: SMU connected to Emitter terminal, constant voltage output

### [Extended Test Parameters]

Ve: Emitter voltage

BaseValue: Pulse base value

VbLimit: Base voltage compliance

HoldTime: Hold time

DelayTime: Delay time

### [Measurement Parameters]

Collector current Icollector

### [User Function]

$IcPerArea = I_{collector} / Le / We$

$VA = I_{collector} * \text{diff}(V_{collector}, I_{collector}) - V_{collector}$

### [X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

Y1 axis: Collector current Icollector (LINEAR)

## 1 BJT

### ***1.29 Ic-Vc Pulse Vb: Ic-Vc characteristics, Vb sweep, SMU Pulse (A.01.11)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector current vs collector voltage characteristics. The SMU pulse is used for the collector voltage output.

[Device Under Test]

Bipolar transistor, 4 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

[Test Parameters]

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

PulsePeriod: Pulse period

PulseWidth: Pulse width

Base: SMU connected to Base terminal, secondary sweep voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Emitter: SMU connected to Emitter terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

[Extended Test Parameters]

Ve: Emitter voltage

BaseValue: Pulse base value

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Collector current Icollector

[User Function]

$IcPerArea = I_{collector} / Le / We$

$VA = I_{collector} * diff(V_{collector}, I_{collector}) - V_{collector}$

[X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

Y1 axis: Collector current Icollector (LINEAR)

### ***1.30 Ic-Vc Pulse Vb[3]: Ic-Vc characteristics, 3-terminal, Vb sweep, SMU Pulse (A.01.11)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector current vs collector voltage characteristics. The SMU pulse is used for the collector voltage output.

[Device Under Test]

Bipolar transistor, 3 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

[Test Parameters]

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

PulsePeriod: Pulse period

PulseWidth: Pulse width

Base: SMU connected to Base terminal, secondary sweep voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]

Ve: Emitter voltage

BaseValue: Pulse base value

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Collector current Icollector

[User Function]

$IcPerArea = I_{collector} / Le / We$

$VA = I_{collector} * diff(V_{collector}, I_{collector}) - V_{collector}$

[X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

Y1 axis: Collector current Icollector (LINEAR)

## 1 BJT

### ***1.31 Ic-Vc Vb: Ic-Vc characteristics, Vb sweep (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector current vs collector voltage characteristics.

[Device Under Test]

Bipolar transistor, 4 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

[Test Parameters]

IntegTime: Integration time

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

Base: SMU connected to Base terminal, secondary sweep voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Emitter: SMU connected to Emitter terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

[Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

CollectorMinRng: Minimum range for the collector current measurement

BaseMinRng: Minimum range for the base current measurement

SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]

Collector current Icollector

Base current Ibase

[User Function]

$I_{bPerArea} = I_{base} / Le / We$

$I_{cPerArea} = I_{collector} / Le / We$

$h_{fe} = I_{collector} / I_{base}$

$VA = I_{collector} * \text{diff}(V_{collector}, I_{collector}) - V_{collector}$

[X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

Y1 axis: Collector current Icollector (LINEAR)

### ***1.32 Ic-Vc Vb[3]: Ic-Vc characteristics, 3-terminal, Vb sweep (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector current vs collector voltage characteristics.

[Device Under Test]

Bipolar transistor, 3 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

[Test Parameters]

IntegTime: Integration time

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

Base: SMU connected to Base terminal, secondary sweep voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

CollectorMinRng: Minimum range for the collector current measurement

BaseMinRng: Minimum range for the base current measurement

[Measurement Parameters]

Collector current Icollector

Base current Ibase

[User Function]

$I_{bPerArea} = I_{base} / L_e / W_e$

$I_{cPerArea} = I_{collector} / L_e / W_e$

$h_{fe} = I_{collector} / I_{base}$

$V_A = I_{collector} * \text{diff}(V_{collector}, I_{collector}) - V_{collector}$

[X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

Y1 axis: Collector current Icollector (LINEAR)

## 1 BJT

### ***1.33 Rb: Base resistance (flyback method, 4-terminal) (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the base voltage, collector voltage vs base current characteristics, and extracts the Base resistance in the high current region. Uses the flyback method.

[Device Under Test]

Bipolar transistor, 4 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Base: SMU connected to Base terminal, primary sweep current output

IbStart: Sweep start current for Base terminal

IbStop: Sweep stop current for Base terminal

IbStep: Sweep step current for Base terminal

VbLimit: Base voltage compliance

Collector: SMU connected to Collector terminal, constant current output

VcLimit: Collector voltage compliance

Emitter: SMU connected to Emitter terminal, constant voltage output

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

[Extended Test Parameters]

Ve: Emitter voltage

Ic: Collector current

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Base voltage Vbase

Collector voltage Vcollector

[User Function]

$Rb = (V_{base} - V_{collector}) / I_{base}$

$Inv\_I_{base} = 1 / I_{base}$

[X-Y Plot]

X axis: Inversed Base current  $Inv\_I_{base}$  (LINEAR)

Y1 axis: Base resistance  $Rb$  (LINEAR)

Y2 axis: Base current  $I_{base}$  (LINEAR)

### ***1.34 Re+Rc: Collector resistance (including Emitter resistance, flyback method, 4-terminal) (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector voltage vs collector current characteristics, and extracts the combined resistance of the collector resistance and the emitter resistance. Uses the flyback method.

[Device Under Test]

Bipolar transistor, 4 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Collector: SMU connected to Collector terminal, primary sweep current output

IcStart: Sweep start current for Collector terminal

IcStop: Sweep stop current for Collector terminal

IcStep: Sweep step current for Collector terminal

VcLimit: Collector voltage compliance

Base: SMU connected to Base terminal, constant current output

Ib: Base current

Emitter: SMU connected to Emitter terminal, constant voltage output

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

[Extended Test Parameters]

Ve: Emitter voltage

VbLimit: Base voltage compliance

HoldTime: Hold time

DelayTime: Delay time

EmitterMinRng: Minimum range for the emitter current measurement

SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]

Collector voltage Vcollector

[User Function]

IePerArea=Iemitter/Le/We

IbPerArea=Ibase/Le/We

IsPerArea=Isubs/Le/We

Rc\_Re=diff(Vcollector,Icollector)

[X-Y Plot]

X axis: Collector current Icollector (LINEAR)

Y1 axis: Collector voltage Vcollector (LINEAR)

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Y2 axis: Combined resistance of Collector resistance and Emitter resistance



### ***1.35 Re: Emitter resistance (flyback method, 4-terminal) (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector voltage vs base current characteristics, and extracts the Emitter resistance. Uses the flyback method.

[Device Under Test]

Bipolar transistor, 4 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Base: SMU connected to Base terminal, primary sweep current output

IbStart: Sweep start current for Base terminal

IbStop: Sweep stop current for Base terminal

IbStep: Sweep step current for Base terminal

VbLimit: Base voltage compliance

Collector: SMU connected to Collector terminal, constant current output

Ic: Collector current

VcLimit: Collector voltage compliance

Emitter: SMU connected to Emitter terminal, constant voltage output

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

[Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

EmitterMinRng: Minimum range for the emitter current measurement

SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]

Collector voltage Vcollector

[User Function]

Emitter current per emitter unit area  $I_{ePerArea} = I_{emitter} / Le / We$

Base current per emitter unit area  $I_{bPerArea} = I_{base} / Le / We$

Substrate current per emitter unit area  $I_{sPerArea} = I_{subs} / Le / We$

Emitter resistance  $Re = diff(V_{collector}, I_{base})$

[X-Y Plot]

X axis: Base current  $I_{base}$  (LINEAR)

Y1 axis: Collector voltage  $V_{collector}$  (LINEAR)

Y2 axis: Emitter resistance  $Re$  (LINEAR)

***1.36 Simple Gummel Plot: Evaluation of Gummel characteristics ( $V_{ce}=const$ )  
(A.01.10)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Application]

This application evaluates the Gummel characteristics of a NPN BJT with three terminals.

[Device Measured]

Single NPN device with three terminals.

[Parameter Setting]

Test parameters are specified for NPN device under test.

[Description of Measurement]

Base and Collector voltage, referenced to emitter voltage (0 V), sweeps synchronously in accordance with the test parameter setting.

Currents flowing in base and collector terminals are measured while the synchronized voltages sweep.

[Plot Display]

Collector and base currents in log scale, as well as the current amplification factor (Beta) in linear scale, are plotted versus base voltage on the linear horizontal axis.

### 1.37 Vbe-Le: hfe, Vbe-Le characteristics (A.01.20)

[Supported Analyzer]

B1500A

[Description]

Measures hfe (current amplification factor)-Vbe (voltage between base and emitter) characteristics of BJT with different Le (emitter length) and plots hfe and Vbe's dependency on Le.

[Device Under Test]

Bipolar transistor, 4 terminals

[Required Modules and Accessories]

Agilent B2200A or B2201A switching matrix 1 unit

GPIO cable

Connect B2200A/B2201A to B1500A with measurement cables and GPIO cable.

Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.

Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the B#/C#/E#/Sb# field (# is an integer from 1 to 12) of Test Parameters area.

The maximum number of devices connected at once depends on the number of matrix modules mounted on B2200A/B2201A. Maximum three devices can be connected to one module at once.

[Setting of Le#/B#/C#/E#/Sb# field (# is an integer from 1 to 12)]

Set one device for Le#(emitter length)/B#(base)/C#(collector)/E#(emitter)/Sb#(substrate).

Le1&lt;Le2&lt;Le3... must be satisfied. Enter zero for a field with no device.

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)

Temp: Temperature

IcMax: Collector current compliance

[Test Parameters]

IntegTime: Integration time

BaseSMU: SMU connected to Base terminal, constant voltage output

CollectorSMU: SMU connected to Collector terminal, constant voltage output

SbSMU: SMU connected to Substrate terminal, constant voltage output

EmitterSMU: SMU connected to Emitter terminal, primary sweep voltage output

VeStart: Sweep start voltage for Emitter terminal

VeStop: Sweep stop voltage for Emitter terminal

VeStep: Sweep step voltage for Emitter terminal

Vsubs: Substrate voltage

Ic@hfe: Collector current determining the hfe (Calculates hfe on a particular Ic)

Ie@Vbe: Emitter current determining the Vbe voltage (Calculates Vbe on a particular Ie)

We: Emitter width

Le1 - Le12: Emitter length

B1 - B12: SWM Pin Assign setting for Base of devices

C1 - C12: SWM Pin Assign setting for Collector of devices

E1 - E12: SWM Pin Assign setting for Emitter of devices

Sb1 - Sb12: SWM Pin Assign setting for Subs of devices

[Extended Test Parameters]

Vb: Base voltage

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Vc: Collector voltage  
IsubsLimit: Substrate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
hfe\_Min: Minimum hfe value for graph scale  
hfe\_Max: Maximum hfe value for graph scale  
BaseMinRng: Minimum range for base current measurement  
CollectorMinRng: Minimum range for collector current measurement  
EmitterMinRng: Minimum range for emitter current measurement

### [Measurement Parameters]

Collector current Icollector  
Base current Ibase  
Emitter current Iemitter

### [User Function]

$hfe = I_{collector} / I_{base}$

### [Analysis Function]

Ic@hfeVal=@L1X (X intercept of Line1)  
Ie@VbeVal=@L2X (X intercept of Line2)

### [Auto Analysis]

Line1: Vertical line for Y1 at  $hfe = Ic@hfe * Ratio$   
Line2: Vertical line for Y2 at  $V_{emitter} = Ie@Vbe * Ratio$

### [X-Y Plot]

X axis: Emitter voltage Vemitter (LINEAR)  
Y1 axis: Base current Ibase (LOG)  
Y2 axis: Current amplification factor hfe (LINEAR)  
Y3 axis: Collector current Icollector (LOG)  
Y4 axis: Emitter current Iemitter (LOG)

### [List Display]

Emitter voltage Vemitter  
Collector current Icollector  
Emitter current Iemitter  
Base current Ibase  
Current amplification factor hfe

### [Parameters Display Area]

Collector current determining the hfe (Calculates hfe on a particular Ic) Ic@hfeVal  
Emitter current determining the Vbe voltage (Calculates Vbe on a particular Ie) Ie@VbeVal

### [Test Output: X-Y Graph]

X axis: Emitter length (Le size) LeList (LINEAR)  
Y1 axis: Current amplification factor at Ic@hfe Ic@hfeList (LINEAR)  
Y2 axis: Emitter voltage at Ie@Vbe Ie@VbeList (LINEAR)

### [Test Output: List Display]

Emitter length (Le size) LeList  
Current amplification factor Ic@hfeList  
Emitter voltage Ie@VbeList

### 1.38 Vbe-We: hfe, Vbe-Le characteristics (A.01.20)

[Supported Analyzer]

B1500A

[Description]

Measures the hfe (current amplification factor) vs Vbe (voltage between base and emitter) characteristics of BJT with different We (emitter width) and plots hfe and Vbe's dependency on We.

[Device Under Test]

Bipolar transistor, 4 terminals

[Required Modules and Accessories]

Agilent B2200A or B2201A switching matrix 1 unit

GPIO cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIO cable.

Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.

Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the B#/C#/E#/Sb# field (# is an integer from 1 to 12) of Test Parameters area.

The maximum number of devices connected at once depends on the number of matrix modules mounted on B2200A/B2201A. Maximum three devices can be connected to one module at once.

[Setting of We#/B#/C#/E#/Sb# field (# is an integer from 1 to 12)]

Set one device for We#(emitter width)/B#(base)/C#(collector)/E#(emitter)/Sb#(sub strate).

We1<We2<We3... must be satisfied. Enter zero for a field with no device.

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)

Temp: Temperature

IcMax: Collector current compliance

[Test Parameters]

IntegTime: Integration time

BaseSMU: SMU connected to Base terminal, constant voltage output

CollectorSMU: SMU connected to Collector terminal, constant voltage output

SbSMU: SMU connected to Substrate terminal, constant voltage output

EmitterSMU: SMU connected to Emitter terminal, primary sweep voltage output

VeStart: Sweep start voltage for Emitter terminal

VeStop: Sweep stop voltage for Emitter terminal

VeStep: Sweep step voltage for Emitter terminal

Vsubs: Substrate voltage

Ic@hfe: Collector current determining the hfe (Calculates hfe on a particular Ic)

Ie@Vbe: Emitter current determining the Vbe voltage (Calculates Vbe on a particular Ie)

Le: Emitter length

We1 - We12: Emitter width

B1 - B12: SWM Pin Assign setting for Base of devices

C1 - C12: SWM Pin Assign setting for Collector of devices

E1 - E12: SWM Pin Assign setting for Emitter of devices

Sb1 - Sb12: SWM Pin Assign setting for Subs of devices

[Extended Test Parameters]

Vb: Base voltage

## 1 BJT

Vc: Collector voltage  
IsubsLimit: Substrate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
hfe\_Min: Minimum hfe value for graph scale  
hfe\_Max: Maximum hfe value for graph scale  
BaseMinRng: Minimum range for base current measurement  
CollectorMinRng: Minimum range for collector current measurement  
EmitterMinRng: Minimum range for emitter current measurement

### [Measurement Parameters]

Collector current Icollector  
Base current Ibase  
Emitter current Iemitter

### [User Function]

$hfe = I_{collector} / I_{base}$

### [Analysis Function]

Ic@hfeVal=@L1X (X intercept of Line1)  
Ie@VbeVal=@L2X (X intercept of Line2)

### [Auto Analysis]

Line1: Vertical line for Y1 at  $hfe = Ic@hfe * Ratio$   
Line2: Vertical line for Y2 at  $V_{emitter} = Ie@Vbe * Ratio$

### [X-Y Plot]

X axis: Emitter voltage Vemitter (LINEAR)  
Y1 axis: Base current Ibase (LOG)  
Y2 axis: Current amplification factor hfe (LINEAR)  
Y3 axis: Collector current Icollector (LOG)  
Y4 axis: Emitter current Iemitter (LOG)

### [List Display]

Emitter voltage Vemitter  
Collector current Icollector  
Emitter current Iemitter  
Base current Ibase  
Current amplification factor hfe

### [Parameters Display Area]

Collector current determining the hfe (Calculates hfe on a particular Ic) Ic@hfeVal  
Emitter current determining the Vbe voltage (Calculates Vbe on a particular Ie) Ie@VbeVal

### [Test Output: X-Y Graph]

X axis: Emitter width (We size) WeList (LINEAR)  
Y1 axis: Current amplification factor at Ic@hfe Ic@hfeList (LINEAR)  
Y2 axis: Emitter voltage at Ie@Vbe Ie@VbeList (LINEAR)

### [Test Output: List Display]

Emitter width (We size) WeList  
Current amplification factor Ic@hfeList  
Emitter voltage Ie@VbeList



## 2 CMOS

|                        |  |
|------------------------|--|
| 1. BVdss:              | Breakdown voltage between source and drain (A.01.20)                   |
| 2. BVgso:              | Breakdown voltage between gate and source (A.01.20)                    |
| 3. Cgb-AC Level:       | Cgb-Vosc characteristics (A.01.11)                                     |
| 4. Cgb-Freq Log:       | Cgb-f characteristics (A.01.20)  |
| 5. Cgb-Vg HighVoltage: | Cgb-Vg characteristics using SCUU (A.01.11)                            |
| 6. Cgb-Vg:             | Cgb-Vg characteristics (A.01.11)                                       |
| 7. Cgc-Freq Log:       | Cgc-f characteristics (A.01.20)  |
| 8. Cgc-Vg:             | Cgc-Vg characteristics (A.01.11)                                       |
| 9. Cgg-Freq Linear:    | Cgg-f characteristics (A.01.20)  |
| 10. Cgg-Freq Log:      | Cgg-f characteristics (A.01.20)  |
| 11. Cgg-Vg 2Freq:      | Cgg-Vg characteristics, 2-frequency method (A.01.11)                   |
| 12. Cgg-Vg:            | Cgg-Vg characteristics (A.01.11)                                       |
| 13. IdRdsGds:          | Drain resistance/conductance (A.01.20)                                 |
| 14. Id-Vd pulse:       | Id-Vd characteristics, SMU Pulse (A.01.11)                             |
| 15. Id-Vd pulse[3] :   | Id-Vd characteristics (3-terminal), SMU Pulse (A.01.11)                |
| 16. Id-Vd:             | Id-Vd Characteristics (A.01.20)  |
| 17. Id-Vd[3]:          | Id-Vd Characteristics (3-terminal) (A.01.20)                           |
| 18. Id-Vg pulse:       | Id-Vg characteristics, SMU Pulse (A.01.12)                             |
| 19. Id-Vg Vpulse[3]:   | Id-Vg characteristics (3-terminal), SMU Pulse (A.01.11)                |
| 20. Id-Vg:             | Id-Vg Characteristics (A.01.20)  |
| 21. Id-Vg[3]:          | Id-Vg Characteristics (3-terminal) (A.01.20)                           |
| 22. IonIoffSlope:      | On current, off current, and subthreshold slope (A.01.20)              |
| 23. Isub-Vg:           | Isub-Lg characteristics (A.01.20)                                      |
| 24. QSCV[4]            | C-Vg, Ig-Vg (4-terminal) (A.03.00)                                     |
| 25. QSCV C Offset Meas | Offset capacitance measurement   |
| 26. Simple Cgb :       | Evaluation of gate-substrate capacitance versus gate voltage (A.01.10) |
| 27. Simple Vth :       | Evaluation of Threshold Voltage (Vth) (A.01.10)                        |
| 28. Vth Const Id:      | Constant current Vth (A.01.20)   |
| 29. Vth gmMax :        | Linear region Vth (A.01.20)  |
| 30. VthAndCgg-Vg ASU:  | Cgg-Vg, Id-Vg, using ASU (A.01.20)                                     |
| 31. VthAndCgg-Vg SCUU: | Cgg-Vg, Id-Vg, using SCUU (A.01.20)                                    |
| 32. Vth-Lg:            | Vth-Lg characteristics (A.01.20)                                       |
| 33. Vth-Wg:            | Vth-Wg characteristics (A.01.20)                                       |



## 2.1 *BVdss: Breakdown voltage between source and drain (A.01.20)*

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the breakdown voltage between source and drain of MOSFET.

### [Device Under Test]

MOSFET, 4 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Is@BVdss: Source current to decide the breakdown

Drain: SMU connected to Drain, primary sweep voltage output

VdStart: Sweep start voltage for Drain

VdStop: Sweep stop voltage for Drain

VdStep: Sweep step voltage for Drain

Gate: SMU connected to Gate, constant voltage output

Subs: SMU connected to Substrate, constant voltage output

Source: SMU connected to Source, constant voltage output

### [Extended Test Parameters]

Vg: Gate voltage

Vs: Source voltage

Vsubs: Substrate voltage

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

GateMinRng: Minimum range for the gate current measurement

SubsMinRng: Minimum range for the substrate current measurement

### [Measurement Parameters]

Drain current Idrain

Source current Isource

Gate current Igate

Substrate current Isubs

For the source terminal, the SMU current compliance is set to Is@BVdss\*1.1.

### [User Function]

Source current per unit gate width  $I_{sourcePerWg} = I_{source}/Wg$

Drain current per unit gate width  $I_{drainPerWg} = I_{drain}/Wg$

### [Analysis Function]

$BVdss = @L1X$  (X intercept of Line1)

### [X-Y Plot]

X axis: Drain voltage Vdrain (LINEAR)

## 2 CMOS

Y1 axis: Drain current  $I_{\text{drain}}$  (LOG)

Y2 axis: Source current  $I_{\text{source}}$  (LOG)

[List Display]

Gate current  $I_{\text{gate}}$

Substrate current  $I_{\text{subs}}$

[Parameters Display Area]

Breakdown voltage between source and drain  $BV_{\text{dss}}$

[Auto Analysis]

Line1: Vertical line through Y2 data at  $I_{\text{source}}=I_{\text{s}}@BV_{\text{dss}}$

## 2.2 *BVgso: Breakdown voltage between gate and source (A.01.20)*

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the breakdown voltage between gate and source of MOSFET when drain is opened.

### [Device Under Test]

MOSFET, 4 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Is@BVgso: Source current to decide the breakdown

Gate: SMU connected to Gate, primary sweep voltage output

VgStart: Sweep start voltage for Gate

VgStop: Sweep stop voltage for Gate

VgStep: Sweep step voltage for Gate

Subs: SMU connected to Substrate, constant voltage output

Source: SMU connected to Source, constant voltage output

### [Extended Test Parameters]

Vsubs: Substrate voltage

Vs: Source voltage

HoldTime: Hold time

DelayTime: Delay time

GateMinRng: Minimum range for the gate current measurement

SourceMinRng: Minimum range for the source current measurement

SubsMinRng: Minimum range for the substrate current measurement

### [Measurement Parameters]

Source current Isource

Gate current Igate

Substrate current Isubs

For the all terminals, the SMU current compliance is set to Is@BVgso\*1.1.

### [User Function]

Gate current per Gate unit area IgatePerGateArea=Igate/Lg/Wg

### [Analysis Function]

BVgso=@L1X (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Source current Isource (LOG)

Y2 axis: Gate current Igate (LOG)

### [List Display]

## 2 CMOS

Substrate current  $I_{\text{subs}}$

[Parameters Display Area]

Breakdown voltage between gate and source  $BV_{\text{gso}}$

[Auto Analysis]

Line1: Vertical line through Y1 data at  $I_{\text{source}}=I_{\text{s}}@BV_{\text{gso}}$

## 2.3 Cgb-AC Level: Cgb-Vosc characteristics (A.01.11)

### [Supported Analyzer]

B1500A

### [Description]

Measures the Gate-Substrate capacitance (Cgs), and plots the Cgs-Vosc characteristics.

DC bias output is fixed at -Vgs. Oscillator level (Vosc) is changed from -OscStart to -OscStop in -OscStep steps. The CMU performs spot measurement of the parallel capacitance (Cp) and conductance (G) at each oscillator level.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

MOSFET, 4 terminals

Connect Gate to the CMU Low and Substrate to the CMU High. And connect Drain and Source to the specified SMU.

### [Device Parameters]

Polarity: Nch (CMU/SMU forces the specified value) or Pch (CMU/SMU forces the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

OscStart: Oscillator level (Vosc) start voltage

OscStop: Vosc stop voltage

OscStep: Vosc step voltage

FREQ: Measurement frequency

Gate: CMU connected between Gate and Substrate (CV spot measurement)

Vgs: DC bias. Gate-Substrate voltage.

Source: SMU connected to Source terminal (constant voltage output)

### [Extended Test Parameters]

Vs: Source voltage

IsLimit: Source current compliance

HoldTime: Hold time

DelayTime: Delay time

### [Measurement Parameters]

Parallel capacitance cp

Conductance g

### [User Function]

PI=3.141592653589

d=g/(2\*PI\*FREQ\*cp)

## 2 CMOS

```
rp=1/g
cs=(1+d^2)*cp
x=-1/(2*PI*FREQ*cs)
rs=d*abs(x)
z=sqrt(rs^2+x^2)
theta=atan(x/rs)
V_gs=-Vsubs
osclevel=OscLevel
```

### [Display Setup: X-Y Graph]

X axis: Oscillator level Vosc (LINEAR)  
Y1 axis: Gate-Substrate capacitance (parallel capacitance) cp (LINEAR)  
Y2 axis: Conductance g (LINEAR)

### [Display Setup: List Display]

Oscillator level osclevel  
Oscillator level Vosc  
Gate-Substrate capacitance (parallel capacitance) cp  
Conductance g  
Gate-Substrate voltage V\_gs

### [Test Output: X-Y Graph]

X axis: Oscillator level OSCLEVEL (LINEAR)  
Y1 axis: Gate-Substrate capacitance (parallel capacitance) Cp (LINEAR)  
Y2 axis: Conductance G (LINEAR)

### [Test Output: List Display]

Oscillator level OSCLEVEL  
Parallel capacitance Cp  
Conductance G  
Series capacitance Cs  
Series resistance Rs  
Parallel resistance Rp  
Dissipation factor D  
Reactance X  
Impedance Z  
Phase Th

## 2.4 Cgb-Freq Log: Cgb-f characteristics (A.01.20)

### [Supported Analyzer]

B1500A

### [Description]

Measures MOSFET's characteristics of gate-to-substrate capacitance (Cgb, linear) vs frequency (f, log). The measurement frequency is 10 points per decade.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

MOSFET, 4 terminals

Connect Gate to the CMU Low and Substrate to the CMU High. And connect Drain and Source to the GNDU.

### [Required Modules and Accessories]

Agilent B1520A MFCMU 1 unit

### [Device Parameters]

Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Gate: CMU connected to Gate terminal, CV sweep measurement

Source: SMU connected to Source terminal, constant voltage output

FreqStart: Sweep start frequency

NoOfDecade: Number of decades for data collection

OscLevel: Measurement signal level

Vgs: Voltage for Gate terminal, constant voltage output

### [Extended Test Parameters]

G\_Min: Minimum transconductance value for graph

G\_Max: Maximum transconductance value for graph

Cp\_Min: Minimum capacitance value for graph

Cp\_Max: Maximum capacitance value for graph

Vs: Voltage for Source terminal

IsLimit: Source current compliance

### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

### [User Function]

Circular constant PI=3.141592653589

## 2 CMOS

Frequency  $\text{Freq} = \text{Freq}$   
Dissipation factor  $D = G / (2 * \pi * \text{Freq} * C_p)$   
Parallel resistance  $R_p = 1 / G$   
Series capacitance  $C_s = (1 + D^2) * C_p$   
Reactance  $X = -1 / (2 * \pi * \text{Freq} * C_s)$   
Series resistance  $R_s = D * \text{abs}(X)$   
Impedance  $Z = \sqrt{R_s^2 + X^2}$   
Phase Theta  $= \text{atan}(X / R_s)$

### [X-Y Plot]

X axis: Frequency  $\text{Freq}$  (LOG)  
Y1 axis: Gate-Substrate capacitance (parallel capacitance)  $C_p$  (LINEAR)  
Y2 axis: Conductance  $G$  (LINEAR)

### [List Display]

Frequency  $\text{Freq}$   
Gate-Substrate capacitance  $C_p$   
Series capacitance  $C_s$   
Series resistance  $R_s$   
Parallel resistance  $R_p$   
Dissipation factor  $D$   
Reactance  $X$   
Impedance  $Z$   
Phase Theta  
Substrate voltage  $V_{\text{subs}}$   
Conductance  $G$

### [Test Output: X-Y Graph]

X axis: Frequency list  $\text{FreqList}$  (LOG)  
Y1 axis: Gate-Substrate capacitance (parallel capacitance) list  $C_p\text{List}$  (LINEAR)  
Y2 axis: Conductance list  $G\text{List}$  (LINEAR)

### [Test Output: List Display]

Frequency  $\text{FreqList}$   
Gate-Substrate capacitance (parallel capacitance)  $C_p\text{List}$   
Conductance  $G\text{List}$   
Series capacitance  $C_s\text{List}$   
Series resistance  $R_s\text{List}$   
Parallel resistance  $R_p\text{List}$   
Dissipation factor  $D\text{List}$   
Reactance  $X\text{List}$   
Impedance  $Z\text{List}$   
Phase ThetaList  
Substrate voltage  $V_{\text{subsList}}$



## 2.5 Cgb-Vg HighVoltage: Cgb-Vg characteristics using SCUU (A.01.11)

### [Supported Analyzer]

B1500A

### [Description]

Measures the Gate-Substrate capacitance (Cgs), and plots the Cgs-Vg characteristics.

DC bias output is performed from -VgsStart to -VgsStop in -VgsStep steps. The CMU performs spot measurement of the parallel capacitance (Cp) and conductance (G) at each bias output. SCUU enables the maximum 100 V DC bias.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

MOSFET, 4 terminals

Connect Gate and Substrate to the SCUU. And connect Drain and Source to the specified SMU.

### [Required Modules and Accessories]

One MFCMU module, three SMU modules, and a set of SCUU/GSWU are required.

SCUU connections: Output1: Substrate, Output2: Gate

Connection wire must be connected between the GSWU and the DUT interface High/Low guard lines.

### [Device Parameters]

Polarity: Nch (CMU/SMU forces the specified value) or Pch (CMU/SMU forces the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

Gate: CMU connected between Gate and Substrate (CV spot measurement)

VgsStart: DC bias start voltage

VgsStop: DC bias stop voltage

VgsStep: DC bias step voltage

Source: SMU connected to Source terminal (constant voltage output)

### [Extended Test Parameters]

IsLimit: Source current compliance

HoldTime: Hold time

DelayTime: Delay time

### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

## 2 CMOS

### [User Function]

```
PI=3.141592653589
D=G/(2*PI*FREQ*Cp)
Rp=1/G
Cs=(1+D^2)*Cp
X=-1/(2*PI*FREQ*Cs)
Rs=D*abs(X)
Z=sqrt(Rs^2+X^2)
Theta=atan(X/Rs)
Subs=Vstart*Polarity
```

### [Display Setup: X-Y Graph]

```
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate-Substrate capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)
```

### [Display Setup: List Display]

```
Substrate voltage Subs
Gate voltage Vgate
Gate-Substrate capacitance (parallel capacitance) Cp
```

### [Test Output: X-Y Graph]

```
X axis: Gate voltage VgList (LINEAR)
Y1 axis: Gate-Substrate capacitance (parallel capacitance) CpList (LINEAR)
Y2 axis: Conductance GList (LINEAR)
```

### [Test Output: List Display]

```
Gate voltage VgList
Gate-Substrate capacitance (parallel capacitance) CpList
Conductance GList
Series capacitance CsList
Series resistance RsList
Parallel resistance RpList
Dissipation factor DList
Reactance XList
Impedance ZList
Phase ThetaList
```

## 2.6 Cgb-Vg: Cgb-Vg characteristics (A.01.11)

### [Supported Analyzer]

B1500A

### [Description]

Measures the Gate-Substrate capacitance (Cgs), and plots the Cgs-Vg characteristics.

DC bias output is performed from -VgsStart to -VgsStop in -VgsStep steps. The CMU performs spot measurement of the parallel capacitance (Cp) and conductance (G) at each bias output.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

MOSFET, 4 terminals

Connect Gate to the CMU Low, and Substrate to the CMU High. And connect Drain and Source to the specified SMU.

### [Device Parameters]

Polarity: Nch (CMU/SMU forces the specified value) or Pch (CMU/SMU forces the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

Gate: CMU connected between Gate and substrate (CV spot measurement)

VgsStart: DC bias start voltage

VgsStop: DC bias stop voltage

VgsStep: DC bias step voltage

Source: SMU connected to Source terminal (constant voltage output)

### [Extended Test Parameters]

Vs: Source voltage

IsLimit: Source current compliance

HoldTime: Hold time

DelayTime: Delay time

### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

### [User Function]

PI=3.141592653589

D=G/(2\*PI\*FREQ\*Cp)

Rp=1/G

## 2 CMOS

$C_s = (1 + D^2) * C_p$   
 $X = -1 / (2 * \pi * \text{FREQ} * C_s)$   
 $R_s = D * \text{abs}(X)$   
 $Z = \sqrt{R_s^2 + X^2}$   
 $\text{Theta} = \text{atan}(X / R_s)$   
 $V_{\text{subs}} = V_{\text{start}} * \text{Polarity}$

[Display Setup: X-Y Graph]

X axis: Gate voltage  $V_{\text{gate}}$  (LINEAR)  
Y1 axis: Gate-Substrate capacitance (parallel capacitance)  $C_p$  (LINEAR)  
Y2 axis: Conductance  $G$  (LINEAR)

[Display Setup: List Display]

Substrate voltage  $V_{\text{subs}}$   
Source voltage  $V_{\text{source}}$   
Gate-Substrate capacitance (parallel capacitance)  $C_p$

[Test Output: X-Y Graph]

X axis: Gate voltage  $V_{\text{gList}}$  (LINEAR)  
Y1 axis: Gate-Substrate capacitance (parallel capacitance)  $C_{\text{pList}}$  (LINEAR)  
Y2 axis: Conductance  $G_{\text{List}}$  (LINEAR)

[Test Output: List Display]

Gate voltage  $V_{\text{gList}}$   
Gate-Substrate capacitance (parallel capacitance)  $C_{\text{pList}}$   
Conductance  $G_{\text{List}}$   
Series capacitance  $C_{\text{sList}}$   
Series resistance  $R_{\text{sList}}$   
Parallel resistance  $R_{\text{pList}}$   
Dissipation factor  $D_{\text{List}}$   
Reactance  $X_{\text{List}}$   
Impedance  $Z_{\text{List}}$   
Phase  $\text{ThetaList}$

## 2.7 Cgc-Freq Log: Cgc-f characteristics (A.01.20)

### [Supported Analyzer]

B1500A

### [Description]

Measures MOSFET's characteristics of gate-to-channel capacitance (Cgc, linear) vs frequency (f, log). The measurement frequency is 10 points per decade.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

MOSFET, 4 terminals

Connect Gate to the CMU Low, and Drain-Source to the CMU High. And connect Substrate to the GNDU.

### [Required Modules and Accessories]

Agilent B1520A MFCMU 1 unit

### [Device Parameters]

Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Gate: CMU connected to Gate terminal, CV sweep measurement

Subs: SMU connected to Substrate terminal, constant voltage output

FreqStart: Sweep start frequency

NoOfDecade: Number of decades for data collection

OscLevel: Measurement signal level

Vgs: Voltage for Gate terminal, constant voltage output

### [Extended Test Parameters]

Vsubs: Voltage for Substrate terminal

IsubsLimit: Substrate current compliance

G\_Min: Minimum transconductance value for graph

G\_Max: Maximum transconductance value for graph

Cp\_Min: Minimum capacitance value for graph

Cp\_Max: Maximum capacitance value for graph

### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

### [User Function]

Circular constant PI=3.141592653589

## 2 CMOS

Frequency  $\text{Freq} = \text{Freq}$   
Dissipation factor  $D = G / (2 * \pi * \text{Freq} * C_p)$   
Parallel resistance  $R_p = 1 / G$   
Series capacitance  $C_s = (1 + D^2) * C_p$   
Reactance  $X = -1 / (2 * \pi * \text{Freq} * C_s)$   
Series resistance  $R_s = D * \text{abs}(X)$   
Impedance  $Z = \sqrt{R_s^2 + X^2}$   
Phase  $\text{Theta} = \text{atan}(X / R_s)$

### [X-Y Plot]

X axis: Frequency  $\text{Freq}$  (LOG)  
Y1 axis: Gate-Channel capacitance (parallel capacitance)  $C_p$  (LINEAR)  
Y2 axis: Conductance  $G$  (LINEAR)

### [List Display]

Frequency  $\text{Freq}$   
Gate-Channel capacitance  $C_p$   
Gate voltage  $G$   
Series capacitance  $C_s$   
Series resistance  $R_s$   
Parallel resistance  $R_p$   
Dissipation factor  $D$   
Reactance  $X$   
Impedance  $Z$   
Phase  $\text{Theta}$   
Source voltage  $V_{\text{source}}$

### [Test Output: X-Y Graph]

X axis: Frequency list  $\text{FreqList}$  (LOG)  
Y1 axis: Gate-Channel capacitance (parallel capacitance) list  $C_p\text{List}$  (LINEAR)  
Y2 axis: Conductance list  $G\text{List}$  (LINEAR)

### [Test Output: List Display]

Frequency  $\text{FreqList}$   
Gate-Channel capacitance (parallel capacitance)  $C_p\text{List}$   
Conductance  $G\text{List}$   
Series capacitance  $C_s\text{List}$   
Series resistance  $R_s\text{List}$   
Parallel resistance  $R_p\text{List}$   
Dissipation factor  $D\text{List}$   
Reactance  $X\text{List}$   
Impedance  $Z\text{List}$   
Phase  $\text{ThetaList}$   
Source voltage  $V_{\text{sourceList}}$

## 2.8 Cgc-Vg: Cgc-Vg characteristics (A.01.11)

### [Supported Analyzer]

B1500A

### [Description]

Measures the Gate-Channel capacitance (Cgc), and plots the Cgc-Vg characteristics.

DC bias output is performed from -VgsStart to -VgsStop in -VgsStep steps. The CMU performs spot measurement of the parallel capacitance (Cp) and conductance (G) at each bias output. The substrate voltage is changed simultaneously with the DC bias output to keep the Channel-Substrate voltage constant. The SMU works as the constant voltage source and realizes the secondary sweep by repeating the output change every DC bias sweep.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

MOSFET, 4 terminals

Connect Gate to the CMU Low, and Drain-Source to the CMU High. And connect Substrate to the specified SMU.

### [Device Parameters]

Polarity: Nch (CMU/SMU forces the specified value) or Pch (CMU/SMU forces the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

Gate: CMU connected between Gate and channel (CV spot measurement)

VgsStart: DC bias start voltage (primary sweep)

VgsStop: DC bias stop voltage (primary sweep)

VgsStep: DC bias step voltage (primary sweep)

Subs: SMU connected to Substrate terminal (constant voltage output)

VbsStart: Substrate start voltage (secondary sweep)

VbsStop: Substrate stop voltage (secondary sweep)

VbsStep: Substrate step voltage (secondary sweep)

IsubsLimit: Substrate current compliance

### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

## 2 CMOS

### [User Function]

```
PI=3.141592653589
D=G/(2*PI*FREQ*Cp)
Rp=1/G
Cs=(1+D^2)*Cp
X=-1/(2*PI*FREQ*Cs)
Rs=D*abs(X)
Z=sqrt(Rs^2+X^2)
Theta=atan(X/Rs)
Vgate=-Vsource
```

### [Display Setup: X-Y Graph]

```
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate-Channel capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)
```

### [Display Setup: List Display]

```
Gate voltage Vgate
Substrate voltage Vsubs
Gate-Channel capacitance (parallel capacitance) Cp
Conductance G
```

### [Test Output: X-Y Graph]

```
X axis: Gate voltage VgList (LINEAR)
Y1 axis: Gate-Channel capacitance (parallel capacitance) CpList (LINEAR)
Y2 axis: Conductance GList (LINEAR)
```

### [Test Output: List Display]

```
Gate voltage VgList
Channel-Substrate voltage VbsList
Gate-Channel capacitance (parallel capacitance) CpList
Conductance GList
Series capacitance CsList
Series resistance RsList
Parallel resistance RpList
Dissipation factor DList
Reactance XList
Impedance ZList
Phase ThetaList
```



## 2.9 Cgg-Freq Linear: Cgg-f characteristics (A.01.20)

### [Supported Analyzer]

B1500A

### [Description]

Measures the gate capacitance (Cgg, linear) vs frequency (f, linear) characteristics of MOSFET.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

MOSFET, 4 terminals

Connect Gate to the CMU Low, and Drain-Source-Substrate to the CMU High.

### [Required Modules and Accessories]

Agilent B1520A MFCMU 1 unit

### [Device Parameters]

Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

FreqStart: Sweep start frequency

NoOfPoint: Number of measurement points

OscLevel: Measurement signal level

Gate: CMU connected to Gate terminal, CV sweep measurement

Vgs: Voltage for Gate terminal, constant voltage output

### [Extended Test Parameters]

G\_Min: Minimum transconductance value for graph

G\_Max: Maximum transconductance value for graph

Cp\_Min: Minimum capacitance value for graph

Cp\_Max: Maximum capacitance value for graph

### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

### [User Function]

Circular constant  $PI=3.141592653589$

Frequency  $Frequency=Freq$

Dissipation factor  $D=G/(2*PI*Freq*Cp)$

Parallel resistance  $Rp=1/G$

Series capacitance  $Cs=(1+D^2)*Cp$

## 2 CMOS

Reactance  $X = -1/(2\pi \text{Freq} \cdot C_s)$   
Series resistance  $R_s = D \cdot \text{abs}(X)$   
Impedance  $Z = \sqrt{R_s^2 + X^2}$   
Phase Theta  $= \text{atan}(X/R_s)$

### [X-Y Plot]

X axis: Frequency Freq (LINEAR)  
Y1 axis: Gate capacitance (parallel capacitance) Cp (LINEAR)  
Y2 axis: Conductance G (LINEAR)

### [List Display]

Frequency Freq  
Gate capacitance (parallel capacitance) Cp  
Conductance G  
Series capacitance Cs  
Series resistance Rs  
Parallel resistance Rp  
Dissipation factor D  
Reactance X  
Impedance Z  
Phase Theta  
Substrate voltage Vsubs

### [Test Output: X-Y Graph]

X axis: Frequency list FreqList (LINEAR)  
Y1 axis: Gate capacitance (parallel capacitance) list CpList (LINEAR)  
Y2 axis: Conductance list GList (LINEAR)

### [Test Output: List Display]

Frequency FreqList  
Gate capacitance (parallel capacitance) CpList  
Conductance GList  
Series capacitance CsList  
Series resistance RsList  
Parallel resistance RpList  
Dissipation factor DList  
Reactance XList  
Impedance ZList  
Phase ThetaList  
Substrate voltage VsubsList

## 2.10 Cgg-Freq Log: Cgg-f characteristics (A.01.20)

### [Supported Analyzer]

B1500A

### [Description]

Measures the gate capacitance (Cgg, linear) vs frequency (f, log) characteristics of MOSFET. The measurement frequency is 10 points per decade.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

MOSFET, 4 terminals

Connect Gate to the CMU Low, and Drain-Source-Substrate to the CMU High.

### [Required Modules and Accessories]

Agilent B1520A MFCMU 1 unit

### [Device Parameters]

Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

FreqStart: Sweep start frequency

NoOfDecade: Number of decades for data collection

OscLevel: Measurement signal level

Gate: CMU connected to Gate terminal, CV sweep measurement

Vgs: Voltage for Gate terminal, constant voltage output

### [Extended Test Parameters]

G\_Min: Minimum transconductance value for graph

G\_Max: Maximum transconductance value for graph

Cp\_Min: Minimum capacitance value for graph

Cp\_Max: Maximum capacitance value for graph

### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

### [User Function]

Circular constant  $PI=3.141592653589$

Frequency  $Frequency=Freq$

Dissipation factor  $D=G/(2*PI*Freq*Cp)$

Parallel resistance  $Rp=1/G$

## 2 CMOS

Series capacitance  $C_s = (1 + D^2) * C_p$   
Reactance  $X = -1 / (2 * \pi * \text{Freq} * C_s)$   
Series resistance  $R_s = D * \text{abs}(X)$   
Impedance  $Z = \sqrt{R_s^2 + X^2}$   
Phase Theta  $= \text{atan}(X / R_s)$

### [X-Y Plot]

X axis: Frequency Freq (LOG)  
Y1 axis: Gate capacitance (parallel capacitance)  $C_p$  (LINEAR)  
Y2 axis: Conductance G (LINEAR)

### [List Display]

Frequency Freq  
Gate capacitance (parallel capacitance)  $C_p$   
Conductance G  
Series capacitance  $C_s$   
Series resistance  $R_s$   
Parallel resistance  $R_p$   
Dissipation factor D  
Reactance X  
Impedance Z  
Phase Theta  
Substrate voltage  $V_{\text{subs}}$

### [Test Output: X-Y Graph]

X axis: Frequency measurement list FreqList (LOG)  
Y1 axis: Gate capacitance (parallel capacitance) list  $C_p\text{List}$  (LINEAR)  
Y2 axis: Conductance list GList (LINEAR)

### [Test Output: List Display]

Frequency FreqList  
Gate capacitance (parallel capacitance)  $C_p\text{List}$   
Conductance GList  
Series capacitance  $C_s\text{List}$   
Series resistance  $R_s\text{List}$   
Parallel resistance  $R_p\text{List}$   
Dissipation factor DList  
Reactance XList  
Impedance ZList  
Phase ThetaList  
Substrate voltage  $V_{\text{subsList}}$

## 2.11 Cgg-Vg 2Freq: Cgg-Vg characteristics, 2-frequency method (A.01.11)

### [Supported Analyzer]

B1500A

### [Description]

Measures the Gate capacitance (Cgg), and plots the Cgg-Vg characteristics. The Cgg value is given by the following formula. Then C1 and C2 are capacitance, D1 and C2 are dissipation factor measured at the frequency (f1 and f2).

$$C_{gg} = [f1^2 * C1 * (1 + D1^2) - f2^2 * C2 * (1 + D2^2)] / [f2^2 - f1^2]$$

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

MOSFET, 4 terminals

Connect Gate to the CMU Low, and the other terminals to the CMU High.

### [Device Parameters]

Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

OscLevel: Measurement signal level

FREQ1: Measurement frequency

FREQ2: Measurement frequency

Gate: CMU connected to Gate terminal (CV sweep measurement)

VgsStart: DC bias start voltage

VgsStop: DC bias stop voltage

VgsStep: DC bias step voltage

### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

### [Measurement Parameters]

Parallel capacitance Cp

Dissipation factor D

### [User Function]

Vgs=-Vsubs

### [Display Setup: X-Y Graph]

## 2 CMOS

X axis: Gate voltage Vgs (LINEAR)  
Y1 axis: Gate capacitance (parallel capacitance) Cp (LINEAR)  
Y2 axis: Dissipation factor D (LINEAR)

[Display Setup: List Display]

Gate voltage Vgs  
Gate capacitance (parallel capacitance) Cp  
Dissipation factor D

[Test Output: X-Y Graph]

X axis: Gate voltage VGS (LINEAR)  
Y1 axis: Gate capacitance (parallel capacitance) Cgg (LINEAR)  
Y2 axis: Gate capacitance (parallel capacitance) Cp\_FREQ1 (LINEAR)  
Y3 axis: Gate capacitance (parallel capacitance) Cp\_FREQ2 (LINEAR)

[Test Output: List Display]

Gate voltage VGS  
Gate capacitance (parallel capacitance) Cgg  
Gate capacitance (parallel capacitance) Cp\_FREQ1  
Gate capacitance (parallel capacitance) Cp\_FREQ2  
Dissipation factor D\_FREQ1  
Dissipation factor D\_FREQ2

## 2.12 Cgg-Vg: Cgg-Vg characteristics (A.01.11)

### [Supported Analyzer]

B1500A

### [Description]

Measures the Gate capacitance (Cgg), and plots the Cgg-Vg characteristics.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

MOSFET, 4 terminals

Connect Gate to the CMU Low, and the other terminals to the CMU High.

### [Device Parameters]

Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

Gate: CMU connected to Gate terminal (CV sweep measurement)

VgsStart: DC bias start voltage

VgsStop: DC bias stop voltage

VgsStep: DC bias step voltage

### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

### [User Function]

PI=3.141592653589

Dval=Gval/(2\*PI\*FREQ\*Cpval)

Rpval=1/Gval

Csval=(1+Dval^2)\*Cpval

Xval=-1/(2\*PI\*FREQ\*Csval)

Rsval=Dval\*abs(Xval)

Zval=sqrt(Rsval^2+Xval^2)

Thetaval=atan(Xval/Rsval)

Vgateval=-Vsubs

## 2 CMOS

### [X-Y Graph]

X axis: Gate voltage  $V_{gateval}$  (LINEAR)

Y1 axis: Gate capacitance (parallel capacitance)  $C_{pval}$  (LINEAR)

Y2 axis: Conductance  $G_{val}$  (LINEAR)

### [List Display]

Gate voltage  $V_{gateval}$

Gate capacitance (parallel capacitance)  $C_{pval}$

Conductance  $G_{val}$

Series capacitance  $C_{sval}$

Series resistance  $R_{sval}$

Parallel resistance  $R_{pval}$

Dissipation factor  $D_{val}$

Reactance  $X_{val}$

Impedance  $Z_{val}$

Phase  $\Theta_{thetaval}$



### 2.13 *IdRdsGds: Drain resistance/conductance (A.01.20)*

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Extracts the early voltage, drain resistance, and drain conductance from the drain current vs drain voltage characteristics of MOSFET.

[Device Under Test]

MOSFET, 4 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

IntegTime: Integration time

Drain: SMU connected to Drain terminal, primary sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

Gate: SMU connected to Gate terminal, secondary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

IsubsLimit: Substrate current compliance

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]

Drain current Idrain

Drain resistance Rds

Early voltage VA

Drain conductance gds

[User Function]

$gds = \text{diff}(\text{Idrain}, \text{Vdrain})$

$Rds = 1/gds$

$VA = Rds * (\text{abs}(\text{Idrain}) - \text{abs}(\text{Vdrain}))$

[X-Y Plot]

X axis: Drain voltage Vdrain (LINEAR)

## 2 CMOS

Y1 axis: Drain current  $I_{\text{drain}}$  (LINEAR)

Y2 axis: Drain resistance  $R_{\text{ds}}$  (LOG)

Y3 axis: Early voltage  $V_A$  (LINEAR)

[List Display]

Drain conductance  $g_{\text{ds}}$

## 2.14 Id-Vd pulse: Id-Vd characteristics, SMU Pulse (A.01.11)

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the drain current vs drain voltage characteristics of MOSFET. SMU pulse output is used for applying the drain voltage.

### [Device Under Test]

MOSFET, 4 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Drain: SMU connected to Drain terminal, primary sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

PulsePeriod: Pulse period

PulseWidth: Pulse width

Gate: SMU connected to Gate terminal, secondary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

IgLimit: Gate current compliance

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

Source: SMU connected to Source terminal, constant voltage output

### [Extended Test Parameters]

Vs: Source voltage

BaseValue: Pulse base voltage

HoldTime: Hold time

DelayTime: Delay time

### [Measurement Parameters]

Drain current Idrain

### [User Function]

IdrainPerWg: Drain current per unit gate width  $\text{IdrainPerWg} = \text{Idrain} / \text{Wg}$

### [X-Y Plot]

X axis: Drain voltage Vdrain (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

### [List Display]

Drain current per unit gate width IdrainPerWg

### ***2.15 Id-Vd pulse[3] : Id-Vd characteristics (3-terminal), SMU Pulse (A.01.11)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the drain current vs drain voltage characteristics of MOSFET. SMU pulse is used for the drain voltage output.

[Device Under Test]

MOSFET, 3 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

Drain: SMU connected to Drain terminal, primary sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

PulsePeriod: Pulse period

PulseWidth: Pulse width

Gate: SMU connected to Gate terminal, secondary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

IgLimit: Gate current compliance

Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]

Vs: Source voltage

BaseValue: Pulse base voltage

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Drain current Idrain

[User Function]

IdrainPerWg: Drain current per unit gate width  $\text{IdrainPerWg} = \text{Idrain} / \text{Wg}$

[X-Y Plot]

X axis: Drain voltage Vdrain (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

[List Display]

Drain current per unit gate width IdrainPerWg

## 2.16 Id-Vd: Id-Vd Characteristics (A.01.20)

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the drain current vs drain voltage characteristics of MOSFET.

### [Device Under Test]

MOSFET, 4 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Drain: SMU connected to Drain terminal, primary sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

Gate: SMU connected to Gate terminal, secondary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

Source: SMU connected to Source terminal, constant voltage output

### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

IsubsLimit: Substrate current compliance

IntegTime: Integration time

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [User Function]

IdrainPerWg: Drain current per unit gate width  $\text{IdrainPerWg} = \text{Idrain} / \text{Wg}$

### [X-Y Plot]

X axis: Drain voltage Vdrain (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

### [List Display]

Drain current per unit gate width IdrainPerWg

## 2 CMOS

### **2.17 Id-Vd[3]: Id-Vd Characteristics (3-terminal) (A.01.20)**

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the drain current vs drain voltage characteristics of MOSFET.

[Device Under Test]

MOSFET, 3 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

Drain: SMU connected to Drain terminal, primary sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

Gate: SMU connected to Gate terminal, secondary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

IntegTime: Integration time

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]

Drain current Idrain

[User Function]

IdrainPerWg: Drain current per unit gate width  $\text{IdrainPerWg} = \text{Idrain} / \text{Wg}$

[X-Y Plot]

X axis: Drain voltage Vdrain (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

[List Display]

Drain current per unit gate width IdrainPerWg

## 2.18 Id-Vg pulse: Id-Vg characteristics, SMU Pulse (A.01.12)

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the drain current vs gate voltage characteristics of MOSFET by using SMU pulse.

### [Device Under Test]

MOSFET, 4 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Drain: SMU connected to Drain terminal, constant voltage output

Vd: Drain voltage

PulsePeriod: Pulse period

PulseWidth: Pulse width

Subs: SMU connected to Substrate, secondary sweep voltage output

VsubsStart: Sweep start voltage for Substrate terminal

VsubsStop: Sweep stop voltage for Substrate terminal

VsubsStep: Sweep step voltage for Substrate terminal

Source: SMU connected to Source terminal, constant voltage output

### [Extended Test Parameters]

Vs: Source voltage

BaseValue: Pulse base voltage

IgLimit: Gate current compliance

IsubsLimit: Substrate current compliance

HoldTime: Hold time

DelayTime: Delay time

### [Measurement Parameters]

Drain current Idrain

### [User Function]

IdrainPerWg: Drain current per unit gate width  $\text{IdrainPerWg} = \text{Idrain} / \text{Wg}$

gm: Transconductance  $\text{gm} = \text{diff}(\text{Idrain}, \text{Vgate})$

gmPerWg: Transconductance per unit gate width  $\text{gmPerWg} = \text{diff}(\text{IdrainPerWg}, \text{Vgate})$

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Transconductance gm (LINEAR)

## 2 CMOS

[List Display]

Drain current per unit gate width  $I_{\text{drainPerWg}}$

Transconductance per unit gate width  $g_{\text{mPerWg}}$



## 2.19 Id-Vg Vpulse[3]: Id-Vg characteristics (3-terminal), SMU Pulse (A.01.11)

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the drain current vs gate voltage characteristics of MOSFET.

### [Device Under Test]

MOSFET, 3 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Drain: SMU connected to Drain terminal, secondary sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

PulsePeriod: Pulse period

PulseWidth: Pulse width

Source: SMU connected to Source terminal, constant voltage output

### [Extended Test Parameters]

Vs: Source voltage

BaseValue: Pulse base voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

### [Measurement Parameters]

Drain current Idrain

### [User Function]

IdrainPerWg: Drain current per unit gate width  $\text{IdrainPerWg} = \text{Idrain} / \text{Wg}$

gm: Transconductance  $\text{gm} = \text{diff}(\text{Idrain}, \text{Vgate})$

gmPerWg: Transconductance per unit gate width  $\text{gmPerWg} = \text{diff}(\text{IdrainPerWg}, \text{Vgate})$

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Transconductance gm (LINEAR)

### [List Display]

Drain current per unit gate width IdrainPerWg

Transconductance per unit gate width gmPerWg

### 2.20 Id-Vg: Id-Vg Characteristics (A.01.20)

#### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

#### [Description]

Measures the drain current vs gate voltage characteristics of MOSFET.

#### [Device Under Test]

MOSFET, 4 terminals

#### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

#### [Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Drain: SMU connected to Drain terminal, constant voltage output

Vd: Drain voltage

Subs: SMU connected to Substrate, secondary sweep voltage output

VsubsStart: Sweep start voltage for Substrate terminal

VsubsStop: Sweep stop voltage for Substrate terminal

VsubsStep: Sweep step voltage for Substrate terminal

Source: SMU connected to Source terminal, constant voltage output

#### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

IsubsLimit: Substrate current compliance

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Measurement minimum range of drain current

SubsMinRng: Measurement minimum range of substrate current

#### [Measurement Parameters]

Drain current Idrain

Substrate current Isubs

#### [User Function]

IdrainPerWg: Drain current per unit gate width  $\text{IdrainPerWg} = \text{Idrain} / \text{Wg}$

IsubsPerWg: Substrate current per unit gate width  $\text{IsubsPerWg} = \text{Isubs} / \text{Wg}$

gm: Transconductance  $\text{gm} = \text{diff}(\text{Idrain}, \text{Vgate})$

gmPerWg: Transconductance per unit gate width  $\text{gmPerWg} = \text{diff}(\text{IdrainPerWg}, \text{Vgate})$

#### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current  $I_{\text{drain}}$  (LOG)

Y3 axis: Substrate current  $I_{\text{subs}}$  (LINEAR)

Y4 axis: Substrate current  $I_{\text{subs}}$  (LOG)

[List Display]

Drain current per unit gate width  $I_{\text{drainPerWg}}$

Substrate current per unit gate width  $I_{\text{subsPerWg}}$

Transconductance  $g_m$

Transconductance per unit gate width  $g_{m\text{PerWg}}$

## 2 CMOS

### 2.21 *Id-Vg[3]: Id-Vg Characteristics (3-terminal) (A.01.20)*

#### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

#### [Description]

Measures the drain current vs gate voltage characteristics of MOSFET.

#### [Device Under Test]

MOSFET, 3 terminals

#### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

#### [Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Drain: SMU connected to Drain terminal, secondary sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

Source: SMU connected to Source terminal, constant voltage output

#### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

#### [Measurement Parameters]

Drain current Idrain

#### [User Function]

IdrainPerWg: Drain current per unit gate width  $\text{IdrainPerWg} = \text{Idrain} / \text{Wg}$

gm: Transconductance  $\text{gm} = \text{diff}(\text{Idrain}, \text{Vgate})$

gmPerWg: Transconductance per unit gate width  $\text{gmPerWg} = \text{diff}(\text{IdrainPerWg}, \text{Vgate})$

#### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

#### [List Display]

Drain current per unit gate width IdrainPerWg

Transconductance gm

Transconductance per unit gate width gmPerWg

## 2.22 IonIoffSlope: On current, off current, and subthreshold slope (A.01.20)

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Extracts the on current, off current, and subthreshold slope from the Id-Vg characteristics.

### [Device Under Test]

MOSFET, 4 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal,  $V_{gStart} < 0$

VgStop: Sweep stop voltage for Gate terminal,  $V_{gStop} = V_d$

VgStep: Sweep step voltage for Gate terminal

Drain: SMU connected to Drain terminal, constant voltage output

Vd: Drain voltage

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

Source: SMU connected to Source terminal, constant voltage output

### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

IsubsLimit: Substrate current compliance

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [User Function]

$Slope = 1 / \text{diff}(\text{Igt}(\text{Idrain}), V_{gate})$

$SlopeMin = \min(\text{abs}(Slope))$

### [Analysis Function]

$I_{on} = @L1Y1$  (Y1 intercept of Line1)

$I_{off} = @L2Y1$  (Y1 intercept of Line2)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LOG)

Y2 axis: Slope (LINEAR)

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### [Parameters Display Area]

SlopeMin: minimum Slope value

Ion: on current (drain current at  $V_g = V_{gStop}$ )

Ioff: off current (drain current at  $V_g = 0$ )

### [Auto Analysis]

Line1: Horizontal line through the Y1 data at  $V_{gate} = V_d (= V_{gStop})$

Line2: Horizontal line through the Y1 data at  $V_{gate} = 0$

Marker: Point of  $Slope = SlopeMin$

## 2.23 *Isub-Vg: Isub-Lg characteristics (A.01.20)*

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the substrate current vs gate voltage characteristics of MOSFET.

### [Device Under Test]

MOSFET, 4 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature (deg)

### [Test Parameters]

IntegTime: Integration time (SHORT, MEDIUM, LONG) default: MEDIUM

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, secondary sweep voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

Vsubs: Substrate terminal voltage

IgLimit: Gate current compliance

IdLimit: Drain current compliance

IsubsLimit: Substrate current compliance

Vs: Source terminal voltage

DrainMinRng: Minimum range for drain current measurement

SubsMinRng: Minimum range for substrate current measurement

GateMinRng: Minimum range for gate current measurement

### [Measurement Parameters]

Substrate current Isubs

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Substrate current Isubs (LOG)

### [List Display]

Gate voltage Vgate

Substrate current Isubs

Drain current Idrain

Gate current Igate

### 2.24 QSCV[4]: C-Vg, Ig-Vg (4-terminal) (A.03.00)

#### [Supported Analyzer]

B1500A

#### [Description]

Measures the oxide film capacitance of a MOSFET by using the quasi-static CV method, and plots the C-V characteristics.

To obtain the measurement data after the capacitance offset cancel, perform the QSCV C Offset Meas application test before this test.

#### [Device Under Test]

MOSFET, 4 terminals

#### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature

#### [Test Parameters]

Source: SMU connected to Source terminal, constant voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Gate: SMU connected to Gate terminal, primary sweep (QSCV) voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

IMeasSMU: SMU to measure current and capacitance, connected to Gate terminal or Substrate terminal

Vstart: Sweep start voltage

Vstop: Sweep stop voltage

Vstep: Sweep step voltage

QSCVMeasV: QSCV measurement voltage

I\_Comp: Current compliance

LeakCompen: Leakage current compensation on/off

MeasRange: Current measurement range used for the QSCV measurement, fixed range

Integ\_C: Integration time for the capacitance measurement

Integ\_L: Integration time for the leakage current measurement

HoldTime: Hold time

DelayTime: Delay time

IOffsetCancel: QSCV smart operation enable/disable

IOffsetSink: SMU to perform QSCV smart operation, connected to terminal which connected to IMeasSMU

QSCV smart operation is effective for QSCV measurements with a large leakage current. The SMU set as the IOffsetSink performs the current force operation to minimize the measurement error caused by an offset current.

#### [Extended Test Parameters]

StepDelay: Step delay time

OutputRange: Ranging type for voltage output

SwpMode: Sweep mode

VCompSinkSMU: Voltage compliance of SMU for QSCV smart operation

Cmin: Minimum capacitance value for graph

Cmax: Maximum capacitance value for graph

IgMin: Minimum leakage current value for graph

IgMax: Maximum leakage current value for graph

#### [Measurement parameters]



Capacitance C  
Leakage current IgLeak

[X-Y Graph]  
X axis: Gate Voltage Vg (LINEAR)  
Y1 axis: Capacitance C (LINEAR)  
Y2 axis: Leakage current Ig (LINEAR)

[List Display]  
Gate voltage Vg  
Capacitance C  
Leakage current Ig

## 2 CMOS

### ***2.25 QSCV C Offset Meas: Offset capacitance measurement (A.03.00)***

[Supported Analyzer]

B1500A

[Description]

Measures the offset capacitance of the cables and DUT interface by using the QSCV method when measurement terminals are open.

[Device Under Test]

MOS capacitance, 2 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature

[Test Parameters]

IMeasSMU: SMU to measure current and capacitance, connected to Gate terminal or Substrate terminal

MeasRange: Current measurement range used for the QSCV measurement, fixed range

Integ\_C: Integration time for the capacitance measurement

Integ\_L: Integration time for the leakage current measurement

HoldTime: Hold time

DelayTime: Delay time

[Extended Test Parameters]

StepDelay: Step delay time

[Measurement parameters]

Capacitance C

[List Display]

Capacitance C

## ***2.26 Simple C<sub>gb</sub> : Evaluation of gate-substrate capacitance versus gate voltage (A.01.10)***

[Supported Analyzer]  
B1500A

### [Application]

This application evaluates the gate-substrate capacitance of an Nch MOSFET.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Measured]

Single device with four terminals.

### [Parameter Setting]

Test parameters are specified for NMOS device under test.

Swept bias voltage parameters are specified by the gate voltage referenced to the source voltage (V<sub>gs</sub>).

### [Description of Measurement]

Gate voltage (V<sub>gs</sub>) sweeps in accordance with the test parameter setting.

Gate capacitances are measured with Cp-G model applied while the bias voltage sweeps.

### [Plot Display]

Measured gate capacitances in linear scale are plotted versus substrate voltage on the linear horizontal axis.

### ***2.27 Simple Vth : Evaluation of Threshold Voltage (Vth) (A.01.10)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Application]

This application evaluates the threshold voltage (Vth) of a Nch MOSFET.

[Device Measured]

Single device with four terminals.

[Parameter Setting]

Test parameters are specified for NMOS device under test.

Swept bias voltage parameters are specified by the gate voltage referenced to the source voltage (Vg).

[Description of Measurement]

Gate voltage (Vg) sweeps in accordance with the test parameter setting.

Currents flowing in drain terminal are measured while the gate voltage sweeps.

[Plot Display]

Measured drain currents and transconductance in linear scale are plotted versus gate voltage on the linear horizontal axis.

Maximum transconductance value (Gmmax) and threshold voltage (Vth) are extracted from the measurement data, then displayed in the parameters display area.

## 2.28 *Vth Const Id: Constant current Vth (A.01.20)*

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the drain current vs gate voltage characteristics, and extracts the threshold voltage ( $V_{th}$ ) by using the constant current method.

### [Device Under Test]

MOSFET, 4 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

IntegTime: Integration time

Id@Vth: Drain current to decide the  $V_{th}$

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Drain: SMU connected to Drain terminal, constant voltage output

Vd: Drain voltage

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

Source: SMU connected to Source terminal, constant voltage output

### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

IsubsLimit: Substrate current compliance

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [User Function]

gm=diff(Idrain,Vgate)

### [Analysis Function]

Vth=@L1X (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

## 2 CMOS

[List Display]

Transconductance gm

[Parameters Display Area]

Threshold voltage Vth

[Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

## 2.29 *Vth gmMax : Linear region Vth (A.01.20)*

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Extracts the threshold voltage ( $V_{th}$ ) by using the extrapolation method for the linear region of the drain current vs gate voltage characteristics.

### [Device Under Test]

MOSFET, 4 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Drain: SMU connected to Drain terminal, constant voltage output

Vd: Drain voltage

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

Source: SMU connected to Source terminal, constant voltage output

### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

IsubsLimit: Substrate current compliance

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [User Function]

$gm = \text{diff}(\text{Idrain}, V_{gate})$

### [Analysis Function]

$gmMax = \max(gm)$

$V_{on} = @L1X$  (X intercept of Line1)

$V_{th} = V_{on} - V_d/2$

$V_{th}$  is given by the following formula.

$V_{th} = V_g(gmMax) - I_d(gmMax)/gmMax$

$V_d/2$  is necessary to compensate the secondary term of  $V_d$  in theory.

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### [X-Y Plot]

X axis: Gate voltage  $V_{gate}$  (LINEAR)

Y1 axis: Drain current  $I_{drain}$  (LINEAR)

Y2 axis: Transconductance  $g_m$  (LINEAR)

Y3 axis: Drain current  $I_{drain}$  (LOG)

### [Parameters Display Area]

Threshold voltage  $V_{th}$

Maximum  $g_m$  value  $g_{mMax}$

### [Auto Analysis]

Line1: Tangent line for Y1 at  $g_m=g_{mMax}$



### 2.30 *VthAndCgg-Vg ASU: Cgg-Vg, Id-Vg, using ASU (A.01.20)*

[Supported Analyzer]

B1500A

[Description]

Measures the gate capacitance vs gate voltage characteristics, the drain current vs gate voltage measurement by using one MFCMU, two sets of HRSMU/ASU, and one SMU.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]

MOSFET, 4 terminals

[Required Modules and Accessories]

One MFCMU module, two sets of HRSMU/ASU, and one SMU module are required.

ASU#1 connections: Output: Gate, SMU: HRSMU, AUX: MFCMU Low

ASU#2 connections for Cgg-Vg: Output: other 3 terminals, SMU: HRSMU, AUX: MFCMU High

ASU#2 connections for Id-Vg: Output: Source and Substrate, SMU: HRSMU, AUX: MFCMU High

Connection wire must be connected between the CMU Return terminals of ASUs.

Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]

Polarity: Nch (CMU/SMU forces the specified value) or Pch (CMU/SMU forces the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

[Test Parameters]

GateAC: CMU connected to Gate terminal (CV sweep measurement)

GateDC: SMU connected to Gate terminal (primary sweep, voltage output)

SourceDC: SMU connected to Source and Substrate terminal (constant voltage output)

Drain: SMU connected to Drain terminal (constant voltage output)

IntegTime: Integration time

IgLimit: Gate current compliance

IdLimit: Drain current compliance

IsubsLimit: Substrate current compliance

HoldTime: Hold time

DelayTime: Delay time

VgsBiasStart: Cgg-Vg measurement start voltage

VgsBiasStop: Cgg-Vg measurement stop voltage

VgsBiasStep: Cgg-Vg measurement step voltage

OscLevel: Cgg-Vg measurement signal level

FREQ: Cgg-Vg measurement frequency

VgsStartDC: Id-Vg measurement start voltage

VgsStopDC: Id-Vg measurement stop voltage

VgsStepDC: Id-Vg measurement step voltage

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Vd: Drain current

[Extended Test Parameters]

DrainMinRng: Minimum range for the drain current measurement

GateMinRng: Minimum range for the gate current measurement

[Cgg-Vg: Measurement Parameters]

Parallel capacitance Cp

Conductance G

[Cgg-Vg: User Function]

$PI=3.141592653589$

$D=G/(2*PI*FREQ*Cp)$

$Rp=1/G$

$Cs=(1+D^2)*Cp$

$X=-1/(2*PI*FREQ*Cs)$

$Rs=D*abs(X)$

$Z=sqrt(Rs^2+X^2)$

$Theta=atan(X/Rs)$

$Vgate=-Vsource$

$Cp\_S=Cp/Lg/Wg$

$Cp\_W=Cp/Wg$

[Cgg-Vg: X-Y Graph]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Gate capacitance (parallel capacitance) Cp (LINEAR)

Y2 axis: Conductance G (LINEAR)

[Cgg-Vg: List Display]

Gate voltage Vgate

Parallel capacitance Cp

Conductance G

Series capacitance Cs

Series resistance Rs

Parallel resistance Rp

Dissipation factor D

Reactance X

Impedance Z

Phase Theta

[Id-Vg: Measurement Parameters]

Drain current Idrain

[Id-Vg: User Function]

$gm=\Delta(Idrain)/\Delta(Vgate)$

$gmMax=\max(gm)$

[Id-Vg: Analysis Function]

$Vth=@L1X$  (X intercept of Line1)

[Id-Vg: X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Transconductance gm (LINEAR)

[Id-Vg: List Display]

Gate current  $I_{gate}$

[Id-Vg: Parameters Display Area]

Maximum gm value gmMax

Threshold voltage  $V_{th}$

[Id-Vg: Auto Analysis]

Line1: Tangent line for Y1 at gm=gmMax

### ***2.31 VthAndCgg-Vg SCUU: Cgg-Vg, Id-Vg, using SCUU (A.01.20)***

[Supported Analyzer]

B1500A

[Description]

Measures the gate capacitance vs gate voltage characteristics, the drain current vs gate voltage measurement by using one MFCMU, three SMUs, and a set of SCUU/GSWU.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]

MOSFET, 4 terminals

[Required Modules and Accessories]

One MFCMU module, three SMU modules, and a set of SCUU/GSWU are required.

SCUU connections (Cgg-Vg): Output1: terminals other than Gate, Output2: Gate

SCUU connections (Id-Vg): Output1: Source and Substrate, Output2: Gate

Connection wire must be connected between the GSWU and the DUT interface High/Low guard lines for the capacitance measurements.

[Device Parameters]

Polarity: Nch (CMU/SMU forces the specified value) or Pch (CMU/SMU forces the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

[Test Parameters]

GateAC: CMU connected to Gate terminal (CV sweep measurement)

GateDC: SMU connected to Gate terminal (primary sweep, voltage output)

SourceDC: SMU connected to Source and Substrate terminal (constant voltage output)

Drain: SMU connected to Drain terminal (constant voltage output)

Vd: Drain current

IntegTime: Integration time

IgLimit: Gate current compliance

IdLimit: Drain current compliance

IsLimit: Source current compliance

HoldTime: Hold time

DelayTime: Delay time

VgsBiasStart: Cgg-Vg measurement start voltage

VgsBiasStop: Cgg-Vg measurement stop voltage

VgsBiasStep: Cgg-Vg measurement step voltage

OscLevel: Cgg-Vg measurement signal level

FREQ: Cgg-Vg measurement frequency

VgsStartDC: Id-Vg measurement start voltage

VgsStopDC: Id-Vg measurement stop voltage

VgsStepDC: Id-Vg measurement step voltage

## [Extended Test Parameters]

DrainMinRng: Minimum range for the drain current measurement

GateMinRng: Minimum range for the gate current measurement

## [Cgg-Vg: Measurement Parameters]

Parallel capacitance Cp

Conductance G

## [Cgg-Vg: User Function]

 $PI=3.141592653589$  $D=G/(2*PI*FREQ*Cp)$  $Rp=1/G$  $Cs=(1+D^2)*Cp$  $X=-1/(2*PI*FREQ*Cs)$  $Rs=D*abs(X)$  $Z=sqrt(Rs^2+X^2)$  $Theta=atan(X/Rs)$  $Vgate=-Vsource$  $Cp\_S=Cp/Lg/Wg$  $Cp\_W=Cp/Wg$ 

## [Cgg-Vg: X-Y Graph]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Gate capacitance (parallel capacitance) Cp (LINEAR)

Y2 axis: Conductance G (LINEAR)

## [Cgg-Vg: List Display]

Gate voltage Vgate

Parallel capacitance Cp

Conductance G

Series capacitance Cs

Series resistance Rs

Parallel resistance Rp

Dissipation factor D

Reactance X

Impedance Z

Phase Theta

## [Id-Vg: Measurement Parameters]

Drain current Idrain

## [Id-Vg: User Function]

 $gm=\Delta(Idrain)/\Delta(Vgate)$  $gmMax=\max(gm)$ 

## [Id-Vg: Analysis Function]

 $Vth=@L1X$  (X intercept of Line1)

## [Id-Vg: X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Transconductance gm (LINEAR)

## [Id-Vg: List Display]

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Gate current  $I_{gate}$

[Id-Vg: Parameters Display Area]

Maximum gm value gmMax

Threshold voltage  $V_{th}$

[Id-Vg: Auto Analysis]

Line1: Tangent line for Y1 at gm=gmMax

## 2.32 *Vth-Lg: Vth-Lg characteristics (A.01.20)*

### [Supported Analyzer]

B1500A

### [Description]

Measures the Id-Vg characteristics of MOSFET with different Lg (gate length) and plots the Vth's dependency on Lg (threshold voltage).

### [Device Under Test]

MOSFET, 4 terminals

### [Required Modules and Accessories]

Agilent B2200A or B2201A switching matrix 1 unit

GPIO cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIO cable.

Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.

Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the G#/D#/E#/S#/Sb# field (# is an integer from 1 to 12) of Test Parameters area.

The maximum number of devices connected at once depends on the number of matrix modules mounted on B2200A/B2201A. Maximum three devices can be connected to one module at once.

### [Setting of Lg#/G#/D#/S#/Sb# field (# is an integer from 1 to 12)]

Set one device for Lg#(gate length)/G#(gate)/D#(drain)/S#(source)/Sb#(substrate). Lg1&lt;Lg2&lt;Lg3... must be satisfied. Enter zero for a field with no device.

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)

Temp: Temperature (deg)

IdMax: Drain current compliance

### [Test Parameters]

IntegTime: Integration time

GateSMU: SMU connected to Gate terminal, primary sweep voltage output

DrainSMU: SMU connected to Drain terminal, constant voltage output

SbSMU: SMU connected to Substrate, constant voltage output

SourceSMU: SMU connected to Source terminal, constant voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage, ideally at around 100mV

Vsubs: Substrate voltage

Wg: Gate width

Lg1 - Lg12: Gate length for MOSFETs

G1 - G12: SWM Pin Assign setting for Gate of devices

D1 - D12: SWM Pin Assign setting for Drain of devices

S1 - S12: SWM Pin Assign setting for Source of devices

Sb1 - Sb12: SWM Pin Assign setting for Subs of devices

### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

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IsubsLimit: Substrate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
Vth\_Min: Minimum Vth value for graph scale  
Vth\_Max: Maximum Vth value for graph scale  
gmMax\_Min: Minimum gmMax value for graph scale  
gmMax\_Max: Maximum gmMax value for graph scale  
DrainMinRng: Minimum range for drain current measurement

### [Measurement Parameters]

Idrain: Drain current

### [User Function]

gm=diff(Idrain,Vgate)

### [Analysis Function]

gmMax=max(gm)  
Von=@L1X (X intercept of Line1)  
Vth=Von-Vd/2

Vth is given by the following formula.

$V_{th} = V_g(gm_{Max}) - I_d(gm_{Max}) / gm_{Max}$

Vd/2 is for compensation of the secondary term of Vd in the theoretical formula.

### [Auto Analysis]

Line1: Tangent line for Y1 at gm=gmMax

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)  
Y2 axis: Transconductance gm (LINEAR)  
Y3 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate  
Source voltage Vsource  
Drain voltage Vdrain  
Substrate voltage Vsubs  
Drain current Idrain  
Transconductance gm

### [Parameters Display Area]

Threshold voltage Vth  
Maximum transconductance value gmMax

### [Test Output: X-Y Graph]

X axis: Gate length LgList (LINEAR)  
Y1 axis: Threshold voltage VthList (LINEAR)  
Y2 axis: Maximum transconductance value gmMaxList (LINEAR)

### [Test Output: List Display]

Gate length LgList  
Threshold voltage VthList  
Maximum transconductance value gmMaxList



### 2.33 *Vth-Wg: Vth-Wg characteristics (A.01.20)*

[Supported Analyzer]

B1500A

[Description]

Measures the Id-Vg characteristics of MOSFET with different Wg (gate width) and plots the Vth's dependency on Wg (threshold voltage).

[Device Under Test]

MOSFET, 4 terminals

[Required Modules and Accessories]

Agilent B2200A or B2201A switching matrix 1 unit

GPIO cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIO cable.

Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.

Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the G#/D#/E#/S#/Sb# field (# is an integer from 1 to 12) of Test Parameters area.

The maximum number of devices connected at once depends on the number of matrix modules mounted on B2200A/B2201A. Maximum three devices can be connected to one module at once.

[Setting of Wg#/G#/D#/S#/Sb# field (# is an integer from 1 to 12)]

Set one device for Wg#(gate width)/G#(gate)/D#(drain)/S#(source)/Sb#(substrate). Wg1<Wg2<Wg3... must be satisfied. Enter zero for a field with no device.

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)

Temp: Temperature (deg)

IdMax: Drain current compliance

[Test Parameters]

IntegTime: Integration time

GateSMU: SMU connected to Gate terminal, primary sweep voltage output

DrainSMU: SMU connected to Drain terminal, constant voltage output

SbSMU: SMU connected to Substrate, constant voltage output

SourceSMU: SMU connected to Source terminal, constant voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage, ideally at around 100mV

Vsubs: Substrate voltage

Lg: Gate length

Wg1 - Wg12: Gate width for MOSFETs

G1 - G12: SWM Pin Assign setting for Gate of devices

D1 - D12: SWM Pin Assign setting for Drain of devices

S1 - S12: SWM Pin Assign setting for Source of devices

Sb1 - Sb12: SWM Pin Assign setting for Subs of devices

[Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

## 2 CMOS

IsubsLimit: Substrate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
Vth\_Min: Minimum Vth value for graph scale  
Vth\_Max: Maximum Vth value for graph scale  
gmMax\_Min: Minimum gmMax value for graph scale  
gmMax\_Max: Maximum gmMax value for graph scale  
DrainMinRng: Minimum range for drain current measurement

### [Measurement Parameters]

Idrain: Drain current

### [User Function]

gm=diff(Idrain,Vgate)

### [Analysis Function]

gmMax=max(gm)  
Von=@L1X (X intercept of Line1)  
Vth=Von-Vd/2

Vth is given by the following formula.

$V_{th} = V_g(gm_{Max}) - I_d(gm_{Max}) / gm_{Max}$

Vd/2 is for compensation of the secondary term of Vd in the theoretical formula.

### [Auto Analysis]

Line1: Tangent line for Y1 at gm=gmMax

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)  
Y2 axis: Transconductance gm (LINEAR)  
Y3 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate  
Source voltage Vsource  
Drain voltage Vdrain  
Substrate voltage Vsubs  
Drain current Idrain  
Transconductance gm

### [Parameters Display Area]

Threshold voltage Vth  
Maximum transconductance value gmMax

### [Test Output: X-Y Graph]

X axis: Gate width WgList (LINEAR)  
Y1 axis: Threshold voltage VthList (LINEAR)  
Y2 axis: Maximum transconductance value gmMaxList (LINEAR)

### [Test Output: List Display]

Gate width WgList  
Threshold voltage VthList  
Maximum transconductance value gmMaxList

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### 3 Discrete

- |                    |   |
|--------------------|---|
| 1. BJT GummelPlot: | Bipolar transistor gummel characteristics (A.01.20) |
| 2. BJT Ic-Vc Ib :  | Bipolar transistor Ic-Vc characteristics (A.01.20)  |
| 3. Diode IV Fwd:   | Diode forward bias characteristics (A.01.20)        |
| 4. Diode IV Rev:   | Diode reverse bias characteristics (A.01.20)        |
| 5. FET Id-Vd:      | MOSFET Id-Vd characteristics (A.01.20)              |
| 6. FET Id-Vg :     | MOSFET Id-Vg characteristics (A.01.20)              |

### 3.1 *BJT GummelPlot: Bipolar transistor gummel characteristics (A.01.20)*

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the gummel characteristics of bipolar transistor.

[Device Under Test]

Bipolar junction transistor

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

Pmax: Power compliance

[Test Parameters]

IntegTime: Integration time

Base: SMU connected to Base terminal, primary sweep voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Collector: SMU connected to Collector terminal, constant voltage output

Vc: Collector voltage

Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng: Minimum range for the base current measurement

CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]

Base current Ibase

Collector current Icurrent

[User Function]

$I_{ePerArea} = I_{emitter} / Le / We$

$I_{bPerArea} = I_{base} / Le / We$

$I_{cPerArea} = I_{collector} / Le / We$

$hfe = I_{collector} / I_{base}$

[Analysis Function]

$hf_{max} = \max(hfe)$

[X-Y Plot]

X axis: Base voltage Vbase (LINEAR)

Y1 axis: Base current Ibase (LOG)

Y2 axis: Collector current Icollector (LOG)

Y3 axis: Current amplification factor hfe (LINEAR)

### 3 Discrete

#### [User Function]

Emitter current per unit area of Emitter  $I_{ePerArea}$   
Base current per unit area of Emitter  $I_{bPerArea}$   
Collector current per unit area of Emitter  $I_{cPerArea}$

#### [Parameters Display Area]

hfe maximum value hfemax

### 3.2 BJT $I_c$ - $V_c$ $I_b$ : Bipolar transistor $I_c$ - $V_c$ characteristics (A.01.20)

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the collector current vs collector voltage characteristics of bipolar transistor.

[Device Under Test]

Bipolar junction transistor

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Temp: Temperature

IcMax: Collector current compliance

Pmax: Power compliance

[Test Parameters]

IntegTime: Integration time

Collector: SMU connected to Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

Base: SMU connected to Base terminal, secondary sweep voltage output

IbStart: Sweep start current for Base terminal

IbStop: Sweep stop current for Base terminal

IbStep: Sweep step current for Base terminal

VbLimit: Base voltage compliance

Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]

Collector current Icollector

Base current Ibase

[User Function]

$h_{fe} = I_{collector} / I_{base}$

$V_A = I_{collector} * \text{diff}(V_{collector}, I_{collector}) - V_{collector}$

[X-Y Plot]

X axis: Collector voltage Vcollector (LINEAR)

Y1 axis: Collector current Icollector (LINEAR)

[User Function]

Current amplifier factor  $h_{fe}$

Early voltage  $V_A$

[List Display]

Base current Ibase

## 3 Discrete

### 3.3 *Diode IV Fwd: Diode forward bias characteristics (A.01.20)*

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the forward bias anode voltage vs anode current characteristics.

[Device Under Test]

Diode

[Device Parameters]

Temp: Temperature

I<sub>max</sub>: Current compliance

[Test Parameters]

IntegTime: Integration time

Anode: SMU connected to Anode terminal, primary sweep voltage output

VanodeStart: Sweep start voltage for Anode terminal

VanodeStop: Sweep stop voltage for Anode terminal

VanodeStep: Sweep step voltage for Anode terminal

Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]

V<sub>cathode</sub>: Cathode voltage

HoldTime: Hold time

DelayTime: Delay time

AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]

Anode current I<sub>anode</sub>

[X-Y Plot]

X axis: Anode voltage Vanode (LINEAR)

Y1 axis: Anode current I<sub>anode</sub> (LINEAR)

Y2 axis: Anode current I<sub>anode</sub> (LOG)



### 3.4 Diode IV Rev: Diode reverse bias characteristics (A.01.20)

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the reverse bias anode voltage vs anode current characteristics.

[Device Under Test]

Diode

[Device Parameters]

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Anode: SMU connected to Anode terminal, primary sweep voltage output

VanodeStart: Sweep start voltage for Anode terminal

VanodeStop: Sweep stop voltage for Anode terminal

VanodeStep: Sweep step voltage for Anode terminal

IanodeLimit: Anode current compliance

Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]

Vcathode: Cathode voltage

HoldTime: Hold time

DelayTime: Delay time

AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]

Anode current Ianode

[X-Y Plot]

X axis: Anode voltage Vanode (LINEAR)

Y1 axis: Anode current Ianode (LOG)

### 3 Discrete

#### 3.5 *FET Id-Vd: MOSFET Id-Vd characteristics (A.01.20)*

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the drain current vs drain voltage characteristics of MOSFET.

[Device Under Test]

MOSFET, 3 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

IntegTime: Integration time

Drain: SMU connected to Drain terminal, primary sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

Gate: SMU connected to Gate terminal, secondary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

IgLimit: Gate current compliance

Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]

Vs: Source voltage

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]

Drain current Idrain

[X-Y Plot]

X axis: Drain voltage Vdrain (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

### 3.6 *FET Id-Vg : MOSFET Id-Vg characteristics (A.01.20)*

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the drain current vs gate voltage characteristics of MOSFET.

[Device Under Test]

MOSFET, 3 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

IgLimit: Gate current compliance

Drain: SMU connected to Drain terminal, secondary sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]

Vs: Source voltage

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]

Drain current Idrain

[User Function]

gm: Transconductance  $gm = \text{diff}(\text{Idrain}, V_{\text{gate}})$

[X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

Y3 axis: Transconductance gm (LINEAR)





## 4 Generic Test

1. Generic C-f C-f characteristics of capacitor (2 terminals) (A.03.00)
2. Generic C-t C-t characteristics of capacitor (2 terminals) (A.03.00)

## 4.1 *Generic C-f: C-f characteristics of capacitor (2 terminals) (A.03.00)*

### [Supported Analyzer]

B1500A

### [Description]

Measures the capacitance and conductance vs frequency characteristics.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

Capacitor, 2 terminals

For a more accurate measurement, connect CMU High to device's Low and CMU Low to device's High.

### [Required Modules and Accessories]

Agilent B1520A MFCMU 1 unit

### [Test Parameters]

Port1: CMU connected between capacitance

Vbias: DC bias voltage

FreqStart: Sweep start frequency

FreqStop: Sweep stop frequency

NoOfSteps: Number of measurements

OscLevel: Measurement signal level

Single\_Double: Sweep direction (Single/Double)

Linear\_Log: Frequency scale (Linear/Log)

OnAbnormalStatus: Auto abort function set up

IntegTime: Integration time

### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

Range: Measurement range

G\_Min: Minimum transconductance value for graph

G\_Max: Maximum transconductance value for graph

Cp\_Min: Minimum capacitance value for graph

Cp\_Max: Maximum capacitance value for graph

### [Measurement parameters]

Susceptance B

Conductance G

DC bias monitor data DcMon

AC level monitor data AcMon

Frequency Freq

### [User Function]

#### 4 Generic Test

Circular constant  $PI=3.141592653589$

Parallel capacitance  $C_p=B/(2*PI*Freq)$

Parallel resistance  $R_p=1/G$

Dissipation factor  $D=G/(2*PI*Freq*C_p)$

Series capacitance  $C_s=(1+D^2)*C_p$

Reactance  $X=-1/(2*PI*Freq*C_s)$

Series resistance  $R_s=D*abs(X)$

Impedance  $Z=sqrt(R_s^2+X^2)$

Phase Theta= $atan(X/R_s)$

[X-Y Plot]

X axis: Frequency Freq (LINEAR/LOG)

Y1 axis: Parallel capacitance  $C_p$  (LINEAR)

Y2 axis: Conductance  $G$  (LINEAR)

[List Display]

Frequency Freq

Parallel capacitance  $C_p$

Conductance  $G$

DC bias voltage  $V_{bias}$

Series capacitance  $C_s$

Series resistance  $R_s$

Parallel resistance  $R_p$

Dissipation factor  $D$

Reactance  $X$

Impedance  $Z$

Phase Theta

DC bias monitor data  $DcMon$

AC level monitor data  $AcMon$



## 4.2 Generic C-t: C-t characteristics of capacitor (2 terminals) (A.03.00)

### [Supported Analyzer]

B1500A

### [Description]

Measures the capacitance and conductance vs time characteristics.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

Capacitor, 2 terminals

For a more accurate measurement, connect CMU High to device's Low and CMU Low to device's High.

### [Required Modules and Accessories]

Agilent B1520A MFCMU 1 unit

### [Test Parameters]

Port1: CMU connected between capacitance

Vbias: Bias voltage

Vbase: Voltage before measurement

Freq: Measurement frequency

OscLevel: Measurement signal level

IntegTime: Integration time

BiasHoldTime: Vbias hold time

BaseHoldTime: Vbase hold time

Interval: Sampling interval time

NoOfSampling: Number of sampling steps

OnAbnormalStatus: Auto abort function set up

Range: Measurement range

### [Extended Test Parameters]

G\_Min: Minimum transconductance value for graph

G\_Max: Maximum transconductance value for graph

Cp\_Min: Minimum capacitance value for graph

Cp\_Max: Maximum capacitance value for graph

InitialVoltage: Initial voltage before Vbase

### [Measurement parameters]

Susceptance B

Conductance G

DC bias monitor data DcMon

AC level monitor data AcMon

### [User Function]

Circular constant  $PI=3.141592653589$

Parallel capacitance  $Cp=B/(2*PI*Freq)$

#### 4 Generic Test

Parallel resistance  $R_p = 1/G$

Dissipation factor  $D = G/(2 \cdot \pi \cdot \text{Freq} \cdot C_p)$

Series capacitance  $C_s = (1 + D^2) \cdot C_p$

Reactance  $X = -1/(2 \cdot \pi \cdot \text{Freq} \cdot C_s)$

Series resistance  $R_s = D \cdot \text{abs}(X)$

Impedance  $Z = \sqrt{R_s^2 + X^2}$

Phase Theta =  $\text{atan}(X/R_s)$

[X-Y Plot]

X axis: Time (LINEAR)

Y1 axis: Parallel capacitance  $C_p$  (LINEAR)

Y2 axis: Conductance  $G$  (LINEAR)

[List Display]

Time Time

Parallel capacitance  $C_p$

Conductance  $G$

Frequency Freq

Series capacitance  $C_s$

Series resistance  $R_s$

Parallel resistance  $R_p$

Dissipation factor  $D$

Reactance  $X$

Impedance  $Z$

Phase Theta

DC bias monitor data DcMon

AC level monitor data AcMon



## 5 Memory

1. Flash Ccf-V: Flash memory cell Control Gate to Floating Gate capacitance (A.01.11)
2. Flash Cfb-V: Flash memory cell Floating Gate-Substrate capacitance (A.01.11)
3. Flash Cgg-Vcg: Flash memory cell Gate capacitance (A.01.11)
4. NandFlash2 Endurance 3devices:  
Repeatedly tests write/erase on a NAND-type flash memory cell, simultaneously using three devices (A.01.20).
5. NandFlash2 Endurance: NAND flash memory cell endurance test (A.01.20)
6. NandFlash2 IV-Erase-IV: NAND flash memory cell Id-Vg, Erase, Id-Vg (A.01.20)
7. NandFlash2 IV-Write-IV: NAND flash memory cell Id-Vg, Write, Id-Vg (A.01.20)
8. NandFlash2 Retention(ErasedCell):  
NAND flash memory cell Data retention test after Erase (A.01.20)
9. NandFlash2 Retention(WrittenCell):  
NAND flash memory cell Data retention test after Write (A.01.20)
10. NandFlash2 Vth(ErasingTimeDependence):  
NAND flash memory cell erasing time dependence test (A.01.20)
11. NandFlash2 Vth(WritingTimeDependence):  
NAND flash memory cell writing time dependence test (A.01.20)
12. NandFlash2 WordDisturb(ErasedCell):  
NAND flash memory cell erase-disturb test (A.01.20)
13. NandFlash2 WordDisturb(WrittenCell):  
NAND flash memory cell read-disturb test (A.01.20)
14. NandFlash3 Endurance: NAND flash memory cell endurance test (A.03.10)
15. NandFlash3 IV-Erase-IV: NAND flash memory cell Id-Vg, Erase, Id-Vg (A.03.10)
16. NandFlash3 IV-Write-IV: NAND flash memory cell Id-Vg, Write, Id-Vg (A.03.10)
17. NandFlash3 Retention(ErasedCell):  
NAND flash memory cell Data retention test after Erase (A.03.10)
18. NandFlash3 Retention(WrittenCell):  
NAND flash memory cell Data retention test after Write (A.03.10)
19. NandFlash3 Vth(ErasingTimeDependence):  
NAND flash memory cell erasing time dependence test (A.03.10)
20. NandFlash3 Vth(WritingTimeDependence):  
NAND flash memory cell writing time dependence test (A.03.10)
21. NandFlash3 WordDisturb(ErasedCell):  
NAND flash memory cell erase-disturb test (A.03.10)
22. NandFlash3 WordDisturb(WrittenCell):  
NAND flash memory cell read-disturb test (A.03.10)
23. NorFlash Endurance: NOR flash memory cell endurance test (A.03.10)
24. NorFlash IV-Erase-IV: NOR flash memory cell Id-Vg, Erase, Id-Vg (A.03.10)
25. NorFlash IV-Write-IV: NOR flash memory cell Id-Vg, Write, Id-Vg (A.03.10)
26. NorFlash Retention(ErasedCell):  
NOR flash memory cell Data retention test after Erase (A.03.10)
27. NorFlash Retention(WrittenCell):  
NOR flash memory cell Data retention test after Write (A.03.10)
28. NorFlash Vth(ErasingTimeDependence):  
NOR flash memory cell erasing time dependence test (A.03.10)
29. NorFlash Vth(WritingTimeDependence):  
NOR flash memory cell writing time dependence test (A.03.10)
30. NorFlash WordDisturb(ErasedCell):  
NOR flash memory cell word disturb test after Erase (A.03.10)
31. NorFlash WordDisturb(WrittenCell):  
NOR flash memory cell word disturb test after Write (A.03.10)
32. NorFlash DataDisturb(ErasedCell):  
NOR flash memory cell data disturb test after Erase (A.03.10)

33. NorFlash DataDisturb(WrittenCell):  
NOR flash memory cell data disturb test after Write (A.03.10)

## 5 Memory

### 5.1 *Flash Ccf-V: Flash memory cell Control Gate to Floating Gate capacitance (A.01.11)*

[Supported Analyzer]  
B1500A

[Description]

Measures the Control Gate to Floating Gate capacitance (Ccf), and plots the Ccf-V characteristics.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]

Flash memory cell

Connect the Control Gate to CMU High and the Floating Gate to CMU Low.

Connect the other terminals to the ground unit (GNDU).

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

M: Number of cells connected in parallel. M=1 for the single cell.

[Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

ControlGate: CMU connected between Control Gate and Floating Gate (CV sweep measurement)

VcfStart: DC bias start voltage

VcfStop: DC bias stop voltage

VcfStep: DC bias step voltage

[Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Parallel capacitance Cp

Conductance G

[User Function]

$PI=3.141592653589$

$D=G/(2*PI*FREQ*Cp)$

$Rp=1/G$

$Cs=(1+D^2)*Cp$

$X=-1/(2*PI*FREQ*Cs)$

$Rs=D*abs(X)$

$$Z = \sqrt{R_s^2 + X^2}$$

$$\text{Theta} = \text{atan}(X/R_s)$$

$$C_{s\text{PerCell}} = C_s/M$$

$$C_{p\text{PerCell}} = C_p/M$$

## [X-Y Graph]

X axis: DC bias Vcontrolgate (LINEAR)

Y1 axis: Control Gate to Floating Gate capacitance (parallel capacitance) Cp (LINEAR)

Y2 axis: Dissipation factor D (LINEAR)

Y3 axis: Conductance G (LINEAR)

## [List Display]

Measurement frequency Freq

DC bias Vcontrolgate

Control Gate to Floating Gate capacitance (parallel capacitance) Cp

Conductance G

Series capacitance Cs

Series resistance Rs

Parallel resistance Rp

Dissipation factor D

Reactance X

Impedance Z

Phase Theta

Series capacitance per cell CsPerCell

Parallel capacitance per cell CpPerCell

## 5 Memory

### 5.2 *Flash Cfb-V: Flash memory cell Floating Gate-Substrate capacitance (A.01.11)*

[Supported Analyzer]  
B1500A

[Description]

Measures the Floating Gate-Substrate capacitance (Ccf), and plots the Cfb-V characteristics.

DC bias output is performed from -VfbStart to -VfbStop in -VfbStep steps.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]

Flash memory cell

Connect the Control Gate to ground unit (GNDU), the Floating Gate to CMU Low, and the other terminals to CMU High.

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

M: Number of cells connected in parallel. M=1 for the single cell.

[Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

FloatingGate: CMU connected between Floating Gate and Substrate (CV sweep measurement)

VfbStart: DC bias start voltage

VfbStop: DC bias stop voltage

VfbStep: DC bias step voltage

[Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Parallel capacitance Cp

Conductance G

[User Function]

$PI=3.141592653589$

$D=G/(2*PI*FREQ*Cp)$

$Rp=1/G$

$Cs=(1+D^2)*Cp$

$X=-1/(2*PI*FREQ*Cs)$



$R_s = D * \text{abs}(X)$   
 $Z = \sqrt{R_s^2 + X^2}$   
 $\text{Theta} = \text{atan}(X/R_s)$   
 $C_{s\text{PerCell}} = C_s/M$   
 $C_{p\text{PerCell}} = C_p/M$   
 $V_{fb} = -V_{subs}$

## [X-Y Graph]

X axis: DC bias  $V_{fb}$  (LINEAR)  
 Y1 axis: Floating Gate-Substrate capacitance (parallel capacitance)  $C_p$  (LINEAR)  
 Y2 axis: Dissipation factor  $D$  (LINEAR)  
 Y3 axis: Conductance  $G$  (LINEAR)

## [List Display]

Measurement frequency Freq  
 DC bias  $V_{fb}$   
 Floating Gate-Substrate capacitance (parallel capacitance)  $C_p$   
 Conductance  $G$   
 Series capacitance  $C_s$   
 Series resistance  $R_s$   
 Parallel resistance  $R_p$   
 Dissipation factor  $D$   
 Reactance  $X$   
 Impedance  $Z$   
 Phase  $\text{Theta}$   
 Series capacitance per cell  $C_{s\text{PerCell}}$   
 Parallel capacitance per cell  $C_{p\text{PerCell}}$

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### 5.3 *Flash Cgg-Vcg: Flash memory cell Gate capacitance (A.01.11)*

#### [Supported Analyzer]

B1500A

#### [Description]

Measures the Gate capacitance (Cgg), and plots the Cgg-Vcs characteristics.

DC bias output is performed from -VcsStart to -VcsStop in -VcsStep steps.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

#### [Device Under Test]

Flash memory cell

Open the Floating Gate, and connect the Control Gate to CMU Low and the other terminals to CMU High.

#### [Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

M: Number of cells connected in parallel. M=1 for the single cell.

#### [Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

ControlGate: CMU connected between Control Gate and Substrate (CV sweep measurement)

VcsStart: DC bias start voltage

VcsStop: DC bias stop voltage

VcsStep: DC bias step voltage

#### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

#### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

#### [User Function]

$PI=3.141592653589$

$D=G/(2*PI*FREQ*Cp)$

$Rp=1/G$

$Cs=(1+D^2)*Cp$

$X=-1/(2*PI*FREQ*Cs)$

$Rs=D*abs(X)$

$Z=sqrt(Rs^2+X^2)$

$Theta=atan(X/Rs)$

$CsPerCell = Cs/M$   
 $CpPerCell = Cp/M$   
 $Vcs = -Vsubs$

[X-Y Graph]

X axis: DC bias  $Vcs$  (LINEAR)  
Y1 axis: Gate capacitance (parallel capacitance)  $Cp$  (LINEAR)  
Y2 axis: Dissipation factor  $D$  (LINEAR)  
Y3 axis: Conductance  $G$  (LINEAR)

[List Display]

Measurement frequency  $Freq$   
DC bias  $Vcs$   
Gate capacitance (parallel capacitance)  $Cp$   
Conductance  $G$   
Series capacitance  $Cs$   
Series resistance  $Rs$   
Parallel resistance  $Rp$   
Dissipation factor  $D$   
Reactance  $X$   
Impedance  $Z$   
Phase  $Theta$   
Series capacitance per cell  $CsPerCell$   
Parallel capacitance per cell  $CpPerCell$

## 5 Memory

### ***5.4 NandFlash2 Endurance 3devices: Repeatedly tests write/erase on a NAND-type flash memory cell, simultaneously using three devices (A.01.20)***

[Supported Analyzer]  
B1500A

[Description]  
Repeatedly tests write/erase on a NAND-type flash memory cell. Plots the number of writes/erases vs threshold voltage characteristic. Maximum three devices can be measured at once.

[Device Under Test]  
NAND-type flash memory cell, 4 terminals x 3 devices  
When some device is destroyed during write/erase, a desired voltage may not be applied to other devices.

[Required Modules and Accessories]  
Agilent B2200A or B2201A switching matrix 1 unit  
Agilent 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit  
GPIB cable

Connect 81110A, B2200A/B2201A and B1500A with measurement cables and GPIB cables.  
Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.  
Set information on 81110A output channel's connection to B2200A/B2201A input port properly in the PulseGate and PulseDrain fields of the Test Parameters area. Set B2200A/B2201A input ports connected to the output channel of a gate pulse and drain pulse in these fields.  
Set the output channel number of B2200A/B2201A connected to each terminal of a measured device properly in the Tr#Gate/Tr#Drain/Tr#Source/Tr#Subs field (# is an integer from 1 to 3) of the Test Parameters area.

[Device Parameters]  
Lg: Gate length  
Wg: Gate width  
Temp: Temperature (deg)  
IdMax: Drain current compliance

[Test Parameters]  
IntegTime: Integration time  
TotalWriteAndEraseCycles: Number of write/erase cycles  
Tr1Gate - Tr3Gate: SWM Pin Assign setting for Gate of devices  
Tr1Drain - Tr3Drain: SWM Pin Assign setting for Drain of devices  
Tr1Source - Tr3Source: SWM Pin Assign setting for Source of devices  
Tr1Subs - Tr3Subs: SWM Pin Assign setting for Subs of devices

PgAdd: GPIB address of pulse generator  
PulseGate: B2200A/B2201A input port for Gate pulse  
PulseDrain: B2200A/B2201A input port for Drain pulse  
ErasePeriod: Write/Erase pulse period  
EraseDelay: Write/Erase pulse delay  
EraseWidth: Write/Erase pulse width  
EraseLeadTime: Pulse leading edge transition time  
EraseTrailTime: Pulse trailing edge transition time  
Verase: Pulse voltage output level, High  
BaseValue: Pulse voltage output level, Low

## [Test Parameters for Vth Acquisition]

MeasGate: SMU connected to Gate terminal  
 MeasDrain: SMU connected to Drain terminal  
 MeasSource: SMU connected to Source terminal  
 VgStart: Sweep start voltage for Gate terminal  
 VgStop: Sweep stop voltage for Gate terminal  
 VgStep: Sweep step voltage for Gate terminal  
 Vd: Drain voltage  
 IgLimit: Gate current compliance  
 Id@Vth: Current determining the threshold voltage

## [Extended Test Parameters for Vth Acquisition]

Vs: Source voltage  
 HoldTime: Hold time  
 DelayTime: Delay time  
 Vth\_Min: Minimum Vth value for graph scale  
 Vth\_Max: Maximum Vth value for graph scale  
 DrainMinRng1: Minimum range for drain current measurement on device 1  
 DrainMinRng2: Minimum range for drain current measurement on device 2  
 DrainMinRng3: Minimum range for drain current measurement on device 3

## [Measurement Parameters]

## [Measurement Parameters for Vth Acquisition after Write Operation]

Drain current: Idrain

## [Measurement Parameters for Vth Acquisition after Erase Operation]

Drain current: Idrain

## [Analysis Function]

## [Analysis Function for Vth Acquisition after Write Operation]

Vth@Id=@L1X (X intercept of Line1)

## [Analysis Function for Vth Acquisition after Erase Operation]

Vth@Id=@L1X (X intercept of Line1)

## [Auto Analysis]

## [Auto Analysis for Vth Acquisition after Write Operation]

Line1: Idrain=X intercept of Id@Vth

## [Auto Analysis for Vth Acquisition after Erase Operation]

Line1: Idrain=X intercept of Id@Vth

## [X-Y Plot]

## [X-Y Plot for Vth Acquisition after Write Operation]

X axis: Gate voltage Vgate (LINEAR)  
 Y1 axis: Drain current Idrain (LOG)

## [X-Y Plot for Vth Acquisition after Erase Operation]

X axis: Gate voltage Vgate (LINEAR)  
 Y1 axis: Drain current Idrain (LOG)

## [List Display]

## [List Display for Vth Acquisition after Write Operation]

Gate voltage Vgate  
 Drain current Idrain

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[List Display for Vth Acquisition after Erase Operation]

Gate voltage Vgate

Drain current Idrain

[Test Output: X-Y Graph]

X axis: Number of write/erase cycles CycleList (LOG)

Y1 axis: Vth value after write operation on device 1 Dev1\_VthWrittenList (LINEAR)

Y2 axis: Vth value after write operation on device 2 Dev2\_VthWrittenList (LINEAR)

Y3 axis: Vth value after write operation on device 3 Dev3\_VthWrittenList (LINEAR)

Y4 axis: Vth value after erase operation on device 1 Dev1\_VthErasedList (LINEAR)

Y5 axis: Vth value after erase operation on device 2 Dev2\_VthErasedList (LINEAR)

Y6 axis: Vth value after erase operation on device 3 Dev3\_VthErasedList (LINEAR)

[Test Output: List Display]

Number of write/erase cycles CycleList

Vth value after write operation on device 1 Dev1\_VthWrittenList

Vth value after write operation on device 2 Dev2\_VthWrittenList

Vth value after write operation on device 3 Dev3\_VthWrittenList

Vth value after erase operation on device 1 Dev1\_VthErasedList

Vth value after erase operation on device 2 Dev2\_VthErasedList

Vth value after erase operation on device 3 Dev3\_VthErasedList

[Test Setup Details]

Refer to "NandFlash2 IV-Write-IV" and "NandFlash2 IV-Erase-IV."

## 5.5 *NandFlash2 Endurance: NAND flash memory cell endurance test (A.01.20)*

### [Supported Analyzer]

B1500A

### [Description]

Performs the endurance test for the NAND type flash memory cell and plots the number of write/erase operation vs threshold voltage characteristics.

### [Device Under Test]

NAND-type flash memory cell

Connect the Control Gate to the ASU1 Output, and the Drain to the ASU2 Output.

Open the Floating Gate, and connect the other terminals to the ASU3 Output.

### [Required Modules and Accessories]

Agilent 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit

HRSMU/ASU 3 sets (ASU1, ASU2, and ASU3)

ASU1 connections: Output: Control Gate, SMU: HRSMU, AUX: PGU1

ASU2 connections: Output: Drain, SMU: HRSMU, AUX: PGU2

ASU3 connections: Output: Source and Substrate, SMU: HRSMU, AUX: PGU2

Setting of ASU I/O Path, ASU tab, Configuration window: AUX

### [Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source and Substrate terminals, constant voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

TotalWriteAndEraseCycles: Total number of write/erase operation

WritePulsePeriod: Write pulse period

WritePulseDelay: Write pulse delay

WritePulseWidth: Write pulse width

WriteLeadingTime: Write pulse leading edge transition time

WriteTrailingTime: Write pulse trailing edge transition time

Vwrite: Write pulse output level

ErasePulsePeriod: Erase pulse period

ErasePulseDelay: Erase pulse delay

ErasePulseWidth: Erase pulse width

EraseLeadingTime: Erase pulse leading edge transition time

EraseTrailingTime: Erase pulse trailing edge transition time

Verase: Erase pulse output level

### [Extended Test Parameters]

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Vs: Source voltage  
IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
PgAdd: GPIB address of pulse generator  
BaseValue: Pulse base value  
NoOfPulse: Number of output pulses

### [Test Output: X-Y Graph]

X axis: Number of write/erase operation (LOG)  
Y1 axis: Threshold voltage after write VthWrittenList (LINEAR)  
Y2 axis: Threshold voltage after erase VthErasedList (LINEAR)

### [Test Setup Details]

See NandFlash2 IV-Write-IV and NandFlash2 IV-Erase-IV.



## 5.6 *NandFlash2 IV-Erase-IV: NAND flash memory cell Id-Vg, Erase, Id-Vg (A.01.20)*

[Supported Analyzer]  
B1500A

[Description]

Measures the Id-Vg characteristics of NAND-type flash memory cell, performs the data erase operation, measures the Id-Vg characteristics again, and plots the both Id-Vg characteristics on a graph. Uses pulse generator (2-output) 1 unit and HRSMU/ASU 2 sets.

Before the Id-Vg measurements, the initial pulse will be applied to the device under test.

[Device Under Test]

NAND-type flash memory cell

Connect the Control Gate to a SMU and the Drain to the ASU1 Output.

Open the Floating Gate. And connect the other terminals to the ASU2 Output.

[Required Modules and Accessories]

Agilent 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit

HRSMU/ASU 2 sets (ASU1 and ASU2)

ASU1 connections: Output: Drain, SMU: HRSMU, AUX: PGU1

ASU2 connections: Output: Source and Substrate, SMU: HRSMU, AUX: PGU1

Setting of ASU I/O Path, ASU tab, Configuration window: AUX

PGU1 is connected to keep the setup for the data write operation.

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

Source: SMU connected to Source and Substrate terminals, constant voltage output

PulsePeriod: Erase pulse period

PulseDelay: Erase pulse delay

PulseWidth: Erase pulse width

LeadingTime: Pulse leading edge transition time

TrailingTime: Pulse trailing edge transition time

Verase: Erase pulse output level

[Extended Test Parameters]

IgLimit: Gate current compliance

HoldTime: Hold time

## 5 Memory

DelayTime: Delay time  
BaseValue: Erase pulse base value  
PgAdd: GPIB address of pulse generator  
NoOfPulse: Number of output pulses for the erase operation

### [Initial pulse setup parameters]

Pulse period Period2=50 s  
Pulse delay Delay2=0 s  
Pulse duty cycle Dcyc2=50 %  
Pulse output level Level2=0 V  
Pulse base value Base2=200 mV  
Number of output pulses TrigCount=1

The parameters are defined in the ForcePG2 setup of the Test Contents, and can be changed by using the Test Definition editor.

### [Measurement Parameters]

Drain current Idrain (defined in Id-Vg\_Initial and Id-Vg\_Erased setup)

### [User Function]

IdrainPerWg=Idrain/Wg (defined in Id-Vg\_Initial and Id-Vg\_Erased setup)

### [Analysis Function]

VthBefore=@L1X (X intercept of Line1, defined in Id-Vg\_Initial setup)  
VthAfter=@L1X (X intercept of Line1, defined in Id-Vg\_Erased setup)

### [Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [Test Output: X-Y Graph]

X axis: Gate voltage VgateList (LINEAR)  
Y1 axis: Drain current before Erase operation IdInitialList (LOG)  
Y2 axis: Drain current after Erase operation IdErasedList (LOG)

### [Test Output: Parameters]

Threshold voltage before Erase operation VthInitial  
Threshold voltage after Erase operation VthErased

## 5.7 *NandFlash2 IV-Write-IV: NAND flash memory cell Id-Vg, Write, Id-Vg (A.01.20)*

### [Supported Analyzer]

B1500A

### [Description]

Measures the Id-Vg characteristics of NAND-type flash memory cell, performs the data write operation, measures the Id-Vg characteristics again, and plots the both Id-Vg characteristics on a graph. Uses pulse generator (2-output) 1 unit and HRSMU/ASU 1 set.

Before the Id-Vg measurements, the initial pulse will be applied to the device under test.

### [Device Under Test]

NAND-type flash memory cell

Connect the Control Gate to the ASU Output, and the Drain to a SMU.

Open the Floating Gate. And connect the other terminals to a SMU.

### [Required Modules and Accessories]

Agilent 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit

HRSMU/ASU 1 set

ASU connections: Output: Control Gate, SMU: HRSMU, AUX: PGU1

Setting of ASU I/O Path, ASU tab, Configuration window: AUX

### [Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

Source: SMU connected to Source and Substrate terminals, constant voltage output

PulsePeriod: Write pulse period

PulseDelay: Write pulse delay

PulseWidth: Write pulse width

LeadingTime: Pulse leading edge transition time

TrailingTime: Pulse trailing edge transition time

Vwrite: Write pulse output level

### [Extended Test Parameters]

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

BaseValue: Write pulse base value

PgAdd: GPIB address of pulse generator

## 5 Memory

NoOfPulse: Number of output pulses for the write operation

[Initial pulse setup parameters]

Pulse period Period2=50 s

Pulse delay Delay2=0 s

Pulse duty cycle Dcyc2=50 %

Pulse output level Level2=0 V

Pulse base value Base2=200 mV

Number of output pulses TrigCount=1

The parameters are defined in the ForcePG2 setup of the Test Contents, and can be changed by using the Test Definition editor.

[Measurement Parameters]

Drain current Idrain (defined in Id-Vg\_Initial and Id-Vg\_Written setup)

[User Function]

IdrainPerWg=Idrain/Wg (defined in Id-Vg\_Initial and Id-Vg\_Written setup)

[Analysis Function]

VthBefore=@L1X (X intercept of Line1, defined in Id-Vg\_Initial setup)

VthAfter=@L1X (X intercept of Line1, defined in Id-Vg\_Written setup)

[Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]

X axis: Gate voltage VgateList (LINEAR)

Y1 axis: Drain current before Write operation IdInitialList (LOG)

Y2 axis: Drain current after Write operation IdWrittenList (LOG)

[Test Output: Parameters]

Threshold voltage before Write operation VthInitial

Threshold voltage after Write operation VthWritten

## 5.8 *NandFlash2 Retention(ErasedCell): NAND flash memory cell Data retention test after Erase (A.01.20)*

### [Supported Analyzer]

B1500A

### [Description]

Performs the data retention test for the NAND type flash memory cell after the erase operation, and plots the accumulated time vs threshold voltage characteristics. The test is performed as follows.

1. Applies the erase pulse.
2. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
3. If the accumulated time is 100 seconds or less:  
Performs the drain current sampling measurement, 10 seconds in 1 second step.  
After the sampling measurement, measures the Id-Vg characteristics and extracts Vth.
4. If the accumulated time is more than 100 seconds:  
Performs the drain current sampling measurement, 100 seconds in 10 seconds step.  
After the sampling measurement, measures the Id-Vg characteristics and extracts Vth.
5. Repeats 3 or 4 until that the accumulated time overs the specified TotalRetentionTime.  
The available TotalRetentionTime value is 10 to 10000 seconds.

### [Device Under Test]

NAND-type flash memory cell

Connect the Source and Substrate to the ASU1 Output, and the Drain to the ASU2 Output.  
Open the Floating Gate, and connect the other terminals to the PGU2 output terminal.

### [Required Modules and Accessories]

Agilent 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit  
HRSMU/ASU 2 sets (ASU1 and ASU2)

ASU1 connections: Output: Source and Substrate, SMU: HRSMU, AUX: PGU1

ASU2 connections: Output: Drain, SMU: HRSMU, AUX: PGU1

Setting of ASU I/O Path, ASU tab, Configuration window: AUX

PGU1 is connected to keep the setup for the data write operation.

### [Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source and Substrate terminals, constant voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulsePeriod: Erase pulse period

PulseDelay: Erase pulse delay

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PulseWidth: Erase pulse width

Verase: Erase pulse output level

LeadingTime: Pulse leading edge transition time

TrailingTime: Pulse trailing edge transition time

TotalRetentionTime: Time to continue the test. 10 to 10000 seconds.

### [Extended Test Parameters]

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

BaseValue: Erase pulse base value

PgAdd: GPIB address of pulse generator

NoOfPulse: Number of output pulses for the erase operation

### [Test Output: X-Y Graph]

X axis: Time TimeList (LOG)

Y1 axis: Threshold voltage VthList (LINEAR)

### [Test Setup Details]

See NandFlash2 IV-Erase-IV.

## 5.9 *NandFlash2 Retention(WrittenCell): NAND flash memory cell Data retention test after Write (A.01.20)*

[Supported Analyzer]  
B1500A

[Description]

Performs the data retention test for the NAND type flash memory cell after the write operation, and plots the accumulated time vs threshold voltage characteristics. The test is performed as follows.

1. Applies the write pulse.
2. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
3. If the accumulated time is 100 seconds or less:  
Performs the drain current sampling measurement, 10 seconds in 1 second step.  
After the sampling measurement, measures the Id-Vg characteristics and extracts Vth.
4. If the accumulated time is more than 100 seconds:  
Performs the drain current sampling measurement, 100 seconds in 10 seconds step.  
After the sampling measurement, measures the Id-Vg characteristics and extracts Vth.
5. Repeats 3 or 4 until that the accumulated time overs the specified TotalRetentionTime.  
The available TotalRetentionTime value is 10 to 10000 seconds.

[Device Under Test]

NAND-type flash memory cell  
Connect the Control Gate to the ASU Output, and the Drain to a SMU.  
Open the Floating Gate, and connect the other terminals to a SMU.

[Required Modules and Accessories]

Agilent 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit  
HRSMU/ASU 1 set

ASU connections: Output: Control Gate, SMU: HRSMU, AUX: PGU1  
Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]

Lg: Gate length  
Wg: Gate width  
Temp: Temperature  
IdMax: Drain current compliance

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output  
Drain: SMU connected to Drain terminal, constant voltage output  
Source: SMU connected to Source and Substrate terminals, constant voltage output  
VgStart: Sweep start voltage for Gate terminal  
VgStop: Sweep stop voltage for Gate terminal  
VgStep: Sweep step voltage for Gate terminal  
Vd: Drain voltage  
Id@Vth: Drain current to decide the Vth  
IntegTime: Integration time  
PulsePeriod: Write pulse period  
PulseDelay: Write pulse delay  
PulseWidth: Write pulse width  
Vwrite: Write pulse output level

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LeadingTime: Pulse leading edge transition time

TrailingTime: Pulse trailing edge transition time

TotalRetentionTime: Time to continue the test. 10 to 10000 seconds.

### [Extended Test Parameters]

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

PgAdd: GPIB address of pulse generator

BaseValue: Write pulse base value

NoOfPulse: Number of output pulses for the write operation

### [Test Output: X-Y Graph]

X axis: Time TimeList (LOG)

Y1 axis: Threshold voltage VthList (LINEAR)

### [Test Setup Details]

See NandFlash2 IV-Write-IV.



### ***5.10 NandFlash2 Vth(ErasingTimeDependence): NAND flash memory cell erasing time dependence test (A.01.20)***

[Supported Analyzer]

B1500A

[Description]

Performs the erasing time dependence test of the NAND-type flash memory cell, and plots the accumulated erasing time (accumulated pulse width) vs threshold voltage characteristics.

[Device Under Test]

NAND-type flash memory cell

Connect the Control Gate to a SMU, and the Drain to the ASU2 Output.

Open the Floating Gate, and connect the other terminals to the ASU1 Output.

[Required Modules and Accessories]

Agilent 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit

HRSMU/ASU 2 sets (ASU1 and ASU2)

ASU1 connections: Output: Source and Substrate, SMU: HRSMU, AUX: PGU1

ASU2 connections: Output: Drain, SMU: HRSMU, AUX: PGU1

Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Vs: Source voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulsePeriod: Erase pulse period

PulseDelay: Erase pulse delay

PulseWidth: Total accumulated pulse width

CheckNoOfTimes: Number of Vth measurement operation

Verase: Erase pulse output level

LeadingTime: Pulse leading edge transition time

TrailingTime: Pulse trailing edge transition time

[Extended Test Parameter]

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

BaseValue: Erase pulse base value

## 5 Memory

PgAdd: GPIB address of pulse generator

NoOfPulse: Number of output pulses for the erase operation

[Measurement Parameters]

Drain current Idrain

[Analysis Function]

Vth=@L1X (X intercept of Line1)

[Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]

X axis: Accumulated erasing pulse width EraseTimeList (LOG)

Y1 axis: Threshold voltage Vth (LINEAR)

### ***5.11 NandFlash2 Vth(WritingTimeDependence): NAND flash memory cell writing time dependence test (A.01.20)***

[Supported Analyzer]  
B1500A

[Description]  
Performs the writing time dependence test of the NAND-type flash memory cell, and plots the accumulated writing time (accumulated pulse width) vs threshold voltage characteristics.

[Device Under Test]  
NAND-type flash memory cell  
Connect the Control Gate to the ASU Output, and the Drain to a SMU.  
Open the Floating Gate, and connect the other terminals to a SMU.

[Required Modules and Accessories]  
Agilent 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit  
HRSMU/ASU 1 set

ASU connections: Output: Control Gate, SMU: HRSMU, AUX: PGU1  
Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]  
Lg: Gate length  
Wg: Gate width  
Temp: Temperature  
IdMax: Drain current compliance

[Test Parameters]  
Gate: SMU connected to Gate terminal, primary sweep voltage output  
Drain: SMU connected to Drain terminal, constant voltage output  
Source: SMU connected to Source terminal, constant voltage output  
VgStart: Sweep start voltage for Gate terminal  
VgStop: Sweep stop voltage for Gate terminal  
VgStep: Sweep step voltage for Gate terminal  
Vd: Drain voltage  
Vs: Source voltage  
Id@Vth: Drain current to decide the Vth  
IntegTime: Integration time  
PulsePeriod: Write pulse period  
PulseDelay: Write pulse delay  
PulseWidth: Total accumulated pulse width  
CheckNoOfTimes: Number of Vth measurement operation  
Vwrite: Write pulse output level  
LeadingTime: Pulse leading edge transition time  
TrailingTime: Pulse trailing edge transition time

[Extended Test Parameter]  
IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
BaseValue: Write pulse base value  
PgAdd: GPIB address of pulse generator

## 5 Memory

NoOfPulse: Number of output pulses for the write operation

[Measurement Parameters]

Drain current Idrain

[Analysis Function]

Vth=@L1X (X intercept of Line1)

[Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]

X axis: Accumulated writing pulse width WriteTimeList (LOG)

Y1 axis: Threshold voltage Vth (LINEAR)

## **5.12 NandFlash2 WordDisturb(ErasedCell): NAND flash memory cell erase-disturb test (A.01.20)**

### [Supported Analyzer]

B1500A

### [Description]

Performs the erase-disturb test of the NAND-type flash memory cell, and plots the accumulated stress time vs threshold voltage characteristics.

### [Device Under Test]

NAND-type flash memory cell

Connect the Control Gate to the ASU1 Output, and the Drain to the ASU2 Output.

Open the Floating Gate, and connect the other terminals to the ASU3 Output.

### [Required Modules and Accessories]

Agilent 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit

HRSMU/ASU 3 sets (ASU1, ASU2, and ASU3)

ASU1 connections: Output: Control Gate, SMU: HRSMU, AUX: PGU1

ASU2 connections: Output: Drain, SMU: HRSMU, AUX: PGU2

ASU3 connections: Output: Source and Substrate, SMU: HRSMU, AUX: PGU2

Setting of ASU I/O Path, ASU tab, Configuration window: AUX

### [Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

VgStress: Stress voltage for Gate terminal

Vd: Drain voltage

Vs: Source voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

TotalStressTime: Total accumulated stress time

CheckNoOfTimes: Number of Vth measurement operation

PulsePeriod: Erase pulse period

PulseDelay: Erase pulse delay

PulseWidth: Erase pulse width

Verase: Erase pulse output level

LeadingTime: Pulse leading edge transition time

TrailingTime: Pulse trailing edge transition time

### [Extended Test Parameter]

## 5 Memory

IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
BaseValue: Erase pulse base value  
PgAdd: GPIB address of pulse generator  
NoOfPulse: Number of output pulses for the erase operation

### [Measurement Parameters]

Drain current Idrain

### [Analysis Function]

Vth=@L1X (X intercept of Line1)

### [Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [Test Output: X-Y Graph]

X axis: Accumulated stress time StressTimeList (LOG)

Y1 axis: Threshold voltage Vth (LINEAR)

### **5.13 NandFlash2 WordDisturb(WrittenCell): NAND flash memory cell read-disturb test (A.01.20)**

[Supported Analyzer]  
B1500A

[Description]  
Performs the read-disturb test of the NAND-type flash memory cell, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]  
NAND-type flash memory cell  
Connect the Control Gate to the ASU Output, and the Drain to a SMU.  
Open the Floating Gate, and connect the other terminals to a SMU.

[Required Modules and Accessories]  
Agilent 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit  
HRSMU/ASU 1 set

ASU connections: Output: Control Gate, SMU: HRSMU, AUX: PGU1  
Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]  
Lg: Gate length  
Wg: Gate width  
Temp: Temperature  
IdMax: Drain current compliance

[Test Parameters]  
Gate: SMU connected to Gate terminal, primary sweep voltage output  
Drain: SMU connected to Drain terminal, constant voltage output  
Source: SMU connected to Source terminal, constant voltage output  
VgStart: Sweep start voltage for Gate terminal  
VgStop: Sweep stop voltage for Gate terminal  
VgStep: Sweep step voltage for Gate terminal  
VgStress: Stress voltage for Gate terminal  
Vd: Drain voltage  
Vs: Source voltage  
Id@Vth: Drain current to decide the Vth  
IntegTime: Integration time  
TotalStressTime: Total accumulated stress time  
CheckNoOfTimes: Number of Vth measurement operation  
PulsePeriod: Write pulse period  
PulseDelay: Write pulse delay  
PulseWidth: Write pulse width  
Vwrite: Write pulse output level  
LeadingTime: Pulse leading edge transition time  
TrailingTime: Pulse trailing edge transition time

[Extended Test Parameter]  
IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time

## 5 Memory

BaseValue: Write pulse base value  
PgAdd: GPIB address of pulse generator  
NoOfPulse: Number of output pulses for the write operation

### [Measurement Parameters]

Drain current Idrain

### [Analysis Function]

Vth=@L1X (X intercept of Line1)

### [Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [Test Output: X-Y Graph]

X axis: Accumulated stress time StressTimeList (LOG)

Y1 axis: Threshold voltage Vth (LINEAR)



### 5.14 NandFlash3 Endurance: NAND flash memory cell endurance test (A.03.10)

[Supported Analyzer]

B1500A

[Description]

Performs the endurance test for the NAND type flash memory cell and plots the number of write/erase operation vs threshold voltage characteristics.

[Device Under Test]

NAND-type flash memory cell

[Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 2 sets or HRSMU/ASU 3 sets)

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source and Substrate terminals, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

Psource: SPGU channel connected to Drain, Source, and Substrate via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

TotalWriteAndEraseCycles: Total number of write/erase operation

WritePulsePeriod: Write pulse period

WritePulseDelay: Write pulse delay

WritePulseWidth: Write pulse width

WriteLeadingTime: Write pulse leading edge transition time

WriteTrailingTime: Write pulse trailing edge transition time

Vwrite: Write pulse output level

ErasePulsePeriod: Erase pulse period

ErasePulseDelay: Erase pulse delay

ErasePulseWidth: Erase pulse width

EraseLeadingTime: Erase pulse leading edge transition time

EraseTrailingTime: Erase pulse trailing edge transition time

Verase: Erase pulse output level

MeasTiming: Timing to perform Vth measurement

[Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

## 5 Memory

BaseValue: Write pulse base value

DrainMinRng: Minimum range of drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

### [Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate

Drain current Idrain

### [Test Output: X-Y Graph]

X axis: Number of write/erase cycles CycleList (LOG)

Y1 axis: Threshold voltage after write VthWrittenList (LINEAR)

Y2 axis: Threshold voltage after erase VthErasedList (LINEAR)

### [Test Output: List Display]

Number of write/erase cycles CycleList

Threshold voltage after write VthWrittenList

Threshold voltage after erase VthErasedList

### [Test Setup Details]

See NandFlash3 IV-Write-IV and NandFlash3 IV-Erase-IV.

TotalWriteAndEraseCycles should be 10, 100, 1000, 10000, 100000, or 1000000.

### **5.15 NandFlash3 IV-Erase-IV: NAND flash memory cell Id-Vg, Erase, Id-Vg (A.03.10)**

[Supported Analyzer]

B1500A

[Description]

Measures the Id-Vg characteristics of NAND-type flash memory cell, performs the data erase operation, measures the Id-Vg characteristics again, and plots the both Id-Vg characteristics on a graph.

Before the Id-Vg measurements, the initial pulse will be applied to the device under test.

[Device Under Test]

NAND-type flash memory cell

[Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 2 sets)

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source and Substrate terminals, constant voltage output

PSource: SPGU channel connected to Drain and Source via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulsePeriod: Erase pulse period

PulseDelay: Erase pulse delay

PulseWidth: Erase pulse width

Verase: Erase pulse output level

LeadingTime: Pulse leading edge transition time

TrailingTime: Pulse trailing edge transition time

[Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

BaseValue: Erase pulse base value

NoOfPulse: Number of output pulses for the erase operation

DrainMinRng: Minimum range of drain current measurement

## 5 Memory

### [Measurement Parameters]

Drain current Idrain

### [User Function]

IdrainPerWg=Idrain/Wg

### [Analysis Function]

VthAfter=@L1X (X intercept of Line1)

### [Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate

Drain voltage Vdrain

Drain current Idrain

### [Test Output: X-Y Graph]

X axis: Gate voltage VgateList (LINEAR)

Y1 axis: Drain current before Erase operation IdInitialList (LOG)

Y2 axis: Drain current after Erase operation IdErasedList (LOG)

### [Test Output: List Display]

Gate voltage VgateList

Drain current before Erase operation IdInitialList

Drain current after Erase operation IdErasedList

### [Test Output: Parameters]

Threshold voltage before Erase operation VthInitial

Threshold voltage after Erase operation VthErased

## 5.16 NandFlash3 IV-Write-IV: NAND flash memory cell Id-Vg, Write, Id-Vg (A.03.10)

### [Supported Analyzer]

B1500A

### [Description]

Measures the Id-Vg characteristics of NAND-type flash memory cell, performs the data write operation, measures the Id-Vg characteristics again, and plots the both Id-Vg characteristics on a graph.

Before the Id-Vg measurements, the initial pulse will be applied to the device under test.

### [Device Under Test]

NAND-type flash memory cell

### [Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 1 sets)

### [Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source and Substrate terminals, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulsePeriod: Write pulse period

PulseDelay: Write pulse delay

PulseWidth: Write pulse width

Vwrite: Write pulse output level

LeadingTime: Pulse leading edge transition time

TrailingTime: Pulse trailing edge transition time

### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

BaseValue: Write pulse base value

NoOfPulse: Number of output pulses for the write operation

DrainMinRng: Minimum range of drain current measurement

## 5 Memory

### [Measurement Parameters]

Drain current Idrain

### [User Function]

$I_{\text{drainPerWg}} = I_{\text{drain}} / W_g$

### [Analysis Function]

$V_{\text{thAfter}} = @L1X$  (X intercept of Line1)

### [Auto Analysis]

Line1: Vertical line for Y1 at  $I_{\text{drain}} = I_d @ V_{\text{th}}$

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate

Drain voltage Vdrain

Drain current Idrain

### [Test Output: X-Y Graph]

X axis: Gate voltage VgateList (LINEAR)

Y1 axis: Drain current before Write operation IdInitialList (LOG)

Y2 axis: Drain current after Write operation IdWrittenList (LOG)

### [Test Output: List Display]

Gate voltage VgateList

Drain current before Write operation IdInitialList

Drain current after Write operation IdWrittenList

### [Test Output: Parameters]

Threshold voltage before Write operation VthInitial

Threshold voltage after Write operation VthWritten

### ***5.17 NandFlash3 Retention(ErasedCell): NAND flash memory cell Data retention test after Erase (A.03.10)***

[Supported Analyzer]

B1500A

[Description]

Performs the data retention test for the NAND type flash memory cell after the erase operation, and plots the accumulated time vs threshold voltage characteristics.

[Device Under Test]

NAND-type flash memory cell

[Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 2 sets)

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source and Substrate terminals, constant voltage output

Psource: SPGU channel connected to Drain, Source, and Substrate via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulsePeriod: Erase pulse period

PulseDelay: Erase pulse delay

PulseWidth: Erase pulse width

Verase: Erase pulse output level

LeadingTime: Pulse leading edge transition time

TrailingTime: Pulse trailing edge transition time

TotalRetentionTime: Time to continue the test. 10 to 10000 seconds

MeasTiming: Timing to perform Vth measurement

[Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

BaseValue: Erase pulse base value

NoOfPulse: Number of output pulses for the erase operation

DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]

## 5 Memory

Drain current Idrain

[User Function]

IdrainPerWg=Idrain/Wg

[Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

[Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

[X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

[List Display]

Gate voltage Vgate

Drain voltage Vdrain

Drain current Idrain

[Test Output: X-Y Graph]

X axis: Time TimeList (LOG)

Y1 axis: Threshold voltage VthList (LINEAR)

[Test Output: List Display]

Time TimeList

Threshold voltage VthList

[Test Setup Details]

See NandFlash3 IV-Erase-IV.



### ***5.18 NandFlash3 Retention(WrittenCell): NAND flash memory cell Data retention test after Write (A.03.10)***

[Supported Analyzer]

B1500A

[Description]

Performs the data retention test for the NAND type flash memory cell after the write operation, and plots the accumulated time vs threshold voltage characteristics.

[Device Under Test]

NAND-type flash memory cell

[Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 1 set)

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source and Substrate terminals, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulsePeriod: Write pulse period

PulseDelay: Write pulse delay

PulseWidth: Write pulse width

Vwrite: Write pulse output level

LeadingTime: Pulse leading edge transition time

TrailingTime: Pulse trailing edge transition time

TotalRetentionTime: Time to continue the test. 10 to 10000 seconds

MeasTiming: Timing to perform Vth measurement

[Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

BaseValue: Write pulse base value

NoOfPulse: Number of output pulses for the write operation

DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]

## 5 Memory

Drain current Idrain

[User Function]

IdrainPerWg=Idrain/Wg

[Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

[Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

[X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

[List Display]

Gate voltage Vgate

Drain voltage Vdrain

Drain current Idrain

[Test Output: X-Y Graph]

X axis: Time TimeList (LOG)

Y1 axis: Threshold voltage VthList (LINEAR)

[Test Output: List Display]

Time TimeList

Threshold voltage VthList

[Test Setup Details]

See NandFlash3 IV-Write-IV.

### ***5.19 NandFlash3 Vth(ErasingTimeDependence): NAND flash memory cell erasing time dependence test (A.03.10)***

[Supported Analyzer]  
B1500A

[Description]

Performs the erasing time dependence test of the NAND-type flash memory cell, and plots the accumulated erasing time (accumulated pulse width) vs threshold voltage characteristics. The test is performed as follows.

1. Applies the erase pulse with pulse width specified by the first element of the PulseWidth parameter.
2. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
3. Applies the erase pulse with pulse width specified by the next element of the PulseWidth parameter.
4. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
5. Repeats 3 and 4 until that the pulse width becomes StopPulseWidth.

[Device Under Test]

NAND-type flash memory cell

[Required Modules and Accessories]

Agilent B1525A SPGU 1 unit  
Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

[Device Parameters]

Lg: Gate length  
Wg: Gate width  
Temp: Temperature  
IdMax: Drain current compliance

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output  
Drain: SMU connected to Drain terminal, constant voltage output  
Source: SMU connected to Source terminal, constant voltage output  
Psource: SPGU channel connected to Drain, Source, and Substrate via Selector  
VgStart: Sweep start voltage for Gate terminal  
VgStop: Sweep stop voltage for Gate terminal  
VgStep: Sweep step voltage for Gate terminal  
Vd: Drain voltage  
Id@Vth: Drain current to decide the Vth  
IntegTime: Integration time  
PulseDelay: Erase pulse delay  
PulseWidth: List of erase pulse width  
StopPulseWidth: Pulse width to stop testing  
Verase: Erase pulse output level  
LeadingTime: Pulse leading edge transition time  
TrailingTime: Pulse trailing edge transition time

[Extended Test Parameters]

Vs: Source voltage  
IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
BaseValue: Erase pulse base value

## 5 Memory

DrainMinRng: Minimum range of drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

### [Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate

Drain voltage Vdrain

Drain current Idrain

### [Test Output: X-Y Graph]

X axis: Accumulated erasing pulse width EraseTimeList (LOG)

Y1 axis: Threshold voltage VthList (LINEAR)

### [Test Output: List Display]

Accumulated erasing pulse width EraseTimeList

Threshold voltage VthList

## 5.20 NandFlash3 Vth(WritingTimeDependence): NAND flash memory cell writing time dependence test (A.03.10)

### [Supported Analyzer]

B1500A

### [Description]

Performs the writing time dependence test of the NAND-type flash memory cell, and plots the accumulated writing time (accumulated pulse width) vs threshold voltage characteristics. The test is performed as follows.

1. Applies the write pulse with pulse width specified by the first element of the PulseWidth parameter.
2. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
3. Applies the write pulse with pulse width specified by the next element of the PulseWidth parameter.
4. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
5. Repeats 3 and 4 until that the pulse width becomes StopPulseWidth.

### [Device Under Test]

NAND-type flash memory cell

### [Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 1 set)

### [Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulseDelay: Write pulse delay

PulseWidth: List of write pulse width

StopPulseWidth: Pulse width to stop testing

Vwrite: Write pulse output level

LeadingTime: Pulse leading edge transition time

TrailingTime: Pulse trailing edge transition time

### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

## 5 Memory

BaseValue: Write pulse base value

DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]

Drain current Idrain

[Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

[Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

[X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

[List Display]

Gate voltage Vgate

Drain voltage Vdrain

Drain current Idrain

[Test Output: X-Y Graph]

X axis: Accumulated writing pulse width WriteTimeList (LOG)

Y1 axis: Threshold voltage VthList (LINEAR)

[Test Output: List Display]

Accumulated writing pulse width WriteTimeList

Threshold voltage VthList

### **5.21 NandFlash3 WordDisturb(ErasedCell): NAND flash memory cell erase-disturb test (A.03.10)**

[Supported Analyzer]

B1500A

[Description]

Performs the erase-disturb test of the NAND-type flash memory cell, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]

NAND-type flash memory cell

[Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 2 set or HRSMU/ASU 3 set)

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

Psource: SPGU channel connected to Drain, Source, and Substrate via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

VgStress: Stress voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

TotalStressTime: Total accumulated stress time

CheckNoOfTimes: Number of Vth measurement operation

PulsePeriod: Erase pulse period

PulseDelay: Erase pulse delay

PulseWidth: Erase pulse width

Verase: Erase pulse output level

LeadingTime: Pulse leading edge transition time

TrailingTime: Pulse trailing edge transition time

[Extended Test Parameter]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

BaseValue: Erase pulse base value

NoOfPulse: Number of output pulses for the erase operation

DrainMinRng: Minimum range of drain current measurement

## 5 Memory

### [Measurement Parameters]

Drain current Idrain

### [Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate

Drain voltage Vdrain

Drain current Idrain

### [Test Contents: Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [Test Output: X-Y Graph]

X axis: Accumulated erasing pulse width EraseTimeList (LOG)

Y1 axis: Threshold voltage VthList (LINEAR)

### [Test Output: List Display]

Accumulated erasing pulse width EraseTimeList

Threshold voltage VthList



## 5.22 NandFlash3 WordDisturb(WrittenCell): NAND flash memory cell read-disturb test (A.03.10)

### [Supported Analyzer]

B1500A

### [Description]

Performs the read-disturb test of the NAND-type flash memory cell, and plots the accumulated stress time vs threshold voltage characteristics.

### [Device Under Test]

NAND-type flash memory cell

### [Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 1 set)

### [Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

VgStress: Stress voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

TotalStressTime: Total accumulated stress time

CheckNoOfTimes: Number of Vth measurement operation

PulsePeriod: Write pulse period

PulseDelay: Write pulse delay

PulseWidth: Total accumulated pulse width

Vwrite: Write pulse output level

LeadingTime: Pulse leading edge transition time

TrailingTime: Pulse trailing edge transition time

### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

BaseValue: Write pulse base value

NoOfPulse: Number of output pulses for the erase operation

DrainMinRng: Minimum range of drain current measurement

## 5 Memory

### [Measurement Parameters]

Drain current Idrain

### [Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate

Drain voltage Vdrain

Drain current Idrain

### [Test Contents: Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [Test Output: X-Y Graph]

X axis: Accumulated writing pulse width WriteTimeList (LOG)

Y1 axis: Threshold voltage Vth (LINEAR)

### [Test Output: List Display]

Accumulated writing pulse width WriteTimeList

Threshold voltage VthList

### 5.23 NorFlash Endurance: NOR flash memory cell endurance test (A.03.10)

[Supported Analyzer]

B1500A

[Description]

Performs the endurance test for the NOR type flash memory cell and plots the number of write/erase operation vs threshold voltage characteristics.

[Device Under Test]

NOR-type flash memory cell

[Required Modules and Accessories]

Agilent B1525A SPGU 2 units

Selector (16440A/16445A 2 sets or HRSMU/ASU 3 sets)

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

Pdrain: SPGU channel connected to Drain terminal via Selector

Psource: SPGU channel connected to Source terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

TotalWriteAndEraseCycles: Total number of write/erase operation

WritePeriod: Write pulse period

WriteGateDelay: Gate write pulse delay

WriteGateWidth: Gate write pulse width

WriteGateVwrite: Gate write pulse output level

WriteGateLeadingTime: Gate write pulse leading edge transition time

WriteGateTrailingTime: Gate write pulse trailing edge transition time

WriteDrainDelay: Drain write pulse delay

WriteDrainWidth: Drain write pulse width

WriteDrainVwrite: Drain write pulse output level

WriteDrainLeadingTime: Drain write pulse leading edge transition time

WriteDrainTrailingTime: Drain write pulse trailing edge transition time

ErasePeriod: Erase pulse period

EraseGateDelay: Gate erase pulse delay

EraseGateWidth: Gate erase pulse width

EraseGateVerase: Gate erase pulse output level

EraseGateLeadingTime: Gate erase pulse leading edge transition time

## 5 Memory

EraseGateTrailingTime: Gate erase pulse trailing edge transition time  
EraseSourceDelay: Source erase pulse delay  
EraseSourceWidth: Source erase pulse width  
EraseSourceVerase: Source erase pulse output level  
EraseSourceLeadingTime: Source erase pulse leading edge transition time  
EraseSourceTrailingTime: Source erase pulse trailing edge transition time

MeasTiming: Timing to perform Vth measurement

### [Extended Test Parameters]

Vs: Source voltage  
Vsub: Substrate voltage  
IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
BaseValue: Pulse base value  
DrainMinRng: Minimum range of drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate  
Drain current Idrain

### [Test Contents: Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [Test Output: X-Y Graph]

X axis: Number of write/erase cycles CycleList (LOG)  
Y1 axis: Threshold voltage after write VthWrittenList (LINEAR)  
Y2 axis: Threshold voltage after erase VthErasedList (LINEAR)

### [Test Output: List Display]

Number of write/erase cycles CycleList  
Threshold voltage after write VthWrittenList  
Threshold voltage after erase VthErasedList

### [Test Setup Details]

See NorFlash IV-Write-IV and NorFlash IV-Erase-IV.  
TotalWriteAndEraseCycles should be 10, 100, 1000, 10000, 100000, or 1000000.

## 5.24 NorFlash IV-Erase-IV: NOR flash memory cell Id-Vg, Erase, Id-Vg (A.03.10)

### [Supported Analyzer]

B1500A

### [Description]

Measures the Id-Vg characteristics of NOR-type flash memory cell, performs the data erase operation, measures the Id-Vg characteristics again, and plots the both Id-Vg characteristics on a graph.

Before the Id-Vg measurements, the initial pulse will be applied to the device under test.

### [Device Under Test]

NOR-type flash memory cell

### [Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 2 sets)

### [Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

Psource: SPGU channel connected to Source terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulsePeriod: Erase pulse period

GateDelay: Gate erase pulse delay

GateWidth: Gate erase pulse width

GateVerase: Gate erase pulse output level

GateLeadingTime: Gate pulse leading edge transition time

GateTrailingTime: Gate pulse trailing edge transition time

SourceDelay: Source erase pulse delay

SourceWidth: Source erase pulse width

SourceVerase: Source erase pulse output level

SourceLeadingTime: Source pulse leading edge transition time

SourceTrailingTime: Source pulse trailing edge transition time

### [Extended Test Parameters]

Vs: Source voltage

Vsubs: Substrate voltage

IgLimit: Gate current compliance

## 5 Memory

HoldTime: Hold time  
DelayTime: Delay time  
BaseValue: Pulse base value  
NoOfPulse: Number of output pulses for the erase operation  
DrainMinRng: Minimum range of drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [User Function]

$I_{\text{drainPerWg}} = I_{\text{drain}} / W_g$

### [Analysis Function]

$V_{\text{thAfter}} = @L1X$  (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)  
Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate  
Drain voltage Vdrain  
Drain current Idrain

### [Test Contents: Auto Analysis]

Line1: Vertical line for Y1 at  $I_{\text{drain}} = I_d @ V_{\text{th}}$

### [Test Output: X-Y Graph]

X axis: Gate voltage VgateList (LINEAR)  
Y1 axis: Drain current before Erase operation IdInitialList (LOG)  
Y2 axis: Drain current after Erase operation IdErasedList (LOG)

### [Test Output: List Display]

Gate voltage VgateList  
Drain current before Erase operation IdInitialList  
Drain current after Erase operation IdErasedList

### [Test Output: Parameters]

Threshold voltage before Erase operation VthInitial  
Threshold voltage after Erase operation VthErased

## 5.25 NorFlash IV-Write-IV: NOR flash memory cell Id-Vg, Write, Id-Vg (A.03.10)

### [Supported Analyzer]

B1500A

### [Description]

Measures the Id-Vg characteristics of NOR-type flash memory cell, performs the data write operation, measures the Id-Vg characteristics again, and plots the both Id-Vg characteristics on a graph.

Before the Id-Vg measurements, the initial pulse will be applied to the device under test.

### [Device Under Test]

NOR-type flash memory cell

### [Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 2 sets)

### [Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

Pdrain: SPGU channel connected to Drain terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulsePeriod: Write pulse period

GateDelay: Gate write pulse delay

GateWidth: Gate write pulse width

GateVwrite: Gate write pulse output level

GateLeadingTime: Gate pulse leading edge transition time

GateTrailingTime: Gate pulse trailing edge transition time

DrainDelay: Drain write pulse delay

DrainWidth: Drain write pulse width

DrainVwrite: Drain write pulse output level

DrainLeadingTime: Drain pulse leading edge transition time

DrainTrailingTime: Drain pulse trailing edge transition time

### [Extended Test Parameters]

Vs: Source voltage

Vsubs: Substrate voltage

IgLimit: Gate current compliance

## 5 Memory

HoldTime: Hold time  
DelayTime: Delay time  
BaseValue: Pulse base value  
NoOfPulse: Number of output pulses for the write operation  
DrainMinRng: Minimum range of drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [User Function]

$I_{\text{drainPerWg}} = I_{\text{drain}} / W_g$

### [Analysis Function]

$V_{\text{thAfter}} = @L1X$  (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)  
Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate  
Drain voltage Vdrain  
Drain current Idrain

### [Test Contents: Auto Analysis]

Line1: Vertical line for Y1 at  $I_{\text{drain}} = I_d @ V_{\text{th}}$

### [Test Output: X-Y Graph]

X axis: Gate voltage VgateList (LINEAR)  
Y1 axis: Drain current before Write operation IdInitialList (LOG)  
Y2 axis: Drain current after Write operation IdWrittenList (LOG)

### [Test Output: List Display]

Gate voltage VgateList  
Drain current before Write operation IdInitialList  
Drain current after Write operation IdWrittenList

### [Test Output: Parameters]

Threshold voltage before Write operation VthInitial  
Threshold voltage after Write operation VthWritten



## ***5.26 NorFlash Retention(ErasedCell): NOR flash memory cell Data retention test after Erase (A.03.10)***

### [Supported Analyzer]

B1500A

### [Description]

Performs the data retention test for the NOR type flash memory cell after the erase operation, and plots the accumulated time vs threshold voltage characteristics.

### [Device Under Test]

NOR-type flash memory cell

### [Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 2 sets)

### [Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

Psource: SPGU channel connected to Source terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulsePeriod: Erase pulse period

GateDelay: Gate erase pulse delay

GateWidth: Gate erase pulse width

GateVerase: Gate erase pulse output level

GateLeadingTime: Gate pulse leading edge transition time

GateTrailingTime: Gate pulse trailing edge transition time

SourceDelay: Source erase pulse delay

SourceWidth: Source erase pulse width

SourceVerase: Source erase pulse output level

SourceLeadingTime: Source pulse leading edge transition time

SourceTrailingTime: Source pulse trailing edge transition time

TotalRetentionTime: Time to continue the test. 10 to 10000 seconds.

MeasTiming: Timing to perform Vth measurement

### [Extended Test Parameters]

Vs: Source voltage

Vsubs: Substrate voltage

## 5 Memory

IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
BaseValue: Pulse base value  
NoOfPulse: Number of output pulses for the erase operation  
DrainMinRng: Minimum range of drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [User Function]

$I_{\text{drainPerWg}} = I_{\text{drain}} / W_g$

### [Analysis Function]

$V_{\text{th@Id}} = @L1X$  (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)  
Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate  
Drain voltage Vdrain  
Drain current Idrain

### [Test Contents: Auto Analysis]

Line1: Vertical line for Y1 at  $I_{\text{drain}} = I_{\text{d}} @ V_{\text{th}}$

### [Test Output: X-Y Graph]

X axis: Time TimeList (LOG)  
Y1 axis: Threshold voltage VthList (LINEAR)

### [Test Output: List Display]

Time TimeList  
Threshold voltage VthList

### [Test Setup Details]

See NorFlash IV-Erase-IV.

### ***5.27 NorFlash Retention(WrittenCell): NOR flash memory cell Data retention test after Write (A.03.10)***

[Supported Analyzer]  
B1500A

[Description]  
Performs the data retention test for the NOR type flash memory cell after the write operation, and plots the accumulated time vs threshold voltage characteristics.

[Device Under Test]  
NOR-type flash memory cell

[Required Modules and Accessories]  
Agilent B1525A SPGU 1 unit  
Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

[Device Parameters]  
Lg: Gate length  
Wg: Gate width  
Temp: Temperature  
IdMax: Drain current compliance

[Test Parameters]  
Gate: SMU connected to Gate terminal, primary sweep voltage output  
Drain: SMU connected to Drain terminal, constant voltage output  
Source: SMU connected to Source terminal, constant voltage output  
Subs: SMU connected to Substrate terminal, constant voltage output  
Pgate: SPGU channel connected to Gate terminal via Selector  
Pdrain: SPGU channel connected to Drain terminal via Selector  
VgStart: Sweep start voltage for Gate terminal  
VgStop: Sweep stop voltage for Gate terminal  
VgStep: Sweep step voltage for Gate terminal  
Vd: Drain voltage  
Id@Vth: Drain current to decide the Vth  
IntegTime: Integration time  
PulsePeriod: Write pulse period  
GateDelay: Gate write pulse delay  
GateWidth: Gate write pulse width  
GateVwrite: Gate write pulse output level  
GateLeadingTime: Gate pulse leading edge transition time  
GateTrailingTime: Gate pulse trailing edge transition time  
DrainDelay: Drain write pulse delay  
DrainWidth: Drain write pulse width  
DrainVwrite: Drain write pulse output level  
DrainLeadingTime: Drain pulse leading edge transition time  
DrainTrailingTime: Drain pulse trailing edge transition time  
TotalRetentionTime: Time to continue the test. 10 to 10000 seconds.  
MeasTiming: Timing to perform Vth measurement

[Extended Test Parameters]  
Vs: Source voltage  
Vsubs: Substrate voltage

## 5 Memory

IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
BaseValue: Pulse base value  
NoOfPulse: Number of output pulses for the write operation  
DrainMinRng: Minimum range of drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [User Function]

$I_{\text{drainPerWg}} = I_{\text{drain}} / W_g$

### [Analysis Function]

$V_{\text{th@Id}} = @L1X$  (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)  
Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate  
Drain voltage Vdrain  
Drain current Idrain

### [Test Contents: Auto Analysis]

Line1: Vertical line for Y1 at  $I_{\text{drain}} = I_{\text{d}} @ V_{\text{th}}$

### [Test Output: X-Y Graph]

X axis: Time TimeList (LOG)  
Y1 axis: Threshold voltage VthList (LINEAR)

### [Test Output: List Display]

Time TimeList  
Threshold voltage VthList

### [Test Setup Details]

See NorFlash IV-Write-IV.

## 5.28 NorFlash Vth(ErasingTimeDependence): NOR flash memory cell erasing time dependence test (A.03.10)

### [Supported Analyzer]

B1500A

### [Description]

Performs the erasing time dependence test of the NOR-type flash memory cell, and plots the accumulated erasing time (accumulated pulse width) vs threshold voltage characteristics. The test is performed as follows.

1. Applies the erase pulse with pulse width specified by the first element of the SourceWidth parameter.
2. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
3. Applies the erase pulse with pulse width specified by the next element of the SourceWidth parameter.
4. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
5. Repeats 3 and 4 until that the pulse width becomes StopPulseWidth.

### [Device Under Test]

NOR-type flash memory cell

### [Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

### [Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

Psource: SPGU channel connected to Source terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

GateWidthOffset: Gate erase pulse width offset

GateVerase: Gate erase pulse output level

GateLeadingTime: Gate pulse leading edge transition time

GateTrailingTime: Gate pulse trailing edge transition time

SourceDelay: Source erase pulse delay

SourceWidth: List of source erase pulse width

StopPulseWidth: Source erase pulse width to stop testing

SourceVerase: Source erase pulse output level

SourceLeadingTime: Source pulse leading edge transition time

SourceTrailingTime: Source pulse trailing edge transition time

## 5 Memory

### [Extended Test Parameters]

Vs: Source voltage  
Vsubs: Substrate voltage  
IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
BaseValue: Pulse base value  
DrainMinRng: Minimum range of drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)  
Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate  
Drain voltage Vdrain  
Drain current Idrain

### [Test Contents: Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [Test Output: X-Y Graph]

X axis: Accumulated erasing pulse width EraseTimeList (LOG)  
Y1 axis: Threshold voltage VthList (LINEAR)

### [Test Output: List Display]

Accumulated erasing pulse width EraseTimeList  
Threshold voltage VthList

## 5.29 NorFlash Vth(WritingTimeDependence): NOR flash memory cell writing time dependence test (A.03.10)

### [Supported Analyzer]

B1500A

### [Description]

Performs the writing time dependence test of the NOR-type flash memory cell, and plots the accumulated writing time (accumulated pulse width) vs threshold voltage characteristics. The test is performed as follows.

1. Applies the write pulse with pulse width specified by the first element of the DrainWidth parameter.
2. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
3. Applies the write pulse with pulse width specified by the next element of the DrainWidth parameter.
4. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
5. Repeats 3 and 4 until that the pulse width becomes StopPulseWidth.

### [Device Under Test]

NOR-type flash memory cell

### [Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

### [Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

Pdrain: SPGU channel connected to Drain terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

GateWidthOffset: Gate write pulse width offset

GateVwrite: Gate write pulse output level

GateLeadingTime: Gate pulse leading edge transition time

GateTrailingTime: Gate pulse trailing edge transition time

DrainDelay: Drain write pulse delay

DrainWidth: List of drain write pulse width

StopPulseWidth: Drain write pulse width to stop testing

DrainVwrite: Drain write pulse output level

DrainLeadingTime: Drain pulse leading edge transition time

DrainTrailingTime: Drain pulse trailing edge transition time

## 5 Memory

### [Extended Test Parameters]

Vs: Source voltage  
Vsubs: Substrate voltage  
IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
BaseValue: Pulse base value  
DrainMinRng: Minimum range of drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)  
Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate  
Drain voltage Vdrain  
Drain current Idrain

### [Test Contents: Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [Test Output: X-Y Graph]

X axis: Accumulated writing pulse width WriteTimeList (LOG)  
Y1 axis: Threshold voltage VthList (LINEAR)

### [Test Output: List Display]

Accumulated writing pulse width WriteTimeList  
Threshold voltage VthList



### ***5.30 NorFlash WordDisturb(ErasedCell): NOR flash memory cell Word disturb test after Erase (A.03.10)***

[Supported Analyzer]

B1500A

[Description]

Performs the word disturb test of the NOR-type flash memory cell after the erase operation, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]

NOR-type flash memory cell

[Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

Psource: SPGU channel connected to Source terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

VgStress: Stress voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulsePeriod: Erase pulse period

GateDelay: Gate erase pulse delay

GateWidth: Gate erase pulse width

GateVerase: Gate erase pulse output level

GateLeadingTime: Gate pulse leading edge transition time

GateTrailingTime: Gate pulse trailing edge transition time

SourceDelay: Source erase pulse delay

SourceWidth: Source erase pulse width

SourceVerase: Source erase pulse output level

SourceLeadingTime: Source pulse leading edge transition time

SourceTrailingTime: Source pulse trailing edge transition time

TotalStressTime: Total accumulated stress time

CheckNoOfTimes: Number of Vth measurement operation

[Extended Test Parameters]

Vs: Source voltage

## 5 Memory

Vsubs: Substrate voltage  
IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
BaseValue: Pulse base value  
NoOfPulse: Number of output pulses for the erase operation  
DrainMinRng: Minimum range of drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)  
Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate  
Drain voltage Vdrain  
Drain current Idrain

### [Test Contents: Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [Test Output: X-Y Graph]

X axis: Accumulated erasing pulse width EraseTimeList (LOG)  
Y1 axis: Threshold voltage VthList (LINEAR)

### [Test Output: List Display]

Accumulated erasing pulse width EraseTimeList  
Threshold voltage VthList

### ***5.31 NorFlash WordDisturb(WrittenCell): NOR flash memory cell Word disturb test after Write (A.03.10)***

[Supported Analyzer]

B1500A

[Description]

Performs the word disturb test of the NOR-type flash memory cell after the write operation, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]

NOR-type flash memory cell

[Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

Pdrain: SPGU channel connected to Drain terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

VgStress: Stress voltage for Gate terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulsePeriod: Write pulse period

GateDelay: Gate write pulse delay

GateWidth: Gate write pulse width

GateVwrite: Gate write pulse output level

GateLeadingTime: Gate pulse leading edge transition time

GateTrailingTime: Gate pulse trailing edge transition time

DrainDelay: Drain write pulse delay

DrainWidth: Drain write pulse width

DrainVwrite: Drain write pulse output level

DrainLeadingTime: Drain pulse leading edge transition time

DrainTrailingTime: Drain pulse trailing edge transition time

TotalStressTime: Total accumulated stress time

CheckNoOfTimes: Number of Vth measurement operation

[Extended Test Parameters]

Vs: Source voltage

## 5 Memory

Vsubs: Substrate voltage  
IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
BaseValue: Pulse base value  
NoOfPulse: Number of output pulses for the write operation  
DrainMinRng: Minimum range of drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)  
Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate  
Drain voltage Vdrain  
Drain current Idrain

### [Test Contents: Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [Test Output: X-Y Graph]

X axis: Accumulated writing pulse width WriteTimeList (LOG)  
Y1 axis: Threshold voltage Vth (LINEAR)

### [Test Output: List Display]

Accumulated writing pulse width WriteTimeList  
Threshold voltage VthList

### ***5.32 NorFlash DataDisturb(ErasedCell): NOR flash memory cell Data disturb test after Erase (A.03.10)***

[Supported Analyzer]

B1500A

[Description]

Performs the data disturb test of the NOR-type flash memory cell after the erase operation, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]

NOR-type flash memory cell

[Required Modules and Accessories]

Agilent B1525A SPGU 2 unit

Selector (16440A/16445A 2 set or HRSMU/ASU 3 set)

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

Psource: SPGU channel connected to Source terminal via Selector

Pdrain: SPGU channel connected to Drain terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

VdStress: Stress voltage for Drain terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulsePeriod: Erase pulse period

GateDelay: Gate erase pulse delay

GateWidth: Gate erase pulse width

GateVerase: Gate erase pulse output level

GateLeadingTime: Gate pulse leading edge transition time

GateTrailingTime: Gate pulse trailing edge transition time

SourceDelay: Source erase pulse delay

SourceWidth: Source erase pulse width

SourceVerase: Source erase pulse output level

SourceLeadingTime: Source pulse leading edge transition time

SourceTrailingTime: Source pulse trailing edge transition time

DrainDelay: Drain stress pulse delay

DrainLeadingTime: Drain pulse leading edge transition time

DrainTrailingTime: Drain pulse trailing edge transition time

TotalStressTime: Total accumulated stress time

## 5 Memory

CheckNoOfTimes: Number of Vth measurement operation

### [Extended Test Parameters]

Vs: Source voltage

Vsubs: Substrate voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

BaseValue: Pulse base value

NoOfPulse: Number of output pulses for the erase operation

DrainMinRng: Minimum range of drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate

Drain voltage Vdrain

Drain current Idrain

### [Test Contents: Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [Test Output: X-Y Graph]

X axis: Accumulated erasing pulse width EraseTimeList (LOG)

Y1 axis: Threshold voltage VthList (LINEAR)

### [Test Output: List Display]

Accumulated erasing pulse width EraseTimeList

Threshold voltage VthList

### ***5.33 NorFlash DataDisturb(WrittenCell): NOR flash memory cell Data disturb test after Write (A.03.10)***

[Supported Analyzer]

B1500A

[Description]

Performs the data disturb test of the NOR-type flash memory cell after the write operation, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]

NOR-type flash memory cell

[Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

[Device Parameters]

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Pgate: SPGU channel connected to Gate terminal via Selector

Pdrain: SPGU channel connected to Drain terminal via Selector

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

VdStress: Stress voltage for Drain terminal

Vd: Drain voltage

Id@Vth: Drain current to decide the Vth

IntegTime: Integration time

PulsePeriod: Write pulse period

GateDelay: Gate write pulse delay

GateWidth: Gate write pulse width

GateVwrite: Gate write pulse output level

GateLeadingTime: Gate pulse leading edge transition time

GateTrailingTime: Gate pulse trailing edge transition time

DrainDelay: Drain write pulse delay

DrainWidth: Drain write pulse width

DrainVwrite: Drain write pulse output level

DrainLeadingTime: Drain pulse leading edge transition time

DrainTrailingTime: Drain pulse trailing edge transition time

TotalStressTime: Total accumulated stress time

CheckNoOfTimes: Number of Vth measurement operation

[Extended Test Parameters]

Vs: Source voltage

## 5 Memory

Vsubs: Substrate voltage  
IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time  
BaseValue: Pulse base value  
NoOfPulse: Number of output pulses for the write operation  
DrainMinRng: Minimum range of drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [Analysis Function]

Vth@Id=@L1X (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)  
Y2 axis: Drain current Idrain (LOG)

### [List Display]

Gate voltage Vgate  
Drain voltage Vdrain  
Drain current Idrain

### [Test Contents: Auto Analysis]

Line1: Vertical line for Y1 at Idrain=Id@Vth

### [Test Output: X-Y Graph]

X axis: Accumulated writing pulse width WriteTimeList (LOG)  
Y1 axis: Threshold voltage Vth (LINEAR)

### [Test Output: List Display]

Accumulated writing pulse width WriteTimeList  
Threshold voltage VthList





## 6 Mixed Signal

1. BJT Varactor CV Mismatch: BJT Varactor capacitance CV characteristics mismatch (A.01.11)
2. Diff-R Mismatch: Diffusion resistor R-I characteristics mismatch, Kelvin conneciton (A.01.11)
3. Diode IV Fwd Mismatch: Diode forward bias characteristics mismatch (A.01.20)
4. Diode IV Rev Mismatch: Diode reverse bias characteristics mismatch (A.01.20)
5. G-Plot ConstVce Mismatch: Gummel characteristics mismatch, Vce=Const (A.01.20)
6. G-Plot ConstVce Mismatch[3]: Gummel characteristics mismatch, Vce=Const, 3-terminal (A.01.20)
7. G-Plot Vbc=0V Mismatch: Gummel characteristics mismatch, Vbc=0 V (A.01.20)
8. G-Plot Vbc=0V Mismatch[3]: Gummel characteristics mismatch, Vbc=0, 3-terminal (A.01.20)
9. Ic-Vc Ib Mismatch: Ic-Vce characteristics mismatch, Ib sweep (A.01.20)
10. Ic-Vc Ib Mismatch[3]: Ic-Vce characteristics mismatch, Ib sweep, 3-terminal (A.01.20)
11. Ic-Vc Vb Mismatch: Ic-Vce characteristics mismatch, Vb sweep (A.01.20)
12. Ic-Vc Vb Mismatch[3]: Ic-Vce characteristics mismatch, Vb sweep, 3-terminal (A.01.20)
13. Id-Vd Mismatch: Id-Vd characteristics mismatch (A.01.20)
14. Id-Vd Mismatch[3]: Id-Vd characteristics mismatch, 3-terminal (A.01.20)
15. Id-Vg Mismatch: Id-Vg characteristics mismatch (A.01.20)
16. Id-Vd Mismatch[3]: Id-Vd characteristics mismatch, 3-terminal (A.01.20)
17. MIM CV Mismatch: MIM capacitor C-V characteristics mismatch (A.01.11)
18. MOS Varactor CV Mismatch: MOS Varactor capacitance CV characteristics mismatch (A.01.11)
19. Poly-R Mismatch: Resistor R-I characteristics mismatch, Kelvin connection (A.01.11)

## 6.1 BJT Varactor CV Mismatch: BJT Varactor capacitance CV characteristics mismatch (A.01.11)

[Supported Analyzer]  
B1500A

[Description]

Measures the BJT varactor capacitance (C-Vce characteristics) of device A, and measures the C-Vce characteristics of device B. After that, calculates the differences between capacitance values by using the following formula, and plots the results.

$\Delta C_p = (C_{pBList} - C_{pAList}) / C_{pAList} * 100$  for parallel capacitance  
 $\Delta C_s = (C_{sBList} - C_{sAList}) / C_{sAList} * 100$  for series capacitance

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]

Bipolar junction transistor, 4 terminals, 2 ea.

Connect Base to the CMU Low, Collector to the CMU High, and the other terminals to the GNDU.

[Device Parameters]

Polarity: NPN (CMU forces the specified value) or PNP (CMU forces the negative specified value).

Lb: Base length

Wb: Base width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

Collector: CMU connected between Collector and Base (CV sweep measurement)

VcbStart: DC bias start voltage

VcbStop: DC bias stop voltage

VcbStep: DC bias step voltage

[Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Parallel capacitance Cp

Conductance G

[User Function]

To specify the device, A or B is added to the actual variable names.

## 6 Mixed Signal

```
PI=3.141592653589
Dval=Gval/(2*PI*FREQ*Cpval)
Rpval=1/Gval
Csval=(1+Dval^2)*Cpval
Xval=-1/(2*PI*FREQ*Csval)
Rsval=Dval*abs(Xval)
Zval=sqrt(Rsval^2+Xval^2)
Thetaval=atan(Xval/Rsval)
Vceval=Vcollector
```

### [X-Y Graph]

To specify the device, A or B is added to the actual variable names.

X axis: Collector-Emitter voltage Vceval (LINEAR)

Y1 axis: Collector capacitance (parallel capacitance) Cpval (LINEAR)

Y2 axis: Conductance Gval (LINEAR)

### [List Display]

To specify the device, A or B is added to the actual variable names.

Collector-Emitter voltage Vceval

Parallel capacitance Cpval

Conductance Gval

Series capacitance Csval

Series resistance Rsval

Parallel resistance Rpval

Dissipation factor Dval

Reactance Xval

Impedance Zval

Phase Thetaval

### [Test Output: X-Y Graph]

X axis: Collector-Emitter voltage VceList (LINEAR)

Y1 axis: Collector capacitance (parallel capacitance) CpAList (LINEAR)

Y2 axis: Collector capacitance (parallel capacitance) CpBList (LINEAR)

Y3 axis: Differences between Cp DeltaCp (LINEAR)

## 6.2 *Diff-R Mismatch: Diffusion resistor R-I characteristics mismatch, Kelvin conneciton (A.01.11)*

[Supported Analyzer]  
B1500A

[Description]  
Measures the resistance vs input current characteristics of diffusion resistors, and plots the differences between the devices.

[Device Under Test]  
Resistor, 2 terminals, 2 ea.  
with substrate

[Device Parameters]  
Polarity: Ntype (SMUs force the specified value) or Ptype (SMUs force the negative specified value).  
L: Resistor length  
W: Resistor width  
Temp: Temperature

[Test Parameters]  
IntegTime: Integration Time  
Port1: SMU connected to device A high terminal, primary sweep current output  
Port2: SMU connected to device B high terminal, synchronous sweep current output  
I1Start: Port1/Port2 sweep start current  
I1Stop: Port1/Port2 sweep stop current  
I1Step: Port1/Port2 sweep step current  
Port3: SMU connected to device A/B low terminal, constant voltage output  
Subs: SMU connected to Substrate, constant voltage output  
VM1: SMU connected to device A high terminal, constant current output  
VM2: SMU connected to device A low terminal, constant current output  
VM3: SMU connected to device B high terminal, constant current output  
VM4: SMU connected to device B low terminal, constant current output

[Extended Test Parameters]  
IM1: VM1 output current  
IM2: VM2 output current  
IM3: VM3 output current  
IM4: VM4 output current  
V3: Port3 output voltage  
Vsubs: Substrate voltage  
V1Limit: Port1 voltage compliance  
VM1Limit: VM1 voltage compliance  
I3Limit: Port3 current compliance  
IsubsLimit: Substrate current compliance  
HoldTime: Hold time  
DelayTime: Deley time

[Measurement Parameters]  
Device A input current Iport1  
Device B input current Iport2  
Device A terminal voltage Vvm1, Vvm2  
Device B terminal voltage Vvm3, Vvm4

## 6 Mixed Signal

### [User Function]

$\Delta V_A = V_{m1} - V_{m2}$

$\Delta V_B = V_{m3} - V_{m4}$

$R_A = \Delta V_A / I_{port1}$

$R_B = \Delta V_B / I_{port2}$

$R_{sheet\_A} = R_A / (W/L)$

$R_{sheet\_B} = R_B / (W/L)$

$\Delta R = (R_A - R_B) / R_A * 100$

### [X-Y Plot]

X axis: Device input current  $I_{port1}$  (LINEAR)

Y1 axis: Device A voltage between terminals  $\Delta V_A$  (LINEAR)

Y2 axis: Device B voltage between terminals  $\Delta V_B$  (LINEAR)

Y3 axis: Device A resistance  $R_A$  (LINEAR)

Y4 axis: Device A resistance  $R_B$  (LINEAR)

Y5 axis: Rate-of-change between  $R_A$  and  $R_B$   $\Delta R$  (LINEAR)

### 6.3 *Diode IV Fwd Mismatch: Diode forward bias characteristics mismatch* (A.01.20)

[Supported Analyzer]  
B1500A

[Description]  
Measures the forward bias anode voltage vs anode current characteristics, and plots the differences between the devices.

[Device Under Test]  
Diode, 2 ea.

[Device Parameters]  
L: Junction length  
W: Junction width  
Temp: Temperature  
IMax: Current compliance

[Test Parameters]  
IntegTime: Integration time  
AnodeA: SMU connected to the device A Anode terminal, primary sweep voltage output  
AnodeB: SMU connected to the device B Anode terminal, synchronous sweep voltage output  
VanodeStart: Sweep start voltage for Anode terminal  
VanodeStop: Sweep stop voltage for Anode terminal  
VanodeStep: Sweep step voltage for Anode terminal  
Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]  
Vcathode: Cathode voltage  
HoldTime: Hold time  
DelayTime: Delay time  
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]  
Anode current IanodeA, IanodeB

[User Function]  
 $\Delta\_I_{anode} = (I_{anodeA} - I_{anodeB}) / I_{anodeA} * 100$

[X-Y Plot]  
X axis: Anode voltage VanodeA (LINEAR)  
Y1 axis: Anode current IanodeA (LINEAR)  
Y2 axis: Anode current IanodeB (LINEAR)  
Y3 axis: Differences between anode current  $\Delta\_I_{anode}$  (LINEAR)

## 6 Mixed Signal

### 6.4 *Diode IV Rev Mismatch: Diode reverse bias characteristics mismatch* (A.01.20)

[Supported Analyzer]  
B1500A

[Description]  
Measures the reverse bias anode voltage vs anode current characteristics, and plots the differences between the devices.

[Device Under Test]  
Diode, 2 ea.

[Device Parameters]  
L: Junction length  
W: Junction width  
Temp: Temperature

[Test Parameters]  
IntegTime: Integration time  
AnodeA: SMU connected to the device A Anode terminal, primary sweep voltage output  
AnodeB: SMU connected to the device B Anode terminal, synchronous sweep voltage output  
VanodeStart: Sweep start voltage for Anode terminal  
VanodeStop: Sweep stop voltage for Anode terminal  
VanodeStep: Sweep step voltage for Anode terminal  
IanodeLimit: Anode current compliance  
Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]  
Vcathode: Cathode voltage  
HoldTime: Hold time  
DelayTime: Delay time  
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]  
Anode current IanodeA, IanodeB

[User Function]  
 $\Delta_{\text{Ianode}} = (\text{IanodeA} - \text{IanodeB}) / \text{IanodeA} * 100$

[X-Y Plot]  
X axis: Anode voltage VanodeA (LINEAR)  
Y1 axis: Anode current IanodeA (LINEAR)  
Y2 axis: Anode current IanodeB (LINEAR)  
Y3 axis: Differences between anode current  $\Delta_{\text{Ianode}}$  (LINEAR)



## 6.5 *G-Plot ConstVce Mismatch: Gummel characteristics mismatch, Vce=Const (A.01.20)*

### [Supported Analyzer]

B1500A

### [Description]

Measures the collector current vs base voltage characteristics and the base current vs base voltage characteristics, extracts the current amplification factor hfe, and plots the gummel characteristics.

### [Device Under Test]

Bipolar transistor, 4 terminals, 2 ea.

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

### [Test Parameters]

IntegTime: Integration time

BaseA: SMU connected to Device A Base terminal, primary sweep voltage output

BaseB: SMU connected to Device B Base terminal, synchronous sweep voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Emitter: SMU connected to Emitter terminal, constant voltage output

CollectorA: SMU connected to Device A Collector terminal, constant voltage output

CollectorB: SMU connected to Device B Collector terminal, constant voltage output

Vc: Collector voltage

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

### [Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng: Minimum range for the base current measurement

CollectorMinRng: Minimum range for the collector current measurement

### [Measurement Parameters]

Collector current IcollectorA

Collector current IcollectorB

Base current IbaseA

Base current IbaseB

### [User Function]

$hfe\_A = I_{collectorA} / I_{baseA}$

$hfe\_B = I_{collectorB} / I_{baseB}$

$\Delta\_hfe = (hfe\_A - hfe\_B) / hfe\_A * 100$

$\Delta\_I_{collector} = (I_{collectorA} - I_{collectorB}) / I_{collectorA} * 100$

## 6 Mixed Signal

Vbe=VbaseA

[X-Y Plot]

X axis: Base-Emitter voltage Vbe (LINEAR)

Y1 axis: Collector current IcollectorA (LOG)

Y2 axis: Base current IbaseA (LOG)

Y3 axis: Collector current IcollectorB (LOG)

Y4 axis: Base current IbaseB (LOG)

Y5 axis: Current amplification factor hfe\_A (LINEAR)

Y6 axis: Current amplification factor hfe\_B (LINEAR)

Y7 axis: Differences of hfe Delta\_hfe (LINEAR)

## 6.6 *G-Plot ConstVce Mismatch[3]: Gummel characteristics mismatch, Vce=Const, 3-terminal (A.01.20)*

[Supported Analyzer]  
B1500A

[Description]  
Measures the collector current vs base voltage characteristics and the base current vs base voltage characteristics, extracts the current amplification factor hfe, and plots the gummel characteristics.

[Device Under Test]  
Bipolar transistor, 3 terminals, 2 ea.

[Device Parameters]  
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).  
Le: Emitter length  
We: Emitter width  
Temp: Temperature  
IcMax: Collector current compliance

[Test Parameters]  
IntegTime: Integration time  
BaseA: SMU connected to Device A Base terminal, primary sweep voltage output  
BaseB: SMU connected to Device B Base terminal, synchronous sweep voltage output  
VbStart: Sweep start voltage for Base terminal  
VbStop: Sweep stop voltage for Base terminal  
VbStep: Sweep step voltage for Base terminal  
Emitter: SMU connected to Emitter terminal, constant voltage output  
CollectorA: SMU connected to Device A Collector terminal, constant voltage output  
CollectorB: SMU connected to Device B Collector terminal, constant voltage output  
Vc: Collector voltage

[Extended Test Parameters]  
Ve: Emitter voltage  
HoldTime: Hold time  
DelayTime: Delay time  
BaseMinRng: Minimum range for the base current measurement  
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]  
Collector current IcollectorA  
Collector current IcollectorB  
Base current IbaseA  
Base current IbaseB

[User Function]  
 $hfe\_A = I_{collectorA} / I_{baseA}$   
 $hfe\_B = I_{collectorB} / I_{baseB}$   
 $\Delta\_hfe = (hfe\_A - hfe\_B) / hfe\_A * 100$   
 $\Delta\_I_{collector} = (I_{collectorA} - I_{collectorB}) / I_{collectorA} * 100$   
 $V_{be} = V_{baseA}$

[X-Y Plot]

## 6 Mixed Signal

X axis: Base-Emitter voltage Vbe (LINEAR)  
Y1 axis: Collector current IcollectorA (LOG)  
Y2 axis: Base current IbaseA (LOG)  
Y3 axis: Collector current IcollectorB (LOG)  
Y4 axis: Base current IbaseB (LOG)  
Y5 axis: Current amplification factor hfe\_A (LINEAR)  
Y6 axis: Current amplification factor hfe\_B (LINEAR)  
Y7 axis: Differences of hfe Delta\_hfe (LINEAR)

## 6.7 *G-Plot Vbc=0V Mismatch: Gummel characteristics mismatch, Vbc=0 V* (A.01.20)

### [Supported Analyzer]

B1500A

### [Description]

Measures the collector current vs emitter voltage characteristics and the base current vs emitter voltage characteristics, extracts the current amplification factor hfe, and plots the gummel characteristics.

### [Device Under Test]

Bipolar transistor, 4 terminals, 2 ea.

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

### [Test Parameters]

IntegTime: Integration time

Emitter: SMU connected to Emitter terminal, primary sweep voltage output

VeStart: Sweep start voltage for Emitter terminal

VeStop: Sweep stop voltage for Emitter terminal

VeStep: Sweep step voltage for Emitter terminal

BaseA: SMU connected to Device A Base terminal, constant voltage output

BaseB: SMU connected to Device B Base terminal, constant voltage output

CollectorA: SMU connected to Device A Collector terminal, constant voltage output

CollectorB: SMU connected to Device B Collector terminal, constant voltage output

Vc: Collector voltage

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

### [Extended Test Parameters]

Vb: Base voltage

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng: Minimum range for the base current measurement

CollectorMinRng: Minimum range for the collector current measurement

### [Measurement Parameters]

Collector current IcollectorA

Collector current IcollectorB

Base current IbaseA

Base current IbaseB

### [User Function]

$hfe\_A = I_{collectorA} / I_{baseA}$

$hfe\_B = I_{collectorB} / I_{baseB}$

$\Delta\_hfe = (hfe\_A - hfe\_B) / hfe\_A * 100$

$\Delta\_I_{collector} = (I_{collectorA} - I_{collectorB}) / I_{collectorA} * 100$

## 6 Mixed Signal

Vbe=-Vemitter

[X-Y Plot]

X axis: Base-Emitter voltage Vbe (LINEAR)

Y1 axis: Collector current IcollectorA (LOG)

Y2 axis: Base current IbaseA (LOG)

Y3 axis: Collector current IcollectorB (LOG)

Y4 axis: Base current IbaseB (LOG)

Y5 axis: Current amplification factor hfe\_A (LINEAR)

Y6 axis: Current amplification factor hfe\_B (LINEAR)

Y7 axis: Differences of hfe Delta\_hfe (LINEAR)

## 6.8 *G-Plot Vbc=0V Mismatch[3]: Gummel characteristics mismatch, Vbc=0, 3-terminal (A.01.20)*

[Supported Analyzer]  
B1500A

[Description]  
Measures the collector current vs emitter voltage characteristics and the base current vs emitter voltage characteristics, extracts the current amplification factor hfe, and plots the gummel characteristics.

[Device Under Test]  
Bipolar transistor, 3 terminals, 2 ea.

[Device Parameters]  
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).  
Le: Emitter length  
We: Emitter width  
Temp: Temperature  
IcMax: Collector current compliance

[Test Parameters]  
IntegTime: Integration time  
Emitter: SMU connected to Emitter terminal, primary sweep voltage output  
VeStart: Sweep start voltage for Emitter terminal  
VeStop: Sweep stop voltage for Emitter terminal  
VeStep: Sweep step voltage for Emitter terminal  
BaseA: SMU connected to Device A Base terminal, constant voltage output  
BaseB: SMU connected to Device B Base terminal, constant voltage output  
CollectorA: SMU connected to Device A Collector terminal, constant voltage output  
CollectorB: SMU connected to Device B Collector terminal, constant voltage output

[Extended Test Parameters]  
Vb: Base voltage  
Vc: Collector voltage  
HoldTime: Hold time  
DelayTime: Delay time  
BaseMinRng: Minimum range for the base current measurement  
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]  
Collector current IcollectorA  
Collector current IcollectorB  
Base current IbaseA  
Base current IbaseB

[User Function]  
 $hfe\_A = I_{collectorA} / I_{baseA}$   
 $hfe\_B = I_{collectorB} / I_{baseB}$   
 $\Delta_{hf} = (hfe\_A - hfe\_B) / hfe\_A * 100$   
 $\Delta_{I_{collector}} = (I_{collectorA} - I_{collectorB}) / I_{collectorA} * 100$   
 $V_{be} = -V_{emitter}$

[X-Y Plot]

## 6 Mixed Signal

X axis: Base-Emitter voltage Vbe (LINEAR)  
Y1 axis: Collector current IcollectorA (LOG)  
Y2 axis: Base current IbaseA (LOG)  
Y3 axis: Collector current IcollectorB (LOG)  
Y4 axis: Base current IbaseB (LOG)  
Y5 axis: Current amplification factor hfe\_A (LINEAR)  
Y6 axis: Current amplification factor hfe\_B (LINEAR)  
Y7 axis: Differences of hfe Delta\_hfe (LINEAR)



## 6.9 *Ic-Vc Ib Mismatch: Ic-Vce characteristics mismatch, Ib sweep (A.01.20)*

### [Supported Analyzer]

B1500A

### [Description]

Measures the collector current vs collector voltage (Ic-Vce) characteristics of device A, and measures the Ic-Vce characteristics of device B. After that, calculates the differences between Ic values by using the following formula, and plots the results.

$$\Delta I_c = (I_{c\_A} - I_{c\_B}) / I_{c\_A} * 100$$

### [Device Under Test]

Bipolar transistor, 4 terminals, 2 ea.

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

### [Test Parameters]

IntegTime: Integration time

CollectorA: SMU connected to Device A Collector terminal, primary sweep voltage output

CollectorB: SMU connected to Device B Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

BaseA: SMU connected to Device A Base terminal, secondary sweep current output

BaseB: SMU connected to Device B Base terminal, secondary sweep current output

IbStart: Sweep start current for Base terminal

IbStop: Sweep stop current for Base terminal

IbStep: Sweep step current for Base terminal

VbLimit: Base voltage compliance

Emitter: SMU connected to Emitter terminal, constant voltage output

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

### [Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

CollectorMinRng: Minimum range for the collector current measurement

### [Device A: Measurement Parameters]

Collector current IcollectorA

### [Device A: User Function]

hfe\_A = IcollectorA / IbaseA

### [Device A: X-Y Plot]

X axis: Collector voltage VcollectorA (LINEAR)

Y1 axis: Collector current IcollectorA (LINEAR)

## 6 Mixed Signal

[Device B: Measurement Parameters]

Collector current  $I_{\text{collectorB}}$

[Device B: User Function]

$hfe\_B = I_{\text{collectorB}} / I_{\text{baseB}}$

[Device B: X-Y Plot]

X axis: Collector voltage  $V_{\text{collectorB}}$  (LINEAR)

Y1 axis: Collector current  $I_{\text{collectorB}}$  (LINEAR)

[Test Output: X-Y Graph]

X axis: Collector-Emitter voltage  $V_{\text{ce}}$  (LINEAR)

Y1 axis: Collector current  $I_{\text{collector\_A}}$  (LINEAR)

Y2 axis: Collector current  $I_{\text{collector\_B}}$  (LINEAR)

Y3 axis: Differences between  $I_{\text{c}}$   $\Delta I_{\text{c}}$  (LINEAR)

### 6.10 *Ic-Vc Ib Mismatch[3]: Ic-Vce characteristics mismatch, Ib sweep, 3-terminal (A.01.20)*

[Supported Analyzer]  
B1500A

[Description]

Measures the collector current vs collector voltage (Ic-Vce) characteristics of device A, and measures the Ic-Vce characteristics of device B. After that, calculates the differences between Ic values by using the following formula, and plots the results.

$$\Delta I_c = (I_{\text{collector\_A}} - I_{\text{collector\_B}}) / I_{\text{collector\_A}} * 100$$

[Device Under Test]

Bipolar transistor, 3 terminals, 2 ea.

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

[Test Parameters]

IntegTime: Integration time

CollectorA: SMU connected to Device A Collector terminal, primary sweep voltage output

CollectorB: SMU connected to Device B Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

BaseA: SMU connected to Device A Base terminal, secondary sweep current output

BaseB: SMU connected to Device B Base terminal, secondary sweep current output

IbStart: Sweep start current for Base terminal

IbStop: Sweep stop current for Base terminal

IbStep: Sweep step current for Base terminal

VbLimit: Base voltage compliance

Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

CollectorMinRng: Minimum range for the collector current measurement

[Device A: Measurement Parameters]

Collector current IcollectorA

[Device A: User Function]

hfe\_A = IcollectorA / IbaseA

[Device A: X-Y Plot]

X axis: Collector voltage VcollectorA (LINEAR)

Y1 axis: Collector current IcollectorA (LINEAR)

## 6 Mixed Signal

[Device B: Measurement Parameters]

Collector current  $I_{\text{collectorB}}$

[Device B: User Function]

$h_{fe\_B} = I_{\text{collectorB}} / I_{\text{baseB}}$

[Device B: X-Y Plot]

X axis: Collector voltage  $V_{\text{collectorB}}$  (LINEAR)

Y1 axis: Collector current  $I_{\text{collectorB}}$  (LINEAR)

[Test Output: X-Y Graph]

X axis: Collector-Emitter voltage  $V_{ce}$  (LINEAR)

Y1 axis: Collector current  $I_{\text{collector\_A}}$  (LINEAR)

Y2 axis: Collector current  $I_{\text{collector\_B}}$  (LINEAR)

Y3 axis: Differences between  $I_c$   $\Delta I_c$  (LINEAR)

**6.11 Ic-Vc Vb Mismatch: Ic-Vce characteristics mismatch, Vb sweep (A.01.20)****[Supported Analyzer]**

B1500A

**[Description]**

Measures the collector current vs collector voltage (Ic-Vce) characteristics of device A, and measures the Ic-Vce characteristics of device B. After that, calculates the differences between Ic values by using the following formula, and plots the results.

$$\Delta I_c = (I_{c\_A} - I_{c\_B}) / I_{c\_A} * 100$$

**[Device Under Test]**

Bipolar transistor, 4 terminals, 2 ea.

**[Device Parameters]**

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

**[Test Parameters]**

IntegTime: Integration time

CollectorA: SMU connected to Device A Collector terminal, primary sweep voltage output

CollectorB: SMU connected to Device B Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

BaseA: SMU connected to Device A Base terminal, secondary sweep voltage output

BaseB: SMU connected to Device B Base terminal, secondary sweep voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Emitter: SMU connected to Emitter terminal, constant voltage output

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

**[Extended Test Parameters]**

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng: Minimum range for the base current measurement

CollectorMinRng: Minimum range for the collector current measurement

**[Device A: Measurement Parameters]**

Collector current IcollectorA

Base current IbaseA

**[Device A: User Function]**

hfe\_A = IcollectorA / IbaseA

**[Device A: X-Y Plot]**

X axis: Collector voltage VcollectorA (LINEAR)

## 6 Mixed Signal

Y1 axis: Collector current  $I_{\text{collectorA}}$  (LINEAR)

[Device B: Measurement Parameters]

Collector current  $I_{\text{collectorB}}$

Base current  $I_{\text{baseB}}$

[Device B: User Function]

$h_{fe\_B} = I_{\text{collectorB}} / I_{\text{baseB}}$

[Device B: X-Y Plot]

X axis: Collector voltage  $V_{\text{collectorB}}$  (LINEAR)

Y1 axis: Collector current  $I_{\text{collectorB}}$  (LINEAR)

[Test Output: X-Y Graph]

X axis: Collector-Emitter voltage  $V_{ce}$  (LINEAR)

Y1 axis: Collector current  $I_{\text{collector\_A}}$  (LINEAR)

Y2 axis: Collector current  $I_{\text{collector\_B}}$  (LINEAR)

Y3 axis: Differences between  $I_c$   $\Delta I_c$  (LINEAR)

## 6.12 *Ic-Vc Vb Mismatch[3]: Ic-Vce characteristics mismatch, Vb sweep, 3-terminal (A.01.20)*

### [Supported Analyzer]

B1500A

### [Description]

Measures the collector current vs collector voltage (Ic-Vce) characteristics of device A, and measures the Ic-Vce characteristics of device B. After that, calculates the differences between Ic values by using the following formula, and plots the results.

$$\Delta I_c = (I_{\text{collector\_A}} - I_{\text{collector\_B}}) / I_{\text{collector\_A}} * 100$$

### [Device Under Test]

Bipolar transistor, 3 terminals, 2 ea.

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).

Le: Emitter length

We: Emitter width

Temp: Temperature

IcMax: Collector current compliance

### [Test Parameters]

IntegTime: Integration time

CollectorA: SMU connected to Device A Collector terminal, primary sweep voltage output

CollectorB: SMU connected to Device B Collector terminal, primary sweep voltage output

VcStart: Sweep start voltage for Collector terminal

VcStop: Sweep stop voltage for Collector terminal

VcStep: Sweep step voltage for Collector terminal

BaseA: SMU connected to Device A Base terminal, secondary sweep voltage output

BaseB: SMU connected to Device B Base terminal, secondary sweep voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Emitter: SMU connected to Emitter terminal, constant voltage output

### [Extended Test Parameters]

Ve: Emitter voltage

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng: Minimum range for the base current measurement

CollectorMinRng: Minimum range for the collector current measurement

### [Device A: Measurement Parameters]

Collector current IcollectorA

Base current IbaseA

### [Device A: User Function]

hfe\_A = IcollectorA / IbaseA

### [Device A: X-Y Plot]

X axis: Collector voltage VcollectorA (LINEAR)

Y1 axis: Collector current IcollectorA (LINEAR)

## 6 Mixed Signal

[Device B: Measurement Parameters]

Collector current  $I_{\text{collectorB}}$

Base current  $I_{\text{baseB}}$

[Device B: User Function]

$h_{fe\_B} = I_{\text{collectorB}} / I_{\text{baseB}}$

[Device B: X-Y Plot]

X axis: Collector voltage  $V_{\text{collectorB}}$  (LINEAR)

Y1 axis: Collector current  $I_{\text{collectorB}}$  (LINEAR)

[Test Output: X-Y Graph]

X axis: Collector-Emitter voltage  $V_{ce}$  (LINEAR)

Y1 axis: Collector current  $I_{\text{collector\_A}}$  (LINEAR)

Y2 axis: Collector current  $I_{\text{collector\_B}}$  (LINEAR)

Y3 axis: Differences between  $I_c$   $\Delta I_c$  (LINEAR)



### 6.13 Id-Vd Mismatch: Id-Vd characteristics mismatch (A.01.20)

[Supported Analyzer]

B1500A

[Description]

Measures the drain current vs drain voltage characteristics of two MOSFETs, and plots the differences of them.

[Device Under Test]

MOSFET, 4 terminals, 2 ea.

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

IntegTime: Integration time

DrainA: SMU connected to the device A Drain terminal, primary sweep voltage output

DrainB: SMU connected to the device B Drain terminal, synchronous sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

Gate: SMU connected to Gate terminal, secondary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

IgLimit: Gate current compliance

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

IsubsLimit: Substrate current compliance

Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]

Vs: Source voltage

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]

Device A Drain current IdrainA

Device B Drain current IdrainB

Substrate current Isubs

Source current Isource

[User Function]

Drain conductance gds\_A=diff(IdrainA,VdrainA)

Drain conductance gds\_B=diff(IdrainB,VdrainB)

Drain resistance Rds\_A=1/gds\_A

Drain resistance Rds\_B=1/gds\_B

Delta\_Ids=(IdrainA-IdrainB)/IdrainA\*100

## 6 Mixed Signal

$\Delta_{\text{gds}} = (\text{gds\_A} - \text{gds\_B}) / \text{gds\_A} * 100$   
 $\Delta_{\text{Rds}} = (\text{Rds\_A} - \text{Rds\_B}) / \text{Rds\_A} * 100$

### [X-Y Graph]

X axis: Drain voltage VdrainA (LINEAR)  
Y1 axis: Device A Drain current IdrainA (LINEAR)  
Y2 axis: Device B Drain current IdrainB (LINEAR)  
Y3 axis: Difference of Drain current Delta\_Ids (LINEAR)

### [List Display]

Drain voltage VdrainA  
Gate voltage Vgate  
Device A Drain current IdrainA  
Device B Drain current IdrainB  
Differences of Drain current Delta\_Ids  
Substrate current Isubs  
Source current Isource

**6.14 Id-Vd Mismatch[3]: Id-Vd characteristics mismatch, 3-terminal (A.01.20)****[Supported Analyzer]**

B1500A

**[Description]**

Measures the drain current vs drain voltage characteristics of two MOSFETs, and plots the differences of them.

**[Device Under Test]**

MOSFET, 3 terminals, 2 ea.

**[Device Parameters]**

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

**[Test Parameters]**

IntegTime: Integration time

DrainA: SMU connected to the device A Drain terminal, primary sweep voltage output

DrainB: SMU connected to the device B Drain terminal, synchronous sweep voltage output

Gate: SMU connected to Gate terminal, secondary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

IgLimit: Gate current compliance

Source: SMU connected to Source terminal, constant voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

**[Extended Test Parameters]**

Vs: Source voltage

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

**[Measurement Parameters]**

Device A Drain current IdrainA

Device B Drain current IdrainB

**[User Function]**Drain conductance  $gds\_A = \text{diff}(\text{IdrainA}, \text{VdrainA})$ Drain conductance  $gds\_B = \text{diff}(\text{IdrainB}, \text{VdrainB})$ Drain resistance  $Rds\_A = 1/gds\_A$ Drain resistance  $Rds\_B = 1/gds\_B$  $\Delta\_Ids = (\text{IdrainA} - \text{IdrainB}) / \text{IdrainA} * 100$  $\Delta\_gds = (gds\_A - gds\_B) / gds\_A * 100$  $\Delta\_Rds = (Rds\_A - Rds\_B) / Rds\_A * 100$ **[X-Y Graph]**

X axis: Drain voltage VdrainA (LINEAR)

## 6 Mixed Signal

Y1 axis: Device A Drain current IdrainA (LINEAR)

Y2 axis: Device B Drain current IdrainB (LINEAR)

Y3 axis: Difference of Drain current Delta\_Ids (LINEAR)

[List Display]

Drain voltage VdrainA

Gate voltage Vgate

Device A Drain current IdrainA

Device B Drain current IdrainB

Differences of Drain current Delta\_Ids

### 6.15 Id-Vg Mismatch: Id-Vg characteristics mismatch (A.01.20)

[Supported Analyzer]

B1500A

[Description]

Measures the drain current vs gate voltage characteristics of two MOSFETs, and plots the differences of them.

[Device Under Test]

MOSFET, 4 terminals, 2 ea.

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

IgLimit: Gate current compliance

DrainA: SMU connected to the device A Drain terminal, constant voltage output

DrainB: SMU connected to the device B Drain terminal, constant voltage output

Vd: Drain voltage

Subs: SMU connected to Substrate, secondary sweep voltage output

VsubsStart: Sweep start voltage for Substrate terminal

VsubsStop: Sweep stop voltage for Substrate terminal

VsubsStep: Sweep step voltage for Substrate terminal

IsubsLimit: Substrate current compliance

Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]

Vs: Source voltage

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

GateMinRng: Minimum range for the gate current measurement

SubsMinRng: Minimum range for the Substrate current measurement

[Measurement Parameters]

Device A Drain current IdrainA

Device B Drain current IdrainB

Gate current Igate

Substrate current Isubs

[User Function]

gm\_A=diff(IdrainA,Vgate)

gm\_B=diff(IdrainB,Vgate)

Delta\_Id=(IdrainA-IdrainB)/IdrainA\*100

Delta\_gm=(gm\_A-gm\_B)/gm\_A\*100

## 6 Mixed Signal

### [X-Y Graph]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Device A Drain current IdrainA (LINEAR)

Y2 axis: Device B Drain current IdrainB (LINEAR)

Y3 axis: Difference of Drain current Delta\_Id (LINEAR)

### [List Display]

Gate voltage Vgate

Drain voltage VdrainA

Device A Drain current IdrainA

Device B Drain current IdrainB

Differences of Drain current Delta\_Id

Gate current Igate

Substrate current Isubs

**6.16 Id-Vd Mismatch[3]: Id-Vd characteristics mismatch, 3-terminal (A.01.20)****[Supported Analyzer]**

B1500A

**[Description]**

Measures the drain current vs drain voltage characteristics of two MOSFETs, and plots the differences of them.

**[Device Under Test]**

MOSFET, 3 terminals, 2 ea.

**[Device Parameters]**

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

**[Test Parameters]**

IntegTime: Integration time

DrainA: SMU connected to the device A Drain terminal, primary sweep voltage output

DrainB: SMU connected to the device B Drain terminal, synchronous sweep voltage output

Gate: SMU connected to Gate terminal, secondary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

IgLimit: Gate current compliance

Source: SMU connected to Source terminal, constant voltage output

Vd: Drain voltage

**[Extended Test Parameters]**

Vs: Source voltage

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

**[Measurement Parameters]**

Device A Drain current IdrainA

Device B Drain current IdrainB

**[User Function]**

Drain conductance gds\_A=diff(IdrainA,VdrainA)

Drain conductance gds\_B=diff(IdrainB,VdrainB)

Drain resistance Rds\_A=1/gds\_A

Drain resistance Rds\_B=1/gds\_B

Delta\_Ids=(IdrainA-IdrainB)/IdrainA\*100

Delta\_gds=(gds\_A-gds\_B)/gds\_A\*100

Delta\_Rds=(Rds\_A-Rds\_B)/Rds\_A\*100

**[X-Y Graph]**

X axis: Drain voltage VdrainA (LINEAR)

Y1 axis: Device A Drain current IdrainA (LINEAR)

Y2 axis: Device B Drain current IdrainB (LINEAR)

Y3 axis: Difference of Drain current Delta\_Ids (LINEAR)

## 6 Mixed Signal

[List Display]

Drain voltage V<sub>drainA</sub>

Gate voltage V<sub>gate</sub>

Device A Drain current I<sub>drainA</sub>

Device B Drain current I<sub>drainB</sub>

Differences of Drain current  $\Delta I_{ds}$



**6.17 MIM CV Mismatch: MIM capacitor C-V characteristics mismatch (A.01.11)****[Supported Analyzer]**

B1500A

**[Description]**

Measures the MIM capacitance (C-V characteristics) of device A, and measures the C-V characteristics of device B. After that, calculates the differences between capacitance values by using the following formula, and plots the results.

$$\Delta C_p = (C_{pBList} - C_{pAList}) / C_{pAList} * 100 \text{ for parallel capacitance}$$

$$\Delta C_s = (C_{sBList} - C_{sAList}) / C_{sAList} * 100 \text{ for series capacitance}$$

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

**[Device Under Test]**

MIM capacitor, 2 terminals, 2 ea.

**[Device Parameters]**

Lg: Device length

Wg: Device width

Temp: Temperature

**[Test Parameters]**

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

Port1: CMU connected to the device (CV sweep measurement)

V1Start: DC bias start voltage

V1Stop: DC bias stop voltage

V1Step: DC bias step voltage

**[Extended Test Parameters]**

HoldTime: Hold time

DelayTime: Delay time

**[Measurement Parameters]**

Parallel capacitance Cp

Conductance G

**[User Function]**

To specify the device, A or B is added to the actual variable names.

$$PI = 3.141592653589$$

$$Dval = Gval / (2 * PI * FREQ * Cpval)$$

$$Rpval = 1 / Gval$$

$$Csval = (1 + Dval^2) * Cpval$$

## 6 Mixed Signal

```
Xval=-1/(2*PI*FREQ*C sval)
Rsval=Dval*abs(Xval)
Zval=sqrt(Rsval^2+Xval^2)
Thetaval=atan(Xval/Rsval)
```

### [X-Y Graph]

To specify the device, A or B is added to the actual variable names.

X axis: DC bias Vport1 (LINEAR)

Y1 axis: MIM capacitance (parallel capacitance) Cpval (LINEAR)

Y2 axis: Conductance Gval (LINEAR)

### [List Display]

To specify the device, A or B is added to the actual variable names.

DC bias Vport1

Parallel capacitance Cpval

Conductance Gval

Series capacitance Csval

Series resistance Rsval

Parallel resistance Rpval

Dissipation factor Dval

Reactance Xval

Impedance Zval

Phase Thetaval

### [Test Output: X-Y Graph]

X axis: DC bias Vport1List (LINEAR)

Y1 axis: MIM capacitance (parallel capacitance) CpAList (LINEAR)

Y2 axis: MIM capacitance (parallel capacitance) CpBList (LINEAR)

Y3 axis: Differences between Cp DeltaCp (LINEAR)

## 6.18 MOS Varactor CV Mismatch: MOS Varactor capacitance CV characteristics mismatch (A.01.11)

[Supported Analyzer]

B1500A

[Description]

Measures the MOS varactor capacitance (C-Vg characteristics) of device A, and measures the C-Vg characteristics of device B. After that, calculates the differences between capacitance values by using the following formula, and plots the results.

$\Delta C_p = (C_{pBList} - C_{pAList}) / C_{pAList} * 100$  for parallel capacitance

$\Delta C_s = (C_{sBList} - C_{sAList}) / C_{sAList} * 100$  for series capacitance

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]

MOSFET, 4 terminals, 2 ea.

Connect Gate to the CMU Low, and the other terminals to the CMU High.

[Device Parameters]

Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

Gate: CMU connected to Gate terminal (CV sweep measurement)

VgsStart: DC bias start voltage

VgsStop: DC bias stop voltage

VgsStep: DC bias step voltage

[Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Parallel capacitance Cp

Conductance G

[User Function]

To specify the device, A or B is added to the actual variable names.

## 6 Mixed Signal

```
PI=3.141592653589
Dval=Gval/(2*PI*FREQ*Cpval)
Rpval=1/Gval
Csval=(1+Dval^2)*Cpval
Xval=-1/(2*PI*FREQ*Csval)
Rsval=Dval*abs(Xval)
Zval=sqrt(Rsval^2+Xval^2)
Thetaval=atan(Xval/Rsval)
Vgateval=-Vsubs
```

### [X-Y Graph]

To specify the device, A or B is added to the actual variable names.

X axis: Gate voltage Vgateval (LINEAR)

Y1 axis: Gate capacitance (parallel capacitance) Cpval (LINEAR)

Y2 axis: Conductance Gval (LINEAR)

### [List Display]

To specify the device, A or B is added to the actual variable names.

Gate voltage Vgateval

Parallel capacitance Cpval

Conductance Gval

Series capacitance Csval

Series resistance Rsval

Parallel resistance Rpval

Dissipation factor Dval

Reactance Xval

Impedance Zval

Phase Thetaval

### [Test Output: X-Y Graph]

X axis: Gate voltage VgList (LINEAR)

Y1 axis: Gate capacitance (parallel capacitance) CpAList (LINEAR)

Y2 axis: Gate capacitance (parallel capacitance) CpBList (LINEAR)

Y3 axis: Differences between Cp DeltaCp (LINEAR)

## 6.19 Poly-R Mismatch: Resistor R-I characteristics mismatch, Kelvin connection (A.01.11)

[Supported Analyzer]  
B1500A

[Description]  
Measures the resistance vs input current characteristics of resistors, and plots the differences between the devices.

[Device Under Test]  
Resistor, 2 terminals, 2 ea.

[Device Parameters]  
L: Resistor length  
W: Resistor width  
Temp: Temperature

[Test Parameters]  
IntegTime: Integration Time  
Port1: SMU connected to device A high terminal, primary sweep current output  
Port2: SMU connected to device B high terminal, synchronous sweep current output  
I1Start: Port1/Port2 sweep start current  
I1Stop: Port1/Port2 sweep stop current  
I1Step: Port1/Port2 sweep step current  
V1Limit: Maximum voltage  
Port3: SMU connected to device A/B low terminal, constant voltage output  
VM1: SMU connected to device A high terminal, constant current output  
VM2: SMU connected to device A low terminal, constant current output  
VM3: SMU connected to device B high terminal, constant current output  
VM4: SMU connected to device B low terminal, constant current output

[Extended Test Parameters]  
V3: Port3 output voltage  
IM1: VM1 output current  
IM2: VM2 output current  
IM3: VM3 output current  
IM4: VM4 output current  
HoldTime: Hold time  
DelayTime: Delay time

[Measurement Parameters]  
Device A input current Iport1  
Device B input current Iport2  
Device A terminal voltage Vvm1, Vvm2  
Device B terminal voltage Vvm3, Vvm4

[User Function]  
 $\Delta V_A = V_{vm1} - V_{vm2}$   
 $\Delta V_B = V_{vm3} - V_{vm4}$   
 $R_A = \Delta V_A / I_{port1}$   
 $R_B = \Delta V_B / I_{port2}$   
 $R_{sheet\_A} = R_A / (W/L)$

## 6 Mixed Signal

$$R_{sheet\_B} = R\_B / (W/L)$$

$$\Delta\_R = (R\_A - R\_B) / R\_A * 100$$

[X-Y Plot]

X axis: Device A input current Iport1 (LINEAR)

Y1 axis: Device A resistance R\_A (LINEAR)

Y2 axis: Device B resistance R\_B (LINEAR)

Y3 axis: Rate-of-change between R\_A and R\_B Delta\_R (LINEAR)

Y4 axis: Device A voltage between terminals DeltaV\_A (LINEAR)

Y5 axis: Device B voltage between terminals DeltaV\_B (LINEAR)



## 7 Nano Tech

1. CNT Differential R[AC]: CNT Differential R-V characteristics (A.01.20)
2. CNT Gate Leak: CNT FET Ig-Vg characteristics (A.01.20)
3. CNT Id-Time: CNT FET Id-Time Characteristic (A.01.20)
4. CNT Id-Vd: CNT FET Id-Vd characteristics (A.01.20)
5. CNT Id-Vg: Carbon Nano Tube FET Id-Vg characteristics (A.01.20)
6. CNT Id-Vg-Time: CNT FET Ig-Vg characteristics (A.01.20)
7. CNT IV Sweep: CNT Differential I-V characteristics (A.01.20)
8. CNT R-I Kelvin 2SMU: CNT R-I characteristics, Kelvin connection (A.01.20)
9. CNT R-V Kelvin 2SMU: CNT R-V characteristics, Kelvin connection (A.01.20)
10. CNT Vth gmMax: CNT FET linear region Vth (A.01.20)



## 7 Nano Tech

Port1 input voltage  $V_{port1}$

Differential resistance  $R$

Conductance  $G$

## 7.2 CNT Gate Leak: CNT FET Ig-Vg characteristics (A.01.20)

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the gate current vs gate voltage (Ig-Vg) characteristics of CNT FET.

Measures Ig before and after applying Vg by using the primary sweep SMU that forces the start and stop voltages only, and extracts the Ig-Vg characteristics by altering the stop value repeatedly.

### [Device Under Test]

Carbon Nano Tube FET capacitor, 2 terminals

Connect SMU to the back gate and side gate and make the source and drain open.

### [Device Parameters]

Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value)

L: CNT length

D: CNT diameter

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

BackGate: SMU connected to Back Gate terminal, primary sweep voltage output

SideGate: SMU connected to Side Gate terminal, constant voltage output

VbgStart: Pulse peak start (sweep start) voltage for Back Gate terminal

VbgStop: Pulse peak stop (sweep stop) voltage for Back Gate terminal

VbgStep: Pulse peak step (sweep step) voltage for Back Gate terminal

VbgLow: Pulse base voltage (primary sweep start voltage)

### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

Vsg: Side Gate terminal voltage

IbgLimit: Back Gate current compliance

BackGateMinRng: Minimum range for Back Gate current measurement

SideGateMinRng: Minimum range for Side Gate current measurement

### [Measurement Parameters]

Ibackgate: Back Gate current

### [X-Y Plot]

X axis: Back Gate voltage Vbackgate (LINEAR)

Y1 axis: Back Gate current Ibackgate (LOG)

### [List Display]

Vbackgate: Back Gate voltage

Ibackgate: Back Gate current

### [Test Output: X-Y Graph]

X axis: Back Gate voltage Vbackgate (LINEAR)

Y1 axis: Back Gate current Ibackgate (LOG)

Y2 axis: Back Gate current with pulse base voltage applied Ibackgate@LowVbg (LOG)

### [Test Output: List Display]

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V\_backgate: Back Gate voltage

I\_backgate: Back Gate current

I\_backgate@LowVbg: Back Gate current with pulse base voltage applied

[Test Output: Parameters]

V\_backgate: Back Gate voltage

I\_backgate: Back Gate current

I\_backgate@LowVbg: Back Gate current with pulse base voltage applied

### 7.3 CNT Id-Time: CNT FET Id-Time Characteristic (A.01.20)

[Supported Analyzer]

B1500A, 4156B, 4156C

[Description]

This Algorithm evaluates the drain current with drain voltage for the gate condition change which is used as the DNA or the antibody sensor.

The IV curves between drain and source is measured with the gate condition change which indicates amount of the DNA or the antibody on the gate surface as a sensor.

The Algorithm is applied the time dependent measurement.

[Device Under Test]

CNT FET, 4 terminals

[Device Parameters]

Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value).

L: CNT length

D: CNT diameter

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

BackGate: SMU connected to Backgate terminal, secondary sweep voltage output

Source: SMU connected to Source terminal, constant voltage output

Drain: SMU connected to Drain terminal, primary sweep voltage output

SideGate: SMU connected to Sidegate, constant voltage output

VbgStart: Sweep start voltage for Backgate terminal

VbgStop: Sweep stop voltage for Backgate terminal

VbgStep: Sweep step voltage for Backgate terminal

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

Vsg: Sidegate voltage

IntegTime: Integration time

T1Stop: T1 stop time

T1Step: T1 step time

T2Stop: T2 stop time

T2Step: T2 step time

[Extended Test Parameters]

Vs: Source voltage

IgLimit: Backgate current compliance

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]

Drain current Idrain

Time ACC\_TIME

ACC\_TIME shows total time of T1Step or T2Step and measured time.

$ACC\_TIME = ACC\_TIME + T1Step \text{ or } T2Step + \text{Measured time of Id-Vd}$

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[X-Y Plot]

X axis: Drain voltage V<sub>drain</sub> (LINEAR)

Y1 axis: Drain current I<sub>drain</sub> (LINEAR)

## 7.4 CNT Id-Vd: CNT FET Id-Vd characteristics (A.01.20)

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the drain current vs drain voltage characteristics of Carbon Nano Tube FET.

### [Device Under Test]

Carbon Nano Tube FET, 4 terminals

### [Device Parameters]

Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value).

L: CNT length

D: CNT diameter

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

IntegTime: Integration time

Drain: SMU connected to Drain, primary sweep voltage output

VdStart: Sweep start voltage for Drain

VdStop: Sweep stop voltage for Drain

VdStep: Sweep step voltage for Drain

BackGate: SMU connected to Backgate, secondary sweep voltage output

VbgStart: Sweep start voltage for Backgate

VbgStop: Sweep stop voltage for Backgate

VbgStep: Sweep step voltage for Backgate

IgLimit: Backgate current compliance

SideGate: SMU connected to Sidegate, constant voltage output

Source: SMU connected to Source, constant voltage output

### [Extended Test Parameters]

Vsg: Sidegate voltage

Vs: Source voltage

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [X-Y Plot]

X axis: Drain voltage Vdrain (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

### 7.5 CNT Id-Vg: Carbon Nano Tube FET Id-Vg characteristics (A.01.20)

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the drain current vs gate voltage characteristics of Carbon Nano Tube FET.

[Device Under Test]

Carbon Nano Tube FET, 4 terminals

[Device Parameters]

Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value).

L: CNT length

D: CNT diameter

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

IntegTime: Integration time

BackGate: SMU connected to Backgate, primary sweep voltage output

VbgStart: Sweep start voltage for Backgate

VbgStop: Sweep stop voltage for Backgate

VbgStep: Sweep step voltage for Backgate

IgLimit: Backgate current compliance

Drain: SMU connected to Drain, secondary sweep voltage output

VdStart: Sweep start voltage for Drain

VdStop: Sweep stop voltage for Drain

VdStep: Sweep step voltage for Drain

SideGate: SMU connected to Sidegate, constant voltage output

Source: SMU connected to Source, constant voltage output

[Extended Test Parameters]

Vsg: Sidegate voltage

Vs: Source voltage

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]

Drain current Idrain

[X-Y Plot]

X axis: Backgate voltage Vbackgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

## 7.6 CNT Id-Vg-Time: CNT FET Ig-Vg characteristics (A.01.20)

### [Supported Analyzer]

B1500A, 4156B, 4156C

### [Description]

Measures the Id-Vg characteristics of CNT FET repeatedly at a specified interval until specified time elapses. This test is designed to use a gate electrode as a sensor and consider the adsorption of DNA and antibody to the gate electrode as a change in Ids. Used for evaluation of a time change in characteristics.

### [Device Under Test]

Carbon Nano Tube FET, 4 terminals

### [Device Parameters]

Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value)

L: CNT length

D: CNT diameter

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

IntegTime: Integration time

Drain: SMU connected to Drain, primary sweep voltage output

VdStart: Sweep start voltage for Drain

VdStop: Sweep stop voltage for Drain

VdStep: Sweep step voltage for Drain

BackGate: SMU connected to Back Gate, secondary sweep voltage output

VbgStart: Sweep start voltage for Back Gate

VbgStop: Sweep stop voltage for Back Gate

VbgStep: Sweep step voltage for Back Gate

SideGate: SMU connected to Side Gate, constant voltage output

Vsg: Side Gate voltage

Source: SMU connected to Source, constant voltage output

T1Stop: T1 stop time

T1Step: T1 step time

T2Stop: T2 stop time

T2Step: T2 step time

### [Extended Test Parameters]

Vs: Source voltage

IbgLimit: Back Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for drain current measurement

### [Measurement Parameters]

Drain current Idrain

Time ACC\_TIME

ACC\_TIME is displayed after adding the sum of T1Step (or T2Step) and the actual measurement time.

ACC\_TIME = ACC\_TIME + T1Step (or T2Step) + Id-Vg measurement time

### [User Function]

ACC\_TIME: Elapsed time



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MaxTS: Maximum time stamp value

### [X-Y Plot]

X axis: Back Gate voltage Vbackgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

### [List Display]

Vbackgate: Back Gate voltage

Idrain: Drain current

Vsidegate: Side Gate voltage

ACC\_TIME: Elapsed time

### [Test Setup Details]

Refer to "CNT Id\_Vg."

## 7.7 CNT IV Sweep: CNT Differential I-V characteristics (A.01.20)

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the I-V (current vs voltage) characteristics of a CNT 2-terminal device.

This test definition allows one to select the direction of a sweep from "Single" and "Double." When the sweep start/stop value is not 0 V, outputs a sweep from 0 V to the start value or from the stop value to 0 V to protect a device.

### [Device Under Test]

Carbon Nano Tube FET, 2 terminals

### [Device Parameters]

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Port1: SMU connected to device under test, primary sweep voltage output

Port2: SMU connected to device under test, constant voltage output

V1Start: Sweep output start voltage

V1Stop: Sweep output stop voltage

V1Step: Sweep output step voltage

I1Limit: Port1 current compliance

SweepDirection: Sweep direction

### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

V2: Port2 voltage

Y\_Min: Minimum Y axis value

Y\_Max: Maximum Y axis value

R\_Max: Maximum Y axis resistance value

Port1MinRng: Minimum range for Port1 current measurement

### [Measurement Parameters]

Iport1: Port1 current

### [User Function]

Resistor terminal voltage  $\Delta V = V_{\text{port1}} - V_{\text{port2}}$

Resistance  $R = \Delta V / I_{\text{port1}}$

### [X-Y Plot]

X axis: Voltage  $\Delta V$  (LINEAR)

Y1 axis: Measured current  $I_{\text{port1}}$  (LINEAR)

Y2 axis: Resistance  $R$  (LINEAR)

### [List Display]

$\Delta V$ : Voltage

$I_{\text{port1}}$ : Measured current

$R$ : Resistance value

### 7.8 *CNT R-I Kelvin 2SMU: CNT R-I characteristics, Kelvin connection* (A.01.20)

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the electric resistance of a CNT 2-terminal device and plots R-I (resistance vs current) characteristics. This test is designed to apply a current between terminals of devices, measure a voltage and calculate resistance. Kelvin connection is used for connecting SMU to a device.

[Device Under Test]

Carbon Nano Tube FET, 2 terminals

[Device Parameters]

L: CNT length

D: CNT diameter

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Port1: SMU connected to resistor, primary sweep current output

I1Start: Sweep output start current

I1Stop: Sweep output stop current

I1Step: Sweep output step current

V1Limit: Port1 voltage compliance

Port2: SMU connected to resistor, constant voltage output

[Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

V2: Port2 voltage

[Measurement Parameters]

Vport1: Port1 voltage

[User Function]

Circular constant  $PI=3.141592653589$

Resistor terminal voltage  $\Delta V = V_{port1} - V_{port2}$

Resistance  $R = \Delta V / I_{port1}$

Sheet resistance  $R_{sheet} = R * (PI * D) / L$

[X-Y Plot]

X axis: Current  $I_{port1}$  (LINEAR)

Y1 axis: Resistance R (LINEAR)

Y2 axis: Measured voltage  $\Delta V$  (LINEAR)

[List Display]

$I_{port1}$ : Input current

R: Resistance value

$\Delta V$ : Resistor terminal voltage

$R_{sheet}$ : Sheet resistance

## 7.9 CNT R-V Kelvin 2SMU: CNT R-V characteristics, Kelvin connection (A.01.20)

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the electric resistance of a CNT 2-terminal device and plots R-V (resistance vs voltage) characteristics. This test is designed to apply a voltage between terminals of devices, measure a current and calculate the resistance. Kelvin connection is used for connecting SMU to a device.

### [Device Under Test]

Carbon Nano Tube FET, 2 terminals

### [Device Parameters]

L: CNT length

D: CNT diameter

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Port1: SMU connected to resistor, primary sweep voltage output

V1Start: Sweep output start voltage

V1Stop: Sweep output stop voltage

V1Step: Sweep output step voltage

I1Limit: Port1 current compliance

Port2: SMU connected to resistor, constant voltage output

V2: Port2 voltage

### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

Port1MinRng: Minimum range for Port1 current measurement

### [Measurement Parameters]

Iport1: Port1 current

### [User Function]

Circular constant  $PI=3.141592653589$

Resistor terminal voltage  $\Delta V = V_{port1} - V_{port2}$

Resistance  $R = \Delta V / I_{port1}$

Sheet resistance  $R_{sheet} = R * (PI * D) / L$

### [X-Y Plot]

X axis: Voltage  $\Delta V$  (LINEAR)

Y1 axis: Measured current  $I_{port1}$  (LINEAR)

Y2 axis: Resistance  $R$  (LINEAR)

### [List Display]

$\Delta V$ : Input voltage

$I_{port1}$ : Measured current

R: Resistance value

$R_{sheet}$ : Sheet resistance

### 7.10 CNT Vth gmMax: CNT FET linear region Vth (A.01.20)

#### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

#### [Description]

Extracts the threshold voltage (Vth) from linear region data by using the extrapolation method for the measurement of CNT FET Id-Vg characteristics.

#### [Device Under Test]

Carbon Nano Tube FET, 4 terminals

#### [Device Parameters]

Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value)

L: CNT length

D: CNT diameter

Temp: Temperature

IdMax: Drain current compliance

#### [Test Parameters]

IntegTime: Integration time

BackGate: SMU connected to Back Gate, primary sweep voltage output

VbgStart: Sweep start voltage for Back Gate

VbgStop: Sweep stop voltage for Back Gate

VbgStep: Sweep step voltage for Back Gate

Drain: SMU connected to Drain, constant voltage output

Vd: Drain voltage, ideally at around 100mV

SideGate: SMU connected to Side Gate, constant voltage output

Source: SMU connected to Source, constant voltage output

#### [Extended Test Parameters]

Vsg: Side Gate voltage

Vs: Source voltage

IbgLimit: Back Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

gm\_Min: Minimum transconductance value for Y axis

gm\_Max: Maximum transconductance value for Y axis

DrainMinRng: Minimum range for drain current measurement

#### [Measurement Parameters]

Drain current Idrain

#### [User Function]

gm=diff(Idrain,Vbackgate)

#### [Analysis Function]

gmMax=max(gm)

Von=@L1X (X intercept of Line1)

Vth=Von-Vd/2

Vth is given by the following formula.

$V_{th} = V_g(gm_{Max}) - I_d(gm_{Max}) / gm_{Max}$

Vd/2 is for compensation of the secondary term of Vd in the theoretical formula.

[Auto Analysis]

Line1: Tangent line for Y1 at  $gm=gmMax$

[X-Y Plot]

X axis: Back Gate voltage  $V_{backgate}$  (LINEAR)

Y1 axis: Drain current  $I_{drain}$  (LINEAR)

Y2 axis: Transconductance  $gm$  (LINEAR)

Y3 axis: Drain current  $I_{drain}$  (LOG)

[List Display]

$V_{backgate}$ : Back Gate voltage

$V_{source}$ : Source voltage

$V_{drain}$ : Drain voltage

$V_{sidegate}$ : Side Gate voltage

$I_{drain}$ : Drain current

$gm$ : Transconductance

[Parameters Display Area]

Threshold voltage  $V_{th}$

Maximum transconductance value  $gmMax$



## 7.1 CNT Differential R[AC]: CNT Differential R-V characteristics (A.01.20)

### [Supported Analyzer]

B1500A

### [Description]

Measures the conductance of a CNT 2-terminal device and plots differential R-V (resistance vs voltage) characteristics. This test is designed to calculate resistance as the inverse of conductance. Additionally, the level of a measurement signal is specified by a peak-to-peak value (normally effective value).

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

### [Device Under Test]

Carbon Nano Tube FET, 2 terminals

### [Required Modules and Accessories]

Agilent B1520A MFCMU 1 unit

### [Device Parameters]

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Port1: CMU connected to device under test, CV sweep measurement

V1Start: Sweep output start voltage

V1Stop: Sweep output stop voltage

V1Step: Sweep output step voltage

FREQ: Measurement frequency

Meas\_Vpp: Measurement signal level, Peak to Peak value of oscillation

### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

AxisY\_RMin: Minimum Y axis (resistance) value

AxisY\_RMax: Maximum Y axis (resistance) value

### [Measurement Parameters]

Conductance G

### [User Function]

Differential resistance  $R=1/G$

### [X-Y Plot]

X axis: Port1 input voltage Vport1 (LINEAR)

Y1 axis: Differential resistance R (LINEAR)

### [List Display]





## 8 Power Device

1. BVdss[3] PwrDevice: Breakdown voltage between source and drain (A.01.20)
2. BVgso[3] PwrDevice: Breakdown voltage between gate and source (A.01.20)
3. Id-Vd pulse[3] PwrDevice: Id-Vd characteristics (3-terminal), SMU Pulse (A.01.20)
4. Id-Vd[3] PwrDevice: Id-Vd Characteristics (3-terminal) (A.01.20)
5. Id-Vg pulse[3] PwrDevice: Id-Vg characteristics (3-terminal), SMU Pulse (A.01.20)
6. Id-Vg[3] PwrDevice: Id-Vg Characteristics (3-terminal) (A.01.20)
7. Vth Const Id[3] PwrDevice:  
Constant current Vth (A.01.20)
8. Vth gmMax[3] PwrDevice: Linear region Vth (A.01.20)

## 8.1 *BVdss*[3] *PwrDevice*: Breakdown voltage between source and drain (A.01.20)

[Supported Analyzer]  
B1500A

[Description]  
Measures the breakdown voltage between source and drain of a power MOSFET. Forces drain sweep voltage in the direction of FET on, and monitors breakdown.

[Device Under Test]  
Power MOSFET, 3 terminals

[Device Parameters]  
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).  
Lg: Gate length  
Wg: Gate width  
Temp: Temperature

[Test Parameters]  
IntegTime: Integration time  
Is@BVdss: Source current deemed to be a breakdown  
Drain: SMU connected to Drain, primary sweep voltage output  
VdStart: Sweep start voltage for Drain  
VdStop: Sweep stop voltage for Drain  
VdStep: Sweep step voltage for Drain  
Gate: SMU connected to Gate, constant voltage output  
Vg: Gate voltage  
Source: SMU connected to Source, constant voltage output  
BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be  $V_{gStart} + \text{BaseOffsetV}$ .

[Extended Test Parameters]  
Vs: Source voltage  
HoldTime: Hold time  
DelayTime: Delay time  
DrainMinRng: Minimum range for drain current measurement  
GateMinRng: Minimum range for gate current measurement  
IgLimit: Gate current compliance

[Measurement Parameters]  
Drain current Idrain  
Source current Isource

For the Source terminal, the SMU current compliance is set to  $I_{s@BVdss} * 1.1$ .

[User Function]  
 $I_{sourcePerWg} = I_{source} / Wg$ : Source current per unit gate width  
 $I_{drainPerWg} = I_{drain} / Wg$ : Drain current per unit gate width

[Analysis Function]

## 8 Power Device

$BV_{dss} = @L1X$  (X intercept of Line1)

[Auto Analysis]

Line1: Vertical line for Y2 at  $I_{source} = I_s @ BV_{dss}$

[X-Y Plot]

X axis: Drain voltage  $V_{drain}$  (LINEAR)

Y1 axis: Drain current  $I_{drain}$  (LOG)

Y2 axis: Source current  $I_{source}$  (LOG)

[List Display]

Drain voltage  $V_{drain}$

Drain current  $I_{drain}$

Source current  $I_{source}$

Gate current  $I_{gate}$

Gate voltage  $V_{gate}$

Source voltage  $V_{source}$

[Parameters Display Area]

Source-Drain breakdown voltage  $BV_{dss}$

## 8.2 *BVgso[3] PwrDevice: Breakdown voltage between gate and source (A.01.20)*

### [Supported Analyzer]

B1500A

### [Description]

Measures the breakdown voltage between gate and source of a power MOSFET when drain is opened. Forces gate sweep voltage in the direction of FET off, and monitors breakdown.

### [Device Under Test]

Power MOSFET, 3 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Is@BVgso: Source current deemed to be a breakdown

Gate: SMU connected to Gate, primary sweep voltage output

VgStart: Sweep start voltage for Gate

VgStop: Sweep stop voltage for Gate

VgStep: Sweep step voltage for Gate

Source: SMU connected to Source, constant voltage output

BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be  $V_{gStart} + \text{BaseOffsetV}$ .

### [Extended Test Parameters]

Vs: Source voltage

HoldTime: Hold time

DelayTime: Delay time

GateMinRng: Minimum range for gate current measurement

SourceMinRng: Minimum range for source current measurement

### [Measurement Parameters]

Source current Isource

Gate current Igate

For the terminals, the SMU current compliance is set to  $I_{s@BVgso} * 1.1$ .

### [User Function]

$I_{gatePerGateArea} = I_{gate} / L_g / W_g$ : Gate current per unit gate area

### [Analysis Function]

$BV_{gso} = @L1X$  (X intercept of Line1)

### [Auto Analysis]

Line1: Vertical line for Y1 at  $I_{source} = I_{s@BVgso}$

### [X-Y Plot]

## 8 Power Device

X axis: Gate voltage  $V_{gate}$  (LINEAR)

Y1 axis: Source current  $I_{source}$  (LOG)

Y2 axis: Gate current  $I_{gate}$  (LOG)

[List Display]

Gate voltage  $V_{gate}$

Source current  $I_{source}$

Gate current  $I_{gate}$

Source voltage  $V_{source}$

[Parameters Display Area]

Gate-Source breakdown voltage  $BV_{gso}$

### 8.3 *Id-Vd pulse[3] PwrDevice: Id-Vd characteristics (3-terminal), SMU Pulse (A.01.20)*

[Supported Analyzer]  
B1500A

[Description]  
Measures the drain current vs drain voltage characteristics of a power MOSFET.

[Device Under Test]  
Power MOSFET, 3 terminals

[Device Parameters]  
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).  
Lg: Gate length  
Wg: Gate width  
Temp: Temperature  
IdMax: Drain current compliance

[Test Parameters]  
IntegTime: Integration time  
Drain: SMU connected to Drain terminal, primary sweep voltage output  
VdStart: Sweep start voltage for Drain terminal  
VdStop: Sweep stop voltage for Drain terminal  
VdStep: Sweep step voltage for Drain terminal  
PulsePeriod: Pulse period  
PulseWidth: Pulse width  
Gate: SMU connected to Gate terminal, secondary sweep voltage output  
VgStart: Sweep start voltage for Gate terminal  
VgStop: Sweep stop voltage for Gate terminal  
VgStep: Sweep step voltage for Gate terminal  
Source: SMU connected to Source terminal, constant voltage output  
BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be  $V_{gStart} + \text{BaseOffsetV}$ .

[Extended Test Parameters]  
Vs: Source voltage  
IgLimit: Gate current compliance  
BaseValue: Pulse base voltage  
HoldTime: Hold time  
DelayTime: Delay time

[Measurement Parameters]  
Drain current Idrain

[User Function]  
 $\text{IdrainPerWg} = \text{Idrain} / \text{Wg}$ : Drain current per unit gate width

[X-Y Plot]  
X axis: Drain voltage Vdrain (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)

## 8 Power Device

[List Display]

Drain voltage  $V_{\text{drain}}$

Drain current  $I_{\text{drain}}$

Source voltage  $V_{\text{source}}$

Gate voltage  $V_{\text{gate}}$

Drain current per unit gate width  $I_{\text{drainPerWg}}$



## 8.4 *Id-Vd[3] PwrDevice: Id-Vd Characteristics (3-terminal) (A.01.20)*

### [Supported Analyzer]

B1500A

### [Description]

Measures the drain current vs drain voltage characteristics of a power MOSFET.

### [Device Under Test]

Power MOSFET, 3 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

IntegTime: Integration time

Drain: SMU connected to Drain terminal, primary sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

Gate: SMU connected to Gate terminal, secondary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Source: SMU connected to Source terminal, constant voltage output

BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be  $VgStart + BaseOffsetV$ .

### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [User Function]

$IdrainPerWg = Idrain / Wg$ : Drain current per unit gate width

### [X-Y Plot]

X axis: Drain voltage Vdrain (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

### [List Display]

Drain voltage Vdrain

Drain current Idrain

## 8 Power Device

Gate voltage  $V_{gate}$

Source voltage  $V_{source}$

Drain current per unit gate width  $I_{drainPerWg}$

## 8.5 *Id-Vg pulse[3] PwrDevice: Id-Vg characteristics (3-terminal), SMU Pulse (A.01.20)*

[Supported Analyzer]  
B1500A

[Description]  
Measures the drain current vs gate voltage characteristics of a power MOSFET.

[Device Under Test]  
Power MOSFET, 3 terminals

[Device Parameters]  
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).  
Lg: Gate length  
Wg: Gate width  
Temp: Temperature  
IdMax: Drain current compliance

[Test Parameters]  
IntegTime: Integration time  
Gate: SMU connected to Gate terminal, primary sweep voltage output  
VgStart: Sweep start voltage for Gate terminal  
VgStop: Sweep stop voltage for Gate terminal  
VgStep: Sweep step voltage for Gate terminal  
Drain: SMU connected to Drain terminal, secondary sweep voltage output  
VdStart: Sweep start voltage for Drain terminal  
VdStop: Sweep stop voltage for Drain terminal  
VdStep: Sweep step voltage for Drain terminal  
PulsePeriod: Pulse period  
PulseWidth: Pulse width  
Source: SMU connected to Source terminal, constant voltage output  
BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be VgStart+BaseOffsetV.

[Extended Test Parameters]  
Vs: Source voltage  
BaseValue: Pulse base voltage  
IgLimit: Gate current compliance  
HoldTime: Hold time  
DelayTime: Delay time

[Measurement Parameters]  
Drain current Idrain

[User Function]  
IdrainPerWg=Idrain/Wg: Drain current per unit gate width  
gm=diff(Idrain,Vgate): gm: Transconductance  
gmPerWg=diff(IdrainPerWg,Vgate): Transconductance per unit gate width

[X-Y Plot]

## 8 Power Device

X axis: Gate voltage  $V_{gate}$  (LINEAR)  
Y1 axis: Drain current  $I_{drain}$  (LINEAR)  
Y2 axis: Drain current  $I_{drain}$  (LOG)

### [List Display]

Gate voltage  $V_{gate}$   
Source voltage  $V_{source}$   
Drain voltage  $V_{drain}$   
Drain current  $I_{drain}$   
Transconductance  $g_m$   
Drain current per unit gate width  $I_{drainPerWg}$   
Transconductance per unit gate width  $g_{mPerWg}$

## 8.6 *Id-Vg[3] PwrDevice: Id-Vg Characteristics (3-terminal) (A.01.20)*

### [Supported Analyzer]

B1500A

### [Description]

Measures the drain current vs gate voltage characteristics of a power MOSFET.

### [Device Under Test]

Power MOSFET, 3 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Drain: SMU connected to Drain terminal, secondary sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

Source: SMU connected to Source terminal, constant voltage output

BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be VgStart+BaseOffsetV.

### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [User Function]

IdrainPerWg=Idrain/Wg: Drain current per unit gate width

gm=diff(Idrain,Vgate): gm: Transconductance

gmPerWg=diff(IdrainPerWg,Vgate): Transconductance per unit gate width

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

## 8 Power Device

[List Display]

Gate voltage  $V_{gate}$

Source voltage  $V_{source}$

Drain voltage  $V_{drain}$

Drain current  $I_{drain}$

Transconductance  $g_m$

Drain current per unit gate width  $I_{drainPerWg}$

Transconductance per unit gate width  $g_{mPerWg}$

## 8.7 *Vth Const Id[3] PwrDevice: Constant current Vth (A.01.20)*

### [Supported Analyzer]

B1500A

### [Description]

Measures the drain current vs gate voltage characteristics, and extracts the threshold voltage ( $V_{th}$ ) by using the constant current method.

### [Device Under Test]

Power MOSFET, 3 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

IntegTime: Integration time

Id@Vth: Drain current to decide the  $V_{th}$

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Drain: SMU connected to Drain terminal, constant voltage output

Vd: Drain voltage

Source: SMU connected to Source terminal, constant voltage output

BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be  $V_{gStart} + \text{BaseOffsetV}$ .

### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [User Function]

$gm = \text{diff}(\text{Idrain}, V_{gate})$

### [Analysis Function]

$V_{th} = @L1X$  (X intercept of Line1)

### [Auto Analysis]

Line1: Vertical line for Y1 at  $\text{Idrain} = \text{Id}@V_{th}$

### [X-Y Plot]

## 8 Power Device

X axis: Gate voltage  $V_{gate}$  (LINEAR)  
Y1 axis: Drain current  $I_{drain}$  (LINEAR)  
Y2 axis: Drain current  $I_{drain}$  (LOG)

### [List Display]

Gate voltage  $V_{gate}$   
Drain current  $I_{drain}$   
Source voltage  $V_{source}$   
Drain voltage  $V_{drain}$   
Transconductance  $g_m$

### [Parameters Display Area]

Threshold voltage  $V_{th}$



## 8.8 *Vth gmMax[3] PwrDevice: Linear region Vth (A.01.20)*

### [Supported Analyzer]

B1500A

### [Description]

Extracts the threshold voltage ( $V_{th}$ ) by using the extrapolation method for the linear region of the drain current vs gate voltage characteristics.

### [Device Under Test]

Power MOSFET, 3 terminals

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

### [Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Drain: SMU connected to Drain terminal, constant voltage output

Vd: Drain voltage, ideally at around 100mV

Source: SMU connected to Source terminal, constant voltage output

BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be  $V_{gStart} + \text{BaseOffsetV}$ .

### [Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

gm\_Min: Minimum gm value for graph scale

gm\_Max: Maximum gm value for graph scale

DrainMinRng: Minimum range for drain current measurement

### [Measurement Parameters]

Drain current Idrain

### [User Function]

$gm = \text{diff}(\text{Idrain}, V_{gate})$

### [Analysis Function]

$gmMax = \max(gm)$

$V_{on} = @L1X$  (X intercept of Line1)

$V_{th} = V_{on} - V_d/2$

$V_{th}$  is given by the following formula.

## 8 Power Device

$$V_{th} = V_g(gm_{Max}) - I_d(gm_{Max})/gm_{Max}$$

$V_d/2$  is for compensation of the secondary term of  $V_d$  in the theoretical formula.

[Auto Analysis]

Line1: Tangent line for Y1 at  $gm=gm_{Max}$

[X-Y Plot]

X axis: Gate voltage  $V_{gate}$  (LINEAR)

Y1 axis: Drain current  $I_{drain}$  (LINEAR)

Y2 axis: Transconductance  $gm$  (LINEAR)

Y3 axis: Drain current  $I_{drain}$  (LOG)

[List Display]

Gate voltage  $V_{gate}$

Source voltage  $V_{source}$

Drain voltage  $V_{drain}$

Drain current  $I_{drain}$

Transconductance  $gm$

[Parameters Display Area]

Threshold voltage  $V_{th}$

Maximum transconductance value  $gm_{Max}$



## 9 Reliability

1. BJT EB RevStress 3devices: Emitter-Base junction Reverse bias Stress test, 4 terminals, 3 devices (A.01.20)
2. BJT EB RevStress 3devices[3]: Emitter-Base junction Reverse bias Stress test, 3 terminals, 3 devices (A.01.20)
3. BJT EB RevStress: Emitter-Base junction Reverse bias Stress test, 4 terminals (A.01.20)
4. BJT EB RevStress2: Emitter-Base junction Reverse bias Stress test, 4 terminals (A.03.10)
5. BJT EB RevStress[3]: Emitter-Base junction Reverse bias Stress test, 3 terminals (A.01.20)
6. BJT EB RevStress2[3]: Emitter-Base junction Reverse bias Stress test, 3 terminals (A.03.10)
7. BTI 3devices: Bias Temperature Instability test, 4 terminals, 3 devices (A.01.20)
8. BTI 3devices[3]: Bias Temperature Instability test, 3 terminals, 3 devices (A.01.20)
9. BTI: Bias Temperature Instability test, 4 terminals (A.01.20)
10. BTI2: Bias Temperature Instability test, 4 terminals (A.03.10)
11. BTI[3]: Bias Temperature Instability test, 3 terminals (A.01.20)
12. BTI2[3]: Bias Temperature Instability test, 3 terminals (A.03.10)
13. Charge Pumping: Evaluation of the interface state using charge pumping method (A.01.20)
14. Charge Pumping2: Evaluation of the interface state using charge pumping method (A.03.10)
15. EM Istress: Electromigration test, current stressed, 4 SMUs (A.01.20)
16. EM Istress2: Electromigration test, current stressed, 4 SMUs (A.03.10)
17. EM Istress[2]: Electromigration test, current stressed, 2 SMUs (A.01.20)
18. EM Istress2[2]: Electromigration test, current stressed, 2 SMUs (A.03.10)
19. EM Istress[6]: Electromigration test, current stressed, 6 SMUs (A.01.20)
20. EM Istress2[6]: Electromigration test, current stressed, 6 SMUs (A.03.10)
21. EM Vstress: Electromigration test, voltage stressed, 4 SMUs (A.01.20)
22. EM Vstress2: Electromigration test, voltage stressed, 4 SMUs (A.03.10)
23. EM Vstress[2]: Electromigration test, voltage stressed, 2 SMUs (A.01.20)
24. EM Vstress2[2]: Electromigration test, voltage stressed, 2 SMUs (A.03.10)
25. EM Vstress[6]: Electromigration test, voltage stressed, 6 SMUs (A.01.20)
26. EM Vstress2[6]: Electromigration test, voltage stressed, 6 SMUs (A.03.10)
27. HCI 3devices: Hot Carrier Injection test, 4 terminals, 3 devices (A.01.20)
28. HCI: Hot Carrier Injection test, 4 terminals (A.01.20)
29. HCI2: Hot Carrier Injection test, 4 terminals (A.03.10)
30. J-Ramp: Insulator lifetime evaluation, current stressed (A.01.20)
31. TDDDB Istress 3devices: TDDDB Test, current stressed, 3 devices (A.01.20)
32. TDDDB Istress2 3devices: TDDDB Test, current stressed, 3 devices (A.03.10)
33. TDDDB Istress: TDDDB Test, current stressed (A.01.20)
34. TDDDB Istress2: TDDDB Test, current stressed (A.03.10)
35. TDDDB Vstress 3devices: TDDDB Test, voltage stressed, 3 devices (A.01.20)
36. TDDDB Vstress2 3devices: TDDDB Test, voltage stressed, 3 devices (A.03.10)
37. TDDDB Vstress: TDDDB Test, voltage stressed (A.01.20)
38. TDDDB Vstress2: TDDDB Test, voltage stressed (A.03.10)
39. TZDB: TZDB Test of oxide layer (A.01.20)
40. V-Ramp: Insulator lifetime evaluation, voltage stressed (A.01.20)

## 9.1 *BJT EB RevStress 3devices: Emitter-Base junction Reverse bias Stress test, 4 terminals, 3 devices (A.01.20)*

### [Supported Analyzer]

B1500A

### [Description]

Performs the bipolar transistor Emitter-Base junction reverse bias stress test, and plots the accumulated stress time vs collector current/base current/current amplification factor characteristics. Maximum three devices can be measured by a test execution. This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

### [Device Under Test]

Bipolar transistor, 4 terminals, 3 devices

### [Required Accessories]

Agilent B2200A or B2201A switching matrix 1 unit  
 GPIB cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIB cable.

Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.

Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the Tr#Base/Tr#Collector/Tr#Emitter/Tr#Subs field (# is an integer from 1 to 3) of Test Parameters area.

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)

Le: Emitter length

We: Emitter width

Temp: Temperature (deg)

IcMax: Maximum collector current value

### [Test Parameters]

IntegTime: Integration time (SHORT, MEDIUM, LONG)

Tr#Base: SWM Pin Assign setting for Base of devices

Tr#Collector: SWM Pin Assign setting for Collector of devices

Tr#Emitter: SWM Pin Assign setting for Emitter of devices

Tr#Subs: SWM Pin Assign setting for Subs of devices

where, # is an integer from 1 to 3.

### [Test Parameters for Sampling\_Stress]

TotalStrsTime: Total stress time

Tr#StrsEmitter: SMU connected to Emitter terminal of devices, constant voltage output

StrsBase: SMU connected to Base terminal, constant voltage output

StrsCollector: SMU connected to Collector terminal, constant voltage output

StrsSubs: SMU connected to Substrate terminal, constant voltage output

Tr#VeStrs: Stress voltage for Emitter terminal of devices

where, # is an integer from 1 to 3.

## 9 Reliability

[Test Parameters for IvSweep\_hfe]

MeasCollector: SMU connected to Collector terminal, constant voltage output

MeasBase: SMU connected to Base terminal, voltage output

MeasEmitter: SMU connected to Emitter terminal, primary sweep constant voltage output

MeasSubs: SMU connected to Substrate terminal, constant voltage output

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Ic@hfe: Collector current determining the hfe

Vc: Collector voltage

[Extended Test Parameters]

[Extended Test Parameters for Sampling\_Stress]

VbStrs: Stress voltage for Base terminal

VcStrs: Stress voltage for Collector terminal

VsubsStrs: Stress voltage for Substrate terminal

IeStrsLimit: Emitter current compliance

[Extended Test Parameters for IvSweep\_hfe]

IsubsLimit: Substrate current compliance

Ve: Emitter voltage

Vsubs: Substrate voltage

hfe\_Min: Minimum hfe value for graph scale

hfe\_Max: Maximum hfe value for graph scale

HoldTime: Hold time

DelayTime: Delay time

BaseMinRng1: Minimum range for base current measurement on device 1

BaseMinRng2: Minimum range for base current measurement on device 2

BaseMinRng3: Minimum range for base current measurement on device 3

CollectorMinRng1: Minimum range for collector current measurement on device 1

CollectorMinRng2: Minimum range for collector current measurement on device 2

CollectorMinRng3: Minimum range for collector current measurement on device 3

[User Function]

[User Function for Sampling\_Stress]

Maximum elapsed time value  $\text{MaxTime} = \max(\text{Time})$

Stress time  $\text{StressTime} = \text{AccTime} + \text{Time}$

[User Function for IvSweep\_hfe]

Current amplification factor  $\text{hfe} = \text{Icollector} / \text{Ibase}$

[Analysis Function]

[Analysis Function for IvSweep\_hfe]

$\text{Ib@Ic} = @\text{L1X}$  (X intercept of Line1)

$\text{hfe@Ic} = @\text{L2Y3}$  (X intercept of Line2)

[Auto Analysis]

[Auto Analysis for IvSweep\_hfe]

Line1: Horizontal line for Y1 at  $\text{Icollector} = \text{Ic@hfe}$

Line2: Horizontal line for Y3 at  $\text{Icollector} = \text{Ic@hfe}$

[Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList (LOG)

Y1 axis: Collector current for device 1 Dev1\_IcList (LINEAR)

Y2 axis: Collector current for device 2 Dev2\_IcList (LINEAR)

Y3 axis: Collector current for device 3 Dev3\_IcList (LINEAR)

Y4 axis: Y3 accumulation data at Icollector=Ic@hfe for device 1 Dev1\_hfe@IcList (LINEAR)

Y5 axis: Y3 accumulation data at Icollector=Ic@hfe for device 2 Dev2\_hfe@IcList (LINEAR)

Y6 axis: Y3 accumulation data at Icollector=Ic@hfe for device 3 Dev3\_hfe@IcList (LINEAR)

[Test Output: List Display]

TimeList: Accumulated stress time

Dev1\_IcList: Collector current for device 1

Dev2\_IcList: Collector current for device 2

Dev3\_IcList: Collector current for device 3

Dev1\_hfe@IcList: Y3 accumulation data at Icollector=Ic@hfe for device 1

Dev2\_hfe@IcList: Y3 accumulation data at Icollector=Ic@hfe for device 2

Dev3\_hfe@IcList: Y3 accumulation data at Icollector=Ic@hfe for device 3

Dev1\_Ib@IcList: Y1 accumulation data at Icollector=Ic@hfe for device 1

Dev2\_Ib@IcList: Y1 accumulation data at Icollector=Ic@hfe for device 2

Dev3\_Ib@IcList: Y1 accumulation data at Icollector=Ic@hfe for device 3

## 9 Reliability

### 9.2 *BJT EB RevStress 3devices[3]: Emitter-Base junction Reverse bias Stress test, 3 terminals, 3 devices (A.01.20)*

[Supported Analyzer]

B1500A

[Description]

Performs the bipolar transistor Emitter-Base junction reverse bias stress test, and plots the accumulated stress time vs collector current/base current/current amplification factor characteristics.

This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]

Bipolar transistor, 3 terminals, 3 devices

[Required Accessories]

Agilent B2200A or B2201A switching matrix 1 unit

GPIB cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIB cable.

Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.

Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the Tr#Base/Tr#Collector/Tr#Emitter field (# is an integer from 1 to 3) of Test Parameters area.

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)

Le: Emitter length

We: Emitter width

Temp: Temperature (deg)

IcMax: Maximum collector current value

[Test Parameters]

IntegTime: Integration time (SHORT, MEDIUM, LONG)

Tr#Base: SWM Pin Assign setting for Base of devices

Tr#Collector: SWM Pin Assign setting for Collector of devices

Tr#Emitter: SWM Pin Assign setting for Emitter of devices

where, # is an integer from 1 to 3.

[Test Parameters for Sampling\_Stress]

TotalStrsTime: Total stress time

Tr#StrsEmitter: SMU connected to Emitter terminal of devices, constant voltage output

StrsBase: SMU connected to Base terminal, constant voltage output

StrsCollector: SMU connected to Collector terminal, constant voltage output

Tr#VeStrs: Stress voltage for Emitter terminal of devices

where, # is an integer from 1 to 3.

[Test Parameters for IvSweep\_hfe]

MeasCollector: SMU connected to Collector terminal, constant voltage output



MeasBase: SMU connected to Base terminal, voltage output  
 MeasEmitter: SMU connected to Emitter terminal, primary sweep constant voltage output  
 VbStart: Sweep start voltage for Base terminal  
 VbStop: Sweep stop voltage for Base terminal  
 VbStep: Sweep step voltage for Base terminal  
 Ic@hfe: Collector current determining the hfe  
 Vc: Collector voltage

[Extended Test Parameters]

[Extended Test Parameters for Sampling\_Stress]

VbStrs: Stress voltage for Base terminal  
 VcStrs: Stress voltage for Collector terminal  
 IeStrsLimit: Emitter current compliance

[Extended Test Parameters for IvSweep\_hfe]

Ve: Emitter voltage  
 hfe\_Min: Minimum hfe value for graph scale  
 hfe\_Max: Maximum hfe value for graph scale  
 HoldTime: Hold time  
 DelayTime: Delay time  
 BaseMinRng1: Minimum range for base current measurement on device 1  
 BaseMinRng2: Minimum range for base current measurement on device 2  
 BaseMinRng3: Minimum range for base current measurement on device 3  
 CollectorMinRng1: Minimum range for collector current measurement on device 1  
 CollectorMinRng2: Minimum range for collector current measurement on device 2  
 CollectorMinRng3: Minimum range for collector current measurement on device 3

[User Function]

[User Function for Sampling\_Stress]

Maximum elapsed time value  $\text{MaxTime} = \max(\text{Time})$   
 Stress time  $\text{StressTime} = \text{AccTime} + \text{Time}$

[User Function for IvSweep\_hfe]

Current amplification factor  $\text{hfe} = \text{Icollector} / \text{Ibase}$

[Analysis Function]

[Analysis Function for IvSweep\_hfe]

$\text{Ib@Ic} = @\text{L1X}$  (X intercept of Line1)  
 $\text{hfe@Ic} = @\text{L2Y3}$  (X intercept of Line2)

[Auto Analysis]

[Auto Analysis for IvSweep\_hfe]

Line1: Horizontal line for Y1 at  $\text{Icollector} = \text{Ic@hfe}$   
 Line2: Horizontal line for Y3 at  $\text{Icollector} = \text{Ic@hfe}$

[Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList (LOG)  
 Y1 axis: Collector current for device 1 Dev1\_IcList (LINEAR)  
 Y2 axis: Collector current for device 2 Dev2\_IcList (LINEAR)  
 Y3 axis: Collector current for device 3 Dev3\_IcList (LINEAR)  
 Y4 axis: Y3 accumulation data at  $\text{Icollector} = \text{Ic@hfe}$  for device 1 Dev1\_hfe@IcList (LINEAR)  
 Y5 axis: Y3 accumulation data at  $\text{Icollector} = \text{Ic@hfe}$  for device 2 Dev2\_hfe@IcList (LINEAR)  
 Y6 axis: Y3 accumulation data at  $\text{Icollector} = \text{Ic@hfe}$  for device 3 Dev3\_hfe@IcList (LINEAR)

## 9 Reliability

[Test Output: List Display]

TimeList: Accumulated stress time

Dev1\_IcList: Collector current for device 1

Dev2\_IcList: Collector current for device 2

Dev3\_IcList: Collector current for device 3

Dev1\_hfe@IcList: Y3 accumulation data at Icollector=Ic@hfe for device 1

Dev2\_hfe@IcList: Y3 accumulation data at Icollector=Ic@hfe for device 2

Dev3\_hfe@IcList: Y3 accumulation data at Icollector=Ic@hfe for device 3

Dev1\_Ib@IcList: Y1 accumulation data at Icollector=Ic@hfe for device 1

Dev2\_Ib@IcList: Y1 accumulation data at Icollector=Ic@hfe for device 2

Dev3\_Ib@IcList: Y1 accumulation data at Icollector=Ic@hfe for device 3

### 9.3 *BJT EB RevStress: Emitter-Base junction Reverse bias Stress test, 4 terminals (A.01.20)*

[Supported Analyzer]

B1500A

[Description]

Performs the bipolar transistor Emitter-Base junction reverse bias stress test, and plots the accumulated stress time vs collector current/base current/current amplification factor characteristics.

This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]

Bipolar transistor, 4 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)

Le: Emitter length

We: Emitter width

Temp: Temperature (deg)

IcMax: Maximum collector current value

[Test Parameters]

IntegTime: Integration time (SHORT, MEDIUM, LONG)

TotalStressTime: Total stress time

Collector: SMU connected to Collector terminal, constant voltage output

Base: SMU connected to Base terminal, constant voltage output

Emitter: SMU connected to Emitter terminal, primary sweep voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

[Test Parameters for Sampling\_Stress]

VeStress: Stress voltage for Emitter terminal

[Test Parameters for IvSweep\_hfe]

Ic@hfe: Collector current determining the hfe

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Vc: Collector voltage

[Extended Test Parameters]

[Extended Test Parameters for Sampling\_Stress]

IeStressLimit: Emitter current compliance

VbStress: Stress voltage for Base terminal

VcStress: Stress voltage for Collector terminal

VsubsStress: Stress voltage for Substrate terminal

## 9 Reliability

[Extended Test Parameters for IvSweep\_hfe]

HoldTime: Hold time

DelayTime: Delay time

IsubsLimit: Substrate current compliance

BaseMinRng: Minimum range for base current measurement

CollectorMinRng: Minimum range for collector current measurement

Ve: Emitter voltage

Vsubs: Substrate voltage

hfe\_Min: Minimum hfe value for graph scale

hfe\_Max: Maximum hfe value for graph scale

[User Function]

[User Function for Sampling\_Stress]

Maximum elapsed time value  $\text{MaxTime} = \text{max}(\text{Time})$

Stress time  $\text{StressTime} = \text{AccTime} + \text{Time}$

[User Function for IvSweep\_hfe]

Current amplification factor  $\text{hfe} = \text{Icollector} / \text{Ibase}$

[Analysis Function]

[Analysis Function for IvSweep\_hfe]

$\text{Ib@Ic} = @\text{L1X}$  (X intercept of Line1)

$\text{hfe@Ic} = @\text{L2Y3}$  (X intercept of Line2)

[Auto Analysis]

[Auto Analysis for IvSweep\_hfe]

Line1: Horizontal line for Y1 at  $\text{Icollector} = \text{Ic@hfe}$

Line2: Horizontal line for Y3 at  $\text{Icollector} = \text{Ic@hfe}$

[Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList (LOG)

Y1 axis: Collector current IcList (LOG)

Y2 axis: Y1 accumulation data at  $\text{Icollector} = \text{Ic@hfe}$   $\text{Ib@IcList}$  (LOG)

Y3 axis: Y3 accumulation data at  $\text{Icollector} = \text{Ic@hfe}$   $\text{Ihfe@IcList}$  (LINEAR)

[Test Output: List Display]

Accumulated stress time TimeList

Collector current IcList

Y1 accumulation data at  $\text{Icollector} = \text{Ic@hfe}$   $\text{Ib@IcList}$

Y3 accumulation data at  $\text{Icollector} = \text{Ic@hfe}$   $\text{hfe@IcList}$

## 9.4 BJT EB RevStress2: Emitter-Base junction Reverse bias Stress test, 4 terminals (A.03.10)

### [Supported Analyzer]

B1500A

### [Description]

Performs the bipolar transistor Emitter-Base junction reverse bias stress test, and plots the accumulated stress time vs collector current/base current/current amplification factor characteristics.

This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

### [Device Under Test]

Bipolar transistor, 4 terminals

### [Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)

Le: Emitter length

We: Emitter width

Temp: Temperature (deg)

IcMax: Maximum collector current value

### [Test Parameters]

IntegTime: Integration time (SHORT, MEDIUM, LONG)

TotalStressTime: Total stress time

Collector: SMU connected to Collector terminal, constant voltage output

Base: SMU connected to Base terminal, constant voltage output

Emitter: SMU connected to Emitter terminal, primary sweep voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

MeasTiming: Timing to measure device parameter

hfeStopRate: Hfe change rate to stop measurement

### [Test Parameters for Sampling\_Stress]

VeStress: Stress voltage for Emitter terminal

VbStress: Stress voltage for Base terminal

VcStress: Stress voltage for Collector terminal

VsubsStress: Stress voltage for Substrate terminal

IeStressLimit: Emitter current compliance

### [Test Parameters for IvSweep\_hfe]

Ic@hfe: Collector current determining the hfe

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Vc: Collector voltage

### [Extended Test Parameters]

StoringRuntimeData: Data save during stress output, Yes or No

## 9 Reliability

[Extended Test Parameters for IvSweep\_hfe]

HoldTime: Hold time

DelayTime: Delay time

IsubsLimit: Substrate current compliance

BaseMinRng: Minimum range for base current measurement

CollectorMinRng: Minimum range for collector current measurement

Ve: Emitter voltage

Vsubs: Substrate voltage

hfe\_Min: Minimum hfe value for graph scale

hfe\_Max: Maximum hfe value for graph scale

[Measurement Parameters]

[Measurement Parameters by Sampling\_Stress]

Emitter current Iemitter

[Measurement Parameters by IvSweep\_hfe]

Base current Ibase

Collector current Icollector

[User Function]

[User Function for IvSweep\_hfe]

Current amplification factor  $hfe = I_{collector} / I_{base}$

[Analysis Function]

[Analysis Function for IvSweep\_hfe]

Ib@Ic=@L1X (X intercept of Line1)

hfe@Ic=@L2Y3 (X intercept of Line2)

[Auto Analysis]

[Auto Analysis for IvSweep\_hfe]

Line1: Horizontal line for Y1 at  $I_{collector} = I_{c@hfe}$

Line2: Horizontal line for Y3 at  $I_{collector} = I_{c@hfe}$

[X-Y Graph]

[X-Y Graph for Sampling\_Stress]

X axis: Stress time StressTime (LINEAR)

Y1 axis: Emitter current Iemitter (LOG)

[X-Y Graph for IvSweep\_hfe]

X axis: Base voltage Vbase (LINEAR)

Y1 axis: Base current Ibase (LOG)

Y2 axis: Collector current Icollector (LOG)

Y3 axis: Current amplification factor hfe (LINEAR)

[List Display]

[List Display for Sampling\_Stress]

Stress time StressTime

Elapsed time Time

Emitter voltage Vemitter

Emitter current Iemitter

Base current Ibase

[List Display for IvSweep\_hfe]

Emitter voltage Vemitter

Base voltage Vbase  
 Collector voltage Vcollector  
 Base current Ibase  
 Collector current Icollector  
 Current amplification factor hfe

[Parameters]

[Parameters for IvSweep\_hfe]  
 Base current Ib at Ic@hfe Ib@Ic  
 Current amplification factor hfe at Ic@hfe hfe@Ic

[Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList (LOG)  
 Y1 axis: Collector current IcList (LINEAR)  
 Y2 axis: Y1 accumulation data at Icollector=Ic@hfe Ib@IcList (LOG)  
 Y3 axis: Y3 accumulation data at Icollector=Ic@hfe Ihfe@IcList (LINEAR)

[Test Output: List Display]

Accumulated stress time TimeList  
 Collector current IcList  
 Y1 accumulation data at Icollector=Ic@hfe Ib@IcList  
 Y3 accumulation data at Icollector=Ic@hfe hfe@IcList

## 9 Reliability

### 9.5 *BJT EB RevStress[3]: Emitter-Base junction Reverse bias Stress test, 3 terminals (A.01.20)*

[Supported Analyzer]  
B1500A

[Description]  
Performs the bipolar transistor Emitter-Base junction reverse bias stress test, and plots the accumulated stress time vs collector current/base current/current amplification factor characteristics.

This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]  
Bipolar transistor, 3 terminals

[Device Parameters]  
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)  
Le: Emitter length  
We: Emitter width  
Temp: Temperature (deg)  
IcMax: Maximum collector current value

[Test Parameters]  
IntegTime: Integration time (SHORT, MEDIUM, LONG)  
TotalStressTime: Total stress time  
Collector: SMU connected to Collector terminal, constant voltage output  
Base: SMU connected to Base terminal, constant voltage output  
Emitter: SMU connected to Emitter terminal, primary sweep voltage output

[Test Parameters for Sampling\_Stress]  
VeStress: Stress voltage for Emitter terminal

[Test Parameters for IvSweep\_hfe]  
Ic@hfe: Collector current determining the hfe  
VbStart: Sweep start voltage for Base terminal  
VbStop: Sweep stop voltage for Base terminal  
VbStep: Sweep step voltage for Base terminal  
Vc: Collector voltage

[Extended Test Parameters]  
[Extended Test Parameters for Sampling\_Stress]  
IeStressLimit: Emitter current compliance  
VbStress: Stress voltage for Base terminal  
VcStress: Stress voltage for Collector terminal

[Extended Test Parameters for IvSweep\_hfe]  
HoldTime: Hold time  
DelayTime: Delay time  
BaseMinRng: Minimum range for base current measurement



CollectorMinRng: Minimum range for collector current measurement

Ve: Emitter voltage

hfe\_Min: Minimum hfe value for graph scale

hfe\_Max: Maximum hfe value for graph scale

[User Function]

[User Function for Sampling\_Stress]

Maximum elapsed time value MaxTime=max(Time)

Stress time StressTime=AccTime+Time

[User Function for IvSweep\_hfe]

hfe=Icollector/Ibase

[Analysis Function]

[Analysis Function for IvSweep\_hfe]

Ib@Ic=@L1X (X intercept of Line1)

hfe@Ic=@L2Y3 (X intercept of Line2)

[Auto Analysis]

[Auto Analysis for IvSweep\_hfe]

Line1: Horizontal line for Y1 at Icollector=Ic@hfe

Line2: Horizontal line for Y3 at Icollector=Ic@hfe

[Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList (LOG)

Y1 axis: Collector current IcList (LOG)

Y2 axis: Y1 accumulation data at Icollector=Ic@hfe Ib@IcList (LOG)

Y3 axis: Y3 accumulation data at Icollector=Ic@hfe Ihfe@IcList (LINEAR)

[Test Output: List Display]

Accumulated stress time TimeList

Collector current IcList

Y1 accumulation data at Icollector=Ic@hfe Ib@IcList

Y3 accumulation data at Icollector=Ic@hfe hfe@IcList

## 9 Reliability

### 9.6 *BJT EB RevStress2[3]: Emitter-Base junction Reverse bias Stress test, 3 terminals (A.03.10)*

[Supported Analyzer]

B1500A

[Description]

Performs the bipolar transistor Emitter-Base junction reverse bias stress test, and plots the accumulated stress time vs collector current/base current/current amplification factor characteristics.

This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]

Bipolar transistor, 3 terminals

[Device Parameters]

Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)

Le: Emitter length

We: Emitter width

Temp: Temperature (deg)

IcMax: Maximum collector current value

[Test Parameters]

IntegTime: Integration time (SHORT, MEDIUM, LONG)

TotalStressTime: Total stress time

Collector: SMU connected to Collector terminal, constant voltage output

Base: SMU connected to Base terminal, constant voltage output

Emitter: SMU connected to Emitter terminal, primary sweep voltage output

MeasTiming: Timing to measure device parameter

hfeStopRate: Hfe change rate to stop measurement

[Test Parameters for Sampling\_Stress]

VeStress: Stress voltage for Emitter terminal

VbStress: Stress voltage for Base terminal

VcStress: Stress voltage for Collector terminal

IeStressLimit: Emitter current compliance

[Test Parameters for IvSweep\_hfe]

Ic@hfe: Collector current determining the hfe

VbStart: Sweep start voltage for Base terminal

VbStop: Sweep stop voltage for Base terminal

VbStep: Sweep step voltage for Base terminal

Vc: Collector voltage

[Extended Test Parameters]

StoringRuntimeData: Data save during stress output, Yes or No

[Extended Test Parameters for IvSweep\_hfe]

Ve: Emitter voltage

HoldTime: Hold time  
 DelayTime: Delay time  
 BaseMinRng: Minimum range for base current measurement  
 CollectorMinRng: Minimum range for collector current measurement  
 hfe\_Min: Minimum hfe value for graph scale  
 hfe\_Max: Maximum hfe value for graph scale

[Measurement Parameters]

[Measurement Parameters by Sampling\_Stress]  
 Emitter current Iemitter

[Measurement Parameters by IvSweep\_hfe]  
 Base current Ibase  
 Collector current Icollector

[User Function]

[User Function for IvSweep\_hfe]  
 $hfe = I_{collector} / I_{base}$

[Analysis Function]

[Analysis Function for IvSweep\_hfe]  
 $I_b @ I_c = @L1X$  (X intercept of Line1)  
 $hfe @ I_c = @L2Y3$  (X intercept of Line2)

[Auto Analysis]

[Auto Analysis for IvSweep\_hfe]  
 Line1: Horizontal line for Y1 at  $I_{collector} = I_c @ hfe$   
 Line2: Horizontal line for Y3 at  $I_{collector} = I_c @ hfe$

[X-Y Graph]

[X-Y Graph for Sampling\_Stress]  
 X axis: Stress time StressTime (LINEAR)  
 Y1 axis: Emitter current Iemitter (LOG)

[X-Y Graph for IvSweep\_hfe]  
 X axis: Base voltage Vbase (LINEAR)  
 Y1 axis: Base current Ibase (LOG)  
 Y2 axis: Collector current Icollector (LOG)  
 Y3 axis: Current amplification factor hfe (LINEAR)

[List Display]

[List Display for Sampling\_Stress]  
 Stress time StressTime  
 Elapsed time Time  
 Emitter voltage Vemitter  
 Emitter current Iemitter  
 Base current Ibase

[List Display for IvSweep\_hfe]  
 Emitter voltage Vemitter  
 Base voltage Vbase  
 Collector voltage Vcollector  
 Base current Ibase  
 Collector current Icollector  
 Current amplification factor hfe

## 9 Reliability

### [Parameters]

[Parameters for IvSweep\_hfe]

Base current Ib at Ic@hfe Ib@Ic

Current amplification factor hfe at Ic@hfe hfe@Ic

### [Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList (LOG)

Y1 axis: Collector current IcList (LINEAR)

Y2 axis: Y1 accumulation data at Icollector=Ic@hfe Ib@IcList (LOG)

Y3 axis: Y3 accumulation data at Icollector=Ic@hfe Ihfe@IcList (LINEAR)

### [Test Output: List Display]

Accumulated stress time TimeList

Collector current IcList

Y1 accumulation data at Icollector=Ic@hfe Ib@IcList

Y3 accumulation data at Icollector=Ic@hfe hfe@IcList

## 9.7 *BTI 3 devices: Bias Temperature Instability test, 4 terminals, 3 devices* (A.01.20)

### [Supported Analyzer]

B1500A

### [Description]

Performs the bias temperature instability test, and plots the accumulated stress time vs threshold voltage/drain current characteristics. Maximum three devices can be measured by a test execution. This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

### [Device Under Test]

MOSFET, 4 terminals, 3 devices

### [Required Accessories]

Agilent B2200A or B2201A switching matrix 1 unit  
 GPIB cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIB cable.

Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.

Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the Tr#Gate/Tr#Drain/Tr#Source/Tr#Subs field (# is an integer from 1 to 3) of Test Parameters area.

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature (deg)

### [Test Parameters]

IntegTime: Integration time (SHORT, MEDIUM, LONG)

Tr#Gate: SWM Pin Assign settings for Gate terminal of devices

Tr#Drain: SWM Pin Assign settings for Drain terminal of devices

Tr#Source: SWM Pin Assign settings for Source terminal of devices

Tr#Subs: SWM Pin Assign settings for Substrate terminal of devices

where, # is an integer from 1 to 3.

### [Test Parameters for Sampling\_Stress]

TotalStrsTime: Total stress time

Tr#StrsGate: SMU connected to Gate terminal of devices, constant voltage output

StrsSource: SMU connected to Gate terminal of devices, constant voltage output (drain/subs short)

Tr#VgStrs: Gate terminal stress voltage for the devices

VsStrs: Source terminal stress voltage

where, # is an integer from 1 to 3.

## 9 Reliability

[Test Parameters for IvSweep\_ConstId]

MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output

MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output

MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output

Id@Vth: Drain current to decide the Vth, per unit area

VgStart1: Sweep start voltage for Gate terminal

VgStop1: Sweep stop voltage for Gate terminal

VgStep1: Sweep step voltage for Gate terminal

Vd1: Drain terminal voltage, constant value

[Test Parameters for IvSweep\_gmmax]

MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output

MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output

MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output

VgStart2: Sweep start voltage for Gate terminal

VgStop2: Sweep stop voltage for Gate terminal

VgStep2: Sweep step voltage for Gate terminal

Vd2: Drain voltage

[Test Parameters for Sampling\_Ids]

MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output

MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output

MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output

Vg3: Gate terminal voltage

Vd3: Drain terminal voltage

[Extended Test Parameters]

[Extended Test Parameters for IvSweep\_ConstId]

HoldTime: Hold time

DelayTime: Delay time

Vs: Source terminal voltage, constant voltage

IgLimit: Gate current compliance

IdLimit: Drain current compliance

DrainMinRng1: Minimum range for drain current measurement on device 1

DrainMinRng2: Minimum range for drain current measurement on device 1

DrainMinRng3: Minimum range for drain current measurement on device 1

[Extended Test Parameters for IvSweep\_gmmax]

HoldTime: Hold time

DelayTime: Delay time

Vs: Source terminal voltage, constant voltage

IgLimit: Gate current compliance

IdLimit: Drain current compliance

Vth\_Min: Minimum Vth value for graph scale

Vth\_Max: Maximum Vth value for graph scale

gmMax\_Min: Minimum gmMax value for graph scale

gmMax\_Max: Maximum gmMax value for graph scale

DrainMinRng1: Minimum range for drain current measurement on device 1

DrainMinRng2: Minimum range for drain current measurement on device 1

DrainMinRng3: Minimum range for drain current measurement on device 1

[Extended Test Parameters for Sampling\_Ids]

Vs: Source terminal voltage, constant voltage

IgLimit: Gate current compliance

IdLimit: Drain current compliance

DrainMinRng1: Minimum range for drain current measurement on device 1

DrainMinRng2: Minimum range for drain current measurement on device 1

DrainMinRng3: Minimum range for drain current measurement on device 1

[User Function]

[User Function for Sampling\_Stress]

Maximum elapsed time value  $\text{MaxTime} = \max(\text{Time})$

Stress time  $\text{StressTime} = \text{AccTime} + \text{Time}$

[User Function for IvSweep\_ConstId]

Maximum drain current value  $\text{IdMax} = \max(\text{abs}(\text{Idrain}))$  (For initial measurement only)

[User Function for IvSweep\_gmmax]

Transconductance  $\text{gm} = \text{diff}(\text{Idrain}, \text{Vgate})$

Maximum transconductance value  $\text{gmmax} = \max(\text{gm})$

Maximum drain current value  $\text{IdMax} = \max(\text{abs}(\text{Idrain}))$  (For initial measurement only)

[Analysis Function]

[Analysis Function for IvSweep\_ConstId]

$\text{Vth@Id} = @L1X$  (X intercept of Line1)

[Analysis Function for IvSweep\_gmmax]

$\text{Vth@Gm} = @L1X$  (X intercept of Line1)

[Auto Analysis]

[Auto Analysis for IvSweep\_ConstId]

Line1: Vertical line for Y1 at  $\text{Idrain} = \text{Id@Vth}$

[Auto Analysis for IvSweep\_gmmax]

Line1: Tangent line for Y1 at  $\text{gm} = \text{gmMax}$

[Test Output: X-Y Graph]

X axis: Elapsed time TimeList (LOG)

Y1 axis: Drain current for device 1 Dev1\_IdsList (LOG)

Y2 axis: Drain current for device 2 Dev2\_IdsList (LOG)

Y3 axis: Drain current for device 3 Dev3\_IdsList (LOG)

Y4 axis: Maximum transconductance value for device 1 Dev1\_GmMaxList (LINEAR)

Y5 axis: Maximum transconductance value for device 2 Dev2\_GmMaxList (LINEAR)

Y6 axis: Maximum transconductance value for device 3 Dev3\_GmMaxList (LINEAR)

[Test Output: List Display]

TimeList: Elapsed time

Dev1\_IdsList: Drain current for device 1

Dev2\_IdsList: Drain current for device 2

Dev3\_IdsList: Drain current for device 3

Dev1\_VthIdList: Vth for device 1, determined by constant current method

Dev2\_VthIdList: Vth for device 2, determined by constant current method

Dev3\_VthIdList: Vth for device 3, determined by constant current method

Dev1\_VthGmList: Vth for device 1, determined by extrapolation method

Dev2\_VthGmList: Vth for device 2, determined by extrapolation method

Dev3\_VthGmList: Vth for device 3, determined by extrapolation method

## 9 Reliability

Dev1\_GmMaxList: Maximum transconductance value for device 1

Dev2\_GmMaxList: Maximum transconductance value for device 2

Dev3\_GmMaxList: Maximum transconductance value for device 3



## 9.8 *BTI 3devices[3]: Bias Temperature Instability test, 3 terminals, 3 devices* (A.01.20)

### [Supported Analyzer]

B1500A

### [Description]

Performs the bias temperature instability test, and plots the accumulated stress time vs threshold voltage/drain current characteristics. Maximum three devices can be measured by a test execution. This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

### [Device Under Test]

MOSFET, 3 terminals, 3 devices

### [Required Accessories]

Agilent B2200A or B2201A switching matrix 1 unit  
 GPIB cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIB cable.

Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.

Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the Tr#Gate/Tr#Drain/Tr#Source field (# is an integer from 1 to 3) of Test Parameters area.

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature (deg)

### [Test Parameters]

IntegTime: Integration time (SHORT, MEDIUM, LONG)

Tr#Gate: SWM Pin Assign settings for Gate terminal of devices

Tr#Drain: SWM Pin Assign settings for Drain terminal of devices

Tr#Source: SWM Pin Assign settings for Source terminal of devices

where, # is an integer from 1 to 3.

### [Test Parameters for Sampling\_Stress]

TotalStrsTime: Total stress time

Tr#StrsGate: SMU connected to Gate terminal of devices, constant voltage output

StrsSource: SMU connected to Gate terminal of devices, constant voltage output (drain/subs short)

Tr#VgStrs: Gate terminal stress voltage for the devices

VsStrs: Source terminal stress voltage

where, # is an integer from 1 to 3.

### [Test Parameters for IvSweep\_ConstId]

MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output

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MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output  
MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output  
Id@Vth: Drain current to decide the Vth, per unit area  
VgStart1: Sweep start voltage for Gate terminal  
VgStop1: Sweep stop voltage for Gate terminal  
VgStep1: Sweep step voltage for Gate terminal  
Vd1: Drain terminal voltage, constant value

[Test Parameters for IvSweep\_gmmax]

MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output

MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output  
MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output  
VgStart2: Sweep start voltage for Gate terminal  
VgStop2: Sweep stop voltage for Gate terminal  
VgStep2: Sweep step voltage for Gate terminal  
Vd2: Drain voltage

[Test Parameters for Sampling\_Ids]

MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output

MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output  
MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output  
Vg3: Gate terminal voltage  
Vd3: Drain terminal voltage

[Extended Test Parameters]

[Extended Test Parameters for IvSweep\_ConstId]

HoldTime: Hold time  
DelayTime: Delay time  
Vs: Source terminal voltage, constant voltage  
IgLimit: Gate current compliance  
IdLimit: Drain current compliance  
DrainMinRng1: Minimum range for drain current measurement on device 1  
DrainMinRng2: Minimum range for drain current measurement on device 2  
DrainMinRng3: Minimum range for drain current measurement on device 3

[Extended Test Parameters for IvSweep\_gmmax]

HoldTime: Hold time  
DelayTime: Delay time  
Vs: Source terminal voltage, constant voltage  
IgLimit: Gate current compliance  
IdLimit: Drain current compliance  
Vth\_Min: Minimum Vth value for graph scale  
Vth\_Max: Maximum Vth value for graph scale  
gmMax\_Min: Minimum gmMax value for graph scale  
gmMax\_Max: Maximum gmMax value for graph scale  
DrainMinRng1: Minimum range for drain current measurement on device 1  
DrainMinRng2: Minimum range for drain current measurement on device 2  
DrainMinRng3: Minimum range for drain current measurement on device 3

[Extended Test Parameters for Sampling\_Ids]

Vs: Source terminal voltage, constant voltage  
IgLimit: Gate current compliance  
IdLimit: Drain current compliance

DrainMinRng1: Minimum range for drain current measurement on device 1  
 DrainMinRng2: Minimum range for drain current measurement on device 2  
 DrainMinRng3: Minimum range for drain current measurement on device 3

[User Function]

[User Function for Sampling\_Stress]

Maximum elapsed time value  $\text{MaxTime} = \max(\text{Time})$

Stress time  $\text{StressTime} = \text{AccTime} + \text{Time}$

[User Function for IvSweep\_ConstId]

Maximum drain current value  $\text{IdMax} = \max(\text{abs}(\text{Idrain}))$  (For initial measurement only)

[User Function for IvSweep\_gmmax]

Transconductance  $\text{gm} = \text{diff}(\text{Idrain}, \text{Vgate})$

Maximum transconductance value  $\text{gmmax} = \max(\text{gm})$

Maximum drain current value  $\text{IdMax} = \max(\text{abs}(\text{Idrain}))$  (For initial measurement only)

[Analysis Function]

[Analysis Function for IvSweep\_ConstId]

$\text{Vth@Id} = @\text{L1X}$  (X intercept of Line1)

[Analysis Function for IvSweep\_gmmax]

$\text{Vth@Gm} = @\text{L1X}$  (X intercept of Line1)

[Auto Analysis]

[Auto Analysis for IvSweep\_ConstId]

Line1: Vertical line for Y1 at  $\text{Idrain} = \text{Id@Vth}$

[Auto Analysis for IvSweep\_gmmax]

Line1: Tangent line for Y1 at  $\text{gm} = \text{gmMax}$

[Test Output: X-Y Graph]

X axis: Elapsed time  $\text{TimeList}$  (LOG)

Y1 axis: Drain current for device 1  $\text{Dev1\_IdsList}$  (LOG)

Y2 axis: Drain current for device 2  $\text{Dev2\_IdsList}$  (LOG)

Y3 axis: Drain current for device 3  $\text{Dev3\_IdsList}$  (LOG)

Y4 axis: Maximum transconductance value for device 1  $\text{Dev1\_GmMaxList}$  (LINEAR)

Y5 axis: Maximum transconductance value for device 2  $\text{Dev2\_GmMaxList}$  (LINEAR)

Y6 axis: Maximum transconductance value for device 3  $\text{Dev3\_GmMaxList}$  (LINEAR)

[Test Output: List Display]

$\text{TimeList}$ : Elapsed time

$\text{Dev1\_IdsList}$ : Drain current for device 1

$\text{Dev2\_IdsList}$ : Drain current for device 2

$\text{Dev3\_IdsList}$ : Drain current for device 3

$\text{Dev1\_VthIdList}$ :  $\text{Vth}$  for device 1, determined by constant current method

$\text{Dev2\_VthIdList}$ :  $\text{Vth}$  for device 2, determined by constant current method

$\text{Dev3\_VthIdList}$ :  $\text{Vth}$  for device 3, determined by constant current method

$\text{Dev1\_VthGmList}$ :  $\text{Vth}$  for device 1, determined by extrapolation method

$\text{Dev2\_VthGmList}$ :  $\text{Vth}$  for device 2, determined by extrapolation method

$\text{Dev3\_VthGmList}$ :  $\text{Vth}$  for device 3, determined by extrapolation method

$\text{Dev1\_GmMaxList}$ : Maximum transconductance value for device 1

$\text{Dev2\_GmMaxList}$ : Maximum transconductance value for device 2

$\text{Dev3\_GmMaxList}$ : Maximum transconductance value for device 3

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### 9.9 BTI: Bias Temperature Instability test, 4 terminals (A.01.20)

[Supported Analyzer]

B1500A

[Description]

Performs the bias temperature instability test, and plots the accumulated stress time vs threshold voltage/drain current characteristics.

This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]

MOSFET, 4 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature (deg)

[Test Parameters]

IntegTime: Integration time (SHORT, MEDIUM, LONG)

TotalStressTime: Total stress time

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

VgStress: Gate terminal stress voltage

[Test Parameters for IvSweep\_ConstId]

Id@Vth: Drain current to decide the Vth, per unit area

VgStart1: Sweep start voltage for Gate terminal

VgStop1: Sweep stop voltage for Gate terminal

VgStep1: Sweep step voltage for Gate terminal

Vd1: Drain terminal voltage, constant value

[Test Parameters for IvSweep\_gmmax]

VgStart2: Sweep start voltage for Gate terminal

VgStop2: Sweep stop voltage for Gate terminal

VgStep2: Sweep step voltage for Gate terminal

Vd2: Drain voltage

[Test Parameters for Sampling\_Ids]

Vg3: Gate terminal voltage

Vd3: Drain terminal voltage

[Extended Test Parameters]

[Extended Test Parameters for Sampling\_Stress]

Vd: Drain terminal voltage, constant voltage

Vs: Source terminal voltage, constant voltage

Vsubs: Substrate terminal voltage, constant voltage  
 IgLimit: Gate current compliance

[Extended Test Parameters for IvSweep\_ConstId]

HoldTime: Hold time  
 DelayTime: Delay time  
 IdLimit: Drain current compliance  
 IsubsLimit: Substrate current compliance  
 Vs: Source terminal voltage, constant voltage  
 Vsubs: Substrate terminal voltage, constant voltage  
 DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for IvSweep\_gmmax]

HoldTime: Hold time  
 DelayTime: Delay time  
 IgLimit: Gate current compliance  
 IdLimit: Drain current compliance  
 IsubsLimit: Substrate current compliance  
 Vs: Source terminal voltage, constant voltage  
 Vsubs: Substrate terminal voltage, constant voltage  
 DrainMinRng: Minimum range for drain current measurement  
 Vth\_Min: Minimum Vth value for graph scale  
 Vth\_Max: Maximum Vth value for graph scale

[Extended Test Parameters for Sampling\_Ids]

IgLimit: Gate current compliance  
 IdLimit: Drain current compliance  
 IsubsLimit: Substrate current compliance  
 Vs: Source terminal voltage, constant voltage  
 Vsubs: Substrate terminal voltage, constant voltage  
 DrainMinRng: Minimum range for drain current measurement

[User Function]

[User Function for Sampling\_Stress]  
 Maximum elapsed time value  $\text{MaxTime} = \max(\text{Time})$   
 Stress time  $\text{StressTime} = \text{AccTime} + \text{Time}$

[User Function for IvSweep\_ConstId]

Maximum drain current value  $\text{IdMax} = \max(\text{abs}(\text{Idrain}))$  (For initial measurement only)

[User Function for IvSweep\_gmmax]

Maximum drain current value  $\text{IdMax} = \max(\text{abs}(\text{Idrain}))$  (For initial measurement only)  
 Transconductance  $\text{gm} = \text{diff}(\text{Idrain}, \text{Vgate})$   
 Maximum transconductance value  $\text{gmMax} = \max(\text{gm})$

[Analysis Function]

[Analysis Function for IvSweep\_ConstId]  
 $\text{Vth@Id} = @L1X$  (X intercept of Line1)

[Analysis Function for IvSweep\_gmmax]  
 $\text{Vth@Gm} = @L1X$  (X intercept of Line1)

[Auto Analysis]

[Auto Analysis for IvSweep\_ConstId]  
 Line1: Vertical line for Y1 at  $\text{Idrain} = \text{Id} @ \text{Vth}$

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[Auto Analysis for IvSweep\_gmmax]

Line1: Tangent line for Y1 at gm=gmMax

[Test Output: X-Y Graph]

X axis: Elapsed time TimeList (LOG)

Y1 axis: Maximum transconductance value gmMaxList (LINEAR)

Y2 axis: Vth by constant current method VthIdList (LINEAR)

Y3 axis: Vth by extrapolation method VthGmList (LINEAR)

Y4 axis: Drain current IdsList (LOG)

[Test Output: List Display]

Elapsed time TimeList

Vth by constant current method VthIdList

Vth by extrapolation method VthGmList

Drain current IdsList

Maximum transconductance value gmMaxList

**9.10 BTI2: Bias Temperature Instability test, 4 terminals (A.03.10)****[Supported Analyzer]**

B1500A

**[Description]**

Performs the bias temperature instability test, and plots the accumulated stress time vs threshold voltage/drain current characteristics.

This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

**[Device Under Test]**

MOSFET, 4 terminals

**[Device Parameters]**

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature (deg)

**[Test Parameters]**

IntegTime: Integration time (SHORT, MEDIUM, LONG)

TotalStressTime: Total stress time

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

VgStress: Gate terminal stress voltage

MeasConstId: Measurement by constant current method, Yes or No

MeasGmmax: Measurement by extrapolation method, Yes or No

MeasIds: Drain current measurement, Yes or No

MeasTiming: Timing to measure device parameter

**[Test Parameters for IvSweep\_ConstId]**

Id@Vth: Drain current to decide the Vth, per unit area

VgStart1: Sweep start voltage for Gate terminal

VgStop1: Sweep stop voltage for Gate terminal

VgStep1: Sweep step voltage for Gate terminal

Vd1: Drain terminal voltage, constant value

VthStopRate: Vth\_ConstId change rate to stop testing

**[Test Parameters for IvSweep\_gmmax]**

VgStart2: Sweep start voltage for Gate terminal

VgStop2: Sweep stop voltage for Gate terminal

VgStep2: Sweep step voltage for Gate terminal

Vd2: Drain voltage

GmStopRate: Vth\_GmMax change rate to stop testing

**[Test Parameters for Sampling\_Ids]**

Vg3: Gate terminal voltage

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Vd3: Drain terminal voltage

IdsStopRate: Ids change rate to stop testing

### [Extended Test Parameters]

StoringRuntimeData: Data save during stress output, Yes or No

### [Extended Test Parameters for Sampling\_Stress]

Vd: Drain terminal voltage, constant voltage

Vs: Source terminal voltage, constant voltage

Vsubs: Substrate terminal voltage, constant voltage

IgLimit: Gate current compliance

### [Extended Test Parameters for IvSweep\_ConstId]

HoldTime: Hold time

DelayTime: Delay time

IdLimit: Drain current compliance

IsubsLimit: Substrate current compliance

Vs: Source terminal voltage, constant voltage

Vsubs: Substrate terminal voltage, constant voltage

DrainMinRng: Minimum range for drain current measurement

### [Extended Test Parameters for IvSweep\_gmmax]

HoldTime: Hold time

DelayTime: Delay time

IgLimit: Gate current compliance

IdLimit: Drain current compliance

IsubsLimit: Substrate current compliance

Vs: Source terminal voltage, constant voltage

Vsubs: Substrate terminal voltage, constant voltage

Vth\_Min: Minimum Vth value for graph scale

Vth\_Max: Maximum Vth value for graph scale

gmMax\_Min: Minimum gmMax value for graph scale

gmMax\_Max: Maximum gmMax value for graph scale

DrainMinRng: Minimum range for drain current measurement

DrainMinRng: Minimum range for drain current measurement

### [Extended Test Parameters for Sampling\_Ids]

IgLimit: Gate current compliance

IdLimit: Drain current compliance

IsubsLimit: Substrate current compliance

Vs: Source terminal voltage, constant voltage

Vsubs: Substrate terminal voltage, constant voltage

DrainMinRng: Minimum range for drain current measurement

### [Measurement Parameters]

#### [Measurement Parameters by Sampling\_Stress]

Gate current Igate

#### [Measurement Parameters by IvSweep\_ConstId]

Drain current Idrain

#### [Measurement Parameters by IvSweep\_gmmax]

Drain current Idrain



[Measurement Parameters by IvSweep\_Ids]  
 Drain current Idrain

[User Function]

[User Function for IvSweep\_ConstId]  
 Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

[User Function for IvSweep\_gmmax]  
 Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)  
 Transconductance gm=diff(Idrain,Vgate)  
 Maximum transconductance value gmMax=max(gm)

[Analysis Function]

[Analysis Function for IvSweep\_ConstId]  
 Vth@Id=@L1X (X intercept of Line1)

[Analysis Function for IvSweep\_gmmax]  
 Vth@Gm=@L1X (X intercept of Line1)

[Auto Analysis]

[Auto Analysis for IvSweep\_ConstId]  
 Line1: Vertical line for Y1 at Idrain=Id@Vth

[Auto Analysis for IvSweep\_gmmax]  
 Line1: Tangent line for Y1 at gm=gmMax

[X-Y Graph]

[X-Y Graph for Sampling\_Stress]  
 X axis: Stress time StressTime (LINEAR)  
 Y1 axis: Gate current Igate (LOG)

[X-Y Graph for IvSweep\_ConstId]  
 X axis: Gate voltage Vgate (LINEAR)  
 Y1 axis: Drain current Idrain (LINEAR)  
 Y2 axis: Drain current Idrain (LOG)

[X-Y Graph for IvSweep\_gmmax]  
 X axis: Gate voltage Vgate (LINEAR)  
 Y1 axis: Drain current Idrain (LINEAR)  
 Y2 axis: Transconductance gm (LINEAR)

[X-Y Graph for Sampling\_Ids]  
 X axis: Elapsed time Time (LINEAR)  
 Y1 axis: Drain current Idrain (LOG)

[List Display]

[List Display for Sampling\_Stress]  
 Stress time StressTime  
 Elapsed time Time  
 Gate voltage Vgate  
 Drain voltage Vdrain  
 Gate current Igate

[List Display for IvSweep\_ConstId]  
 Gate voltage Vgate

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Drain voltage Vdrain  
Drain current Idrain

[List Display for IvSweep\_gmmax]  
Gate voltage Vgate  
Drain voltage Vdrain  
Drain current Idrain  
Transconductance gm

[List Display for Sampling\_Ids]  
Elapsed time Time  
Drain current Idrain

[Test Output: X-Y Graph]  
X axis: Elapsed time TimeList (LOG)  
Y1 axis: Maximum transconductance value gmMaxList (LINEAR)  
Y2 axis: Vth by constant current method VthIdList (LINEAR)  
Y3 axis: Vth by extrapolation method VthGmList (LINEAR)  
Y4 axis: Drain current IdsList (LOG)

[Test Output: List Display]  
Elapsed time TimeList  
Vth by constant current method VthIdList  
Vth by extrapolation method VthGmList  
Drain current IdsList  
Maximum transconductance value gmMaxList

**9.11 BTI[3]: Bias Temperature Instability test, 3 terminals (A.01.20)****[Supported Analyzer]**

B1500A

**[Description]**

Performs the bias temperature instability test, and plots the accumulated stress time vs threshold voltage/drain current characteristics.

This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

**[Device Under Test]**

MOSFET, 3 terminals

**[Device Parameters]**

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature (deg)

**[Test Parameters]**

IntegTime: Integration time (SHORT, MEDIUM, LONG)

TotalStressTime: Total stress time

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

VgStress: Gate terminal stress voltage

**[Test Parameters for IvSweep\_ConstId]**

Id@Vth: Drain current to decide the Vth, per unit area

VgStart1: Sweep start voltage for Gate terminal

VgStop1: Sweep stop voltage for Gate terminal

VgStep1: Sweep step voltage for Gate terminal

Vd1: Drain terminal voltage, constant value

**[Test Parameters for IvSweep\_gmmax]**

VgStart2: Sweep start voltage for Gate terminal

VgStop2: Sweep stop voltage for Gate terminal

VgStep2: Sweep step voltage for Gate terminal

Vd2: Drain voltage

**[Test Parameters for Sampling\_Ids]**

Vg3: Gate terminal voltage

Vd3: Drain terminal voltage

**[Extended Test Parameters]****[Extended Test Parameters for Sampling\_Stress]**

Vd: Drain terminal voltage, constant voltage

Vs: Source terminal voltage, constant voltage

IgLimit: Gate current compliance

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[Extended Test Parameters for IvSweep\_ConstId]

HoldTime: Hold time

DelayTime: Delay time

IdLimit: Drain current compliance

Vs: Source terminal voltage, constant voltage

DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for IvSweep\_gmmax]

HoldTime: Hold time

DelayTime: Delay time

IgLimit: Gate current compliance

IdLimit: Drain current compliance

Vs: Source terminal voltage, constant voltage

DrainMinRng: Minimum range for drain current measurement

Vth\_Min: Minimum Vth value for graph scale

Vth\_Max: Maximum Vth value for graph scale

[Extended Test Parameters for Sampling\_Ids]

IgLimit: Gate current compliance

IdLimit: Drain current compliance

Vs: Source terminal voltage, constant voltage

DrainMinRng: Minimum range for drain current measurement

[User Function]

[User Function for Sampling\_Stress]

Maximum elapsed time value  $\text{MaxTime}=\text{max}(\text{Time})$

Stress time  $\text{StressTime}=\text{AccTime}+\text{Time}$

[User Function for IvSweep\_ConstId]

Maximum drain current value  $\text{IdMax}=\text{max}(\text{abs}(\text{Idrain}))$  (For initial measurement only)

[User Function for IvSweep\_gmmax]

Maximum drain current value  $\text{IdMax}=\text{max}(\text{abs}(\text{Idrain}))$  (For initial measurement only)

Transconductance  $\text{gm}=\text{diff}(\text{Idrain}, \text{Vgate})$

Maximum transconductance value  $\text{gmMax}=\text{max}(\text{gm})$

[Analysis Function]

[Analysis Function for IvSweep\_ConstId]

$\text{Vth@Id}=@\text{L1X}$  (X intercept of Line1)

[Analysis Function for IvSweep\_gmmax]

$\text{Vth@Gm}=@\text{L1X}$  (X intercept of Line1)

[Auto Analysis]

[Auto Analysis for IvSweep\_ConstId]

Line1: Vertical line for Y1 at  $\text{Idrain}=\text{Id@Vth}$

[Auto Analysis for IvSweep\_gmmax]

Line1: Tangent line for Y1 at  $\text{gm}=\text{gmMax}$

[Test Output: X-Y Graph]

X axis: Elapsed time TimeList (LOG)

Y1 axis: Maximum transconductance value gmMaxList (LINEAR)

Y2 axis: Vth by constant current method VthIdList (LINEAR)

Y3 axis: Vth by extrapolation method VthGmList (LINEAR)

Y4 axis: Drain current IdsList (LOG)

[Test Output: List Display]

Elapsed time TimeList

Vth by constant current method VthIdList

Vth by extrapolation method VthGmList

Drain current IdsList

Maximum transconductance value gmMaxList

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### 9.12 BTI2[3]: Bias Temperature Instability test, 3 terminals (A.03.10)

#### [Supported Analyzer]

B1500A

#### [Description]

Performs the bias temperature instability test, and plots the accumulated stress time vs threshold voltage/drain current characteristics.

This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

#### [Device Under Test]

MOSFET, 3 terminals

#### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature (deg)

#### [Test Parameters]

IntegTime: Integration time (SHORT, MEDIUM, LONG)

TotalStressTime: Total stress time

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

VgStress: Gate terminal stress voltage

IdLimit: Drain current compliance

MeasConstId: Measurement by constant current method, Yes or No

MeasGmmax: Measurement by extrapolation method, Yes or No

MeasIds: Drain current measurement, Yes or No

MeasTiming: Timing to measure device parameter

#### [Test Parameters for IvSweep\_ConstId]

Id@Vth: Drain current to decide the Vth, per unit area

VgStart1: Sweep start voltage for Gate terminal

VgStop1: Sweep stop voltage for Gate terminal

VgStep1: Sweep step voltage for Gate terminal

Vd1: Drain terminal voltage, constant value

VthStopRate: Vth\_ConstId change rate to stop testing

#### [Test Parameters for IvSweep\_gmmax]

VgStart2: Sweep start voltage for Gate terminal

VgStop2: Sweep stop voltage for Gate terminal

VgStep2: Sweep step voltage for Gate terminal

Vd2: Drain voltage

GmStopRate: Vth\_GmMax change rate to stop testing

#### [Test Parameters for Sampling\_Ids]

Vg3: Gate terminal voltage

Vd3: Drain terminal voltage  
 IdsStopRate: Ids change rate to stop testing

[Extended Test Parameters]

StoringRuntimeData: Data save during stress output, Yes or No

[Extended Test Parameters for Sampling\_Stress]

Vd: Drain terminal voltage, constant voltage  
 Vs: Source terminal voltage, constant voltage  
 IgLimit: Gate current compliance

[Extended Test Parameters for IvSweep\_ConstId]

HoldTime: Hold time  
 DelayTime: Delay time  
 Vs: Source terminal voltage, constant voltage  
 DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for IvSweep\_gmmax]

HoldTime: Hold time  
 DelayTime: Delay time  
 IgLimit: Gate current compliance  
 Vs: Source terminal voltage, constant voltage  
 DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for Sampling\_IdS]

IgLimit: Gate current compliance  
 Vs: Source terminal voltage, constant voltage  
 DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]

[Measurement Parameters by Sampling\_Stress]

Gate current Igate

[Measurement Parameters by IvSweep\_ConstId]

Drain current Idrain

[Measurement Parameters by IvSweep\_gmmax]

Drain current Idrain

[Measurement Parameters by IvSweep\_IdS]

Drain current Idrain

[User Function]

[User Function for IvSweep\_ConstId]

Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

[User Function for IvSweep\_gmmax]

Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

Transconductance gm=diff(Idrain,Vgate)

Maximum transconductance value gmMax=max(gm)

[Analysis Function]

[Analysis Function for IvSweep\_ConstId]

Vth@Id=@L1X (X intercept of Line1)

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[Analysis Function for IvSweep\_gmmax]  
Vth@Gm=@L1X (X intercept of Line1)

[Auto Analysis]  
[Auto Analysis for IvSweep\_ConstId]  
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Auto Analysis for IvSweep\_gmmax]  
Line1: Tangent line for Y1 at gm=gmMax

[X-Y Graph]  
[X-Y Graph for Sampling\_Stress]  
X axis: Stress time StressTime (LINEAR)  
Y1 axis: Gate current Igate (LOG)

[X-Y Graph for IvSweep\_ConstId]  
X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)  
Y2 axis: Drain current Idrain (LOG)

[X-Y Graph for IvSweep\_gmmax]  
X axis: Gate voltage Vgate (LINEAR)  
Y1 axis: Drain current Idrain (LINEAR)  
Y2 axis: Transconductance gm (LINEAR)

[X-Y Graph for Sampling\_Ids]  
X axis: Elapsed time Time (LINEAR)  
Y1 axis: Drain current Idrain (LOG)

[List Display]  
[List Display for Sampling\_Stress]  
Stress time StressTime  
Elapsed time Time  
Gate voltage Vgate  
Drain voltage Vdrain  
Gate current Igate

[List Display for IvSweep\_ConstId]  
Gate voltage Vgate  
Drain voltage Vdrain  
Drain current Idrain

[List Display for IvSweep\_gmmax]  
Gate voltage Vgate  
Drain voltage Vdrain  
Drain current Idrain  
Transconductance gm

[List Display for Sampling\_Ids]  
Elapsed time Time  
Drain current Idrain

[Test Output: X-Y Graph]  
X axis: Elapsed time TimeList (LOG)  
Y1 axis: Maximum transconductance value gmMaxList (LINEAR)



Y2 axis: Vth by constant current method VthIdList (LINEAR)

Y3 axis: Vth by extrapolation method VthGmList (LINEAR)

Y4 axis: Drain current IdsList (LOG)

[Test Output: List Display]

Elapsed time TimeList

Vth by constant current method VthIdList

Vth by extrapolation method VthGmList

Drain current IdsList

Maximum transconductance value gmMaxList

## 9 Reliability

### ***9.13 Charge Pumping: Evaluation of the interface state using charge pumping method (A.01.20)***

[Supported Analyzer]  
B1500A

[Description]  
Measures the Substrate current vs Gate pulse base voltage characteristics, and extracts the interface state density (Nss). This test uses the Agilent 81110A pulse generator.

[Test Setup used in this test definition]  
ForcePGC: Used to apply Gate pulse  
I/V-t Sampling: Used to perform the Substrate current measurement  
ResetPG: Used to reset the pulse generator

[Device Under Test]  
MOSFET, 3 terminals or 4 terminals

[Device Parameters]  
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).  
Lg: Gate length  
Wg: Gate width  
Temp: Temperature

[Test Parameters]  
IntegTime: Integration time  
Source: SMU connected to Source, constant voltage output  
Vs: Source voltage  
IsLimit: Source current compliance  
Subs: SMU connected to Substrate, constant voltage output  
Vsubs: Substrate voltage  
IsubsLimit: Substrate current compliance

[Extended Test Parameters]  
SubsMinRng: Minimum range for the substrate current measurement

[Test Parameters for Gate Pulse]  
PulseLevel: Pulse output level  
VbaseStart: Sweep start value of Gate pulse base voltage  
VbaseStop: Sweep stop value of Gate pulse base voltage  
VbaseStep: Sweep step value of Gate pulse base voltage  
PulsePeriod: Pulse period  
PulseDelay: Pulse delay  
DutyCycle: Duty cycle  
LeadingTime: Leading transition time  
TrailingTime: Trailing transition time  
PgAdd: GPIB address of Agilent 81110A

[Test Output: X-Y Graph]  
X axis: Gate pulse base voltage VbaseList (LINEAR)  
Y1 axis: Substrate current IcpList (LOG)

[Test Output: Parameters]

Interface state density Nss

[Nss calculation]

$$N_{ss} = I_{cpMax} / q * PulsePeriod / L_g / W_g$$

## 9 Reliability

### ***9.14 Charge Pumping2: Evaluation of the interface state using charge pumping method (A.03.10)***

[Supported Analyzer]

B1500A

[Description]

Measures the Substrate current vs Gate pulse base voltage characteristics, and extracts the interface state density (Nss).

[Required Modules and Accessories]

Agilent B1525A SPGU 1 unit

[Device Under Test]

MOSFET, 3 terminals or 4 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

[Test Parameters]

Source: SMU connected to Source, constant voltage output

Subs: SMU connected to Substrate, constant voltage output

Gate: SPGU connected to Gate, pulse voltage output

PulsePeriod: Pulse period

PulseDelay: Pulse delay

DutyCycle: Duty cycle

PulseLevel: Pulse output level

LeadingTime: Leading transition time

TrailingTime: Trailing transition time

VbaseStart: Sweep start value of Gate pulse base voltage

VbaseStop: Sweep stop value of Gate pulse base voltage

VbaseStep: Sweep step value of Gate pulse base voltage

Vs: Source voltage

IsubsLimit: Substrate current compliance

IntegTime: Integration time

Vsubs: Substrate voltage

IsLimit: Source current compliance

[Extended Test Parameters]

SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]

Isubs Substrate current

[X-Y Graph]

X axis: Elapsed time Time (LINEAR)

Y1 axis: Substrate current Isubs (LOG)

**[List Display]**

Elapsed time Time

Substrate current Isubs

**[Test Output: X-Y Graph]**

X axis: Gate pulse base voltage VbaseList (LINEAR)

Y1 axis: Substrate current IcpList (LOG)

**[Test Output: List Display]**

Gate pulse base voltage VbaseList

Substrate current IcpList

**[Test Output: Parameters]**

Maximum substrate current IcpMax

Interface state density Nss

**[Nss calculation]**
$$Nss = IcpMax / q * PulsePeriod / Lg / Wg$$

## 9 Reliability

### 9.15 EM Istress: Electromigration test, current stressed, 4 SMUs (A.01.20)

[Supported Analyzer]

B1500A

[Description]

Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode.

[Device Under Test]

Wiring (resistor), 4 terminals

[Device Parameters]

L: Length of pattern

W: Width of pattern

Temp: Temperature

[Test Parameters]

Port1: SMU for Port1 stress force

Port2: SMU for Port2 stress force

VM1: SMU for Port1 voltage monitor

VM2: SMU for Port2 voltage monitor

TotalStressTime: Total stress time.

StopCondition: Measurement stop condition (%changes of wire resistance)

I1Stress: Port1 stress current

IntegTime: Integration time

[Extended Test Parameters]

V2: Port2 terminal voltage

V1Limit: Port1 voltage compliance

I2Limit: Port2 current compliance

HoldTime: Hold time

[User Function]

IPort1PerArea (A/cm<sup>2</sup>) Port1 terminal current per unit area

IPort2PerArea (A/cm<sup>2</sup>) Port2 terminal current per unit area

R (ohm) Resistance of wiring

DeltaR (%) Difference from initial resistance

[X-Y Plot]

X axis: Stress time TimeList (LOG)

Y1 axis: Port1 terminal voltage Vport1List (LOG)

Y2 axis: Resistance RList (LINEAR)

Y3 axis: Difference from initial resistance DeltaRList (LINEAR)

**9.16 EM Istress2: Electromigration test, current stressed, 4 SMUs (A.03.10)****[Supported Analyzer]**

B1500A

**[Description]**

Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode.

**[Device Under Test]**

Wiring (resistor), 4 terminals

**[Device Parameters]**

L: Length of pattern

W: Width of pattern

Temp: Temperature

**[Test Parameters]**

Port1: SMU for Port1 stress force

Port2: SMU for Port2 stress force

VM1: SMU for Port1 voltage monitor

VM2: SMU for Port2 voltage monitor

TotalStressTime: Total stress time.

V1Limit: Port1 voltage compliance

FailureCondition: Measurement stop condition (%changes of wire resistance)

I1Stress: Port1 stress current

NoOfSamples: Number of samples

IntegTime: Integration time

PointPerDecade: Number of samples in 1 decade

Interval: Sampling interval

**[Extended Test Parameters]**

V2: Port2 terminal voltage

I2Limit: Port2 current compliance

HoldTime: Hold time

R\_Max: Y axis maximum value for resistance

StoringRuntimeData: Data save during stress output, Yes or No

**[Measurement Parameters]**

Port1 current Iport1

**[User Function]**

DeltaV Voltage between terminals of wiring device

R Resistance of wiring device

MaxTime Maximum elapsed time

**[X-Y Graph]**

X axis: Stress time Time (LOG)

Y1 axis: Voltage between terminals of wiring device DeltaV (LINEAR)

Y2 axis: Resistance of wiring device R (LINEAR)

## 9 Reliability

### [List Display]

Stress time Time

Voltage between terminals of wiring device DeltaV

Resistance of wiring device R

### [Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList (LOG)

Y1 axis: Voltage between terminals of wiring device DeltaVList (LINEAR)

Y2 axis: Resistance of wiring device RList (LINEAR)

Y3 axis: Difference from initial resistance DeltaRList (LINEAR)

### [Test Output: List Display]

Accumulated stress time TimeList

Voltage between terminals of wiring device DeltaVList

Resistance of wiring device RList

Difference from initial resistance DeltaRList

### [Test Output: Parameters]

Time to failure FailureTime



**9.17 EM Istress[2]: Electromigration test, current stressed, 2 SMUs (A.01.20)****[Supported Analyzer]**

B1500A

**[Description]**

Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.

1. applies stress current
2. performs measurement and saves measurement data
3. calculates the device failure time

**[Device Under Test]**

Wiring device, 2 terminals

**[Device Parameters]**

D: Wiring pattern length

W: Wiring pattern width

Temp: Temperature (deg)

**[Test Parameters]**

IntegTime: Integration time

TotalStressTime: Total stress time

StopCondition: Measurement stop condition (%changes of wire resistance)

Port1: SMU connected to Port1, constant current output

Port2: SMU connected to Port2, constant voltage output

I1Stress: Port1 stress current

**[Extended Test Parameters]**

V2: Port2 voltage

V1Limit: Port1 voltage compliance

I2Limit: Port2 current compliance

HoldTime: Hold time

DelayTime: Delay time

**[User Function]**Wiring resistance value  $R = V_{port1} / I_{port1}$ **[Test Output: X-Y Graph]**

X axis: Accumulated stress time TimeList

Y1 axis: Port1 voltage Vport1List

Y2 axis: Wiring resistance value RList

Y3 axis: Offset from initial resistance value DeltaRList

**[Test Output: List Display]**

Accumulated stress time TimeList

Port1 voltage Vport1List

Wiring resistance value RList

Offset from initial resistance value DeltaRList

**[Test Output: Parameters]**

FailureTime: Time to failure

## 9 Reliability

### 9.18 EM Istress2[2]: Electromigration test, current stressed, 2 SMUs (A.03.10)

#### [Supported Analyzer]

B1500A

#### [Description]

Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.

1. applies stress current
2. performs measurement and saves measurement data
3. calculates the device failure time

#### [Device Under Test]

Wiring (resistor), 2 terminals

#### [Device Parameters]

D: Length of pattern

W: Width of pattern

Temp: Temperature

#### [Test Parameters]

Port1: SMU connected to Port1, constant current output

Port2: SMU connected to Port2, constant voltage output

TotalStressTime: Total stress time.

FailureCondition: Measurement stop condition (%changes of wire resistance)

I1Stress: Port1 stress current

V1Limit: Port1 voltage compliance

IntegTime: Integration time

PointPerDecade: Number of samples in 1 decade

Interval: Sampling interval

#### [Extended Test Parameters]

V2: Port2 terminal voltage

I2Limit: Port2 current compliance

HoldTime: Hold time

R\_Max: Y axis maximum value for resistance

StoringRuntimeData: Data save during stress output, Yes or No

#### [Measurement Parameters]

Port1 voltage Vport1

Port1 current Iport1

#### [User Function]

Resistance of wiring device  $R = V_{port1} / I_{port1}$

#### [X-Y Graph]

X axis: Stress time Time (LOG)

Y1 axis: Port1 voltage Vport1 (LINEAR)

Y2 axis: Resistance of wiring device R (LINEAR)

#### [List Display]

Stress time Time

Port1 voltage Vport1

Resistance of wiring device R

### [Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList (LOG)

Y1 axis: Port1 voltage Vport1List (LINEAR)

Y2 axis: Resistance of wiring device RList (LINEAR)

Y3 axis: Difference from initial resistance DeltaRList (LINEAR)

### [Test Output: List Display]

Accumulated stress time TimeList

Port1 voltage Vport1List

Resistance of wiring device RList

Difference from initial resistance DeltaRList

### [Test Output: Parameters]

Time to failure FailureTime

## 9 Reliability

### 9.19 EM Istress[6]: Electromigration test, current stressed, 6 SMUs (A.01.20)

#### [Supported Analyzer]

B1500A

#### [Description]

Performs the Electromigration (EM) test for a wiring device with extrusion lines, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.

1. applies stress current
2. performs measurement and saves measurement data
3. calculates the device failure time

#### [Device Under Test]

Wiring device with extrusion lines, 6 terminals

#### [Device Parameters]

D: Wiring pattern length

W: Wiring pattern width

Temp: Temperature (deg)

#### [Test Parameters]

IntegTime: Integration time

TotalStressTime: Total stress time

StopCondition: Measurement stop condition 1 (%changes of wire resistance)

ExtCondition: Measurement stop condition 2 (current to extrusion line)

Port1: SMU connected to Port1, constant current output

Port2: SMU connected to Port2, constant voltage output

Port3: SMU connected to Extrusion Line, constant voltage output

Port4: SMU connected to Extrusion Line, constant voltage output

VM1: SMU for Port1 voltage monitoring, constant voltage output

VM2: SMU for Port2 voltage monitoring, constant voltage output

I1Stress: Port1 stress current

V1Limit: Port1 voltage compliance

#### [Extended Test Parameters]

V2: Port2 voltage

V3: Port3 voltage

V4: Port4 voltage

I2Limit: Port2 current compliance

I3Limit: Port3 current compliance

I4Limit: Port4 current compliance

HoldTime: Hold time

Port2MinRng: Minimum range for Port2 current measurement

Port3MinRng: Minimum range for Port3 current measurement

Port4MinRng: Minimum range for Port4 current measurement

R\_Max: Y axis maximum value for resistance

#### [User Function]

Potential difference between lines  $\Delta V = V_{m1} - V_{m2}$

Wiring resistance value  $R = \Delta V / I_{port1}$

#### [Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList

Y1 axis: Wiring resistance value RList

Y2 axis: Offset from initial resistance value DeltaRList  
Y3 axis: Port2 current Iport2List  
Y4 axis: Port3 current Iport3List  
Y5 axis: Port4 current Iport4List

[Test Output: List Display]

Accumulated stress time TimeList  
Wiring resistance value RList  
Offset from initial resistance value DeltaRList  
Port2 current Iport2List  
Port3 current Iport3List  
Port4 current Iport4List

[Test Output: Parameters]

Time to failure given by rate of resistance change R\_FailureTime  
Time to failure given by monitoring extrusion lines E\_FailureTime

## 9 Reliability

### 9.20 EM Istress2[6]: Electromigration test, current stressed, 6 SMUs (A.03.10)

#### [Supported Analyzer]

B1500A

#### [Description]

Performs the Electromigration (EM) test for a wiring device with extrusion lines, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.

1. applies stress current
2. performs measurement and saves measurement data
3. calculates the device failure time

#### [Device Under Test]

Wiring device with extrusion lines, 6 terminals

#### [Device Parameters]

L: Length of pattern

W: Width of pattern

Temp: Temperature

#### [Test Parameters]

Port1: SMU connected to Port1, constant current output

Port2: SMU connected to Port2, constant voltage output

Port3: SMU connected to Extrusion Line, constant voltage output

Port4: SMU connected to Extrusion Line, constant voltage output

VM1: SMU for Port1 voltage monitoring, constant voltage output

VM2: SMU for Port2 voltage monitoring, constant voltage output

TotalStressTime: Total stress time.

FailureCondition: Measurement stop condition 1 (%changes of wire resistance)

ExtCondition: Measurement stop condition 2 (current to extrusion line)

I1Stress: Port1 stress current

IntegTime: Integration time

V1Limit: Port1 voltage compliance

I3Limit: Port3 current compliance

I4Limit: Port4 current compliance

PointPerDecade: Number of samples in 1 decade

Interval: Sampling interval

#### [Extended Test Parameters]

V2: Port2 voltage

V3: Port3 voltage

V4: Port4 voltage

I2Limit: Port2 current compliance

HoldTime: Hold time

Port2MinRng: Minimum range for Port2 current measurement

Port3MinRng: Minimum range for Port3 current measurement

Port4MinRng: Minimum range for Port4 current measurement

R\_Max: Y axis maximum value for resistance

StoreOfRuntimeData: Data save during stress output, Yes or No

#### [Measurement Parameters]

Port1 voltage Vm1

Port2 voltage Vm2

Port2 current Iport2

Port3 current Iport3  
 Port4 current Iport4

[User Function]

Voltage between terminals of wiring device  $\Delta V = V_{m1} - V_{m2}$   
 Resistance of wiring device  $R = V_{port1} / I_{port2}$

[X-Y Graph]

X axis: Stress time Time (LOG)  
 Y1 axis: Resistance of wiring device R (LINEAR)  
 Y2 axis: Voltage between terminals of wiring device  $\Delta V$  (LINEAR)  
 Y3 axis: Port3 current Iport3 (LOG)  
 Y4 axis: Port4 current Iport4 (LOG)

[List Display]

Stress time Time  
 Resistance of wiring device R  
 Voltage between terminals of wiring device  $\Delta V$   
 Port2 current Iport2  
 Port3 current Iport3  
 Port4 current Iport4

[Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList (LOG)  
 Y1 axis: Resistance of wiring device RList (LINEAR)  
 Y2 axis: Difference from initial resistance  $\Delta RList$  (LINEAR)  
 Y3 axis: Port2 current Iport2List (LOG)  
 Y4 axis: Port3 current Iport3List (LOG)  
 Y5 axis: Port4 current Iport4List (LOG)

[Test Output: List Display]

Accumulated stress time TimeList  
 Resistance of wiring device RList  
 Difference from initial resistance  $\Delta RList$   
 Port2 current Iport2List  
 Port3 current Iport3List  
 Port4 current Iport4List

[Test Output: Parameters]

Time to failure given by rate of resistance change R\_FailureTime  
 Time to failure given by monitoring extrusion lines E\_FailureTime

## 9 Reliability

### 9.21 EM Vstress: Electromigration test, voltage stressed, 4 SMUs (A.01.20)

[Supported Analyzer]

B1500A

[Description]

Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode.

[Device Under Test]

Wiring (resistor), 4 terminals

[Device Parameters]

L: Length of pattern

W: Width of pattern

Temp: Temperature

[Test Parameters]

Port1: SMU for Port1 stress force

Port2: SMU for Port2 stress force

VM1: SMU for Port1 voltage monitor

VM2: SMU for Port2 voltage monitor

TotalStressTime: Total stress time.

StopCondition: Measurement stop condition (%changes of wire resistance)

V1Stress: Port1 stress voltage

NoOfSamples: Number of samples

IntegTime: Integration time

[Extended Test Parameters]

V2: Port2 terminal voltage

I1Limit: Port1 current compliance

HoldTime: Hold time

Port1MinRng: Minimum range for the port1 current measurement

[User Function]

IPort1PerArea (A/cm<sup>2</sup>) Port1 terminal current per unit area

IPort2PerArea (A/cm<sup>2</sup>) Port2 terminal current per unit area

R (ohm) Resistance of wiring

DeltaR (%) Difference from initial resistance

[X-Y Plot]

X axis: Stress time TimeList (LOG)

Y1 axis: Port1 terminal current Iport1List (LOG)

Y2 axis: Resistance RList (LINEAR)

Y3 axis: Difference from initial resistance DeltaRList (LINEAR)



**9.22 EM Vstress2: Electromigration test, voltage stressed, 4 SMUs (A.03.10)**

## [Supported Analyzer]

B1500A

## [Description]

Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode.

## [Device Under Test]

Wiring (resistor), 4 terminals

## [Device Parameters]

L: Length of pattern

W: Width of pattern

Temp: Temperature

## [Test Parameters]

Port1: SMU for Port1 stress force

Port2: SMU for Port2 stress force

VM1: SMU for Port1 voltage monitor

VM2: SMU for Port2 voltage monitor

TotalStressTime: Total stress time.

FailureCondition: Measurement stop condition (%changes of wire resistance)

V1Stress: Port1 stress voltage

I1Limit: Port1 current compliance

IntegTime: Integration time

PointPerDecade: Number of samples in 1 decade

Interval: Sampling interval

## [Extended Test Parameters]

V2: Port2 terminal voltage

HoldTime: Hold time

Port1MinRng: Minimum range for the port1 current measurement

R\_Max: Y axis maximum value for resistance

StoringRuntimeData: Data save during stress output, Yes or No

## [Measurement Parameters]

Port1 current Iport1

Port2 current Iport2

## [User Function]

IPort1PerArea (A/cm2) Port1 terminal current per unit area

IPort2PerArea (A/cm2) Port2 terminal current per unit area

R Resistance of wiring device

DeltaV Voltage between terminals of wiring device

MaxTime Maximum elapsed time

## [X-Y Graph]

X axis: Stress time Time (LOG)

Y1 axis: Port1 current Iport1 (LINEAR)

Y2 axis: Voltage between terminals of wiring device DeltaV (LINEAR)

Y3 axis: Resistance of wiring device R (LINEAR)

## 9 Reliability

### [List Display]

Stress time Time  
Port1 current Iport1  
Voltage between terminals of wiring device DeltaV  
Resistance of wiring device R

### [Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList (LOG)  
Y1 axis: Port1 current Iport1List (LINEAR)  
Y2 axis: Resistance of wiring device RList (LINEAR)  
Y3 axis: Difference from initial resistance DeltaRList (LINEAR)

### [Test Output: List Display]

Accumulated stress time TimeList  
Port1 current Iport1List  
Resistance of wiring device RList  
Difference from initial resistance DeltaRList

### [Test Output: Parameters]

Time to failure FailureTime

**9.23 EM Vstress[2]: Electromigration test, voltage stressed, 2 SMUs (A.01.20)****[Supported Analyzer]**

B1500A

**[Description]**

Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.

1. applies stress voltage
2. performs measurement and saves measurement data
3. calculates the device failure time

**[Device Under Test]**

Wiring device, 2 terminals

**[Device Parameters]**

D: Wiring pattern length

W: Wiring pattern width

Temp: Temperature (deg)

**[Test Parameters]**

IntegTime: Integration time

TotalStressTime: Total stress time

StopCondition: Measurement stop condition (%changes of wire resistance)

Port1: SMU connected to Port1, constant voltage output

Port2: SMU connected to Port2, constant voltage output

V1Stress: Port1 stress voltage

**[Extended Test Parameters]**

V2: Port2 voltage

I1Limit: Port1 current compliance

HoldTime: Hold time

Port1MinRng: Minimum range for Port1 current measurement

**[User Function]**Wiring resistance value  $R = V_{port1} / I_{port1}$ **[Test Output: X-Y Graph]**

X axis: Accumulated stress time TimeList

Y1 axis: Port1 current Iport1List

Y2 axis: Wiring resistance value RList

Y3 axis: Offset from initial resistance value DeltaRList

**[Test Output: List Display]**

Accumulated stress time TimeList

Port1 current Iport1List

Wiring resistance value RList

Offset from initial resistance value DeltaRList

**[Test Output: Parameters]**

FailureTime: Time to failure

## 9 Reliability

### 9.24 EM Vstress2[2]: Electromigration test, voltage stressed, 2 SMUs (A.03.10)

#### [Supported Analyzer]

B1500A

#### [Description]

Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.

1. applies stress voltage
2. performs measurement and saves measurement data
3. calculates the device failure time

#### [Device Under Test]

Wiring device, 2 terminals

#### [Device Parameters]

D: Wiring pattern length

W: Wiring pattern width

Temp: Temperature (deg)

#### [Test Parameters]

Port1: SMU connected to Port1, constant voltage output

Port2: SMU connected to Port2, constant voltage output

TotalStressTime: Total stress time

FailureCondition: Measurement stop condition (%changes of wire resistance)

V1Stress: Port1 stress voltage

I1Limit: Port1 current compliance

IntegTime: Integration time

PointPerDecade: Number of samples in 1 decade

Interval: Sampling interval

#### [Extended Test Parameters]

V2: Port2 terminal voltage

HoldTime: Hold time

Port1MinRng: Minimum range for the port1 current measurement

R\_Max: Y axis maximum value for resistance

StoringRuntimeData: Data save during stress output, Yes or No

#### [Measurement Parameters]

Port1 current Iport1

Port1 voltage Vport2

#### [User Function]

Wiring resistance value  $R = V_{port1} / I_{port1}$

#### [X-Y Graph]

X axis: Stress time Time (LOG)

Y1 axis: Port1 current Iport1 (LOG)

Y2 axis: Resistance of wiring device R (LINEAR)

#### [List Display]

Stress time Time

Port1 current Iport1

Resistance of wiring device R

### [Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList (LOG)

Y1 axis: Port1 current Iport1List (LINEAR)

Y2 axis: Resistance of wiring device RList (LINEAR)

Y3 axis: Difference from initial resistance DeltaRList (LINEAR)

### [Test Output: List Display]

Accumulated stress time TimeList

Port1 current Iport1List

Resistance of wiring device RList

Difference from initial resistance DeltaRList

### [Test Output: Parameters]

Time to failure FailureTime

## 9 Reliability

### 9.25 EM Vstress[6]: Electromigration test, voltage stressed, 6 SMUs (A.01.20)

#### [Supported Analyzer]

B1500A

#### [Description]

Performs the Electromigration (EM) test for a wiring device with extrusion lines, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.

1. applies stress voltage
2. performs measurement and saves measurement data
3. calculates the device failure time

#### [Device Under Test]

Wiring device with extrusion lines, 6 terminals

#### [Device Parameters]

D: Wiring pattern length

W: Wiring pattern width

Temp: Temperature (deg)

#### [Test Parameters]

IntegTime: Integration time

TotalStressTime: Total stress time

StopCondition: Measurement stop condition 1 (%changes of wire resistance)

ExtCondition: Measurement stop condition 2 (current to extrusion line)

Port1: SMU connected to Port1, constant voltage output

Port2: SMU connected to Port2, constant voltage output

Port3: SMU connected to Extrusion Line, constant voltage output

Port4: SMU connected to Extrusion Line, constant voltage output

VM1: SMU for Port1 voltage monitoring, constant voltage output

VM2: SMU for Port2 voltage monitoring, constant voltage output

V1Stress: Port1 stress voltage

#### [Extended Test Parameters]

V2: Port2 voltage

V3: Port3 voltage

V4: Port4 voltage

IM1: VM1 output current

IM2: VM2 output current

I1Limit: Port1 current compliance

I3Limit: Port3 current compliance

I4Limit: Port4 current compliance

HoldTime: Hold time

DelayTime: Delay time

Port1MinRng: Minimum range for Port1 current measurement

#### [User Function]

Potential difference between lines  $\Delta V = VM1 - VM2$

Wiring resistance value  $R = \Delta V / I_{port1}$

#### [Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList

Y1 axis: Wiring resistance value RList

Y2 axis: Port1 current Iport1List

Y3 axis: Port3 current Iport3List  
Y4 axis: Port4 current Iport4List  
Y5 axis: Offset from initial resistance value DeltaRList

[Test Output: List Display]

Accumulated stress time TimeList  
Port1 current Iport1List  
Wiring resistance value RList  
Port3 current Iport3List  
Port4 current Iport4List  
Offset from initial resistance value DeltaRList

[Test Output: Parameters]

R\_FailureTime: Time to failure (Resistance)  
E\_FailureTime: Time to failure (Extrusion)

## 9 Reliability

### 9.26 *EM Vstress2[6]: Electromigration test, voltage stressed, 6 SMUs (A.03.10)*

[Supported Analyzer]

B1500A

[Description]

Performs the Electromigration (EM) test for a wiring device with extrusion lines, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.

1. applies stress voltage
2. performs measurement and saves measurement data
3. calculates the device failure time

[Device Under Test]

Wiring device with extrusion lines, 6 terminals

[Device Parameters]

D: Wiring pattern length

W: Wiring pattern width

Temp: Temperature (deg)

[Test Parameters]

Port1: SMU connected to Port1, constant voltage output

Port2: SMU connected to Port2, constant voltage output

Port3: SMU connected to Extrusion Line, constant voltage output

Port4: SMU connected to Extrusion Line, constant voltage output

VM1: SMU for Port1 voltage monitoring, constant voltage output

VM2: SMU for Port2 voltage monitoring, constant voltage output

TotalStressTime: Total stress time.

FailureCondition: Measurement stop condition 1 (%changes of wire resistance)

ExtCondition: Measurement stop condition 2 (current to extrusion line)

V1Stress: Port1 stress voltage

I1Limit: Port1 current compliance

I3Limit: Port3 current compliance

I4Limit: Port4 current compliance

IntegTime: Integration time

PointPerDecade: Number of samples in 1 decade

Interval: Sampling interval

[Extended Test Parameters]

V2: Port2 voltage

V3: Port3 voltage

V4: Port4 voltage

IM1: VM1 output current

IM2: VM2 output current

HoldTime: Hold time

Port1MinRng: Minimum range for Port1 current measurement

Port3MinRng: Minimum range for Port3 current measurement

Port4MinRng: Minimum range for Port4 current measurement

R\_Max: Y axis maximum value for resistance

StoringRuntimeData: Data save during stress output, Yes or No



## [Measurement Parameters]

Port1 current Iport1  
 Port3 current Iport3  
 Port4 current Iport4

## [User Function]

Voltage between terminals of wiring device  $\Delta V = V_{m1} - V_{m2}$   
 Resistance of wiring device  $R = V_{port1} / I_{port2}$

## [X-Y Graph]

X axis: Stress time Time (LOG)  
 Y1 axis: Resistance of wiring device R (LINEAR)  
 Y2 axis: Port1 current Iport1 (LINEAR)  
 Y3 axis: Port3 current Iport3 (LINEAR)  
 Y4 axis: Port4 current Iport4 (LINEAR)  
 Y5 axis: Voltage between terminals of wiring device  $\Delta V$  (LINEAR)

## [List Display]

Stress time Time  
 Resistance of wiring device R  
 Port1 current Iport1  
 Port3 current Iport3  
 Port4 current Iport4  
 Voltage between terminals of wiring device  $\Delta V$

## [Test Output: X-Y Graph]

X axis: Accumulated stress time TimeList (LOG)  
 Y1 axis: Resistance of wiring device RList (LINEAR)  
 Y2 axis: Port1 current Iport1List (LINEAR)  
 Y3 axis: Port3 current Iport3List (LINEAR)  
 Y4 axis: Port4 current Iport4List (LINEAR)  
 Y5 axis: Difference from initial resistance  $\Delta R$ List (LINEAR)

## [Test Output: List Display]

Accumulated stress time TimeList  
 Resistance of wiring device RList  
 Port1 current Iport1List  
 Port3 current Iport3List  
 Port4 current Iport4List  
 Difference from initial resistance  $\Delta R$ List

## [Test Output: Parameters]

Time to failure given by rate of resistance change R\_FailureTime  
 Time to failure given by monitoring extrusion lines E\_FailureTime

## 9 Reliability

### 9.27 HCI 3devices: Hot Carrier Injection test, 4 terminals, 3 devices (A.01.20)

[Supported Analyzer]

B1500A

[Description]

Performs the hot carrier injection test, and plots the accumulated stress time vs threshold voltage/drain current characteristics. Maximum three devices can be measured by a test execution. This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]

MOSFET, 4 terminals, 3 devices

[Required Accessories]

Agilent B2200A or B2201A switching matrix 1 unit  
GPIB cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIB cable.

Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.

Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the Tr#Gate/Tr#Drain/Tr#Source/Tr#Subs field (# is an integer from 1 to 3) of Test Parameters area.

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature (deg)

[Test Parameters]

IntegTime: Integration time (SHORT, MEDIUM, LONG)

Tr#Gate: SWM Pin Assign settings for Gate terminal of devices

Tr#Drain: SWM Pin Assign settings for Drain terminal of devices

Tr#Source: SWM Pin Assign settings for Source terminal of devices

Tr#Subs: SWM Pin Assign settings for Substrate terminal of devices

where, # is an integer from 1 to 3.

[Test Parameters for Sampling\_Stress]

TotalStrsTime: Total stress time

Tr#StrsGate: SMU connected to Gate terminal of devices, constant voltage output

Tr#StrsDrain: SMU connected to Drain terminal of devices, constant voltage output

StrsSource: SMU connected to Source terminal of devices, constant voltage output

StrsSubs: SMU connected to Substrate terminal of devices, constant voltage output

Tr#VgStrs: Gate terminal stress voltage for the devices

Tr#VdStrs: Drain terminal stress voltage for the devices

VsubsStrs: Substrate terminal stress voltage for the devices

VsStrs: Source terminal stress voltage for the devices

where, # is an integer from 1 to 3.

## [Test Parameters for IvSweep\_ConstId]

MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output

MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output

MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output

MeasSubs: SMU connected to the basic characteristics acquisition Substrate terminal, constant voltage output

Id@Vth: Drain current to decide the Vth, per unit area

VgStart1: Sweep start voltage for Gate terminal

VgStop1: Sweep stop voltage for Gate terminal

VgStep1: Sweep step voltage for Gate terminal

Vd1: Drain terminal voltage

## [Test Parameters for IvSweep\_gmmax]

MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output

MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output

MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output

MeasSubs: SMU connected to the basic characteristics acquisition Substrate terminal, constant voltage output

VgStart2: Sweep start voltage for Gate terminal

VgStop2: Sweep stop voltage for Gate terminal

VgStep2: Sweep step voltage for Gate terminal

Vd2: Drain voltage

## [Test Parameters for Sampling\_Ids]

MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output

MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output

MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output

MeasSubs: SMU connected to the basic characteristics acquisition Substrate terminal, constant voltage output

Vg3: Gate terminal voltage

Vd3: Drain terminal voltage

## [Extended Test Parameters]

## [Extended Test Parameters for IvSweep\_ConstId]

HoldTime: Hold time

DelayTime: Delay time

Vsubs: Substrate terminal voltage

Vs: Source terminal voltage

IgLimit: Gate current compliance of devices

IdLimit: Drain current compliance of devices

IsubsLimit: Substrate current compliance

DrainMinRng1: Minimum range for drain current measurement on device 1

DrainMinRng2: Minimum range for drain current measurement on device 2

DrainMinRng3: Minimum range for drain current measurement on device 3

## [Extended Test Parameters for IvSweep\_gmmax]

HoldTime: Hold time

DelayTime: Delay time

Vsubs: Substrate terminal voltage

Vs: Source terminal voltage

IgLimit: Gate current compliance of devices

IdLimit: Drain current compliance of devices

IsubsLimit: Substrate current compliance

gmMax\_Min: Minimum gmMax value for graph scale

## 9 Reliability

gmMax\_Max: Maximum gmMax value for graph scale  
DrainMinRng1: Minimum range for drain current measurement on device 1  
DrainMinRng2: Minimum range for drain current measurement on device 2  
DrainMinRng3: Minimum range for drain current measurement on device 3

[Extended Test Parameters for Sampling\_Ids]

Vsubs: Substrate terminal voltage

Vs: Source terminal voltage

IgLimit: Gate current compliance of devices

IdLimit: Drain current compliance of devices

IsubsLimit: Substrate current compliance

DrainMinRng1: Minimum range for drain current measurement on device 1

DrainMinRng2: Minimum range for drain current measurement on device 2

DrainMinRng3: Minimum range for drain current measurement on device 3

[User Function]

[User Function for Sampling\_Stress]

Maximum elapsed time value MaxTime=max(Time)

Stress time StressTime=AccTime+Time

[User Function for IvSweep\_ConstId]

Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

[User Function for IvSweep\_gmmax]

Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

Transconductance gm=diff(Idrain,Vgate)

Maximum transconductance value gmMax=max(gm)

[Analysis Function]

[Analysis Function for IvSweep\_ConstId]

Vth@Id=@L1X (X intercept of Line1)

[Analysis Function for IvSweep\_gmmax]

Vth@Gm=@L1X (X intercept of Line1)

[Auto Analysis]

[Auto Analysis for IvSweep\_ConstId]

Line1: Vertical line for Y1 at Idrain=Id@Vth

[Auto Analysis for IvSweep\_gmmax]

Line1: Tangent line for Y1 at gm=gmMax

[Test Output: X-Y Graph]

X axis: Elapsed time TimeList (LOG)

Y1 axis: Drain current for device 1 Dev1\_IdsList (LOG)

Y2 axis: Drain current for device 2 Dev2\_IdsList (LOG)

Y3 axis: Drain current for device 3 Dev3\_IdsList (LOG)

Y4 axis: Maximum transconductance value for device 1 Dev1\_gmMaxList (LINEAR)

Y5 axis: Maximum transconductance value for device 2 Dev2\_gmMaxList (LINEAR)

Y6 axis: Maximum transconductance value for device 3 Dev3\_gmMaxList (LINEAR)

[Test Output: List Display]

TimeList: Elapsed time

Dev1\_IdsList: Drain current for device 1

Dev2\_IdsList: Drain current for device 2

Dev3\_IdList: Drain current for device 3  
Dev1\_VthIdList: Vth for device 1, determined by constant current method  
Dev2\_VthIdList: Vth for device 2, determined by constant current method  
Dev3\_VthIdList: Vth for device 3, determined by constant current method  
Dev1\_VthGmList: Vth for device 1, determined by extrapolation method  
Dev2\_VthGmList: Vth for device 2, determined by extrapolation method  
Dev3\_VthGmList: Vth for device 3, determined by extrapolation method  
Dev1\_gmMaxList: Maximum transconductance value for device 1  
Dev2\_gmMaxList: Maximum transconductance value for device 2  
Dev3\_gmMaxList: Maximum transconductance value for device 3

## 9 Reliability

### 9.28 HCI: Hot Carrier Injection test, 4 terminals (A.01.20)

[Supported Analyzer]

B1500A

[Description]

Performs the hot carrier injection test, and plots the accumulated stress time vs threshold voltage/drain current characteristics.

This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]

MOSFET, 4 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature (deg)

[Test Parameters]

IntegTime: Integration time (SHORT, MEDIUM, LONG)

TotalStressTime: Total stress time

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

VgStress: Gate terminal stress voltage

VdStress: Drain terminal stress voltage

VsubsStress: Substrate terminal stress voltage

Vsubs: Substrate terminal voltage

[Test Parameters for IvSweep\_ConstId]

Id@Vth: Drain current to decide the Vth, per unit area

VgStart1: Sweep start voltage for Gate terminal

VgStop1: Sweep stop voltage for Gate terminal

VgStep1: Sweep step voltage for Gate terminal

Vd1: Drain terminal voltage, constant value

[Test Parameters for IvSweep\_gmmax]

VgStart2: Sweep start voltage for Gate terminal

VgStop2: Sweep stop voltage for Gate terminal

VgStep2: Sweep step voltage for Gate terminal

Vd2: Drain voltage

[Test Parameters for Sampling\_Ids]

Vg3: Gate terminal voltage

Vd3: Drain terminal voltage

[Extended Test Parameters]

[Extended Test Parameters for IvSweep\_ConstId]

HoldTime: Hold time

DelayTime: Delay time

Vs: Source terminal voltage

IgLimit: Gate current compliance

IdLimit: Drain current compliance

IsubsLimit: Substrate current compliance

DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for IvSweep\_gmmax]

HoldTime: Hold time

DelayTime: Delay time

Vs: Source terminal voltage

IgLimit: Gate current compliance

IdLimit: Drain current compliance

IsubsLimit: Substrate current compliance

Vth\_Min: Minimum Vth value for graph scale

Vth\_Max: Maximum Vth value for graph scale

gmMax\_Min: Minimum gmMax value for graph scale

gmMax\_Max: Maximum gmMax value for graph scale

DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for Sampling\_Ids]

Vs: Source terminal voltage

IgLimit: Gate current compliance

IdLimit: Drain current compliance

IsubsLimit: Substrate current compliance

DrainMinRng: Minimum range for drain current measurement

[User Function]

[User Function for Sampling\_Stress]

Maximum elapsed time value  $\text{MaxTime} = \max(\text{Time})$

Stress time  $\text{StressTime} = \text{AccTime} + \text{Time}$

[User Function for IvSweep\_ConstId]

Maximum drain current value  $\text{IdMax} = \max(\text{abs}(\text{Idrain}))$  (For initial measurement only)

[User Function for IvSweep\_gmmax]

Maximum drain current value  $\text{IdMax} = \max(\text{abs}(\text{Idrain}))$  (For initial measurement only)

Transconductance  $\text{gm} = \text{diff}(\text{Idrain}, \text{Vgate})$

Maximum transconductance value  $\text{gmMax} = \max(\text{gm})$

[Analysis Function]

[Analysis Function for IvSweep\_ConstId]

$\text{Vth@Id} = @L1X$  (X intercept of Line1)

[Analysis Function for IvSweep\_gmmax]

$\text{Vth@Gm} = @L1X$  (X intercept of Line1)

[Auto Analysis]

[Auto Analysis for IvSweep\_ConstId]

Line1: Vertical line for Y1 at  $\text{Idrain} = \text{Id@Vth}$

[Auto Analysis for IvSweep\_gmmax]

Line1: Tangent line for Y1 at  $\text{gm} = \text{gmMax}$

## 9 Reliability

[Test Output: X-Y Graph]

X axis: Elapsed time TimeList (LOG)

Y1 axis: Maximum transconductance value gmMaxList (LINEAR)

Y2 axis: Vth by constant current method VthIdList (LINEAR)

Y3 axis: Vth by extrapolation method VthGmList (LINEAR)

Y4 axis: Drain current IdsList (LOG)

[Test Output: List Display]

Elapsed time TimeList

Vth by constant current method VthIdList

Vth by extrapolation method VthGmList

Drain current IdsList

Maximum transconductance value gmMaxList



**9.29 HCI2: Hot Carrier Injection test, 4 terminals (A.03.10)****[Supported Analyzer]**

B1500A

**[Description]**

Performs the hot carrier injection test, and plots the accumulated stress time vs threshold voltage/drain current characteristics.

This test is performed as follows.

1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

**[Device Under Test]**

MOSFET, 4 terminals

**[Device Parameters]**

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature (deg)

**[Test Parameters]**

IntegTime: Integration time (SHORT, MEDIUM, LONG)

TotalStressTime: Total stress time

Gate: SMU connected to Gate terminal, primary sweep voltage output

Drain: SMU connected to Drain terminal, constant voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

Source: SMU connected to Source terminal, constant voltage output

VgStress: Gate terminal stress voltage

VdStress: Drain terminal stress voltage

VsubsStress: Substrate terminal stress voltage

IdLimit: Drain current compliance

MeasConstId: Measurement by constant current method, Yes or No

MeasGmmax: Measurement by extrapolation method, Yes or No

MeasIds: Drain current measurement, Yes or No

MeasTiming: Timing to measure device parameter

**[Test Parameters for IvSweep\_ConstId]**

Id@Vth: Drain current to decide the Vth, per unit area

VgStart1: Sweep start voltage for Gate terminal

VgStop1: Sweep stop voltage for Gate terminal

VgStep1: Sweep step voltage for Gate terminal

Vd1: Drain terminal voltage, constant value

VthStopRate: Vth\_ConstId change rate to stop testing

**[Test Parameters for IvSweep\_gmmax]**

VgStart2: Sweep start voltage for Gate terminal

VgStop2: Sweep stop voltage for Gate terminal

VgStep2: Sweep step voltage for Gate terminal

Vd2: Drain voltage

GmStopRate: Vth\_GmMax change rate to stop testing

## 9 Reliability

[Test Parameters for Sampling\_Ids]

Vg3: Gate terminal voltage

Vd3: Drain terminal voltage

IdsStopRate: Ids change rate to stop testing

[Extended Test Parameters]

StoringRuntimeData: Data save during stress output, Yes or No

[Extended Test Parameters for IvSweep\_ConstId]

HoldTime: Hold time

DelayTime: Delay time

Vs: Source terminal voltage

Vsubs: Substrate terminal voltage

IgLimit: Gate current compliance

IsubsLimit: Substrate current compliance

DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for IvSweep\_gmmax]

HoldTime: Hold time

DelayTime: Delay time

Vs: Source terminal voltage

Vsubs: Substrate terminal voltage

IgLimit: Gate current compliance

IsubsLimit: Substrate current compliance

Vth\_Min: Minimum Vth value for graph scale

Vth\_Max: Maximum Vth value for graph scale

gmMax\_Min: Minimum gmMax value for graph scale

gmMax\_Max: Maximum gmMax value for graph scale

DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for Sampling\_Ids]

Vs: Source terminal voltage

Vsubs: Substrate terminal voltage

IgLimit: Gate current compliance

IsubsLimit: Substrate current compliance

DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]

[Measurement Parameters by Sampling\_Stress]

Drain current Idrain

[Measurement Parameters by IvSweep\_ConstId]

Drain current Idrain

[Measurement Parameters by IvSweep\_gmmax]

Drain current Idrain

[Measurement Parameters by IvSweep\_Ids]

Drain current Idrain

[User Function]

[User Function for IvSweep\_ConstId]

Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

[User Function for IvSweep\_gmmax]

Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

Transconductance gm=diff(Idrain,Vgate)

Maximum transconductance value gmMax=max(gm)

[Analysis Function]

[Analysis Function for IvSweep\_ConstId]

Vth@Id=@L1X (X intercept of Line1)

[Analysis Function for IvSweep\_gmmax]

Vth@Gm=@L1X (X intercept of Line1)

[Auto Analysis]

[Auto Analysis for IvSweep\_ConstId]

Line1: Vertical line for Y1 at Idrain=Id@Vth

[Auto Analysis for IvSweep\_gmmax]

Line1: Tangent line for Y1 at gm=gmMax

[X-Y Graph]

[X-Y Graph for Sampling\_Stress]

X axis: Stress time StressTime (LINEAR)

Y1 axis: Drain current Idrain (LOG)

[X-Y Graph for IvSweep\_ConstId]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

[X-Y Graph for IvSweep\_gmmax]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Transconductance gm (LINEAR)

[X-Y Graph for Sampling\_Ids]

X axis: Elapsed time Time (LINEAR)

Y1 axis: Drain current Idrain (LOG)

[List Display]

[List Display for Sampling\_Stress]

Stress time StressTime

Elapsed time Time

Gate voltage Vgate

Drain voltage Vdrain

Drain current Idrain

[List Display for IvSweep\_ConstId]

Gate voltage Vgate

Drain voltage Vdrain

Drain current Idrain

[List Display for IvSweep\_gmmax]

Gate voltage Vgate

Drain voltage Vdrain

## 9 Reliability

Drain current Idrain  
Transconductance gm

[List Display for Sampling\_Ids]  
Elapsed time Time  
Drain current Idrain

[Test Output: X-Y Graph]  
X axis: Elapsed time TimeList (LOG)  
Y1 axis: Maximum transconductance value gmMaxList (LINEAR)  
Y2 axis: Vth by constant current method VthIdList (LINEAR)  
Y3 axis: Vth by extrapolation method VthGmList (LINEAR)  
Y4 axis: Drain current IdsList (LOG)

[Test Output: List Display]  
Elapsed time TimeList  
Vth by constant current method VthIdList  
Vth by extrapolation method VthGmList  
Drain current IdsList  
Maximum transconductance value gmMaxList

**9.30 J-Ramp: Insulator lifetime evaluation, current stressed (A.01.20)**

## [Supported Analyzer]

B1500A

## [Description]

Measures the time vs current/voltage characteristics with current stress, and extracts the lifetime of the gate oxide, insulator and so on.

## [Device Under Test]

MOS capacitor, oxide layer, insulator and so on

## [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

## [Test Parameters]

IntegTime: Integration time

TimeMax: Maximum value of X axis

Gate: SMU connected to Gate, primary sweep, current output

IgStart: Sweep start current

IgStop: Sweep stop current

VgLimit: Gate voltage compliance

Subs: SMU connected to Substrate, constant voltage output

## [Extended Test Parameters]

Vsubs: Substrate voltage

HoldTime: Hold time

DelayTime: Delay time

SubsMinRng: Minimum range for the substrate current measurement

## [User Function]

$I_{gatePerArea} = I_{gate} / L_g / W_g$

$I_{subsPerArea} = I_{subs} / L_g / W_g$

$Q_{bdi} = \text{integ}(I_{gate}, \text{Time}) / L_g / W_g$

## [Test Output: X-Y Graph]

X axis: Time stamp TimeList (LINEAR)

Y1 axis: Gate current IgateList (LOG)

Y2 axis: Gate voltage VgateList (LINEAR)

## [Test Output: List Display]

Time stamp TimeList

Gate current IgateList

Gate voltage VgateList

## [Test Output: Parameters]

Breakdown voltage Vbd

Time to breakdown Tbd

Charge to breakdown Qbd

## 9 Reliability

### 9.31 TDDDB Istress 3devices: TDDDB Test, current stressed, 3 devices (A.01.20)

#### [Supported Analyzer]

B1500A

#### [Description]

Performs the TDDDB (time dependent dielectric breakdown) test, and plots the stress time vs voltage characteristics. This test is performed by the sampling measurement mode. This test also supports 3-device connection.

#### [Device Under Test]

MOS capacitor, insulator, oxide layer, and so on

#### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

L: Length of pattern

W: Width of pattern

Temp: Temperature

#### [Test Parameters]

Port1: SMU connected to Port1 terminal

Port2: SMU connected to Port2 terminal

Port3: SMU connected to Port3 terminal

Port4: SMU connected to Port4 terminal

TotalStressTime: Total stress time.

StopCondition: Terminal voltage to decide the breakdown

I1Stress: Port1 stress current

I2Stress: Port2 stress current

I3Stress: Port3 stress current

NoOfSamples: Number of samples

IntegTime: Integration time

#### [Extended Test Parameters]

V4: Port4 terminal voltage

V1Limit: Port1/Port2/Port3 voltage compliance

I4Limit: Port4 current compliance

HoldTime: Hold time

Port4MinRng: Minimum range for the port4 current measurement

#### [User Function]

IPort1PerArea=Iport1/L/W

IPort2PerArea=Iport2/L/W

IPort3PerArea=Iport3/L/W

IPort4PerArea=Iport4/L/W

#### [Test Output: X-Y Graph]

X axis: Stress time TimeList (LOG)

Y1 axis: Port1 terminal voltage Vport1List (LOG)

Y2 axis: Port2 terminal voltage Vport2List (LOG)

Y3 axis: Port3 terminal voltage Vport3List (LOG)

#### [Test Output: Parameters]

Device1 breakdown voltage Vbd1

Device2 breakdown voltage Vbd2

Device3 breakdown voltage Vbd3  
Device1 time to breakdown Tbd1  
Device2 time to breakdown Tbd2  
Device3 time to breakdown Tbd3  
Device1 charge to breakdown Qbd1  
Device2 charge to breakdown Qbd2  
Device3 charge to breakdown Qbd3

## 9 Reliability

### 9.32 *TDDDB Istress2 3devices: TDDDB Test, current stressed, 3 devices (A.03.10)*

#### [Supported Analyzer]

B1500A

#### [Description]

Performs the TDDDB (time dependent dielectric breakdown) test, and plots the stress time vs voltage characteristics. This test is performed by the sampling measurement mode. This test also supports 3-device connection.

#### [Device Under Test]

MOS capacitor, insulator, oxide layer, and so on

#### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

L: Length of pattern

W: Width of pattern

Temp: Temperature

#### [Test Parameters]

Port1: SMU connected to Port1 terminal

Port2: SMU connected to Port2 terminal

Port3: SMU connected to Port3 terminal

Port4: SMU connected to Port4 terminal

TotalStressTime: Total stress time.

I1Stress: Port1 stress current

I2Stress: Port2 stress current

I3Stress: Port3 stress current

IntegTime: Integration time

PointPerDecade: Number of samples in 1 decade

Interval: Sampling interval

FailureCondition: Measurement stop condition

#### [Extended Test Parameters]

V4: Port4 terminal voltage

V1Limit: Port1/Port2/Port3 voltage compliance

I4Limit: Port4 current compliance

HoldTime: Hold time

Port4MinRng: Minimum range for the port4 current measurement

StoringRuntimeData: Data save during stress output, Yes or No

#### [Measurement Parameters]

Port1 voltage Vport1

Port2 voltage Vport2

Port3 voltage Vport3

#### [User Function]

IPort1PerArea=Iport1/L/W

IPort2PerArea=Iport2/L/W

IPort3PerArea=Iport3/L/W

IPort4PerArea=Iport4/L/W

#### [X-Y Graph]

X axis: Stress time Time (LOG)



Y1 axis: Port1 terminal voltage Vport1 (LOG)  
Y2 axis: Port2 terminal voltage Vport2 (LOG)  
Y3 axis: Port3 terminal voltage Vport3 (LOG)

[List Display]

Stress time Time  
Port1 terminal voltage Vport1  
Port2 terminal voltage Vport2  
Port3 terminal voltage Vport3  
Port1 current Iport1  
Port2 current Iport2  
Port3 current Iport3

[Test Output: X-Y Graph]

X axis: Stress time TimeList (LOG)  
Y1 axis: Port1 terminal voltage Vport1List (LOG)  
Y2 axis: Port2 terminal voltage Vport2List (LOG)  
Y3 axis: Port3 terminal voltage Vport3List (LOG)

[Test Output: List Display]

Stress time Time  
Port1 terminal voltage Vport1  
Port2 terminal voltage Vport2  
Port3 terminal voltage Vport3

[Test Output: Parameters]

Device1 breakdown voltage Vbd1  
Device2 breakdown voltage Vbd2  
Device3 breakdown voltage Vbd3  
Device1 time to breakdown Tbd1  
Device2 time to breakdown Tbd2  
Device3 time to breakdown Tbd3  
Device1 charge to breakdown Qbd1  
Device2 charge to breakdown Qbd2  
Device3 charge to breakdown Qbd3

## 9 Reliability

### 9.33 *TDDB Istress: TDDB Test, current stressed (A.01.20)*

[Supported Analyzer]

B1500A

[Description]

Performs the TDDB (time dependent dielectric breakdown) test, and plots the stress time vs voltage characteristics. This test is performed by the sampling measurement mode.

[Device Under Test]

MOS capacitor, insulator, oxide layer, and so on

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

L: Port1 terminal length

W: Port1 terminal width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

TotalStressTime: Total stress time. 10 to 10000 seconds.

NoOfSamples: Number of samples

Port1: SMU connected to Port1 terminal

I1Stress: Port1 stress current

Port2: SMU connected to Port2 terminal

[Extended Test Parameters]

V2: Port2 terminal voltage

V1Limit: Port1 voltage compliance

I2Limit: Port2 current compliance

HoldTime: Hold time

Port2MinRng: Minimum range for the port2 current measurement

[User Function]

I1PerArea=Iport1/L/W

I2PerArea=Iport2/L/W

[Test Output: X-Y Graph]

X axis: Stress time TimeList (LOG)

Y1 axis: Port1 terminal voltage Vport1List (LINEAR)

[Test Output: List Display]

Stress time TimeList

Port1 terminal voltage Vport1List

[Test Output: Parameters]

Breakdown voltage Vbd

Time to breakdown Tbd

Charge to breakdown Qbd

[Qbd calculation]

$Qbd = I1Stress * Tbd / L / W$

**9.34 TDDB Istress2: TDDB Test, current stressed (A.03.10)****[Supported Analyzer]**

B1500A

**[Description]**

Performs the TDDB (time dependent dielectric breakdown) test, and plots the stress time vs voltage characteristics. This test is performed by the sampling measurement mode.

**[Device Under Test]**

MOS capacitor, insulator, oxide layer, and so on

**[Device Parameters]**

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

L: Port1 terminal length

W: Port1 terminal width

Temp: Temperature

**[Test Parameters]**

Port1: SMU connected to Port1 terminal

Port2: SMU connected to Port2 terminal

TotalStressTime: Total stress time. 10 to 10000 seconds.

I1Stress: Port1 stress current

V1Limit: Port1 voltage compliance

I2Limit: Port2 current compliance

IntegTime: Integration time

PointPerDecade: Number of samples in 1 decade

Interval: Sampling interval

FailureCondition: Measurement stop condition

**[Extended Test Parameters]**

V2: Port2 terminal voltage

HoldTime: Hold time

Port2MinRng: Minimum range for the port2 current measurement

StoringRuntimeData: Data save during stress output, Yes or No

**[Measurement Parameters]**

Port1 voltage Vport1

**[User Function]**

I1PerArea=Iport1/L/W

I2PerArea=Iport2/L/W

**[X-Y Graph]**

X axis: Stress time Time (LOG)

Y1 axis: Port1 terminal voltage Vport1 (LINEAR)

**[List Display]**

Stress time Time

Port1 terminal voltage Vport1

**[Test Output: X-Y Graph]**

X axis: Stress time TimeList (LOG)

Y1 axis: Port1 terminal voltage Vport1List (LINEAR)

## 9 Reliability

[Test Output: List Display]

Stress time TimeList

Port1 terminal voltage Vport1List

[Test Output: Parameters]

Breakdown voltage Vbd

Time to breakdown Tbd

Charge to breakdown Qbd

[Qbd calculation]

$Qbd = I_{\text{Stress}} * Tbd / L / W$

**9.35 TDDDB Vstress 3devices: TDDDB Test, voltage stressed, 3 devices (A.01.20)****[Supported Analyzer]**

B1500A

**[Description]**

Performs the TDDDB (time dependent dielectric breakdown) test, and plots the stress time vs current characteristics. This test is performed by the sampling measurement mode. This test also supports 3-device connection.

**[Device Under Test]**

MOS capacitor, insulator, oxide layer, and so on

**[Device Parameters]**

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

L: Length of pattern

W: Width of pattern

Temp: Temperature

**[Test Parameters]**

Port1: SMU connected to Port1 terminal

Port2: SMU connected to Port2 terminal

Port3: SMU connected to Port3 terminal

Port4: SMU connected to Port4 terminal

TotalStressTime: Total stress time.

StopCondition: Terminal current to decide the breakdown

V1Stress: Port1 stress voltage

V2Stress: Port2 stress voltage

V3Stress: Port3 stress voltage

NoOfSamples: Number of samples

IntegTime: Integration time

**[Extended Test Parameters]**

V4: Port4 terminal voltage

I1Limit: Port1/Port2/Port3 current compliance

HoldTime: Hold time

Port1MinRng: Minimum range for the port1 current measurement

Port2MinRng: Minimum range for the port2 current measurement

Port3MinRng: Minimum range for the port3 current measurement

Port4MinRng: Minimum range for the port4 current measurement

**[User Function]** $I_{Port1PerArea} = I_{port1}/L/W$  $I_{Port2PerArea} = I_{port2}/L/W$  $I_{Port3PerArea} = I_{port3}/L/W$  $I_{Port4PerArea} = I_{port4}/L/W$  $Q_{bd1val} = \text{integ}(I_{port1}, \text{Time})/L/W$  $Q_{bd2val} = \text{integ}(I_{port2}, \text{Time})/L/W$  $Q_{bd3val} = \text{integ}(I_{port3}, \text{Time})/L/W$

## 9 Reliability

[Test Output: X-Y Graph]

X axis: Stress time TimeList (LOG)

Y1 axis: Port1 terminal current Iport1List (LOG)

Y2 axis: Port2 terminal current Iport2List (LOG)

Y3 axis: Port3 terminal current Iport3List (LOG)

[Test Output: Parameters]

Device1 time to breakdown Tbd1

Device2 time to breakdown Tbd2

Device3 time to breakdown Tbd3

Device1 charge to breakdown Qbd1

Device2 charge to breakdown Qbd2

Device3 charge to breakdown Qbd3

**9.36 TDDDB Vstress2 3devices: TDDDB Test, voltage stressed, 3 devices (A.03.10)****[Supported Analyzer]**

B1500A

**[Description]**

Performs the TDDDB (time dependent dielectric breakdown) test, and plots the stress time vs current characteristics. This test is performed by the sampling measurement mode. This test also supports 3-device connection.

**[Device Under Test]**

MOS capacitor, insulator, oxide layer, and so on

**[Device Parameters]**

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

L: Length of pattern

W: Width of pattern

Temp: Temperature

**[Test Parameters]**

Port1: SMU connected to Port1 terminal

Port2: SMU connected to Port2 terminal

Port3: SMU connected to Port3 terminal

Port4: SMU connected to Port4 terminal

TotalStressTime: Total stress time.

FailureCondition: Measurement stop condition

V1Stress: Port1 stress voltage

V2Stress: Port2 stress voltage

V3Stress: Port3 stress voltage

IntegTime: Integration time

PointPerDecade: Number of samples in 1 decade

Interval: Sampling interval

**[Extended Test Parameters]**

V4: Port4 terminal voltage

I1Limit: Port1/Port2/Port3 current compliance

HoldTime: Hold time

Port1MinRng: Minimum range for the port1 current measurement

Port2MinRng: Minimum range for the port2 current measurement

Port3MinRng: Minimum range for the port3 current measurement

Port4MinRng: Minimum range for the port4 current measurement

StoringRuntimeData: Data save during stress output, Yes or No

**[Measurement Parameters]**

Port1 current Iport1

Port2 current Iport2

Port3 current Iport3

Port4 current Iport4

**[User Function]**

IPort1PerArea=Iport1/L/W

IPort2PerArea=Iport2/L/W

IPort3PerArea=Iport3/L/W

Qbd1val=integ(Iport1,Time)/L/W

## 9 Reliability

$Qbd2val = \text{integ}(Iport2, Time) / L / W$   
 $Qbd3val = \text{integ}(Iport3, Time) / L / W$

### [X-Y Graph]

X axis: Stress time Time (LOG)  
Y1 axis: Port1 current Iport1 (LOG)  
Y2 axis: Port2 current Iport2 (LOG)  
Y3 axis: Port3 current Iport3 (LOG)  
Y4 axis: Port4 current Iport4 (LOG)

### [List Display]

Stress time Time  
Port1 current Iport1  
Port2 current Iport2  
Port3 current Iport3  
Port4 current Iport4  
Port1 voltage Vport1  
Port2 voltage Vport2  
Port3 voltage Vport3  
Port4 voltage Vport4

### [Test Output: X-Y Graph]

X axis: Stress time TimeList (LOG)  
Y1 axis: Port1 current Iport1List (LOG)  
Y2 axis: Port2 current Iport2List (LOG)  
Y3 axis: Port3 current Iport3List (LOG)

### [Test Output: List Display]

Stress time TimeList  
Port1 current Iport1List  
Port2 current Iport2List  
Port3 current Iport3List  
Device1 charge to breakdown Qbd1List  
Device2 charge to breakdown Qbd2List  
Device3 charge to breakdown Qbd3List

### [Test Output: Parameters]

Device1 time to breakdown Tbd1  
Device2 time to breakdown Tbd2  
Device3 time to breakdown Tbd3  
Device1 charge to breakdown Qbd1  
Device2 charge to breakdown Qbd2  
Device3 charge to breakdown Qbd3



**9.37 TDDDB Vstress: TDDDB Test, voltage stressed (A.01.20)****[Supported Analyzer]**

B1500A

**[Description]**

Performs the TDDDB (time dependent dielectric breakdown) test, and plots the stress time vs current characteristics. This test is performed by the sampling measurement mode.

**[Device Under Test]**

MOS capacitor, insulator, oxide layer, and so on

**[Device Parameters]**

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

L: Port1 terminal length

W: Port1 terminal width

Temp: Temperature

**[Test Parameters]**

IntegTime: Integration time

TotalStressTime: Total stress time. 10 to 10000 seconds.

StopCondition: Port1 terminal current to decide the breakdown

NoOfSamples: Number of samples

Port1: SMU connected to Port1 terminal

V1Stress: Port1 stress voltage

Port2: SMU connected to Port2 terminal

**[Extended Test Parameters]**

V2: Port2 terminal voltage

I1Limit: Current compliance

HoldTime: Hold time

Port1MinRng: Minimum range for the port1 current measurement

**[User Function]**

$I_{Port1PerArea} = I_{port1}/L/W$

$I_{Port2PerArea} = I_{port2}/L/W$

$Q_{bdval} = \text{integ}(I_{port1}, \text{Time})/L/W$

**[Test Output: X-Y Graph]**

X axis: Stress time TimeList (LOG)

Y1 axis: Port1 terminal current Iport1List (LOG)

**[Test Output: List Display]**

Stress time TimeList

Port1 terminal current Iport1List

Charge to breakdown QbdList

**[Test Output: Parameters]**

Time to breakdown Tbd

Charge to breakdown Qbd

## 9 Reliability

### 9.38 *TDDDB Vstress2: TDDDB Test, voltage stressed (A.03.10)*

#### [Supported Analyzer]

B1500A

#### [Description]

Performs the TDDDB (time dependent dielectric breakdown) test, and plots the stress time vs current characteristics. This test is performed by the sampling measurement mode.

#### [Device Under Test]

MOS capacitor, insulator, oxide layer, and so on

#### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

L: Port1 terminal length

W: Port1 terminal width

Temp: Temperature

#### [Test Parameters]

Port1: SMU connected to Port1 terminal

Port2: SMU connected to Port2 terminal

TotalStressTime: Total stress time. 10 to 10000 seconds.

FailureCondition: Port1 terminal current to decide the breakdown

V1Stress: Port1 stress voltage

IntegTime: Integration time

PointPerDecade: Number of samples in 1 decade

Interval: Sampling interval

#### [Extended Test Parameters]

V2: Port2 terminal voltage

I1Limit: Current compliance

HoldTime: Hold time

Port1MinRng: Minimum range for the port1 current measurement

StoringRuntimeData: Data save during stress output, Yes or No

#### [Measurement Parameters]

Port1 current Iport1

#### [User Function]

$I_{Port1PerArea} = I_{port1} / L / W$

$I_{Port2PerArea} = I_{port2} / L / W$

$Q_{bdval} = \text{integ}(I_{port1}, \text{Time}) / L / W$

#### [X-Y Graph]

X axis: Stress time Time (LOG)

Y1 axis: Port1 current Iport1 (LOG)

#### [List Display]

Stress time Time

Port1 current Iport1

#### [Test Output: X-Y Graph]

X axis: Stress time TimeList (LOG)

Y1 axis: Port1 current Iport1List (LOG)

[Test Output: List Display]

Stress time TimeList

Port1 current Iport1List

Charge to breakdown QbdList

[Test Output: Parameters]

Time to breakdown Tbd

Charge to breakdown Qbd

## 9 Reliability

### 9.39 TZDB: TZDB Test of oxide layer (A.01.20)

[Supported Analyzer]

B1500A

[Description]

Performs the TZDB (time zero dielectric breakdown) test, and plots the current vs voltage characteristics.

[Device Under Test]

MOS capacitor, oxide layer, and so on

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate, primary sweep, voltage output

VgStart: Sweep start voltage

VgStop: Sweep stop voltage

VgStep: Sweep step voltage

IgLimit: Gate current compliance

Subs: SMU connected to Substrate, constant voltage output

[Extended Test Parameters]

Vsubs: Substrate voltage

HoldTime: Hold time

DelayTime: Delay time

GateMinRng: Minimum range for the gate current measurement

SubsMinRng: Minimum range for the substrate current measurement

[User Function]

IgatePerArea=Igate/L/W

IsubsPerArea=Isubs/L/W

[X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Gate current Igate (LOG)

Y2 axis: Gate current per unit area IgatePerArea (LOG)

**9.40 V-Ramp: Insulator lifetime evaluation, voltage stressed (A.01.20)****[Supported Analyzer]**

B1500A

**[Description]**

Measures the time vs current/voltage characteristics with voltage stress, and extracts the lifetime of the gate oxide, insulator and so on.

**[Device Under Test]**

MOS capacitor, oxide layer, insulator and so on

**[Device Parameters]**

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

**[Test Parameters]**

IntegTime: Integration time

TimeMax: Maximum value of X axis

Gate: SMU connected to Gate, primary sweep, voltage output

VgStart: Sweep start voltage

VgStop: Sweep stop voltage

VgStep: Sweep step voltage

Ibd: Gate current to decide the breakdown

Subs: SMU connected to Substrate, constant voltage output

**[Extended Test Parameters]**

Vsubs: Substrate voltage

HoldTime: Hold time

DelayTime: Delay time

GateMinRng: Minimum range for the gate current measurement

SubsMinRng: Minimum range for the substrate current measurement

**[User Function]**

$I_{gatePerArea} = I_{gate} / L_g / W_g$

$I_{subsPerArea} = I_{subs} / L_g / W_g$

$Q_{bdi} = \text{integ}(I_{gate}, \text{Time}) / L_g / W_g$

**[Test Output: X-Y Graph]**

X axis: Time stamp TimeList (LINEAR)

Y1 axis: Gate current IgateList (LOG)

Y2 axis: Gate voltage VgateList (LINEAR)

**[Test Output: List Display]**

Time stamp TimeList

Gate current IgateList

Gate voltage VgateList

Charge to breakdown QbdList

## 9 Reliability

[Test Output: Parameters]

Breakdown voltage  $V_{bd}$

Charge to breakdown  $Q_{bd}$

Time to breakdown  $T_{bd}$

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## **10            Structure**

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## 10 Structure

1. BVgb ThinOx: MOS capacitor Ig-Vg characteristics (A.01.20)
2. BVgb: MOS capacitor Gate-Substrate breakdown voltage (A.01.20)
3. Cgb-Freq[2] Log: Cgb-f characteristics, 2 terminals (A.01.20)
4. Cgb-Vg 2Freq: MOS capacitor Cgb-Vg characteristics, 2-frequency method (A.01.11)
5. Cgb-Vg[2]: MOS capacitor Cgb-Vg characteristics (A.01.11)
6. Cj-Freq Log: Cj-f characteristics, junction device (A.01.20)
7. Cj-V: Junction capacitance Cj-V characteristics (A.01.11)
8. Diode BVAndCj-V ASU: Diode junction capacitance and breakdown voltage measurement using ASUs (A.01.20)
9. Diode BVAndCj-V SCUU: Diode junction capacitance and breakdown voltage measurement using SCUU (A.01.20)
10. Ig-Vg Iforce: MOS capacitor Ig-Vg characteristics, current sweep (A.01.20)
11. Ig-Vg Vforce: MOS capacitor Ig-Vg characteristics, voltage sweep (A.01.20)
12. Interconnect CouplingCap: Interconnection capacitance (A.01.11)
13. Interconnect OverlapCap: Layer to layer film capacitance (A.01.11)
14. Junction BV: Junction device breakdown voltage (A.01.20)
15. Junction DcParam: Junction device DC parameters (Is,N,Rs) (A.01.20)
16. Junction IV Fwd: Diode forward bias characteristics (A.01.20)
17. Junction IV Rev: Diode reverse bias characteristics (A.01.20)
18. QSCV[2] C-Vg, Ig-Vg (2-terminal) (A.03.00)
19. QSCV C Offset Meas: Offset capacitance measurement
20. Rdiff-I kelvin: Diffusion resistor R-I characteristics, Kelvin connection (A.01.11)
21. Rdiff-I: Diffusion resistor R-I characteristics (A.01.11)
22. Rdiff-V kelvin: Diffusion resistor R-V characteristics, Kelvin connection (A.01.20)
23. Rdiff-V: Diffusion resistor R-V characteristics (A.01.20)
24. R-I DVM: Low resistance measurement using 3458A, current force (A.01.20)
25. R-I kelvin: Resistor R-I characteristics, Kelvin connection (A.01.11)
26. R-I: Resistor R-I characteristics (A.01.11)
27. R-V DVM: Low resistance measurement using 3458A, voltage force (A.01.20)
28. R-V kelvin: Resistor R-V characteristics, Kelvin connection (A.01.20)
29. R-V: Resistor R-V characteristics (A.01.20)
30. VanDerPauw Square: Van Der Pauw pattern sheet resistance (A.01.11)



## 10.1 BVgb ThinOx: MOS capacitor Ig-Vg characteristics (A.01.20)

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Extracts the gate current vs gate voltage (Ig-Vg) characteristics of MOS capacitor which has an ultra thin gate insulator. The primary sweep channel applies the quasi-pulsed voltage to Gate terminal, and measures Gate current at both pulse base and peak. The measurements are repeated  $\text{ABS}(\text{VgStop}-\text{VgStart})/\text{VgStep}$  times to extract the Ig-Vg characteristics. The pulse base value is the primary sweep start value and can be set by the VgLow parameter. The pulse peak value is the primary sweep stop value and corresponds to Vg.

### [Device Under Test]

MOS capacitor

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate, primary sweep voltage output

VgStart: Pulse peak start value

VgStop: Pulse peak stop value

VgStep: Pulse peak step value

VgLow: Pulse base value, primary sweep start value

IgLimit: Gate current compliance

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

VgStart, VgStop, VgStep values are used to calculate the primary sweep stop value.

### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

GateMinRng: Minimum range for the gate current measurement

SubsMinRng: Minimum range for the substrate current measurement

### [Measurement Parameters]

Gate current Igate

Substrate current Isubs

### [User Function]

Gate current per Gate unit area  $\text{IgatePerArea} = \text{Igate}/\text{Lg}/\text{Wg}$

Substrate current per Gate unit area  $\text{IsubsPerArea} = \text{Isubs}/\text{Lg}/\text{Wg}$

### [Calculation After Measurement]

Buffer=getVectorData("Vgate")

V\_gate=storeAt(Vgate,I,1,at(Buffer,2,1))

Buffer=getVectorData("Igate")

I\_gate=storeAt(Igate,I,1,at(Buffer,2,1))

I\_gate@LowVg=storeAt(Igate,I,1,at(Buffer,1,1))

## 10 Structure

```
Val=at(Buffer,1,1)
Val=Val/Lg/Wg*1E-12
I_gate@LowVgPerArea=storeAt(I_gate@LowVgPerArea,I,1,Val)
Buffer=getVectorData("IgatePerArea")
I_gatePerArea=storeAt(I_gatePerArea,I,1,at(Buffer,1,1))
I=I+1
```

[Test Output: X-Y Graph]

X axis: Gate voltage V\_gate (LINEAR)  
Y1 axis: Gate current I\_gate (LOG)  
Y2 axis: Gate current at pulse base voltage I\_gate@LowVg (LOG)

[Test Output: List Display]

Gate voltage V\_gate  
Gate current I\_gate  
Gate current at pulse base voltage I\_gate@LowVg  
Gate current per Gate unit area I\_gatePerArea  
I\_gate@LowVg per Gate unit area I\_gate@LowVgPerArea

## 10.2 BVgb: MOS capacitor Gate-Substrate breakdown voltage (A.01.20)

### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

### [Description]

Measures the gate current vs gate voltage characteristics and extracts the breakdown voltage between gate and substrate (BVgb) of MOS capacitor.

### [Device Under Test]

MOS capacitor

### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Ig@BVgb: Gate current to decide the breakdown

Gate: SMU connected to Gate, primary sweep voltage output

VgStart: Sweep start voltage for Gate

VgStop: Sweep stop voltage for Gate

VgStep: Sweep step voltage for Gate

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

GateMinRng: Minimum range for the gate current measurement

### [Measurement Parameters]

Gate current Igate

For the all terminals, the SMU current compliance is set to Ig@BVgb\*1.1.

### [User Function]

Gate current per Gate unit area Igate\_Area=Igate/Lg/Wg

### [Analysis Function]

BVgb=@L1X (X intercept of Line1)

### [X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Gate current Igate (LOG)

Y2 axis: Gate current per Gate unit area Igate\_Area (LOG)

### [Parameters Display Area]

Gate-Substrate breakdown voltage BVgb

### [Auto Analysis]

Line1: Vertical line through Y1 data at Igate=Ig@BVgb

## 10 Structure

### 10.3 Cgb-Freq[2] Log: Cgb-f characteristics, 2 terminals (A.01.20)

#### [Supported Analyzer]

B1500A

#### [Description]

Measures MOS capacitor's characteristics of gate-to-substrate capacitance (Cgb, linear) vs frequency (f, log). The measurement frequency is 10 points per decade.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

#### [Device Under Test]

MOS capacitor, 2 terminals

Connect CMU High and CMU Low to the substrate and gate respectively.

#### [Required Modules and Accessories]

Agilent B1520A MFCMU 1 unit

#### [Device Parameters]

Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature (deg)

#### [Test Parameters]

IntegTime: Integration time

FreqStart: Sweep start frequency, LOG sweep

NoOfDecade: Number of decades for data collection

OscLevel: Measurement signal level

Gate: CMU connected to Gate terminal

Vgs: Voltage for Gate terminal, constant voltage

#### [Extended Test Parameters]

G\_Min: Minimum transconductance value for graph

G\_Max: Maximum transconductance value for graph

Cp\_Min: Minimum capacitance value for graph

Cp\_Max: Maximum capacitance value for graph

#### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

#### [User Function]

Circular constant  $PI=3.141592653589$

Frequency  $Frequency=Freq$

Dissipation factor  $D=G/(2*PI*Freq*Cp)$

Parallel resistance  $Rp=1/G$

Series capacitance  $C_s = (1 + D^2) * C_p$   
 Reactance  $X = -1 / (2 * \pi * \text{Freq} * C_s)$   
 Series resistance  $R_s = D * \text{abs}(X)$   
 Impedance  $Z = \sqrt{R_s^2 + X^2}$   
 Phase Theta  $= \text{atan}(X / R_s)$

## [X-Y Plot]

X axis: Frequency Freq (LOG)  
 Y1 axis: Gate capacitance (parallel capacitance)  $C_p$  (LINEAR)  
 Y2 axis: Conductance G (LINEAR)

## [List Display]

Frequency Freq  
 Gate capacitance (parallel capacitance)  $C_p$   
 Conductance G  
 Series capacitance  $C_s$   
 Series resistance  $R_s$   
 Parallel resistance  $R_p$   
 Dissipation factor D  
 Reactance X  
 Impedance Z  
 Phase Theta  
 Substrate voltage  $V_{\text{subs}}$

## [Test Output: X-Y Graph]

X axis: Frequency list FreqList (LOG)  
 Y1 axis: Gate capacitance (parallel capacitance) list  $C_p\text{List}$  (LINEAR)  
 Y2 axis: Conductance list GList (LINEAR)

## [Test Output: List Display]

Frequency FreqList  
 Gate capacitance (parallel capacitance)  $C_p\text{List}$   
 Conductance GList  
 Series capacitance  $C_s\text{List}$   
 Series resistance  $R_s\text{List}$   
 Parallel resistance  $R_p\text{List}$   
 Dissipation factor DList  
 Reactance XList  
 Impedance ZList  
 Phase ThetaList  
 Substrate voltage  $V_{\text{subsList}}$

## 10 Structure

### ***10.4 Cgb-Vg 2Freq: MOS capacitor Cgb-Vg characteristics, 2-frequency method (A.01.11)***

[Supported Analyzer]  
B1500A

[Description]

Measures the Gate-Substrate capacitance (Cgb) by using two-frequency method, and plots the Cgb-Vg characteristics.

DC bias output is performed from -VgbStart to -VgbStop in -VgbStep steps.

The Cgb value is given by the following formula. Then C1 and C2 are capacitance, D1 and C2 are dissipation factor measured at the frequency (f1 and f2).

$$C_{gb} = [f1^2 * C1 * (1 + D1^2) - f2^2 * C2 * (1 + D2^2)] / [f2^2 - f1^2]$$

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]

MOS capacitor

Connect Gate to the CMU Low, and Substrate to the CMU High.

[Device Parameters]

Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

FREQ1: Measurement frequency #1

FREQ2: Measurement frequency #2

OscLevel: Measurement signal level

Gate: CMU connected between Gate and channel (CV sweep measurement)

VgbStart: DC bias start voltage

VgbStop: DC bias stop voltage

VgbStep: DC bias step voltage

[Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Parallel capacitance Cp

Dissipation factor D

## [User Function]

Vgb=-Vsubs

## [Display Setup: X-Y Graph]

X axis: Gate voltage Vgb (LINEAR)

Y1 axis: Gate capacitance (parallel capacitance) Cp (LINEAR)

Y2 axis: Dissipation factor D (LINEAR)

## [Display Setup: List Display]

Measurement frequency Freq

Gate voltage Vgb

Gate capacitance (parallel capacitance) Cp

Dissipation factor D

## [Test Output: X-Y Graph]

X axis: Gate voltage VGB (LINEAR)

Y1 axis: Gate capacitance (parallel capacitance) Cgb (LINEAR)

Y2 axis: Gate capacitance (parallel capacitance) Cp\_FREQ1 (LINEAR)

Y3 axis: Gate capacitance (parallel capacitance) Cp\_FREQ2 (LINEAR)

## [Test Output: List Display]

Gate voltage VGB

Gate capacitance (parallel capacitance) Cgb

Gate capacitance (parallel capacitance) Cp\_FREQ1

Gate capacitance (parallel capacitance) Cp\_FREQ2

Dissipation factor D\_FREQ1

Dissipation factor D\_FREQ2

## 10 Structure

### 10.5 Cgb-Vg[2]: MOS capacitor Cgb-Vg characteristics (A.01.11)

#### [Supported Analyzer]

B1500A

#### [Description]

Measures the Gate-Substrate capacitance (Cgb), and plots the Cgb-Vg characteristics.

DC bias output is performed from -VgbStart to -VgbStop in -VgbStep steps.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

#### [Device Under Test]

MOS capacitor

Connect Gate to the CMU Low, and Substrate to the CMU High.

#### [Device Parameters]

Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

#### [Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

Gate: CMU connected between Gate and channel (CV sweep measurement)

VgbStart: DC bias start voltage

VgbStop: DC bias stop voltage

VgbStep: DC bias step voltage

#### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

#### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

#### [User Function]

$PI=3.141592653589$

$D=G/(2*PI*FREQ*Cp)$

$Rp=1/G$

$Cs=(1+D^2)*Cp$

$X=-1/(2*PI*FREQ*Cs)$

$Rs=D*abs(X)$

$Z=sqrt(Rs^2+X^2)$

$Theta=atan(X/Rs)$



$V_{gate} = -V_{subs}$   
 $C_{pPerArea} = C_p / L_g / W_g$   
 $C_{pPerWg} = C_p / W_g$

[X-Y Graph]

X axis: Gate voltage  $V_{gate}$  (LINEAR)  
Y1 axis: Gate capacitance (parallel capacitance)  $C_p$  (LINEAR)  
Y2 axis: Conductance  $G$  (LINEAR)

[List Display]

Gate voltage  $V_{gate}$   
Gate capacitance (parallel capacitance)  $C_p$   
Conductance  $G$   
Series capacitance  $C_s$   
Series resistance  $R_s$   
Parallel resistance  $R_p$   
Dissipation factor  $D$   
Reactance  $X$   
Impedance  $Z$   
Phase  $\Theta$   
Gate-Substrate capacitance per Gate unit area  $C_{pPerArea}$   
Gate-Substrate capacitance per Gate unit width  $C_{pPerWg}$

## 10 Structure

### 10.6 Cj-Freq Log: Cj-f characteristics, junction device (A.01.20)

#### [Supported Analyzer]

B1500A

#### [Description]

Measures the junction capacitance (Cj, linear) vs frequency (f, log) characteristics of a junction device. The measurement frequency is 10 points per decade.

#### [Device Under Test]

Junction device (diode), 2 terminals

Connect CMU High and CMU Low to the anode and cathode respectively.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

#### [Required Modules and Accessories]

Agilent B1520A MFCMU 1 unit

#### [Device Parameters]

L: Junction length

W: Junction width

Temp: Temperature (deg)

#### [Test Parameters]

IntegTime: Integration time

FreqStart: Sweep start frequency, LOG sweep

NoOfDecade: Number of decades for data collection

OscLevel: Measurement signal level

Anode: CMU connected between Anode and Cathode

Vanode: Voltage applied on Anode

#### [Extended Test Parameters]

G\_Min: Minimum transconductance value for graph

G\_Max: Maximum transconductance value for graph

Cp\_Min: Minimum capacitance value for graph

Cp\_Max: Maximum capacitance value for graph

#### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

#### [User Function]

Circular constant  $PI=3.141592653589$

Frequency  $Frequency=Freq$

Dissipation factor  $D=G/(2*PI*Freq*Cp)$

Parallel resistance  $Rp=1/G$

Series capacitance  $Cs=(1+D^2)*Cp$

Reactance  $X = -1/(2\pi \text{Freq} \cdot C_s)$   
 Series resistance  $R_s = D \cdot \text{abs}(X)$   
 Impedance  $Z = \sqrt{R_s^2 + X^2}$   
 Phase Theta  $= \text{atan}(X/R_s)$

## [X-Y Plot]

X axis: Frequency Freq (LOG)  
 Y1 axis: Junction capacitance (parallel capacitance) Cp (LINEAR)  
 Y2 axis: Conductance G (LINEAR)

## [List Display]

Frequency Freq  
 Anode voltage Vanode  
 Junction capacitance (parallel capacitance) Cp  
 Conductance G  
 Series capacitance Cs  
 Series resistance Rs  
 Parallel resistance Rp  
 Dissipation factor D  
 Reactance X  
 Impedance Z  
 Phase Theta

## [Test Output: X-Y Graph]

X axis: Frequency list FreqList (LOG)  
 Y1 axis: Gate capacitance (parallel capacitance) list CpList (LINEAR)  
 Y2 axis: Conductance list GList (LINEAR)

## [Test Output: List Display]

Frequency FreqList  
 Anode voltage VaList  
 Gate capacitance (parallel capacitance) CpList  
 Conductance GList  
 Series capacitance CsList  
 Series resistance RsList  
 Parallel resistance RpList  
 Dissipation factor DList  
 Reactance XList  
 Impedance ZList  
 Phase ThetaList

## 10 Structure

### 10.7 *Cj-V: Junction capacitance Cj-V characteristics (A.01.11)*

#### [Supported Analyzer]

B1500A

#### [Description]

Measures the junction capacitance ( $C_j$ ), and plots the  $C_j$ -V characteristics.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

#### [Device Under Test]

Junction device, diode

#### [Device Parameters]

L: Junction length

W: Junction width

Temp: Temperature

#### [Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

Anode: CMU connected between Anode and Cathode (CV sweep measurement)

VacStart: DC bias start voltage

VacStop: DC bias stop voltage

VacStep: DC bias step voltage

#### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

#### [Measurement Parameters]

Parallel capacitance  $C_p$

Conductance  $G$

#### [User Function]

$PI=3.141592653589$

$D=G/(2*PI*FREQ*C_p)$

$R_p=1/G$

$C_s=(1+D^2)*C_p$

$X=-1/(2*PI*FREQ*C_s)$

$R_s=D*abs(X)$

$Z=sqrt(R_s^2+X^2)$

$Theta=atan(X/R_s)$

$V_{gate}=-V_{subs}$

$C_{pPerArea}=C_p/L/W$

$C_{pPerWg}=C_p/W$

## [X-Y Graph]

X axis: Anode voltage Vanode (LINEAR)

Y1 axis: Junction capacitance (parallel capacitance) Cp (LINEAR)

Y2 axis: Conductance G (LINEAR)

## [List Display]

Anode voltage Vanode

Junction capacitance (parallel capacitance) Cp

Conductance G

Series capacitance Cs

Series resistance Rs

Parallel resistance Rp

Dissipation factor D

Reactance X

Impedance Z

Phase Theta

Junction capacitance per unit area CpPerArea

Junction capacitance per unit width CpPerWg

## 10 Structure

### ***10.8 Diode BVAndCj-V ASU : Diode junction capacitance and breakdown voltage measurement using ASUs (A.01.20)***

[Supported Analyzer]

B1500A

[Description]

Measures the reverse bias junction capacitance and breakdown voltage by using one MFCMU and two sets of the HRSMU/ASU.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]

Diode

[Required Modules and Accessories]

One MFCMU module and two sets of HRSMU/ASU are required.

ASU#1 connections: Output: anode, SMU: HRSMU, AUX: MFCMU High

ASU#2 connections: Output: cathode, SMU: HRSMU, AUX: MFCMU Low

Connection wire must be connected between the CMU Return terminals of ASUs.

Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]

L: Diode length

W: Diode width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

[Test Parameters: for Junction Capacitance Measurements]

AnodeAC: CMU connected to Anode terminal

FREQ: Measurement frequency

OscLevel: Measurement signal level

VBiasStart: DC bias start voltage

VBiasStop: DC bias stop voltage

VBiasStep: DC bias step voltage

[Test Parameters: for Breakdown Voltage Measurements]

AnodeDC: SMU connected to Anode terminal, primary sweep voltage output

VanodeStart: Sweep start voltage for Anode terminal

VanodeStop: Sweep stop voltage for Anode terminal

VanodeStep: Sweep step voltage for Anode terminal

Ianode@BV: Anode current to decide the breakdown

CathodeDC: SMU connected to Cathode terminal, constant voltage output

## [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

AnodeMinRng: Minimum range for the anode current measurement

## [Junction Capacitance Measurements: Measurement Parameters]

Parallel capacitance  $C_p$

Conductance  $G$

## [Junction Capacitance Measurements: X-Y Plot]

X axis: Anode voltage (LINEAR)

Y1 axis: Junction capacitance  $C_p$  (LINEAR)

Y2 axis: Conductance  $G$  (LINEAR)

## [Junction Capacitance Measurements: List Display]

Impedance  $Z$

Phase Theta

Series capacitance  $C_s$

Series resistance  $R_s$

Parallel resistance  $R_p$

Dissipation factor  $D$

Reactance  $X$

Capacitance per junction unit area  $C_{p\_S}$

## [Junction Capacitance Measurements: Parameters Display Area]

Zero bias capacitance value  $C_{j0}$

## [Breakdown Voltage Measurements: Measurement Parameters]

Anode current

For the anode terminal, the SMU current compliance is set to  $I_{anode@BD} * 1.1$ .

## [Breakdown Voltage Measurements: User Function]

Anode current per junction unit area  $I_{anode\_S}$

## [Breakdown Voltage Measurements: X-Y Plot]

X axis: Anode voltage (LINEAR)

Y1 axis: Anode current (LOG)

## [Breakdown Voltage Measurements: Parameters Display Area]

Junction breakdown voltage  $BV$

Zero bias capacitance value  $C_{j0}$

## 10 Structure

### ***10.9 Diode BVAndCj-V SCUU: Diode junction capacitance and breakdown voltage measurement using SCUU (A.01.20)***

[Supported Analyzer]  
B1500A

[Description]

Measures the reverse bias junction capacitance and breakdown voltage by using one MFCMU, two SMUs, and a set of SCUU/GSWU.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]  
Diode

[Required Modules and Accessories]

One MFCMU module, two SMU modules, and a set of SCUU/GSWU are required.

SCUU connections: Output1: anode, Output2: cathode

Connection wire must be connected between the GSWU and the DUT interface High/Low guard lines for the capacitance measurements.

[Device Parameters]

L: Diode length

W: Diode width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

[Test Parameters: for Junction Capacitance Measurements]

AnodeAC: CMU connected to Anode terminal

FREQ: Measurement frequency

OscLevel: Measurement signal level

VBiasStart: DC bias start voltage

VBiasStop: DC bias stop voltage

VBiasStep: DC bias step voltage

[Test Parameters: for Breakdown Voltage Measurements]

AnodeDC: SMU connected to Anode terminal, primary sweep voltage output

VanodeStart: Sweep start voltage for Anode terminal

VanodeStop: Sweep stop voltage for Anode terminal

VanodeStep: Sweep step voltage for Anode terminal

Ianode@BV: Anode current at breakdown

CathodeDC: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]



HoldTime: Hold time  
 DelayTime: Delay time  
 AnodeMinRng: Minimum range for the anode current measurement

[Junction Capacitance Measurements: Measurement Parameters]

Parallel capacitance  $C_p$   
 Conductance  $G$

[Junction Capacitance Measurements: X-Y Plot]

X axis: Anode voltage (LINEAR)  
 Y1 axis: Junction capacitance  $C_p$  (LINEAR)  
 Y2 axis: Conductance  $G$  (LINEAR)

[Junction Capacitance Measurements: List Display]

Impedance  $Z$   
 Phase Theta  
 Series capacitance  $C_s$   
 Series resistance  $R_s$   
 Parallel resistance  $R_p$   
 Dissipation factor  $D$   
 Reactance  $X$   
 Capacitance per junction unit area  $C_{p\_S}$

[Junction Capacitance Measurements: Parameters Display Area]

Zero bias capacitance value  $C_{j0}$

[Breakdown Voltage Measurements: Measurement Parameters]

Anode current  
 For the anode terminal, the SMU current compliance is set to  $I_{anode@BD} * 1.1$ .

[Breakdown Voltage Measurements: User Function]

Anode current per junction unit area  $I_{anode\_S}$

[Breakdown Voltage Measurements: X-Y Plot]

X axis: Anode voltage (LINEAR)  
 Y1 axis: Anode current (LOG)

[Breakdown Voltage Measurements: Parameters Display Area]

Junction breakdown voltage  $BV$   
 Zero bias capacitance value  $C_{j0}$

## 10 Structure

### ***10.10 Ig-Vg Iforce: MOS capacitor Ig-Vg characteristics, current sweep (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures gate current vs gate voltage (Ig-Vg) characteristics of MOS capacitor gate insulator.

[Device Under Test]

MOS capacitor

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate terminal, primary sweep current output

IgStart: Sweep start current for Gate terminal

IgStop: Sweep stop current for Gate terminal

VgLimit: Gate voltage compliance

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

[Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]

Gate voltage Vgate

Substrate current Isubs

[User Function]

IgatePerArea: Gate current per unit gate area  $I_{gatePerArea} = I_{gate} / L_g / W_g$

IsubsPerArea: Substrate current per unit gate area  $I_{subsPerArea} = I_{subs} / L_g / W_g$

[X-Y Plot]

X axis: Gate current Igate (LOG)

Y1 axis: Gate voltage Vgate (LINEAR)

### ***10.11 Ig-Vg Vforce: MOS capacitor Ig-Vg characteristics, voltage sweep (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures gate current vs gate voltage (Ig-Vg) characteristics of MOS capacitor gate insulator.

[Device Under Test]

MOS capacitor

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

IgLimit: Gate current compliance

Subs: SMU connected to Substrate, constant voltage output

Vsubs: Substrate voltage

[Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

GateMinRng: Minimum range for the gate current measurement

SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]

Gate current Igate

Substrate current Isubs

[User Function]

IgatePerArea: Gate current per unit gate area  $I_{gatePerArea} = I_{gate}/L_g/W_g$

IsubsPerArea: Substrate current per unit gate area  $I_{subsPerArea} = I_{subs}/L_g/W_g$

[X-Y Plot]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Gate current Igate (LOG)

[List Display]

Gate voltage Vgate

Gate current Igate

Substrate current Isubs

## 10 Structure

### ***10.12 Interconnect CouplingCap: Interconnection capacitance (A.01.11)***

#### [Supported Analyzer]

B1500A

#### [Application]

Measures the interconnection capacitance, and plots the C-V characteristics.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

#### [Device Under Test]

Capacitor generated between two interconnections in the same layer

#### [Device Parameters]

L: Metal length

Temp: Temperature

#### [Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

MetalA: CMU connected between MetalA and MetalB (CV sweep measurement)

Vstart: DC bias start voltage

Vstop: DC bias stop voltage

Vstep: DC bias step voltage

#### [Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

#### [Measurement Parameters]

Parallel capacitance Cp

Conductance G

#### [User Function]

$PI=3.141592653589$

$D=G/(2*PI*FREQ*Cp)$

$Rp=1/G$

$Cs=(1+D^2)*Cp$

$X=-1/(2*PI*FREQ*Cs)$

$Rs=D*abs(X)$

$Z=sqrt(Rs^2+X^2)$

$Theta=atan(X/Rs)$

$CsPerLength=Cs/L$

$CpPerLength=Cp/L$

#### [X-Y Graph]

X axis: DC bias VmetalA (LINEAR)  
Y1 axis: Interconnection capacitance (parallel capacitance) Cp (LINEAR)  
Y2 axis: Dissipation factor D (LINEAR)  
Y3 axis: Conductance G (LINEAR)

[List Display]

Measurement frequency Freq  
DC bias VmetalA  
Interconnection capacitance (parallel capacitance) Cp  
Conductance G  
Series capacitance Cs  
Series resistance Rs  
Parallel resistance Rp  
Dissipation factor D  
Reactance X  
Impedance Z  
Phase Theta  
Cs per unit length CpPerLength  
Cp per unit length CpPerLength

## 10 Structure

### ***10.13 Interconnect OverlapCap: Layer to layer film capacitance (A.01.11)***

[Supported Analyzer]

B1500A

[Application]

Measures the capacitance of the film between two interconnection layers, and plots the C-V characteristics.

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]

Film capacitor generated between two interconnection layers

[Device Parameters]

L: Metal length

W: Metal width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

FREQ: Measurement frequency

OscLevel: Measurement signal level

MetalA: CMU connected between MetalA and MetalB (CV sweep measurement)

Vstart: DC bias start voltage

Vstop: DC bias stop voltage

Vstep: DC bias step voltage

[Extended Test Parameters]

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

Parallel capacitance Cp

Conductance G

[User Function]

$PI=3.141592653589$

$D=G/(2*PI*FREQ*Cp)$

$Rp=1/G$

$Cs=(1+D^2)*Cp$

$X=-1/(2*PI*FREQ*Cs)$

$Rs=D*abs(X)$

$Z=sqrt(Rs^2+X^2)$

$Theta=atan(X/Rs)$

[X-Y Graph]

X axis: DC bias VmetalA (LINEAR)

Y1 axis: Film capacitance (parallel capacitance)  $C_p$  (LINEAR)

Y2 axis: Dissipation factor  $D$  (LINEAR)

Y3 axis: Conductance  $G$  (LINEAR)

[List Display]

Measurement frequency  $F_{req}$

DC bias  $V_{metalA}$

Film capacitance (parallel capacitance)  $C_p$

Conductance  $G$

Series capacitance  $C_s$

Series resistance  $R_s$

Parallel resistance  $R_p$

Dissipation factor  $D$

Reactance  $X$

Impedance  $Z$

Phase  $\Theta$

## 10 Structure

### ***10.14 Junction BV: Junction device breakdown voltage (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the junction device reverse bias characteristics, and extracts the breakdown voltage.

[Device Under Test]

Junction device, diode

[Device Parameters]

L: Junction length

W: Junction width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Ianode@BV: Anode current to decide the breakdown

Anode: SMU connected to Anode terminal, primary sweep voltage output

VanodeStart: Sweep start voltage for Anode terminal

VanodeStop: Sweep stop voltage for Anode terminal

VanodeStep: Sweep step voltage for Anode terminal

Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]

Vcathode: Cathode voltage

HoldTime: Hold time

DelayTime: Delay time

AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]

Anode current Ianode

Cathode current Icathode

[User Function]

IanodePerArea=Ianode/L/W

IcathodePerArea=Icathode/L/W

[Analysis Function]

BV=@L1X (X intercept of Line1)

[X-Y Plot]

X axis: Anode voltage Vanode (LINEAR)

Y1 axis: Anode current Ianode (LINEAR)

Y2 axis: Anode current Ianode (LOG)

Y3 axis: Cathode current Icathode (LINEAR)

Y4 axis: Cathode current Icathode (LOG)



[List Display]

Anode voltage Vanode

Anode current Ianode

Anode current per unit area IanodePerArea

Cathode current Icathode

Cathode current per unit area IcathodePerArea

[Parameters Display Area]

Junction breakdown voltage BV

[Auto Analysis]

Line1: Vertical line through Y1 data at Ianode=Ianode@BV

## 10 Structure

### 10.15 Junction DcParam: Junction device DC parameters ( $I_s, N, R_s$ ) (A.01.20)

#### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

#### [Description]

Measures the forward bias anode voltage vs anode current characteristics, and extracts the slope minimum value ( $N\_Min$ ), the reverse direction saturation current minimum value ( $I_{sMin}$ ,  $I_{sMin2}$ ), and the series resistance ( $R_s$ ).

#### [Device Under Test]

Junction device, diode

#### [Device Parameters]

L: Junction length

W: Junction width

Temp: Temperature

Imax: Current compliance

#### [Test Parameters]

IntegTime: Integration time

Anode: SMU connected to Anode terminal, primary sweep voltage output

VanodeStart: Sweep start voltage for Anode terminal

VanodeStop: Sweep stop voltage for Anode terminal

VanodeStep: Sweep step voltage for Anode terminal

Cathode: SMU connected to Cathode terminal, constant voltage output

#### [Extended Test Parameters]

Vcathode: Cathode voltage

HoldTime: Hold time

DelayTime: Delay time

AnodeMinRng: Minimum range for the anode current measurement

#### [Measurement Parameters]

Anode current  $I_{anode}$

Cathode current  $I_{cathode}$

#### [User Function]

$I_{anodePerArea} = I_{anode} / L / W$

$I_{cathodePerArea} = I_{cathode} / L / W$

$V_t = k * (Temp + 273.15) / q$

$N = 1 / V_t / (\text{diff}(\log(I_{anode}), Vanode))$

$N\_Min = \min(N)$

$Slope = \text{diff}(\log(I_{anode}), Vanode)$

$I_s = \log(I_{anode}) - Slope * Vanode$

$I_{sMin} = \min(I_s)$

$SmplNum = \text{abs}((VanodeStop - VanodeStart) / VanodeStep) + 1$

$I\_Rs = \text{at}(I_{anode}, SmplNum, 1)$

$\Delta V\_Rs = VanodeStop - N\_Min * V_t * \log(I\_Rs / I_{sMin})$

$R_s = \Delta V\_Rs / I\_Rs$

#### [Analysis Function]

$I_{sMin2} = @L1Y$  (Y intercept of Line1)

## [X-Y Plot]

X axis: Anode voltage Vanode (LINEAR)

Y1 axis: Anode current Ianode (LOG)

Y2 axis: Anode current Ianode (LINEAR)

Y3 axis: Slope N (LINEAR)

## [Parameters Display Area]

Slope minimum value N\_Min

Reverse direction saturation current minimum value IsMin

Reverse direction saturation current minimum value IsMin2

Series resistance Rs

## [Auto Analysis]

Line1: Tangent line through Y1 data at Slope=max(Slope)

## 10 Structure

### ***10.16 Junction IV Fwd: Diode forward bias characteristics (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the forward bias anode voltage vs anode current characteristics.

[Device Under Test]

Junction device, diode

[Device Parameters]

L: Junction length

W: Junction width

Temp: Temperature

I<sub>max</sub>: Current compliance

[Test Parameters]

IntegTime: Integration time

Anode: SMU connected to Anode terminal, primary sweep voltage output

VanodeStart: Sweep start voltage for Anode terminal

VanodeStop: Sweep stop voltage for Anode terminal

VanodeStep: Sweep step voltage for Anode terminal

Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]

Vcathode: Cathode voltage

HoldTime: Hold time

DelayTime: Delay time

AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]

Anode current I<sub>anode</sub>

Cathode current I<sub>cathode</sub>

[User Function]

I<sub>anodePerArea</sub>=I<sub>anode</sub>/L/W

I<sub>cathodePerArea</sub>=I<sub>cathode</sub>/L/W

[X-Y Plot]

X axis: Anode voltage Vanode (LINEAR)

Y1 axis: Anode current I<sub>anode</sub> (LINEAR)

Y2 axis: Anode current I<sub>anode</sub> (LOG)

**10.17 Junction IV Rev: Diode reverse bias characteristics (A.01.20)****[Supported Analyzer]**

B1500A, 4155B, 4155C, 4156B, 4156C

**[Description]**

Measures the reverse bias anode voltage vs anode current characteristics.

**[Device Under Test]**

Junction device, diode

**[Device Parameters]**

L: Junction length

W: Junction width

Temp: Temperature

**[Test Parameters]**

IntegTime: Integration time

Anode: SMU connected to Anode terminal, primary sweep voltage output

VanodeStart: Sweep start voltage for Anode terminal

VanodeStop: Sweep stop voltage for Anode terminal

VanodeStep: Sweep step voltage for Anode terminal

IanodeLimit: Anode current compliance

Cathode: SMU connected to Cathode terminal, constant voltage output

**[Extended Test Parameters]**

Vcathode: Cathode voltage

HoldTime: Hold time

DelayTime: Delay time

AnodeMinRng: Minimum range for the anode current measurement

**[Measurement Parameters]**

Anode current Ianode

Cathode current Icathode

**[User Function]** $I_{anodePerArea} = I_{anode} / L / W$  $I_{cathodePerArea} = I_{cathode} / L / W$ **[X-Y Plot]**

X axis: Anode voltage Vanode (LINEAR)

Y1 axis: Anode current Ianode (LOG)

Y2 axis: Cathode current Icathode (LOG)

## 10 Structure

### 10.18 QSCV[2]: C-Vg, Ig-Vg (2-terminal) (A.03.00)

[Supported Analyzer]

B1500A

[Description]

Measures the oxide film capacitance of a MOSFET by using the quasi-static CV method, and plots the C-V characteristics.

To obtain the measurement data after the capacitance offset cancel, perform the QSCV C Offset Meas application test before this test.

[Device Under Test]

MOS capacitance, 2 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature

[Test Parameters]

Gate: SMU connected to Gate terminal, primary sweep (QSCV) voltage output

Subs: SMU connected to Substrate terminal, constant voltage output

IMeasSMU: SMU to measure current and capacitance, connected to Gate terminal or Substrate terminal

Vstart: Sweep start voltage

Vstop: Sweep stop voltage

Vstep: Sweep step voltage

QSCVMeasV: QSCV measurement voltage

I\_Comp: Current compliance

LeakCompen: Leakage current compensation on/off

MeasRange: Current measurement range used for the QSCV measurement, fixed range

Integ\_C: Integration time for the capacitance measurement

Integ\_L: Integration time for the leakage current measurement

HoldTime: Hold time

DelayTime: Delay time

IOffsetCancel: QSCV smart operation enable/disable

IOffsetSink: SMU to perform QSCV smart operation, connected to terminal which connected to IMeasSMU

QSCV smart operation is effective for QSCV measurements with a large leakage current. The SMU set as the IOffsetSink performs the current force operation to minimize the measurement error caused by an offset current.

[Extended Test Parameters]

StepDelay: Step delay time

OutputRange: Ranging type for voltage output

SwpMode: Sweep mode

VCompSinkSMU: Voltage compliance of SMU for QSCV smart operation

Cmin: Minimum capacitance value for graph

Cmax: Maximum capacitance value for graph

IgMin: Minimum leakage current value for graph

IgMax: Maximum leakage current value for graph

[Measurement parameters]

Capacitance C

Leakage current  $I_{gLeak}$

[X-Y Graph]

X axis: Gate Voltage  $V_g$  (LINEAR)

Y1 axis: Capacitance C (LINEAR)

Y2 axis: Leakage current  $I_g$  (LINEAR)

[List Display]

Gate voltage  $V_g$

Capacitance C

Leakage current  $I_g$

## 10 Structure

### ***10.19 QSCV C Offset Meas: Offset capacitance measurement (A.03.00)***

[Supported Analyzer]

B1500A

[Description]

Measures the offset capacitance of the cables and DUT interface by using the QSCV method when measurement terminals are open.

[Device Under Test]

MOS capacitance, 2 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature

[Test Parameters]

IMeasSMU: SMU to measure current and capacitance, connected to Gate terminal or Substrate terminal

MeasRange: Current measurement range used for the QSCV measurement, fixed range

Integ\_C: Integration time for the capacitance measurement

Integ\_L: Integration time for the leakage current measurement

HoldTime: Hold time

DelayTime: Delay time

[Extended Test Parameters]

StepDelay: Step delay time

[Measurement parameters]

Capacitance C

[List Display]

Capacitance C



## ***10.20 Rdiff-I kelvin: Diffusion resistor R-I characteristics, Kelvin connection (A.01.11)***

### [Supported Analyzer]

B1500A

### [Description]

Measures the resistance vs current characteristics (R-I characteristic).

### [Device Under Test]

Diffusion resistor, 3 terminals

Connect the Port1 and VM1 modules to a terminal, the Port2 and VM2 modules to the other terminal.

### [Device Parameters]

Polarity: Ntype (SMUs force the specified value) or Ptype (SMUs force the negative specified value).

L: Resistor length

W: Resistor width

Temp: Temperature

### [Test Parameters]

IntegTime: Integration time

Port1: SMU connected to resistor, primary sweep current output

I1Start: Primary sweep start current

I1Stop: Primary sweep stop current

I1Step: Primary sweep step current

V1Limit: Port1 voltage compliance

Subs: SMU connected to substrate, secondary sweep voltage output

VsubsStart: Secondary sweep start voltage

VsubsStop: Secondary sweep stop voltage

VsubsStep: Secondary sweep step voltage

IsubsLimit: Subs current compliance

Port2: SMU connected to resistor, constant voltage output

VM1: SMU connected to resistor, constant current output

VM2: SMU connected to resistor, constant current output

### [Extended Test Parameters]

V2: Port2 output voltage

IM1: VM1 output current

IM2: VM2 output current

HoldTime: Hold time

DelayTime: Delay time

### [Measurement Parameters]

Port1 measurement voltage V1

VM1 measurement voltage Vm1

VM2 measurement voltage Vm2

### [User Function]

Voltage between terminals  $\Delta V = V_{m1} - V_{m2}$

Resistance  $R = \Delta V / I_1$

Sheet resistance  $R_{sheet} = R * W / L$

### [X-Y Graph]

## 10 Structure

X axis: Port1 output current I1 (LINEAR)

Y1 axis: Resistance R (LINEAR)

Y2 axis: Voltage between terminals DeltaV (LINEAR)

[List Display]

Port1 output current I1

Port1 measurement voltage V1

Subs output voltage Vsubs

Voltage between terminals DeltaV

Resistance R

Sheet resistance Rsheet

**10.21 Rdiff-I: Diffusion resistor R-I characteristics (A.01.11)****[Supported Analyzer]**

B1500A, 4155B, 4155C, 4156B, 4156C

**[Description]**

Measures the resistance vs current characteristics (R-I characteristic).

**[Device Under Test]**

Diffusion resistor, 3 terminals

**[Device Parameters]**

Polarity: Ntype (SMUs force the specified value) or Ptype (SMUs force the negative specified value).

L: Resistor length

W: Resistor width

Temp: Temperature

**[Test Parameters]**

IntegTime: Integration time

Port1: SMU connected to resistor, primary sweep current output

I1Start: Primary sweep start current

I1Stop: Primary sweep stop current

I1Step: Primary sweep step current

V1Limit: Port1 voltage compliance

Subs: SMU connected to substrate, secondary sweep voltage output

VsubsStart: Secondary sweep start voltage

VsubsStop: Secondary sweep stop voltage

VsubsStep: Secondary sweep step voltage

IsubsLimit: Subs current compliance

Port2: SMU connected to resistor, constant voltage output

**[Extended Test Parameters]**

V2: Port2 output voltage

HoldTime: Hold time

DelayTime: Delay time

**[Measurement Parameters]**

Port1 measurement voltage V1

**[User Function]**

Resistance  $R = V1/I1$

Sheet resistance  $R_{sheet} = R * W/L$

**[X-Y Graph]**

X axis: Port1 output current I1 (LINEAR)

Y1 axis: Port1 measurement voltage V1 (LINEAR)

Y2 axis: Resistance R (LINEAR)

**[List Display]**

Port1 output current I1

Port1 measurement voltage V1

Resistance R

Sheet resistance  $R_{sheet}$

## 10 Structure

### ***10.22 Rdiff-V kelvin: Diffusion resistor R-V characteristics, Kelvin connection (A.01.20)***

[Supported Analyzer]  
B1500A

[Description]  
Measures the resistance vs voltage characteristics (R-V characteristic).

[Device Under Test]  
Diffusion resistor, 3 terminals  
Connect the Port1 and VM1 modules to a terminal, the Port2 and VM2 modules to the other terminal.

[Device Parameters]  
Polarity: Ntype (SMUs force the specified value) or Ptype (SMUs force the negative specified value).  
L: Resistor length  
W: Resistor width  
Temp: Temperature

[Test Parameters]  
IntegTime: Integration time  
Port1: SMU connected to resistor, primary sweep voltage output  
V1Start: Primary sweep start voltage  
V1Stop: Primary sweep stop voltage  
V1Step: Primary sweep step voltage  
I1Limit: Port1 current compliance  
Subs: SMU connected to substrate, secondary sweep voltage output  
VsubsStart: Secondary sweep start voltage  
VsubsStop: Secondary sweep stop voltage  
VsubsStep: Secondary sweep step voltage  
IsubsLimit: Subs current compliance  
Port2: SMU connected to resistor, constant voltage output  
VM1: SMU connected to resistor, constant current output  
VM2: SMU connected to resistor, constant current output

[Extended Test Parameters]  
V2: Port2 output voltage  
IM1: VM1 output current  
IM2: VM2 output current  
HoldTime: Hold time  
DelayTime: Delay time  
Port1MinRng: Minimum range for the port1 current measurement

[Measurement Parameters]  
Port1 measurement current I1  
VM1 measurement voltage Vm1  
VM2 measurement voltage Vm2

[User Function]  
Voltage between terminals  $\Delta V = V_{m1} - V_{m2}$   
Resistance  $R = \Delta V / I_1$   
Sheet resistance  $R_{sheet} = R * W / L$

**[X-Y Graph]**

X axis: Port1 output voltage V1 (LINEAR)

Y1 axis: Port1 measurement current I1 (LINEAR)

Y2 axis: Resistance R (LINEAR)

**[List Display]**

Port1 output voltage V1

Voltage between terminals DeltaV

Port1 measurement current I1

Resistance R

Sheet resistance Rsheet

## 10 Structure

### ***10.23 Rdiff-V: Diffusion resistor R-V characteristics (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the resistance vs voltage characteristics (R-V characteristic).

[Device Under Test]

Diffusion resistor, 3 terminals

[Device Parameters]

Polarity: Ntype (SMUs force the specified value) or Ptype (SMUs force the negative specified value).

L: Resistor length

W: Resistor width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Port1: SMU connected to resistor, primary sweep voltage output

V1Start: Primary sweep start voltage

V1Stop: Primary sweep stop voltage

V1Step: Primary sweep step voltage

I1Limit: Port1 current compliance

Subs: SMU connected to substrate, secondary sweep voltage output

VsubsStart: Secondary sweep start voltage

VsubsStop: Secondary sweep stop voltage

VsubsStep: Secondary sweep step voltage

IsubsLimit: Subs current compliance

Port2: SMU connected to resistor, constant voltage output

[Extended Test Parameters]

V2: Port2 output voltage

HoldTime: Hold time

DelayTime: Delay time

Port1MinRng: Minimum range for the port1 current measurement

[Measurement Parameters]

Port1 measurement current I1

[User Function]

Resistance  $R = V1/I1$

Sheet resistance  $R_{sheet} = R * W/L$

[X-Y Graph]

X axis: Port1 output voltage V1 (LINEAR)

Y1 axis: Resistance R (LINEAR)

Y2 axis: Port1 measurement current I1 (LINEAR)

[List Display]

Port1 output voltage V1

Port1 measurement current I1

Resistance R

Sheet resistance Rsheet

## ***10.24 R-I DVM: Low resistance measurement using 3458A, current force (A.01.20)***

### [Supported Analyzer]

B1500A

### [Description]

Measures the low resistance of a 2-terminal device. SMU forces current and DVM (3458A) measures voltage between terminals. Resistance is calculated from the output value of a current and measured value of a voltage between terminals. For the purpose of excluding thermoelectric power, this test is designed to measure resistance again by switching the direction of voltage and to get the average value of resistance as a test result.

### [Device Under Test]

Resistor element, 2 terminals

### [Required Modules and Accessories]

Agilent 3458A digital multimeter 1 unit  
 GPIB cable

### [Required Test Definition]

Measure Diff-V

### [Device Parameters]

L: Resistor length  
 W: Resistor width  
 Temp: Temperature (deg)

### [Test Parameters]

IntegTime: Integration time  
 Port1: SMU connected to resistor, current output  
 I1: Applied current  
 V1Limit: Port1 voltage compliance  
 Port2: SMU connected to resistor, constant voltage output  
 GPIB\_Adr: GPIB address of DVM

### [Extended Test Parameters]

V2: Port2 output voltage  
 HoldTime: Hold time  
 DelayTime: Delay time  
 PortMinRng: Minimum range for port current measurement

### [Measurement Parameters]

[Measurement Parameters for first measurement (Vpos)]  
 Vport1: Port1 voltage

[Measurement Parameters for second measurement (Vneg)]  
 Vport2: Port2 voltage

### [X-Y Plot]

[X-Y Plot for first measurement (Vpos)]  
 X axis: Applied current Iport1 (LINEAR)  
 Y1 axis: Measured voltage Vport1 (LINEAR)

## 10 Structure

[X-Y Plot for second measurement (Vneg)]  
X axis: Applied current Iport2 (LINEAR)  
Y1 axis: Measured voltage Vport2 (LINEAR)

[List Display]

[X-Y Plot for first measurement (Vpos)]  
Applied current Iport1  
Measured voltage Vport1

[X-Y Plot for second measurement (Vneg)]  
Applied current Iport2  
Measured voltage Vport2

[Test Output: X-Y Graph]

X axis: Applied current IsmuList (LINEAR)  
Y1 axis: DVM measurement result voltage VdvmList (LINEAR)  
Y2 axis: Measured voltage VsmuList (LINEAR)  
Y3 axis: Resistance value (LINEAR)

[Test Output: List Display]

IsmuList: Applied current  
VsmuList: Measured voltage  
VdvmList: DVM measured voltage  
RList: Resistance value

[Test Output: Parameters]

Rav: Average resistance value of 2 measurements



**10.25 R-I kelvin: Resistor R-I characteristics, Kelvin connection (A.01.11)****[Supported Analyzer]**

B1500A, 4155B, 4155C, 4156B, 4156C

**[Description]**

Measures the resistance vs current characteristics (R-I characteristic).

**[Device Under Test]**

Resistor, 2 terminals

Connect the Port1 and VM1 modules to a terminal, the Port2 and VM2 modules to the other terminal.

**[Device Parameters]**

L: Resistor length

W: Resistor width

Temp: Temperature

**[Test Parameters]**

IntegTime: Integration time

Port1: SMU connected to resistor, primary sweep current output

I1Start: Sweep start current

I1Stop: Sweep stop current

I1Step: Sweep step current

V1Limit: Port1 voltage compliance

Port2: SMU connected to resistor, constant voltage output

VM1: SMU connected to resistor, constant current output

VM2: SMU connected to resistor, constant current output

**[Extended Test Parameters]**

V2: Port2 output voltage

IM1: VM1 output current

IM2: VM2 output current

HoldTime: Hold time

DelayTime: Delay time

**[Measurement Parameters]**

Port1 measurement voltage V1

VM1 measurement voltage Vm1

VM2 measurement voltage Vm2

**[User Function]**

Voltage between terminals  $\Delta V = V_{m1} - V_{m2}$

Resistance  $R = \Delta V / I_1$

Sheet resistance  $R_{sheet} = R * W / L$

**[X-Y Graph]**

X axis: Port1 output current I1 (LINEAR)

Y1 axis: Resistance R (LINEAR)

Y2 axis: Voltage between terminals  $\Delta V$  (LINEAR)

## 10 Structure

[List Display]

Port1 output current I1

Port1 measurement voltage V1

Resistance R

Voltage between terminals DeltaV

**10.26 R-I: Resistor R-I characteristics (A.01.11)**

## [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

## [Description]

Measures the resistance vs current characteristics (R-I characteristic).

## [Device Under Test]

Resistor, 2 terminals

## [Device Parameters]

L: Resistor length

W: Resistor width

Temp: Temperature

## [Test Parameters]

IntegTime: Integration time

Port1: SMU connected to resistor, primary sweep current output

I1Start: Sweep start current

I1Stop: Sweep stop current

I1Step: Sweep step current

V1Limit: Port1 voltage compliance

Port2: SMU connected to resistor, constant voltage output

## [Extended Test Parameters]

V2: Port2 output voltage

HoldTime: Hold time

DelayTime: Delay time

## [Measurement Parameters]

Port1 measurement voltage V1

## [User Function]

Resistance  $R = V1/I1$ Sheet resistance  $R_{sheet} = R * W/L$ 

## [X-Y Graph]

X axis: Port1 output current I1 (LINEAR)

Y1 axis: Port1 measurement voltage V1 (LINEAR)

Y2 axis: Resistance R (LINEAR)

## [List Display]

Port1 output current I1

Port1 measurement voltage V1

Resistance R

Sheet resistance  $R_{sheet}$

## 10 Structure

### ***10.27 R-V DVM: Low resistance measurement using 3458A, voltage force (A.01.20)***

#### [Supported Analyzer]

B1500A

#### [Description]

Measures the low resistance of a 2-terminal device. SMU forces voltage and measures current, and DVM (3458A) measures voltage between terminals. Resistance is calculated from the measured value of a current and that of a voltage between terminals. For the purpose of excluding thermoelectric power, this test is designed to measure resistance again by switching the direction of voltage and to get the average value of resistance as a test result.

#### [Device Under Test]

Resistor element, 2 terminals

#### [Required Modules and Accessories]

Agilent 3458A digital multimeter 1 unit  
GPIB cable

#### [Required Test Definition]

Measure Diff-V

#### [Device Parameters]

L: Resistor length  
W: Resistor width  
Temp: Temperature (deg)

#### [Test Parameters]

IntegTime: Integration time  
Port1: SMU connected to resistor, voltage output  
V1: Applied voltage  
I1Limit: Port1 current compliance  
Port2: SMU connected to resistor, constant voltage output  
GPIB-Adr: GPIB address of DVM

#### [Extended Test Parameters]

V2: Output voltage  
HoldTime: Hold time  
DelayTime: Delay time  
PortMinRng: Minimum range for port current measurement

#### [Measurement Parameters]

[Measurement Parameters for first measurement (Vpos)]

Iport2: Measured current

[Measurement Parameters for second measurement (Vneg)]

Iport1: Measured current

#### [X-Y Plot]

[X-Y Plot for first measurement (Vpos)]

X axis: Applied voltage on Port1 Vport1 (LINEAR)

Y1 axis: Measured current Iport2 (LINEAR)

[X-Y Plot for second measurement (Vneg)]  
X axis: Applied voltage on Port2 Vport2 (LINEAR)  
Y1 axis: Measured current Iport1 (LINEAR)

[List Display]

[X-Y Plot for first measurement (Vpos)]  
Applied voltage Vport1  
Measured current Iport2

[X-Y Plot for second measurement (Vneg)]  
Applied voltage Vport2  
Measured current Iport1

[Test Output: X-Y Graph]

X axis: Applied voltage VsmuList (LINEAR)  
Y1 axis: DVM measurement result voltage VdvmList (LINEAR)  
Y2 axis: Measured current IsmuList (LINEAR)  
Y3 axis: Resistance value RList (LINEAR)

[Test Output: List Display]

VdvmList: DVM measured voltage  
IsmuList: Measured current  
RList: Resistance value

[Test Output: Parameters]

Rav: Average resistance value of 2 measurements

## 10 Structure

### ***10.28 R-V kelvin: Resistor R-V characteristics, Kelvin connection (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the resistance vs voltage characteristics (R-V characteristic).

[Device Under Test]

Resistor, 2 terminals

Connect the Port1 and VM1 modules to a terminal, the Port2 and VM2 modules to the other terminal.

[Device Parameters]

L: Resistor length

W: Resistor width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Port1: SMU connected to resistor, primary sweep voltage output

V1Start: Sweep start voltage

V1Stop: Sweep stop voltage

V1Step: Sweep step voltage

I1Limit: Port1 current compliance

Port2: SMU connected to resistor, constant voltage output

VM1: SMU connected to resistor, constant current output

VM2: SMU connected to resistor, constant current output

[Extended Test Parameters]

V2: Port2 output voltage

IM1: VM1 output current

IM2: VM2 output current

HoldTime: Hold time

DelayTime: Delay time

Port1MinRng: Minimum range for the port1 current measurement

[Measurement Parameters]

Port1 measurement current I1

VM1 measurement voltage Vm1

VM2 measurement voltage Vm2

[User Function]

Voltage between terminals  $\Delta V = V_{m1} - V_{m2}$

Resistance  $R = \Delta V / I_1$

Sheet resistance  $R_{sheet} = R * W / L$

[X-Y Graph]

X axis: Port1 output voltage V1 (LINEAR)

Y1 axis: Resistance R (LINEAR)

Y2 axis: Port1 measurement current I1 (LINEAR)

[List Display]

Port1 output voltage V1

Voltage between terminals  $\Delta V$

Port1 measurement current I1  
Resistance R  
Sheet resistance Rsheet

## 10 Structure

### ***10.29 R-V: Resistor R-V characteristics (A.01.20)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the resistance vs voltage characteristics (R-V characteristic).

[Device Under Test]

Resistor, 2 terminals

[Device Parameters]

L: Resistor length

W: Resistor width

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Port1: SMU connected to resistor, primary sweep voltage output

V1Start: Sweep start voltage

V1Stop: Sweep stop voltage

V1Step: Sweep step voltage

I1Limit: Port1 current compliance

Port2: SMU connected to resistor, constant voltage output

[Extended Test Parameters]

V2: Port2 output voltage

HoldTime: Hold time

DelayTime: Delay time

Port1MinRng: Minimum range for the port1 current measurement

[Measurement Parameters]

Port1 measurement current I1

[User Function]

Resistance  $R = V1/I1$

Sheet resistance  $R_{sheet} = R * W/L$

[X-Y Graph]

X axis: Port1 output voltage V1 (LINEAR)

Y1 axis: Resistance R (LINEAR)

Y2 axis: Port1 measurement current I1 (LINEAR)

[List Display]

Port1 output voltage V1

Port1 measurement current I1

Resistance R

Sheet resistance  $R_{sheet}$



### ***10.30 VanDerPauw Square: Van Der Pauw pattern sheet resistance (A.01.11)***

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the sheet resistance of the Van Der Pauw pattern, and plots the sheet resistance vs input current characteristics.

[Device Under Test]

Van Der Pauw pattern, 4 terminals

[Device Parameters]

Temp: Temperature

[Test Parameters]

IntegTime: Integration time

Port1: SMU connected to pattern, primary sweep current output

I1Start: Sweep start current

I1Stop: Sweep stop current

I1Step: Sweep step current

V1Limit: Port1 voltage compliance

Port2: SMU connected to pattern, constant voltage output

VM1: SMU connected to pattern, constant current output

VM2: SMU connected to pattern, constant current output

[Extended Test Parameters]

V2: Port2 output voltage

IM1: VM1 output current

IM2: VM2 output current

HoldTime: Hold time

DelayTime: Delay time

[Measurement Parameters]

VM1 measurement voltage Vm1

VM2 measurement voltage Vm2

[User Function]

Voltage between terminals  $\Delta V = V_{m1} - V_{m2}$

Sheet resistance  $R_{sheet} = (3.141592 / \log(2)) * (\Delta V / I1)$

[X-Y Graph]

X axis: Port1 output current I1 (LINEAR)

Y1 axis: Voltage between terminals  $\Delta V$  (LINEAR)

Y2 axis: Sheet resistance  $R_{sheet}$  (LINEAR)

[List Display]

Port1 output current I1

Voltage between terminals  $\Delta V$

Sheet resistance  $R_{sheet}$



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**11**            **TFT**

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## 11 TFT

1. TFT Id-Vd: TFT Id-Vd characteristics (A.01.20)
2. TFT Id-Vg: TFT Id-Vg characteristics (A.01.20)

### 11.1 TFT Id-Vd: TFT Id-Vd characteristics (A.01.20)

[Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

[Description]

Measures the drain current vs drain voltage characteristic of TFT.

[Device Under Test]

Thin Film Transistor, 3 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

[Test Parameters]

IntegTime: Integration time

Drain: SMU connected to Drain terminal, primary sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

Gate: SMU connected to Gate terminal, secondary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]

Vs: Source voltage

IgLimit: Gate current compliance

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]

Drain current Idrain

[User Function]

gds: Output conductance  $gds = \text{diff}(\text{Idrain}, \text{Vdrain})$

Rds: Output resistance  $Rds = 1/gds$

[X-Y Graph]

X axis: Drain voltage Vdrain (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

[List Display]

Drain voltage Vdrain

Gate voltage Vgate

Drain current Idrain

Output conductance gds

Output resistance Rds

## 11 TFT

### 11.2 TFT Id-Vg: TFT Id-Vg characteristics (A.01.20)

#### [Supported Analyzer]

B1500A, 4155B, 4155C, 4156B, 4156C

#### [Description]

Measures the drain current vs gate voltage characteristics of TFT.

#### [Device Under Test]

Thin Film Transistor, 3 terminals

#### [Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).

Lg: Gate length

Wg: Gate width

Temp: Temperature

IdMax: Drain current compliance

#### [Test Parameters]

IntegTime: Integration time

Gate: SMU connected to Gate terminal, primary sweep voltage output

VgStart: Sweep start voltage for Gate terminal

VgStop: Sweep stop voltage for Gate terminal

VgStep: Sweep step voltage for Gate terminal

IgLimit: Gate current compliance

Drain: SMU connected to Drain terminal, secondary sweep voltage output

VdStart: Sweep start voltage for Drain terminal

VdStop: Sweep stop voltage for Drain terminal

VdStep: Sweep step voltage for Drain terminal

Source: SMU connected to Source terminal, constant voltage output

#### [Extended Test Parameters]

Vs: Source voltage

HoldTime: Hold time

DelayTime: Delay time

DrainMinRng: Minimum range for the drain current measurement

#### [Measurement Parameters]

Drain current Idrain

#### [User Function]

IdrainPerWg: Drain current per unit gate width  $\text{IdrainPerWg} = \text{Idrain} / \text{Wg}$

gm: Transconductance  $\text{gm} = \text{diff}(\text{Idrain}, \text{Vgate})$

gmPerWg: Transconductance per unit gate width  $\text{gmPerWg} = \text{diff}(\text{IdrainPerWg}, \text{Vgate})$

#### [X-Y Graph]

X axis: Gate voltage Vgate (LINEAR)

Y1 axis: Drain current Idrain (LINEAR)

Y2 axis: Drain current Idrain (LOG)

Y3 axis: Transconductance gm (LINEAR)

#### [List Display]

Gate voltage Vgate

Drain voltage Vdrain

Drain current  $I_{\text{drain}}$

Transconductance  $g_m$

Drain current per unit gate width  $I_{\text{drainPerWg}}$

Transconductance per unit gate width  $g_{m\text{PerWg}}$







## 12 Utility

- |                       |   |
|-----------------------|---|
| 1. ForcePG1:          | PG Output1 (A.01.20)                      |
| 2. ForcePG2:          | PG Output2 (A.01.20)                      |
| 3. ForcePG2P:         | PG Output1/Output2 (A.01.20)              |
| 4. ForcePG12:         | PG Output1/Output2 (A.01.20)              |
| 5. ForcePG:           | PG OutputX (A.01.20)                      |
| 6. ForcePGC:          | PG Output1 Continuous Output (A.01.20)    |
| 7. Measure Diff-V:    | Voltage measurement by 3458A (A.01.20)    |
| 8. QSCV C Offset Meas | Offset capacitance measurement            |
| 9. ResetPG:           | PG reset (A.01.20)                        |
| 10. Subsite move:     | Probing next subsite (A.02.00)            |
| 11. CVSweep4284_a:    | C-V measurement by 4284A/E4980A (A.03.10) |

### ***12.1 ForcePG1: PG Output1 (A.01.20)***

[Supported Analyzer]

B1500A

[Description]

Sets the Output1 of the Agilent 81110A Pulse Generator, and triggers it.

[Input Parameters]

Address: GPIB address of the Agilent 81110A Pulse Generator

Period1: Output1 pulse period [s]

Delay1: Output1 delay time [s]

Dcyc1: Output1 duty cycle [%]

Level1: Output1 pulse level [V]

Base1: Output1 base level [V]

TrigCount: Number of output pulses (1 to 65536)

## 12 Utility

### ***12.2 ForcePG2: PG Output2 (A.01.20)***

[Supported Analyzer]

B1500A

[Description]

Sets the Output2 of the Agilent 81110A Pulse Generator, and triggers it.

[Input Parameters]

Address: GPIB address of the Agilent 81110A Pulse Generator

Period2: Output2 pulse period [s]

Delay2: Output2 delay time [s]

Dcyc2: Output2 duty cycle [%]

Level2: Output2 pulse level [V]

Base2: Output2 base level [V]

TrigCount: Number of output pulses (1 to 65536)

### ***12.3 ForcePG2P: PG Output1/Output2 (A.01.20)***

**[Supported Analyzer]**

B1500A

**[Description]**

Sets Output1 and Output2 of Agilent 81110A Pulse Generator, and triggers it. Pulse leading/trailing edge transition time can be set.

Execute ResetPG to stop pulse output before the specified pulses are applied.

**[Required Modules and Accessories]**

Agilent 81110A Pulse Generator (2-output, PGU1 and PGU2)

GPIO cable

**[Test Parameters]**

Address: GPIO address of Agilent 81110A Pulse Generator

Period1: Pulse period [s] for port 1

Delay1: Pulse delay time [s] for port 1

Width1: Pulse width [s] for port 1

LeadTime1: Pulse leading edge transition time [s] for port 1

TrailTime1: Pulse trailing edge transition time [s] for port 1

Level1: Pulse High level [V] for port 1

Base1: Pulse Low level [V] for port 1

ExtImp1: Load impedance [ohm] for port 1

Period2: Pulse period [s] for port 2

Delay2: Pulse delay time [s] for port 2

Width2: Pulse width [s] for port 2

LeadTime2: Pulse leading edge transition time [s] for port 2

TrailTime2: Pulse trailing edge transition time [s] for port 2

Level2: Pulse High level [V] for port 2

Base2: Pulse Low level [V] for port 2

ExtImp2: Load impedance [ohm] for port 2

NoOfPulse12: Number of output pulses

## 12 Utility

### ***12.4 ForcePG12: PG Output1/Output2 (A.01.20)***

[Supported Analyzer]

B1500A

[Description]

Sets Output1 and Output2 of Agilent 81110A Pulse Generator, and triggers it. Pulse leading/trailing edge transition time can be set.

Execute ResetPG to stop pulse output before the specified pulses are applied.

[Required Modules and Accessories]

Agilent 81110A Pulse Generator (2-output, PGU1 and PGU2)

PIB cable

[Test Parameters]

Address: GPIB address of the Agilent 81110A Pulse Generator

Period1: Output1 pulse period [s]

Delay1: Output1 delay time [s]

Dcyc1: Output1 duty cycle [%]

LeadTime1: Output1 pulse leading edge transition time [s]

TrailTime1: Output1 pulse trailing edge transition time [s]

Level1: Output1 pulse high level [V]

Base1: Output1 pulse low level [V]

ExtImp1: Output1 load impedance [ohm]

NoOfPulse12: Number of output pulses (1 to 65536)

Period2: Output2 pulse period [s]

Delay2: Output2 delay time [s]

Dcyc2: Output2 duty cycle [%]

LeadTime2: Output2 pulse leading edge transition time [s]

TrailTime2: Output2 pulse trailing edge transition time [s]

Level2: Output2 pulse high level [V]

Base2: Output2 pulse low level [V]

ExtImp2: Output2 load impedance [ohm]

### ***12.5 ForcePG: PG OutputX (A.01.20)***

[Supported Analyzer]

B1500A

[Description]

Sets Output1 or Output2 of Agilent 81110A Pulse Generator, and triggers it. Pulse leading/trailing edge transition time can be set.

Execute ResetPG to stop pulse output before the specified pulses are applied.

[Required Modules and Accessories]

Agilent 81110A Pulse Generator (2-output, PGU1 and PGU2)

GPIO cable

[Test Parameters]

Address: GPIO address of Agilent 81110A Pulse Generator

SelectPort: Pulse output port

Period: Pulse period [s]

Delay: Pulse delay time [s]

Width: Pulse width [s]

LeadTime: Pulse leading edge transition time [s]

TrailTime: Pulse trailing edge transition time [s]

Level: Pulse High level [V]

Base: Pulse Low level [V]

ExtImp: Load impedance [ohm]

NoOfPulse: Number of output pulses

## 12 Utility

### ***12.6 ForcePGC: PG Output1 Continuous Output (A.01.20)***

[Supported Analyzer]

B1500A

[Description]

Sets Output1 of Agilent 81110A Pulse Generator, and triggers continuous pulse output. Pulse leading/trailing edge transition time can be set.

Execute ResetPG to stop pulse output before the specified pulses are applied.

[Required Modules and Accessories]

Agilent 81110A Pulse Generator (2-output, PGU1 and PGU2)

GPIO cable

[Test Parameters]

Address: GPIO address of Agilent 81110A Pulse Generator

Period1: Pulse period [s]

Delay1: Pulse delay time [s]

Dcyc1: Duty cycle [%]

LeadTime1: Pulse leading edge transition time [s]

TrailTime1: Pulse trailing edge transition time [s]

Level1: Pulse High level [V]

Base1: Pulse Low level [V]

ExtImp1: Load impedance [ohm]



## ***12.7 Measure Diff-V: Voltage measurement by 3458A (A.01.20)***

[Supported Analyzer]

B1500A

[Description]

Performs voltage measurement between two terminals by using Agilent 3458A Digital Multimeter.  
Measurement data is stored to DVM\_Val variable.

[Required Modules and Accessories]

Agilent 3458A Digital Multimeter  
GPIB cable

[Input Parameters]

Adrs: GPIB address of Agilent 3458A Digital Multimeter

[Test Output: Analysis Parameters]

DVM\_Val: Voltage measurement data [V]

## 12 Utility

### ***12.8 QSCV C Offset Meas: Offset capacitance measurement (A.03.00)***

[Supported Analyzer]

B1500A

[Description]

Measures the offset capacitance of the cables and DUT interface by using the QSCV method when measurement terminals are open.

[Device Under Test]

MOS capacitance, 2 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force negative specified value)

Lg: Gate length

Wg: Gate width

Temp: Temperature

[Test Parameters]

IMeasSMU: SMU to measure current and capacitance, connected to Gate terminal or Substrate terminal

MeasRange: Current measurement range used for the QSCV measurement, fixed range

Integ\_C: Integration time for the capacitance measurement

Integ\_L: Integration time for the leakage current measurement

HoldTime: Hold time

DelayTime: Delay time

[Extended Test Parameters]

StepDelay: Step delay time

[Measurement parameters]

Capacitance C

[List Display]

Capacitance C

## ***12.9 ResetPG: PG reset (A.01.20)***

[Supported Analyzer]

B1500A

[Description]

Resets Agilent 81110A Pulse Generator.

[Required Modules and Accessories]

Agilent 81110A Pulse Generator (2-output, PGU1 and PGU2)

GPIB cable

[Input Parameter]

GPIB address of Agilent 81110A Pulse Generator

## 12 Utility

### ***12.10 Subsite move: Probing next subsite (A.02.00)***

[Supported Analyzer]

B1500A

[Description]

Moves wafer prober chuck to the next subsite, reads device ID from the prober, and sets it to the Device ID of the test record.

[Supported Probers]

While this application test supports Cascade Microtech, SUSS MicroTec and Vector Semiconductor wafer prober drivers as standard basis, you may specify a command path name into the CustomProber entry field to operate with a non-standard wafer prober driver.

[Test Parameters]

ProberType: Type of wafer prober

CustomProber: Command path name for non-standard wafer probers

If CustomProber is not blank, ProberType field is ignored.

***12.11 CVSweep4284\_a: C-V measurement by 4284A/E4980A (A.03.10)*****[Supported Analyzer]**

B1500A

**[Description]**

Performs the capacitance vs DC bias voltage measurement by using Agilent 4284A/E4980A LCR meter.

**[Device Under Test]**

Capacitor, 2 terminals

Connect the LCR meter high terminal to the DUT low terminal and the LCR meter low terminal to the DUT high terminal.

**[Required Modules and Accessories]**Agilent 4284A Precision LCR Meter or Agilent E4980A Precision LCR Meter  
 GPIB cable**[Test Parameters]**Address: GPIB address of LCR meter  
 Osc\_Level: Measurement signal level  
 Frequency: Measurement frequency  
 Integ\_Time: Integration time  
 Vstart: C-V measurement start voltage  
 Vstop: C-V measurement stop voltage  
 Sweep\_Pts: Number of sweep points  
 Cmax: Maximum value of graph axis for plotting capacitance**[Extended Test Parameters]**Delay\_Time: Delay time  
 Hold\_Time: Hold time  
 Real\_Time\_Display: Run time automatic update of graph display**[Measurement Parameters]**Capacitance Cdata  
 Dissipation factor Dispersion**[X-Y Graph]**X axis: Bias voltage Vsweep (LINEAR)  
 Y1-axis: Parallel capacitance Cdata (LINEAR)  
 Y2-axis: Dissipation factor Dispersion (LINEAR)**[List Display]**Bias voltage Vsweep  
 Parallel capacitance Cdata  
 Dissipation factor Dispersion

