Performing High-Speed Parameter Extractions On High-Power Devices Using the HP 4142B Modular DC Source/Monitor

Application Note 1216-1

1. Introduction

The HP 4142B has the widest source/measurement range in the industry, from 20fA to 10A and 40uV to 1000V. These ranges can be further expanded by combining multiple modules. In addition, the HP 4142B's extensive list of measurement modes like spot, pulsed spot, pulsed sweep, 2 channel pulsed spot and many others will allow you to make the most accurate measurements possible.

The HP 4142B's Program Memory and Module Selector will save you time by allowing you to automate your measurements and DUT connections. Using a HP controller can further increase your programming productivity and measurement throughput.

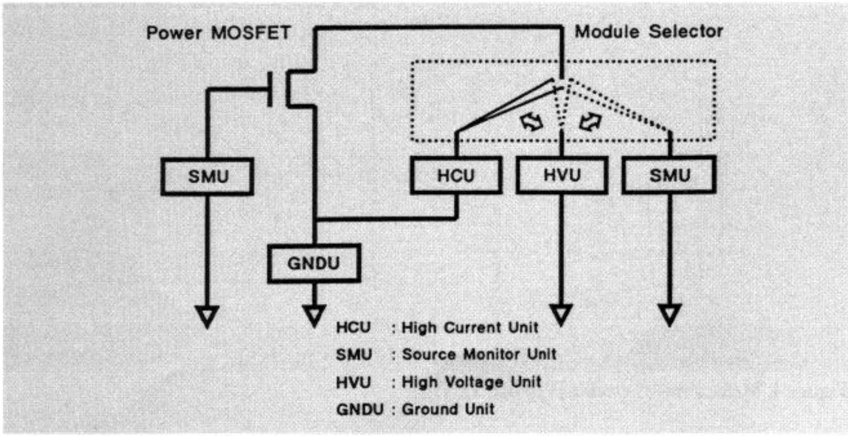

Figure 1. Automatically change measurement setups with the Module Selector

1-1. Program Memory

The HP 4142B can store and execute test sequences from its internal memory. This minimizes the HP-IB command transfer time thus decreasing your total test time. This saving can be significant when performing spot, pulsed spot and 2 channel spot measurements which are especially important when extracting DC parameters on power devices.

1-2. Module Selector

You will need to change the measurement configurations in order to extract and obtain the most accurate dc parameters on a power device. The Module Selector (HP 16087A or HP 16088B Opt. 300) enables you to change the measurement configuration via your test program, thus saving you time and minimizing the chance of making connection errors. The Module selector is typically used to switch a SMU, HCU or HVU to a given DUT terminal. Refer to figure 1.

By utilizing the HP 4142B's program memory and module selector you can extract all seven basis dc parameters in only 1.4 seconds. This is more than 10 times faster (comparison performed by HP) than a curve tracer.

2. Measurement Parameters and Conditions

This section describes the seven measurement parameters.

2-1. Drain-Source ON State Voltage (Vds_on) and Drain-Source ON State Resistance (Rds_on)

The drain-source On state voltage (Vds_on) is measured when a specific gate voltage (Vgs) and drain current (Id) are applied. The drain-source On resistance (Rds_on) is equal to Vds_on/Id.

The Vds_on measurement circuit is shown in figure 2.

2-2. Forward Transfer Admittance (Yfs)

The forward transfer admittance is defined as the device's ability to vary its drain current in response to gate-source voltage variations when the drain voltage is held constant.

Figure 3 graphically describes this measurement. Two different gate-source voltages Vgs1 and Vgs2 are applied and the resulting drain currents Ids1 and Ids2 are measured. The following equation is used to compute Yfs.

Yfs = (Ids2 - Ids1) / (Vgs2 - Vgs1)

The Yfs and Vds_on measurement circuits are the same.

2-3. Gate Threshold Voltage (Vth)

The gate threshold is defined as the gate voltage required to turn on the flow of drain current. The measurement is performed in the non-saturation region.

In order to minimize thermal generation affects which can corrupt your measurement results and decrease your measurement time, the HP 41425A Analog Feedback Unit (AFU) should be used.

The Vth measurement circuit is shown in figure 4.

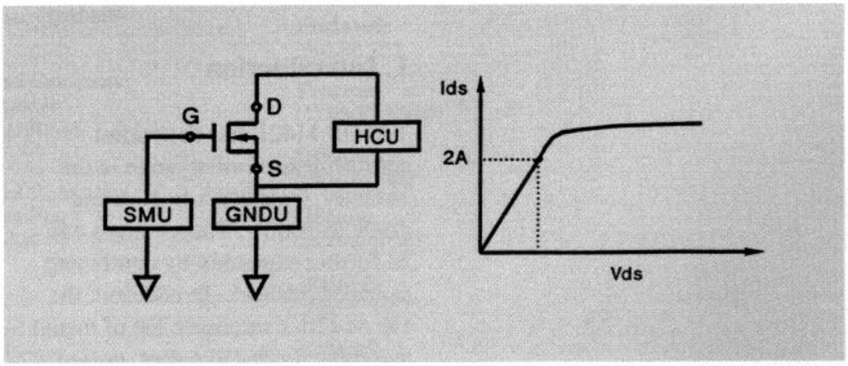

Figure 2. Measurement circuit (Vds_on, Rds_on and Yfs)

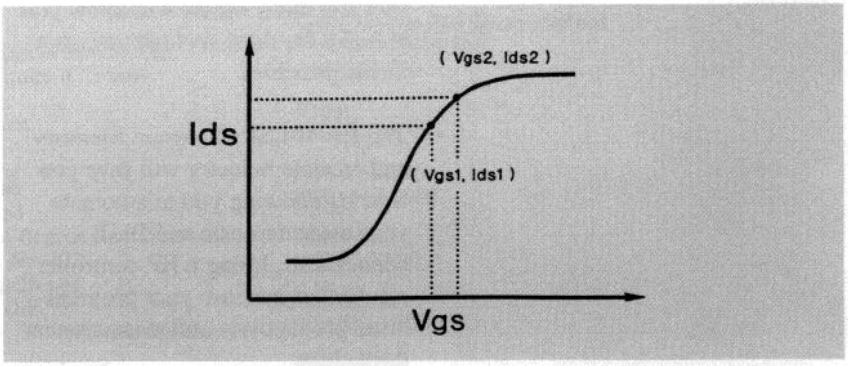

Figure 3. Vgs-Ids characteristics

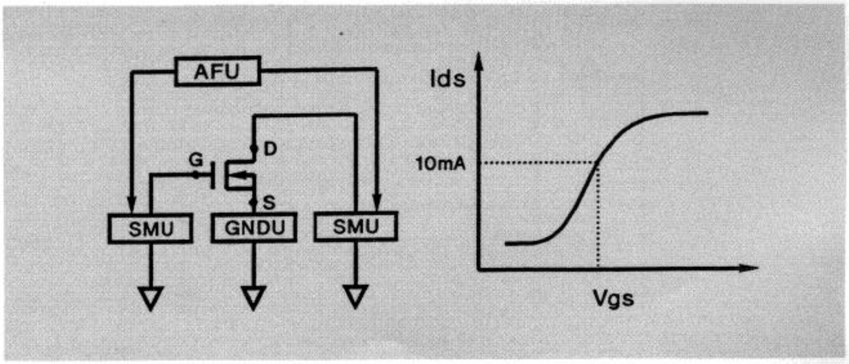

Figure 4. Measurement circuit (Vth and Igss)

2-4. Gate Leakage Current (Igss)

The gate leakage current is defined as the gate to source current when the drain and source are shorted and a specific gate voltage (Vgs) is applied.

The Igss measurement circuit is shown in figure 4. The drain and source are effectively shorted together by programming the drain SMU to zero volts. The GNDU continuously outputs zero volts.

2-5. Drain Cut-Off Current (Idss)

The drain cut-off current is defined as the drain to source current when the gate and source are shorted and a specific drain voltage (Vd) is applied.

The Idss measurement circuit is shown in figure 5. The gate and source are effectively shorted together by programming the gate SMU to zero volts. The GNDU continuously outputs zero volts.

2-6. Drain-Source Breakdown Voltage (Bvdss)

The HP 4142B's quasi-pulse measurement mode* is superior to conventional force current/monitor voltage measurement methods. This special measurement mode minimizes thermal drift and device stress thus improving measurement quality and accuracy. It can also significantly improve your measurement time.

The Bvdss measurement circuit is shown in figure 5.

*Quasi-pulse measurement mode summary

The measurement sequence is:

1) Force current as specified by the current compliance.
2) Monitor the voltage and calculate the voltage slew rate.
3) When the Device Under Test (DUT) starts to enter breakdown, the voltage slew rate will decrease. At this time the SMU waits the user-specified delay time and measures the output voltage.
4) After the voltage measurement has been completed, the output voltage is quickly returned to the start voltage.

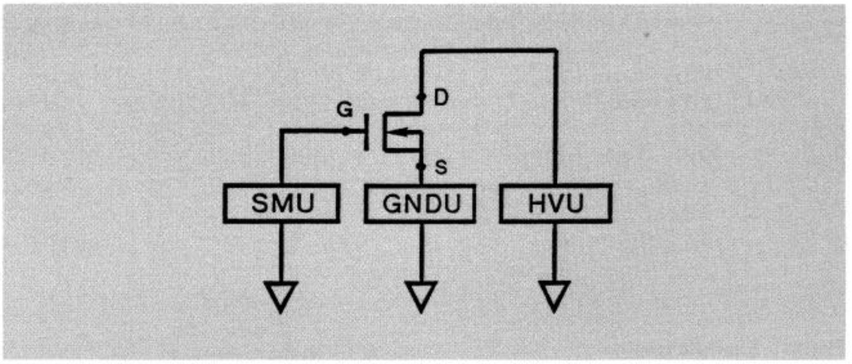

Figure 5. Measurement circuit (Idss and Bvdss)

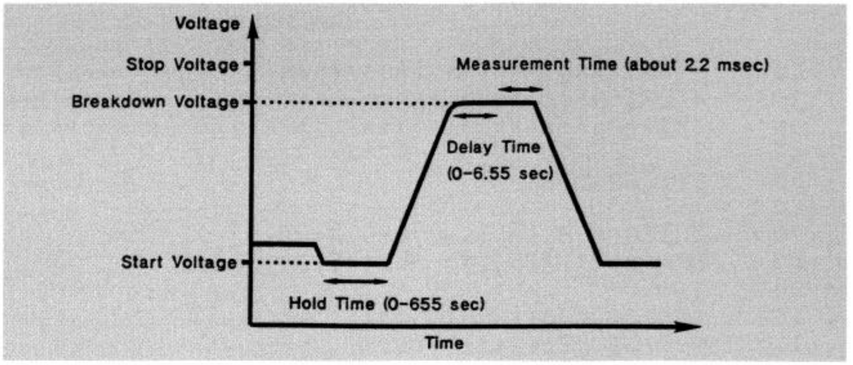

Figure 6. Quasi-pulse measurement mode voltage waveform

3. Measurement Results

Example measurement results are shown in figure 7. These were obtained in only 1.4 seconds. The tests are those described in Section 2 and the program used to derive these results in Section 4.

```
*********** Parameter Measurement (Power MOSFET) *************

Vds(on)          =    4.724      (V)    (Id=2A,Vg=15V)        [HCU]
Rds(on)          =    2.362      (Ohm)  (Id=2A,Vg=15V)        [HCU]
Yfs              =    .699       (S)    (Vd=10V)              [HCU]
Vth (by AFU)     =    3.904      (V)    (Vd=10V,Id=10mA)    [MPSMU]
Igss             =    1.57E-10   (A)    (Vg=20V)            [MPSMU]
Idss             =    8.82E-9    (A)    (Vd=320V)             [HVU]
Bvdss            =    493.9      (V)    (Id=10uA)             [HVU]
```

Figure 7. Example results

4. Measurement Program

```
10     !*****************************************************************
20     !  High speed measurement using program memory and module selector
30     !*****************************************************************
40     !
50     OPTION BASE 1
60     !
70     INTEGER Hpsmu,Smu,Hcu,Hvu
80     DIM A$(7)[15],Vg_no2(2),Id_no2(2)
90     !
100    ASSIGN @Hp4142 TO 724
110    OUTPUT @Hp4142;"*RST"
120    Hpsmu=2
130    Smu=3
140    Hcu=5
150    Hvu=7
160    !
170    !*********************************************
180    !            Parameter settings
190    !*********************************************
200    !-------#1 Parameter settings [HCU]------
210    !            Vds_on,Rds_on measurement
220    !
230    Vg_on=15                 ! Vg=15V
240    Igcomp_no1=.1            ! Igcomp=100mA
250    Id_on=2                  ! Id=2A
260    Vdcomp_no1=10            ! Vdcomp=10V
270    P_width=1.E-4            ! P_width=0.1ms
```

```
280   P_cycle=1.E-2            ! P_cycle=10ms
290   !
300   !------#2 Parameter settings [HCU]-------
310   !          Yfs measurement
320   !
330   Vd_no2=10                ! Vd=10V
340   P_width_no2=1.E-4        ! P_width=100us
350   Vg_no2(1)=5.5            ! Vg_point1=5.5V
360   Vg_no2(2)=6.0            ! Vg_point2=6.0V
370   Idcomp_no2=5             ! Idcomp=5A
380   Igcomp_no2=.1            ! Igcomp=100mA
390   !
400   !-----#3 Parameter settings [SMU]--------
410   !          Igss measurement
420   !
430   Vg_no3=20                !  Vg=20V
440   Igcomp_no3=1.E-4         !  Igcomp=100uA
450   Vd_no3=0                 !  Vd=0V
460   Idcomp_no3=1.E-1         !  Idcomp=100mA
470   !
480   !-----#4 Parameter settings [SMU]--------
490   !          Vth_afu measurement
500   !
510   Vg_start_no4=3           !  Vg_start=3V
520   Vg_stop_no4=4            !  Vg_stop=4V
530   Vg_rate_no4=5000         !  Vg_rate=5000
540   Igcomp_no4=1.E-4         !  Igcomp=100us
550   Vd_no4=10                !  Vd=10V
560   Id_target=.01            !  Id_target=10mA
570   Idcomp_no4=.1            !  Idcomp=100mA
580   Integ_time=4.5E-4        !  Integ_time=450us
590   Delay_time=1.E-4         !  Delay_time=100us
600   !
610   !-----#5 Parameter settings [HVU]-------
620   !          Idss measurement
630   !
640   Vd_no5=320               !  Vd_no5=320V
650   Vg_no5=0                 !  Vg_no5=0V
660   Idcomp_no5=1.E-5         !  Idcomp=10uA
670   Igcomp_no5=1.E-4         !  Igcomp=100uA
680   !
690   !-----#6 Parameter settings [HVU]-------
700   !          Bvdss measurement
710   !
720   Vg_no6=0                 !  Vg=0V
730   Igcomp_no6=1.E-4         !  Igcomp=100uA
740   Hold_time_no6=0          !  Hold_time=0s
750   Delay_time_no6=0         !  Delay_time=0s
760   Vd_start_no6=450         !  Vd_start=450V
770   Vd_stop_no6=600          !  Vd_stop=600V
780   Idcomp_no6=1.00E-5       !  Id_comp=10uA
790   !
800   !************************************************************
810   !               Program #1
820   !       Vds_on,Rds_on measurement using the HCU
830   !************************************************************
840   !
```

```
850   OUTPUT @Hp4142;"ST";1
860   OUTPUT @Hp4142;"ERC";1,3
870   OUTPUT @Hp4142;"FL";0,Hpsmu
880   OUTPUT @Hp4142;"PDI";Hcu,21,0,Id_on,Vdcomp_no1
890   OUTPUT @Hp4142;"PT";0,P_width,P_cycle
900   OUTPUT @Hp4142;"PV";Hpsmu,12,0,Vg_on,Igcomp_no1
910   OUTPUT @Hp4142;"MM";7,Hcu
920   OUTPUT @Hp4142;"XE"
930   OUTPUT @Hp4142;"END"
940   !
950   !************************************************************
960   !                 Program #2
970   !           Yfs measurement using the HCU
980   !************************************************************
990   !
1000  OUTPUT @Hp4142;"ST";2
1010  OUTPUT @Hp4142;"DV";Hpsmu,12,Vg_no2(1),Igcomp_no2
1020  OUTPUT @Hp4142;"PT";0,1.00E-4,1.0E-2
1030  OUTPUT @Hp4142;"PV";Hcu,12,0,Vd_no2,Idcomp_no2
1040  OUTPUT @Hp4142;"MM";3,Hcu
1050  OUTPUT @Hp4142;"XE"
1060  OUTPUT @Hp4142;"DV";Hpsmu,12,Vg_no2(2),Igcomp_no2
1070  OUTPUT @Hp4142;"PT";0,1.00E-4,1.0E-2
1080  OUTPUT @Hp4142;"PV";Hcu,0,0,Vd_no2,Idcomp_no2
1090  OUTPUT @Hp4142;"MM";3,Hcu
1100  OUTPUT @Hp4142;"XE"
1110  OUTPUT @Hp4142;"END"
1120  !
1130  !************************************************************
1140  !                 Program #3
1150  !           Igss measurement using the SMU
1160  !************************************************************
1170  !
1180  OUTPUT @Hp4142;"ST";3
1190  OUTPUT @Hp4142;"ERC";1,1
1200  OUTPUT @Hp4142;"DV";Smu,12,Vd_no3,Idcomp_no3
1210  OUTPUT @Hp4142;"DV";Hpsmu,12,Vg_no3,Igcomp_no3
1220  OUTPUT @Hp4142;"MM";1,Hpsmu
1230  OUTPUT @Hp4142;"XE"
1240  OUTPUT @Hp4142;"END"
1250  !
1260  !************************************************************
1270  !                 Program #4
1280  !           Vth(by AFU) measurement using the SMU
1290  !************************************************************
1300  !
1310  OUTPUT @Hp4142;"ST";4
1320  OUTPUT
      @Hp4142;"ASV";Hpsmu,Vg_start_no4,Vg_stop_no4,Vg_rate_no4,Igcomp_no
1330  OUTPUT @Hp4142;"AVI";Smu,Vd_no4,Id_target,Idcomp_no4
1340  OUTPUT @Hp4142;"ASM";1,1,Integ_time
1350  OUTPUT @Hp4142;"AT";0,Delay_time
1360  OUTPUT @Hp4142;"MM";6
1370  OUTPUT @Hp4142;"XE"
1380  OUTPUT @Hp4142;"END"
1390  !
```

```
1400 !***********************************************************
1410 !                 Program #5
1420 !             Idss measurement using the HVU
1430 !***********************************************************
1440 !
1450 OUTPUT @Hp4142;"ST";5
1460 OUTPUT @Hp4142;"ERC";1,2
1470 OUTPUT @Hp4142;"DV";Hpsmu,12,Vg_no5,Igcomp_no5
1480 OUTPUT @Hp4142;"DV";Hvu,17,Vd_no5,Idcomp_no5
1490 OUTPUT @Hp4142;"MM";1,Hvu
1500 OUTPUT @Hp4142;"XE"
1510 OUTPUT @Hp4142;"END"
1520 !
1530 !**********************************************************
1540 !                 Program #6
1550 !             Bvdss measurement using the HVU
1560 !**********************************************************
1570 !
1580 OUTPUT @Hp4142;"ST";6
1590 OUTPUT @Hp4142;"POL";Hvu,0
1600 OUTPUT @Hp4142;"MM";9,Hvu
1610 OUTPUT @Hp4142;"DV";Hpsmu,12,Vg_no6,Igcomp_no6
1620 OUTPUT @Hp4142;"BDT";Hold_time_no6,Delay_time_no6
1630 OUTPUT @Hp4142;"BDM";1,0
1640 OUTPUT @Hp4142;"BDV";Hvu,17,Vd_start_no6,Vd_stop_no6,Idcomp_no6
1650 OUTPUT @Hp4142;"XE"
1660 OUTPUT @Hp4142;"END"
1670 !
1680 !**********************************************************
1690 !                Measure parameters
1700 !**********************************************************
1710 !
1720 !----------------------------------------------------------
1730 OUTPUT @Hp4142;"CN";Hpsmu,Smu,Hcu,Hvu    ! OUTPUT RELAY ON
1740 !----------------------------------------------------------
1750 !
1760 OUTPUT @Hp4142;"DO";1
1770 ENTER @Hp4142 USING "#,3A,12D,2X";A$(1),Vdson
1780 !
1790 OUTPUT @Hp4142;"DO";2
1800 ENTER @Hp4142 USING "#,3A,12D,2X";A$(6),Id_no2(1)
1810 ENTER @Hp4142 USING "#,3A,12D,2X";A$(7),Id_no2(2)
1820 !
1830 OUTPUT @Hp4142;"DO";3
1840 ENTER @Hp4142 USING "#,3A,12D,2X";A$(2),Igss
1850 !
1860 OUTPUT @Hp4142;"DO";4
1870 ENTER @Hp4142 USING "#,3A,12D,2X";A$(3),Vth_afu
1880 !
1890 OUTPUT @Hp4142;"DO";5
1900 ENTER @Hp4142 USING "#,3A,12D,2X";A$(4),Idss
1910 !
1920 OUTPUT @Hp4142;"DO";6
1930 ENTER @Hp4142 USING "#,3A,12D,2X";A$(5),Bvdss
1940 !
```

```
1950  !------------------------------------------------------------
1960  OUTPUT @Hp4142;"CL"                        ! OUTPUT RELAY OFF
1970  !------------------------------------------------------------
1980  !
1990  !************************************************************
2000  !                    Parameter analysis
2010  !************************************************************
2020  !
2030  !----Rds_on--------------------------------------------------
2040  Rdson=Vdson/Id_on
2050  !
2060  !----Yfs (2 point method)------------------------------------
2070  Ccc=(Id_no2(2)-Id_no2(1))/(Vg_no2(2)-Vg_no2(1))
2080  Yfs=Ccc
2090  !
2100  !************************************************************
2110  !                Print parameters
2120  !************************************************************
2130  !
2140  PRINT USING "@"
2150  PRINT "*********** Parameter Measurement (Power MOSFET)
      **************"
2160  PRINT
2170  PRINT "Vds(on)          =",PROUND(Vdson,-3),"  (V)    (Id=2A,Vg=15V
      [HCU]"
2180  PRINT "Rds(on)          =",PROUND(Rdson,-3),"  (Ohm) (Id=2A,Vg=15V
      [HCU]"
2190  PRINT "Yfs              =",PROUND(Yfs,-3),"  (S)    (Vd=10V)
      [HCU]"
2200  PRINT "Vth (by AFU)     =",PROUND(Vth_afu,-3),"  (V)
      (Vd=10V,Id=10mA)  [MPSMU]"
2210  PRINT "Igss             =",PROUND(Igss,-12);"  (A)    (Vg=20V)
      [MPSMU]"
2220  PRINT "Idss             =",PROUND(Idss,-11);"   (A)    (Vd=320V)
      [HVU]"
2230  PRINT "Bvdss            =",PROUND(Bvdss,-1),"  (V)    (Id=10uA)
      [HVU]"
2240  KEY LABELS OFF
2250 !DUMP ALPHA #701
2260  KEY LABELS ON
2270  !
2280  END
```

Description

200-280	Defines the Vds_on measurement parameters.
300-380	Defines the Yfs measurement parameters.
400-460	Defines the Igss measurement parameters.
480-590	Defines the Vth measurement parameters.
610-670	Defines the Idss measurement parameters.
690-780	Defines the Bvdss measurement parameters.
800-930	Stores Vds_on measurement program in memory.
950-1110	Stores Yfs measurement program in memory.
1130-1240	Stores Igss measurement program in memory.
1260-1380	Stores Vth measurement program in memory.
1400-1510	Stores Idss measurement program in memory.
1530-1660	Stores Bvdss measurement program in memory.
1730	Sets the output relay to on.
1760-1930	Executes each program.
1960	Sets the output relay to off.
2030-2040	Calculates Rds_on.
2060-2080	Calculates Yfs.
2100-2230	Displays measurement results.

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