Adapting Agilent 4070 series to Open/Short Measurement of "Yield Test Chip" for Quick Yield Ramp up

Agilent 4070 Series
Semiconductor Parametric Tester
Application Note 4070 - 5

Agilent Technologies

Introduction

Semiconductor devices are continuously evolving toward high performance and high added value, making process scale down and high device integration more and more important. Because of the small dimensions, the difficulty of yield ramp-up is more critical than ever, particularly for lower than 0.13 micrometer processes. For semiconductor manufacturers, quick yield ramp-up is very important in light of manufacturing cost, manufacturing volume, and time to market.

Recently, a new method for quick yield ramp up has attracted much attention because of above background. In the new method, a special test chip (Yield Test Chip) has to be measured with very fast measurement speed. This application note describes the techniques required for adapting the Agilent 4070 series to quick yield ramp-up using Yield Test Chip testing.

Concept of Yield Improvement Using Open/Short Yield Test Chip

This new method to improve the yield focuses particularly on the interconnect process, because the quality of interconnect process influences the yield of wafers. Therefore, it is important to find defects in the interconnect process and optimize the process based on this analysis for quick yield ramp up.

The Yield Test Chip, a dedicated special test chip, is usually measured to evaluate the quality of the interconnect process. The characteristics of the interconnect process are utilized to improve the process for ramping yield up. The process characteristics are also fed back to a design department to optimize device layout for the process, too. Most Yield Test Chip measurements are performed when establishing new process technologies.

The Yield Test Chip consists of simple open and short tests as shown in Figures 1 and 2. Though the measurement is very simple, the number of tests is tremendous, so high speed testing is required to reduce the test time and test cost.

Agilent 4070 Is Flexible Enough to Perform Ultra Fast Open/Short Test

The Agilent 4070 series Semiconductor Parametric Test System is commonly used as the de-facto standard in process integration/process monitoring because of its accurate measurement performance and high throughput.
Even for the Yield Test Chip measurement that requires very fast measurement speed, the appropriate tunings tap the full potential of the Agilent 4070 series and enable to adapt it to performing very fast open/short measurement up to the microampere order, which is usually requested for this application.
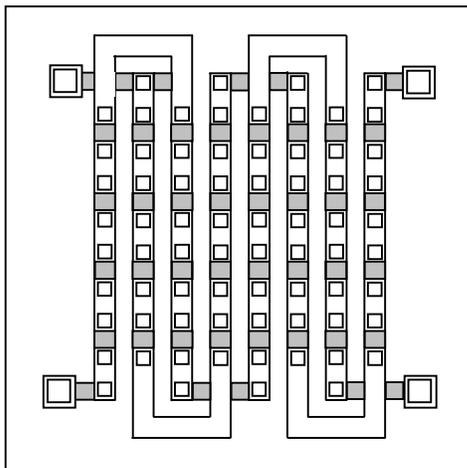

Figure. 1 Test Structure of Yield Test Chip
(Contact/via chain)

Test Structure (contact/via chain structure)
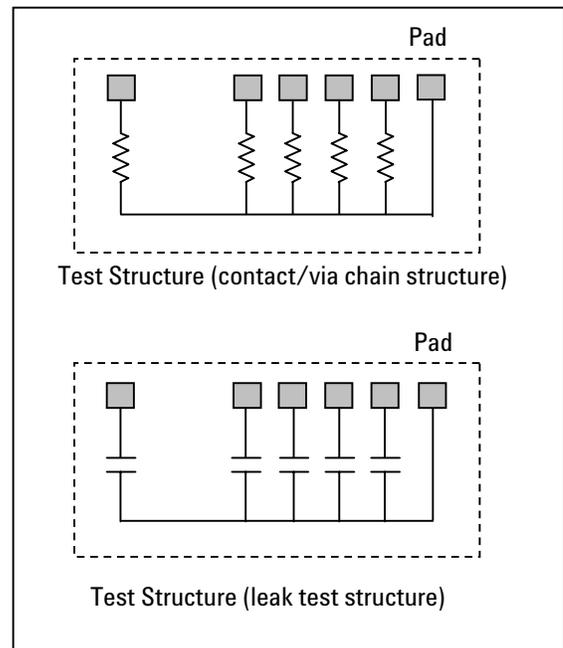
Test Structure (leak test structure)

Figure. 2 Simple Test of Yield Test Chip

Benefits of Using Agilent 4070 Series

Available to Measure Parametric Test Items for Other Processes

As device dimensions become smaller and smaller, it becomes much more important to measure not only open/short of interconnect, but also capacitance of interconnect, sheet resistance by Van der Pauw, basic characteristics of transistor such as Vth, Idoff and Tox and so on. By using the Agilent 4070 series, it is possible to evaluate other parametric test items for other processes as well as open/short in the interconnect process.

Familiar User Interface, Software, Environment and Data Management

The user interface, software, algorithm development tool, data management, etc. are familiar to Agilent 4070 users. By using Agilent 4070 series, it is possible to evaluate Yield Test Chip under familiar environment.

Maximize Utilization of Equipment

The Agilent 4070 series can be available both for measuring the Yield Test Chip and process integration/process monitoring according to your request.
This saves related equipment such as probers and the test floor, and helps maximize the utilization of equipment and save costs of evaluating the Yield Test Chip efficiently.

Techniques to tune up the Agilent 4070 series extremely fast are introduced in the next section.

Techniques for Extremely Fast Open/Short Yield Test Chip Measurement

Set Fixed Range

SMUs in the Agilent 4070 series support full auto ranging for performing appropriate measurements from the fA range to the mA range according to device characteristics. However, full auto ranging is not required for this kind of high-speed open/short measurement. If an expected resistance value is already known beforehand, it is possible to reduce the measurement time dramatically by using a fixed range.

The fixed range on the Agilent 4070 series is accomplished by using a quasi-fixed range technique. The quasi-fixed range is possible by setting up a compliance and measurement range appropriately. If you specify the same compliance value as the lowest range of the limited auto range, it is almost equivalent to the fixed range. For example, when you want to use a 1 uA fixed range, set the 1 uA limited auto range and 1 uA compliance.

Use HS-ADC

The Agilent 4070 series has two types of A-D converter, HR-ADC (High Resolution ADC) and HS-ADC (High Speed ADC). You can choose an ADC type according to your measurement requirements. The HR-ADC is an integration type ADC enabling precise measurement. The HS-ADC is a sampling type ADC enabling faster measurement than with the HR-ADC.

For these ADCs, you can select from four integration modes; long, medium, short or manual. In the measurement range up to microampere generally required for this application, the short integration mode performs sufficiently accurate and fast measurement.

As well as the integration mode, you can specify integration time for the ADCs. It is specified as an integration time for the HR-ADC or the number of sampling for the HS-ADC. You can use the default setting in most of cases, when using the short integration mode. You will obtain very fast measurement time by choosing the HS-ADC with short integration mode.

Even with short integration mode, Agilent 4070 series perform reliable measurement because of the thorough guarding technique and high performance ADC. The default setting HS-ADC in short integration mode usually has sufficient accuracy for this application and enables very fast open/short measurement.

Note:
Increase the number of sampling according to the required accuracy and speed, when the default setting is not accurate enough for measurement such as via chain measurement requiring relatively lower current. Generally, accuracy and measurement speed are in a trade-off relationship.

Hint:
If you want much faster measurement speed, you can choose the manual integration mode. The measurement speed can be faster than short mode in general, though the variation of result may be wider. You will get the fastest measurement time by choosing the HS-ADC with one

(Program Example)
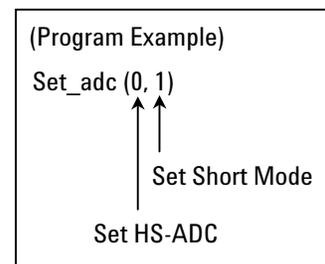
Set_adc (0, 1)

Set Short Mode

Set HS-ADC

Figure. 3 How to set ADC

sampling in the manual mode. You can increase the number of sampling according to the required accuracy and speed, when one sampling is not accurate enough for the measurement.

Set Filter OFF

When you set the SMU filter to OFF, the measurement speed gets faster than for filter ON. The SMUs of the Agilent 4070 series are designed to suppress the spikes and noise on the output waveform, even when the filter is OFF.
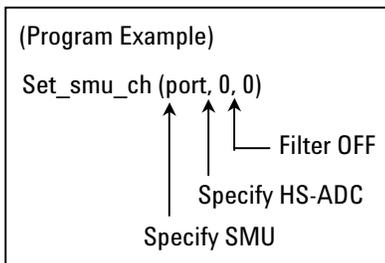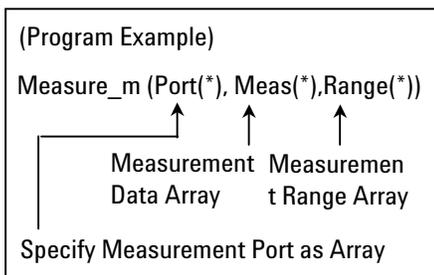
(Program Example)

Set_smu_ch (port, 0, 0)

Filter OFF

Specify HS-ADC

Specify SMU

Figure. 4 How to set filer off

(Program Example)

Measure_m (Port(*), Meas(*),Range(*))

Measurement Data Array

Measuremen t Range Array

Specify Measurement Port as Array

Figure. 5 How to perform multiple measurement

(Program Example)

Set_wait_time (0, 1)

Force Internal Wait Factor

Measure Internal Wait Factor
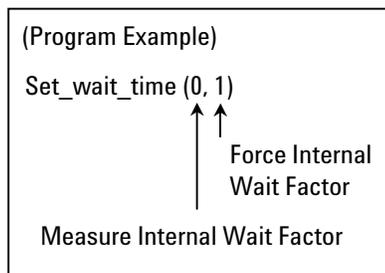
Figure. 6 How to reduce internal wait time

Perform Multiple Measurement

When multiple resistances are measured by using multiple SMUs, use the **"measure_m"** command with up to eight available SMUs. The **measure_m** command allows faster measurement than repeated spot measurement.

Reduce Internal Wait Time

Agilent 4070 series has a pre-defined internal wait time. Except for measurement requiring additional wait time for settling, accurate and stable measurement can be performed with this internal wait time. However, if such a wait time is unnecessary, you may want to reduce the pre-defined wait time.
The **"set_wait_time"** command is for this purpose, and you can reduce even the pre-defined internal wait time. As a result, faster measurement is possible by reducing unnecessary internal wait time.

For spot measurement, change the first parameter (force wait time) of **"set_wait_time"** from 1 to 0 as shown in Figure 6.

Note-1:
If the measurement is not stable after changing this parameter 0, optimize this parameter between 0 and 1.

Note-2:
Internal wait time can be reduced further by reducing the second parameter (measure wait time) as well, though it might affect the measurement result. If you change the second parameter, adjust it carefully according to the device.

Specifying Port for "Disable_port"

When you reset the output of the SMU, the **"disable_port"** command is usually used without specifying any ports. It can be faster if you specify the measurement port to disable output.

The **"disable_port"** command always changes the range to the 100 uA range, so it may take range-changing time. If you do not need to reset the fixed range that is already set, just use the **"force_v"** command as an alternative.
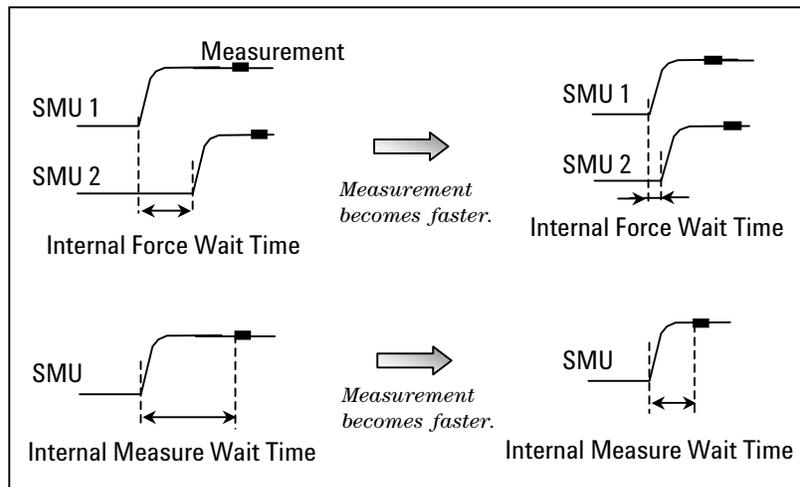

Figure. 7 Reduce Internal wait time

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Note for "Connect"

When you disconnect the measurement pin or port, the **"connect"** command is usually used without specifying any pins or ports. It can be faster if you specify the measurement pins because this resets only specified pins.

When the output voltage is lower than 2 V and compliance is lower than 10 mA, pins can be switched without a command to disable the output. This reduces the time to reset output and enables faster measurement.
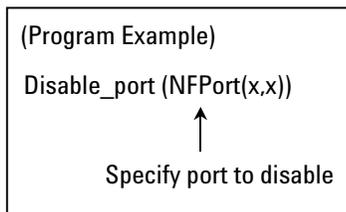
```
(Program Example)

Disable_port (NFPort(x,x))
                 ↑
          Specify port to disable
```

Figure. 8 Disable_port

```
(Program Example)

Force_v (NFPort(x,x),0)
          ↑       ↑
                Specify 0 V
       Specify port to disable
```

Figure. 9 Force 0 V

```
(Program Example)

Connect (NFPort(x,x), 0)
            ↑       ↑
                 Disconnect
                 from any pins
       Specify connected port
```
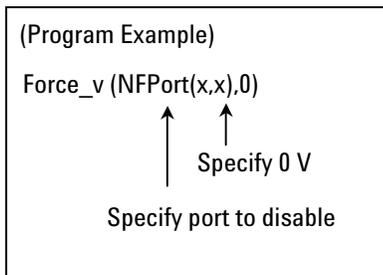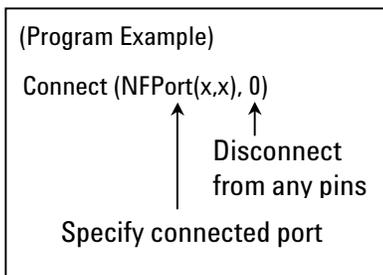
Figure. 10 Disconnect pins

Tips of Pad Layout to Reduce Probing Time

When the Yield Test Chip is measured by the Agilent 4070 series, the layout of Yield Test Chip is also an important factor. Normally, the Yield Test Chip has many pads, for example 256. Therefore, the probing position must be changed multiple times to cover all pads.

When the measurement speed is extremely improved, the probing/indexing time of the prober is not negligible for total measurement time. The Agilent 4070 series can expand the number of pins up to 48 pins, so it is better to probe as many pads as possible up to 48 pins in a touch down. As the result, the number of probing is reduced, and total measurement time is also reduced.

Note that the structure of the Yield Test Chip must be closed in the 48 pins block because the measurement is performed separately in each block.

With these techniques, the measurement time is estimated a little less than two hours per lot including prober indexing and wafer loading time. The assumed condition is as follows.

Test System: Agilent 4073B
Measurement Range: 100 uA
Number of Devices:
            10000 devices/wafer
Number of Wafers: 25 wafers/lot

Note:
This is reference data, and actual measurement time depends on the device, setting and prober index/loading time.

A program example is shown in Figure 11.

Summary

Appropriate adjustments enable the Agilent 4070 series to adapt to very fast open/short measurement of the Yield Test Chip up to the microampere range. Because Agilent 4070 is available both for Yield Test Chip measurement and process integration/process monitoring, equipment including the prober can be used with maximum efficiency.

The Agilent 4070 series helps boost low cost quick yield with the Yield Test Chip.

References

[1] Christopher Hess, Howard Read, John Ren, Larg H. Weiland, Jainjun Cheng, Chock Gan, Hossein Karbasi, and Steven Winters, "Test Time Reduction Methods for Yield Test Structures", Microelectronic Test Structures, 2003. International Conference on , March 17 - 20, 2003, Page(s): 64 – 69

[2] Christopher Hess, Brain E. Stine, Larg H. Weiland, Todd Mitchell, Martin P. Karnett, and Keith Gardner, "Passive Multiplexer Test Structure For Fast and Accurate Contact and Via Fail- Rate Evaluation", Semiconductor Manufacturing, IEEE Transactions on , Volume: 16 Issue: 2 , May 2003, Page(s): 259 - 265

```
10    OPTION BASE 1
20    INTEGER Mports(8), I, J, N
30    REAL Measure(8),Range(8), R(47), Imeas(47)
40    Vout=1
50    Comp=1.E-4
60    Ith=1.E8  ! Threshold Current Value
70    FOR I=1 TO 8
80      Range(I)=1.E-4  ! Measurement Range Array
90    NEXT I
100   !
110   FOR I=1 TO 8
120     Mports(I)=FNPort(0,(I))  ! Port Array
130   NEXT I
140   !
150   Set_adc(0,1,1) ! Set SHORT integration mode
160   Set_smu_ch(0,0,0) ! Set HS-ADC for all SMUs
170   Set_wait_time(0,1) ! Set internal wait time factor
180   !
190   FOR I=1 TO 41 STEP 8
200   ! SMU connection
210     Connect(FNPort(0,1),(I))
220     Connect(FNPort(0,2),I+1)
230     Connect(FNPort(0,3),I+2)
240     Connect(FNPort(0,4),I+3)
250     Connect(FNPort(0,5),I+4)
260     Connect(FNPort(0,6),I+5)
270     Connect(FNPort(0,7),I+6)
280     IF I<40 THEN
290       Connect(FNPort(0,8),I+7)
300     ELSE
310       Mports(8)=0
320     END IF
330   ! GNDU connection
340     Connect(FNPort(0,9),48)

350   ! apply voltage
360     Force_v(FNPort(0,1),Vout,20,Comp)
370     Force_v(FNPort(0,2),Vout,20,Comp)
380     Force_v(FNPort(0,3),Vout,20,Comp)
390     Force_v(FNPort(0,4),Vout,20,Comp)
400     Force_v(FNPort(0,5),Vout,20,Comp)
410     Force_v(FNPort(0,6),Vout,20,Comp)
420     Force_v(FNPort(0,7),Vout,20,Comp)
430     Force_v(FNPort(0,8),Vout,20,Comp)
440   !
450     Measure_m(Mports(*),Measure(*),Range(*))
460   !
470     N=7
480     IF I=41 THEN N=6
490     FOR J=0 TO N
500       Imeas(I+J)=Measure(J+1)
510       IF ABS(Imeas(I+J))<=Ith THEN
520         R(I+J)=9.E+99
530       ELSE
540         R(I+J)=Vout/Imeas(I+J)
550       END IF
560     NEXT J
570     Connect(FNPort(0,1),0)
580     Connect(FNPort(0,2),0)
590     Connect(FNPort(0,3),0)
600     Connect(FNPort(0,4),0)
610     Connect(FNPort(0,5),0)
620     Connect(FNPort(0,6),0)
630     Connect(FNPort(0,7),0)
640     Connect(FNPort(0,8),0)
650   NEXT I
660   !
670   Disable_port(0)
680   Connect
690   END
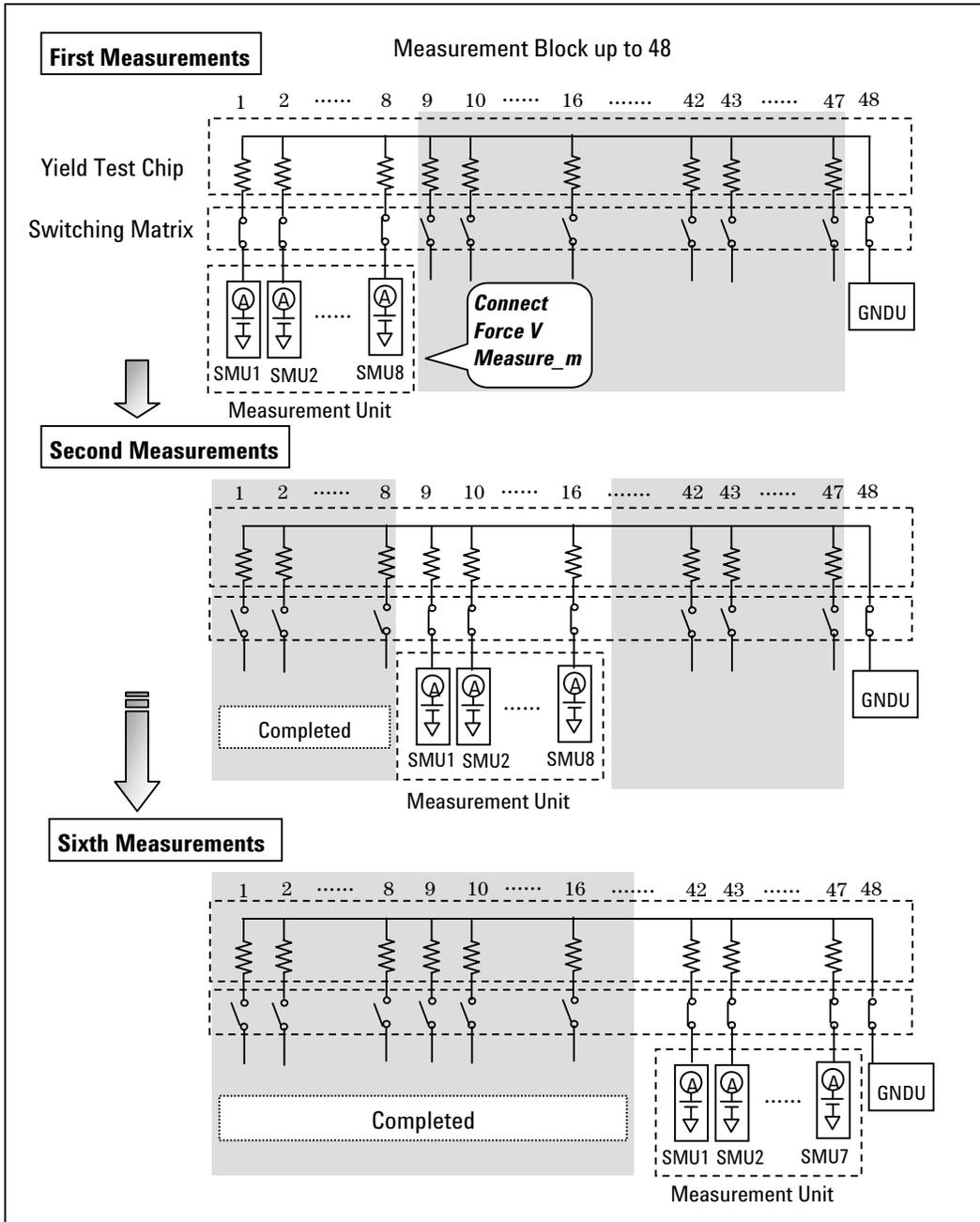```

Figure. 11 Program Example

Figure. 12 Measurement procedure in a program example

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