

# IV and CV Measurement Using the Agilent B1500A MFCMU and SCUU

Application Note B1500-3

## Agilent B1500A Semiconductor Device Analyzer

### Introduction

Parametric characterization requires both current-voltage (IV) and capacitance-voltage (CV) measurements. Recent developments in process technology typically require accurate IV and CV measurements be made with a single pass of the devices on the wafer. The Agilent B1500A Semiconductor Device Analyzer supports single-pass IV and CV measurements within the same mainframe using a new, single-slot multi-frequency capacitance measurement unit (MFCMU) and two SMUs.

Performing both IV and CV measurements on a single probe station is not easy. SMU-based IV measurements use triaxial connectors, while CMU-based CV measurements use BNC connectors. Switching between these two measurements can be confusing and time-consuming and can often cause measurement errors. An example would be where the measurement cables are manually switched, while keeping the probing needle on the wafer. In this case, the electrical charge generated



by friction when the cables are switched may damage the device. In addition to cable connection issues, an error compensation parameter associated with the capacitance measurements must be set correctly in order to obtain accurate results.

The B1500A's SMU CMU Unify Unit (SCUU) solves these measurement problems. The SCUU

enables accurate and effortless switching between IV and CV measurement without the complexity and expense of an external switching matrix.

This application note illustrates how you can easily configure an accurate IV and CV measurement system using the B1500A.



Agilent Technologies

## Making Basic Capacitance Measurements with the B1500A

Figure 1 shows a basic cable configuration diagram for making CV measurements on a wafer. First, the four terminal pair (4TP) extension test cable is connected to the measurement terminals of the B1500A's MFCMU. The 4TP configuration is similar to a Kelvin connection in IV measurements, and it can minimize errors caused by measurement cable parasitics. It also provides the best accuracy when extending the test cable.

To obtain the best accuracy, the 4TP extension should be routed as closely as possible to the device under test (DUT). Then the shielded two terminal (2T) cable or three terminal (3T) cable should be connected to the probing manipulator. The path to the probing needle is basically a 3T configuration.

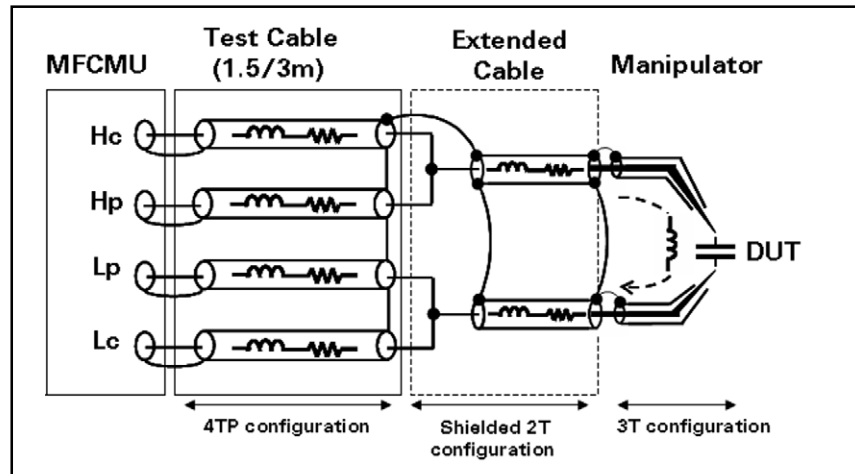


Figure 1. Basic cable configuration for manipulator connection.

Figure 2 illustrates the difference between the shielded 2T configuration and the 3T configuration. In the shielded 2T configuration, the measurement cable guard shields are connected together at the end of the measurement cable. In the 3T configuration, the guard shields are not connected together at the end of the measurement cable. The shielded 2T configuration produces more stable measurements and better accuracy than the 3T configuration. This is because the residual inductance in the shielded 2T configuration is a fixed value determined by the construction of the cable.

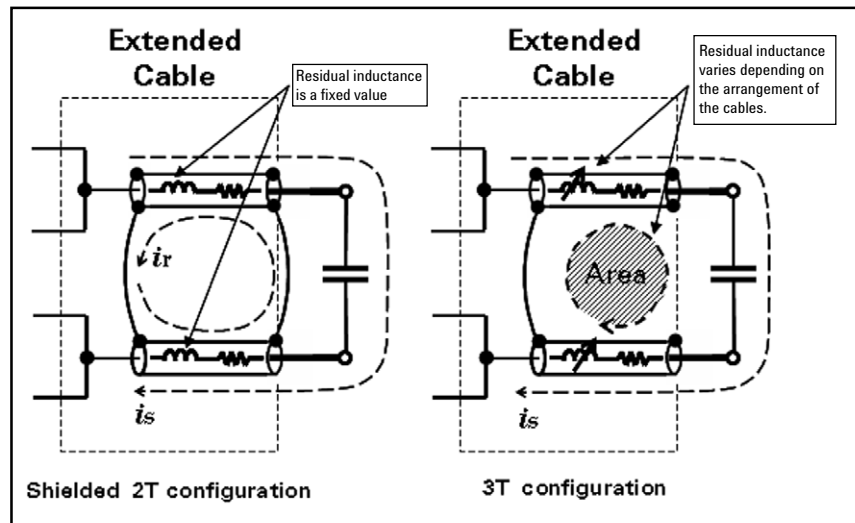


Figure 2. Differences between the shielded 2T and the 3T cable configurations.

The residual inductance does not change, even if you move the cables going to the DUT, thus providing stable and accurate results.

The residual inductance in the shielded 2T configuration is fixed because an induced current flows in the guard shield that is of the same magnitude but in the opposite direction as the current flowing in the center conductor. This induced current helps to seal the magnetic flux created

by the measurement current, thereby keeping the residual cable inductance to a small and fixed value. In contrast, there is no return current path generated in the 3T configuration. In this configuration, residual inductance is determined by the random arrangement of the cables. Since the configuration of the cables varies in an uncontrolled fashion, it is difficult to keep the residual inductance constant and stable. Vibration in the test environment changes

the residual inductance of the measurement cable, making it unstable. This makes it difficult to compensate for the residual inductance of the measurement cables in the 3T configuration. This is sometimes referred to as the "return path issue," which arises when the guard shields at the end of cable in the 3T configuration are not shorted together. You can solve this problem by connecting guard shields as shown in Figure 2.

There are three basic steps you must take in order to get accurate capacitance measurements: first, minimize errors caused by parasitics; second, stabilize the errors; and, third, effectively compensate for the errors. Figure 3 illustrates that using a shielded 2T configuration produces a relatively short path to the tip of the probe needle. The shorter the path to the probe tip, the less chance there is for parasitics to cause errors (a typical error would be residual inductance in the measurement cable). By using a shielded 2T configuration all the way to the probe tips, you minimize the length of the shielded 3T cable. This minimizes the length of the unstable portion of the measurement setup, and makes it easier to compensate for measurement error using compensation techniques.

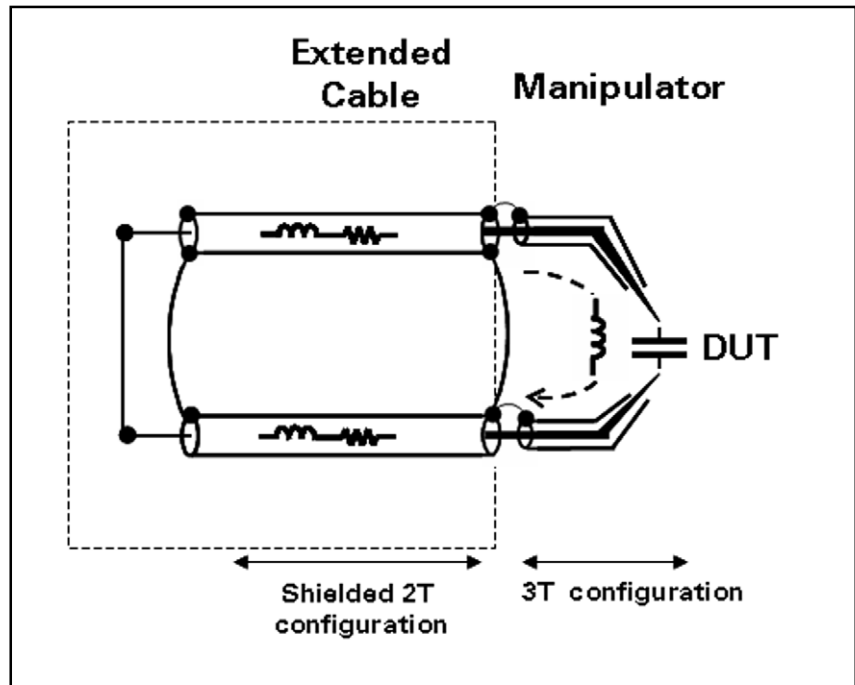


Figure 3. The residual inductance of the positioners does not significantly impact measurement accuracy.

## Considerations when Automating IV and CV Measurements

As previously described in this application note, making a simple, accurate CV measurement is accomplished relatively easily. However, it is not so easy in an automated test environment when you want to accurately measure both IV and CV. Figure 4 shows an ideal precision, low-current IV measurement setup where the triaxial cable from an SMU connects to the input terminal of the wafer prober manipulator. The measurement center conductor and guard shield are routed to the DUT via the shielded probe needle.

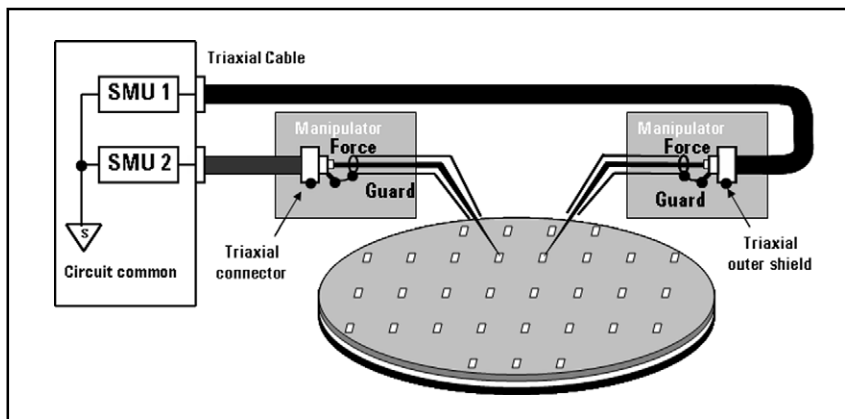


Figure 4. Illustration of an ideal (non-Kelvin) on-wafer IV measurement setup.

A contrasting yet similar setup for a precision CV measurement is shown in Figure 5. The cable routing after the 4TP-to-shielded-2T conversion looks similar to the IV setup, but there are two major differences. First, where triaxial cable is used in the IV measurement setup, coaxial cable is used in the CV setup. Second, there is a guard connection wire in between the measurement cable and the manipulator needle in the CV setup, where there is none in the IV setup.

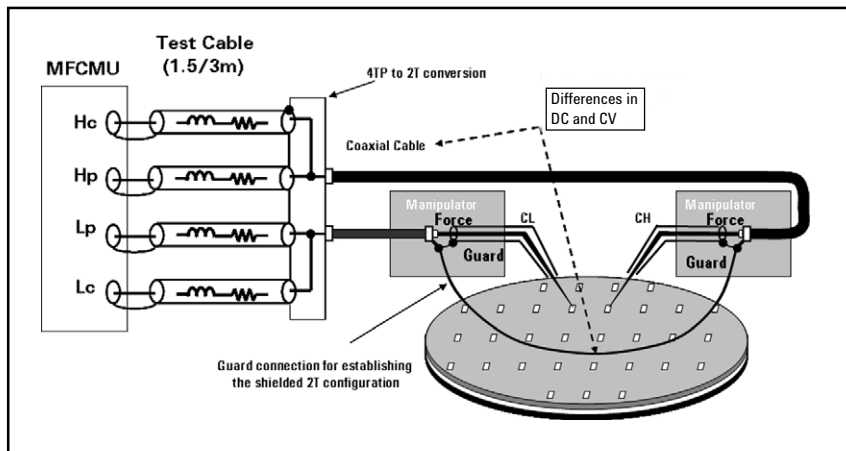


Figure 5. Illustration of an ideal on-wafer CV measurement setup.

Although the cabling configurations for making separate CV and IV measurements, as shown in Figures 4 and 5, are similar, the differences pose a significant challenge in constructing a single configuration that allows you to switch between IV and CV measurements in an automated test environment. The following section in this application note shows how you can use the B1500A to make both IV and CV measurements using a single cabling configuration, without degrading measurement accuracy, and without any special knowledge regarding making CV measurements.

## Agilent B1500A IV/CV Solutions

Figure 6 shows the basic cable configuration for the B1500A when it is used for switching between IV and CV measurements. The B1500A's SCUU can switch between IV and CV measurements without degrading measurement accuracy, and both 1.5 m and 3.0 m cables are available to enable the SCUU to mount on the wafer prober. The measurement cables from the SCUU are extended to the wafer prober manipulator using two triaxial cables or two pairs of Kelvin (force and sense) triaxial cables that satisfy the requirements of both IV and CV measurements. For both IV and CV measurements, the center signal line of the triaxial cable connects to the center conductor of the measurement needle, and the driven guard of the triaxial cable connects to the outer shield of the measurement needle. Tying the outer shield to the guard of the measurement needle protects against outside noise.

Just as is shown in Figure 5, the guard of the CH and CL measurement terminals of the prober manipulator are shorted together at the end of each coaxial measurement cable in order to establish an accurate CV measurement system. The B1500A's guard switch unit (GSWU) is used to short the guard of the measurement cable while CV measurements are performed. The GSWU switch

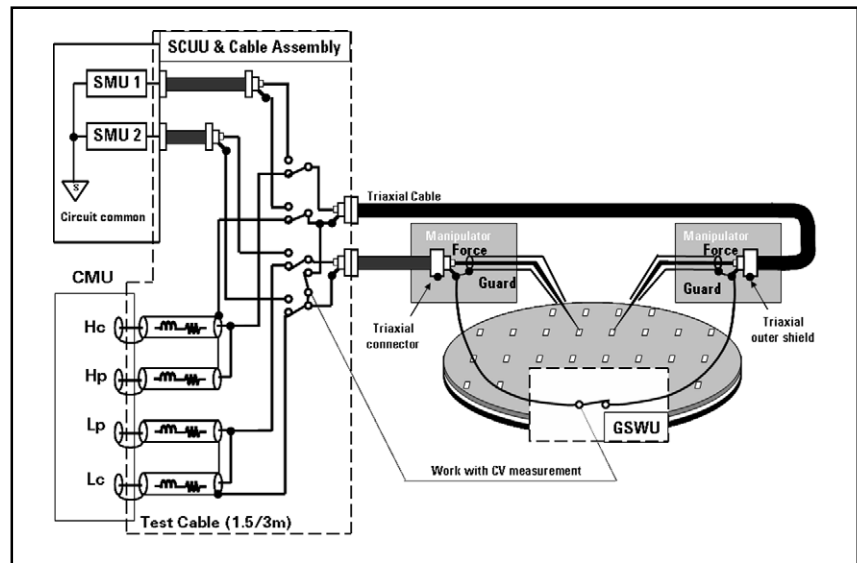


Figure 6: B1500A implementation of on-wafer CV measurement using the SCUU and GSWU.

opens automatically during IV measurements to prevent potential SMU damage, since otherwise the guards of the two SMUs (which are presumably at different potentials) would be shorted together.

Even if you implement a Kelvin triaxial connection between the SCUU and the prober manipulator, it will not affect the measurement accuracy if the cable is not too long. All you have to do is establish this simple connection system as well as collect and save the residual error components data using the open/short and (optional) load compensation routines built into the B1500A's EasyEXPERT software.

The EasyEXPERT software handles all IV-CV switching and error compensation and, by controlling the GSWU, also handles capacitance measurement current return path issues. The EasyEXPERT software provides more than 100 IV and CV application tests. You simply select a CV algorithm, and push a button to begin making accurate CV measurements. If you use the SCUU, you can extend the DC bias voltage of CV measurements to  $\pm 100$  V, well beyond the inherent  $\pm 25$  V capability of the MFCMU. In the case of the SCUU, the  $\pm 100$  V of DC bias is automatically provided by the SMUs connected to the SCUU.

# Agilent B1500A IV/CV Solutions (continued)

Figure 7 shows how the B1500A's MFCMU and HRSMUs are connected to the SCUU using a 3 m SCUU cable adapter. The GSWU is connected to the SCUU control terminal, which allows the GSWU switch to be controlled automatically.

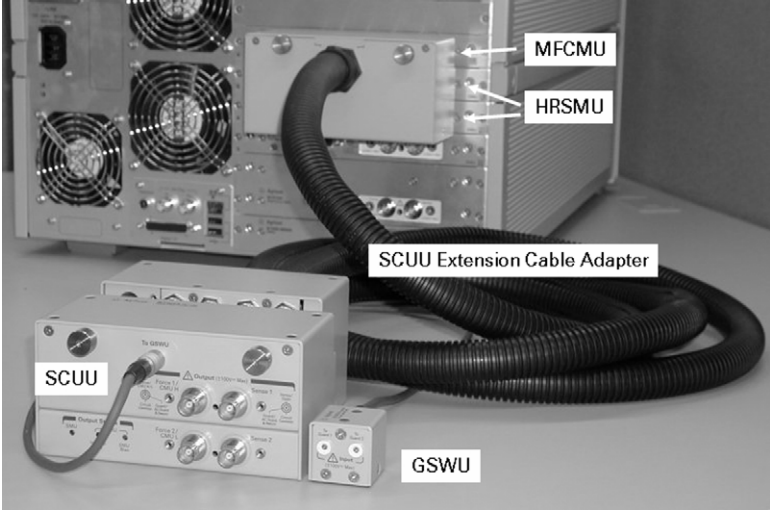


Figure 7. B1500A's MFCMU and HRSMUs connected to the SCUU using an SCUU cable adapter

Figure 8 shows the cabling from the SCUU and GSWU to the wafer prober manipulator. The GSWU is connected to the guard of the wafer prober manipulator needle near the base of the manipulator needle holder. This connection creates a return path when CV measurements are performed, thus ensuring accurate and stable measurements.

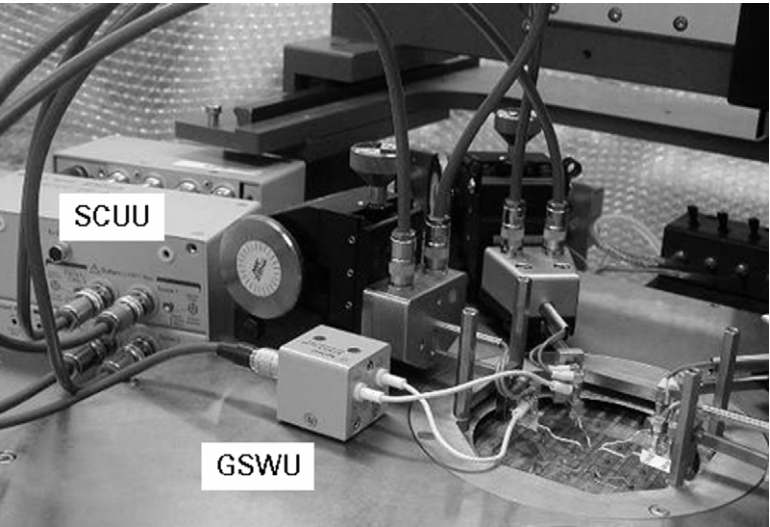


Figure 8. SCUU and GSWU cabling to the wafer prober manipulator

## **Conclusion**

The Agilent B1500A, in combination with its MFCMU, SMUs, SCUU and GSWU, provides an accurate and effortless system for switching between IV and CV measurements.

The B1500A's EasyEXPERT software handles all of the IV-CV switching and error compensation. You have only to select an IV or CV algorithm and push a button in order to begin making accurate measurements.

For more information about Agilent and its products, go to [www.agilent.com](http://www.agilent.com).

For more information about Agilent Technologies semiconductor test products, applications, and services, visit our Website: [www.agilent.com/go/semiconductor](http://www.agilent.com/go/semiconductor) or call one of the centers listed and ask to speak with a semiconductor test sales representative.

**Americas**

Brazil (11) 4197-3600  
Canada (French) 1 877 894-4414  
Canada (English) 1 800 447-8378  
Mexico 33 134-5841  
United States 1 800 447-8378

**Asia/Asia Pacific**

Australia 1 800 629-485  
China 1 800 276-3059  
Hong Kong 852 2599 7889  
India 91/11 690-6156  
Japan 0120 421-345  
Malaysia 1 800 880-780  
New Zealand 0 800 738 378  
Philippines 1 800 1651-0135  
Singapore 1 800 276-3059  
South Korea 080 778-0011  
Taiwan 0 800 047-662  
Thailand 1 800 2758-5822

**Europe**

Austria (01) 25 125-7183  
Belgium (0) 2 404-9380  
Denmark 080301040  
Finland 20 547-9999  
France (0) 825 010710  
Germany (0) 18 05 24-63 34  
Greece 20 547-9999  
Ireland 016158393  
Italy 02 92 60 8333  
Luxembourg (0) 2 404-9340  
Netherlands (0) 20 547-9999  
Poland 20 547-9999  
Russia 20 547-9999  
Spain 91 631 3383  
Sweden 020 120-9975  
Switzerland (Italian) (0) 2 92 60 8484  
Switzerland (German) (0) 1 735-9300  
Switzerland (French) (0) 825 010 700  
United Kingdom (0) 7004 222-222

**Middle East**

Israel 20 547-9999

Technical data subject to change without notice.

© Agilent Technologies, Inc. 2005

Printed in USA August 1, 2005

5989-3608EN