Create Your Own Testing Innovation.

2015

How to Achieve High Speed/Accuracy Sourcing & Measurement by Using PXI Based SMU

Jeff Lee / Mike Costello
Chroma ATE Inc

2015/5/7 & 2015/5/12

Agenda

- **Chroma ATE Inc at a Glimpse**
- Accuracy – By Definition
- Factors Affect Accuracy & Speed & Solutions
  - Fundamentals
  - Output Slew Rate
  - Timing Impact
  - Simultaneous Measurement
  - Dielectric Absorption
  - Noise Floor
  - Path to DUT
  - Capacitive Loads
- Chroma PXI/PXIe SMU
- Chroma PXIe Device Power Supply

Chroma ATE Inc

• **Founded**	:	**Nov. 8, 1984**
• **Paid-in Capital**	:	**US$ 126.3 Million**
• **IPO**	:	**Dec., 1996** (TAIEX : 2360)
• **Chairman**	:	**Leo Huang**
• **CEO**	:	**Leo Huang**
• **Employees**	:	**Global – 1,850; Taiwan – 1,400** (1/2015)
• **Headquarters**	:	**Taoyuan, Taiwan**
• **Revenue**	:	**US$ 171.2 Million** (2014) **US$ 343.7 Million** (2014 Consolidated)
• **Products**	:	**Test & Measurement Instruments** **Automated Test Systems** **Manufacturing Execution Systems** **Turnkey Solutions**

Operation Sites

Global Employees : 1,850 , Branch Offices x16, Distributors x65

Taiwan (HQ) :
Taoyuan /
Shinzhu /
Kaoshung




US :
Irvine/ Santa Clara/
Foothill Ranch, CA
Tempe, AZ

Europe : Netherlands

Hong Kong : Neworld

Japan: Yokohama


China : Beijing / Nanjing / Shanghai / Suzhou
Chongqing / Xiamen / Shenzhen / Dongguan

Product Mix

Turnkey Test & Automation Solution Provider

- Video & Color Test Solution
- Flat Panel Display Test Solution
- Power Electronic Test Solution
- Passive Component Test Solution
- Electrical Safety Test Solution
- Automated Optical Inspection
- Semiconductor/IC Test Solution
- LED/Lighting Test Solution
- Photovoltaic Test Solution
- Electrical Vehicle Test Solution
- Battery Test Solution
- Optical Devices Test Solution
- Thermoelectric Test & Control Solution
- Manufacturing Execution System

Automation Integration

Test & Measurement

Manufacturing Execution Sys.

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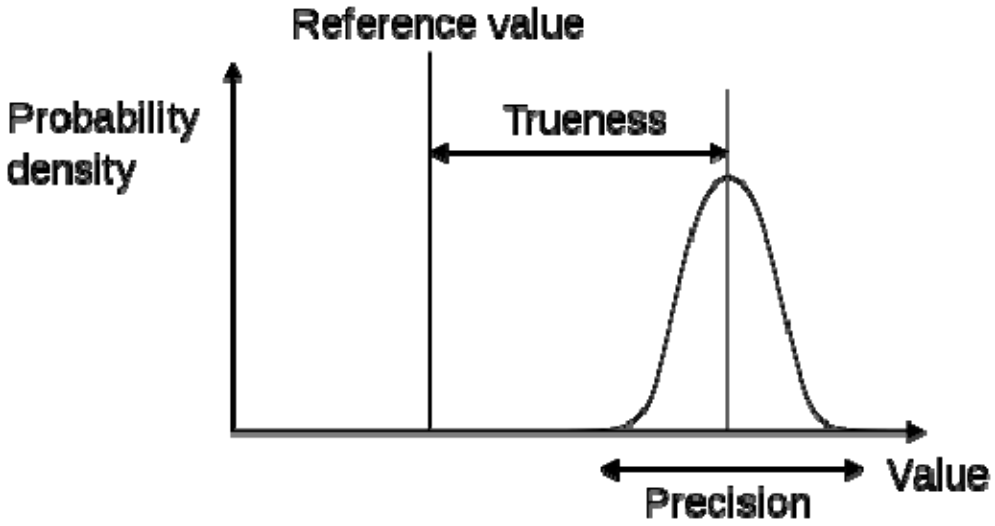
Accuracy – By Definition

According to **ISO 5725-1**, the general term **"accuracy"** is used to describe **the closeness of a measurement to the true value**. When the term is applied to sets of measurements of the same *measurand*, the "**trueness**" is **the closeness of the mean of a set of measurement results to the actual (true) value** and **precision** is **the closeness of agreement among a set of results**

Accuracy : when only one measurement is taken



Low accuracy, poor precision, good trueness

Low accuracy, good precision, poor trueness

When we talk about good accuracy, we need good precision too!

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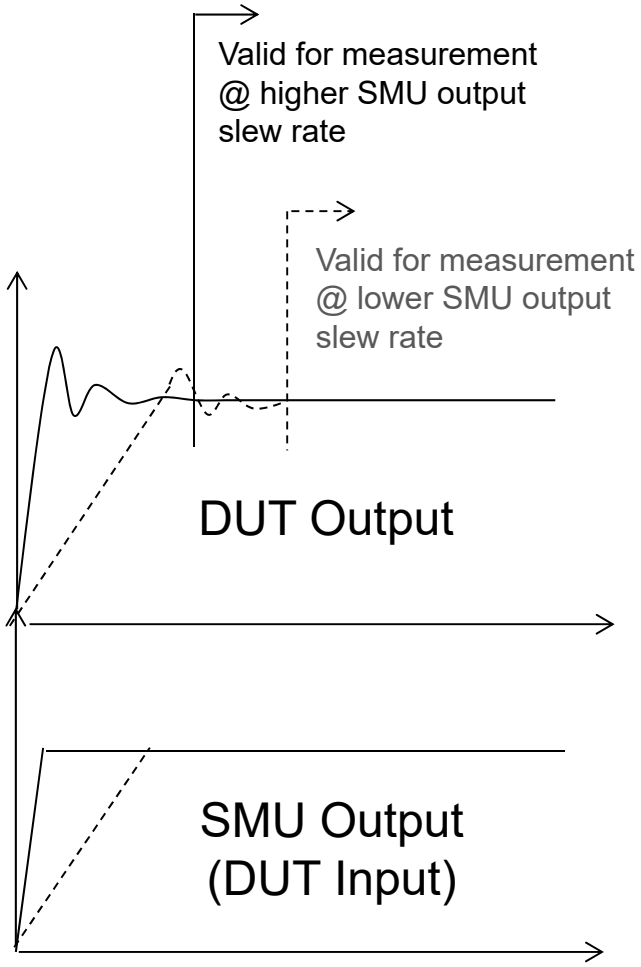
Fundamentals

- **ADC/DAC Bit Resolutions**
  - Higher is Better for Accuracy
  - But, Higher Bit Resolution May Result Slower Measurement Speed
- **Accuracy Spec**
  - Various Ways to Express
    - Spec is Reading (Setting) Error + Range (Full Scale) Error.
    - aa% + bb% ; aa% + bb
  - Highly Conditional
    - Temperature Range
    - Measurement Speed or Aperture

Output Slew Rate

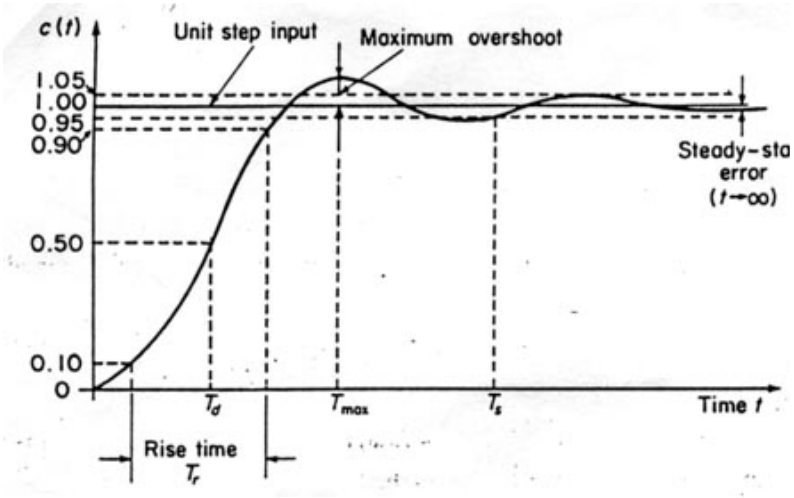
- If SMU is used as input source of DUT, the DUT output will respond to SMU output.
- When SMU output slew rate is high, shorter settling need for DUT output measurement .
- However, if the SMU output slew rate is low, longer settling time need before measurement can be taken on DUT output.
- ***Higher SMU output slew rate*** (when allowed) ***may help to speed up the test.***

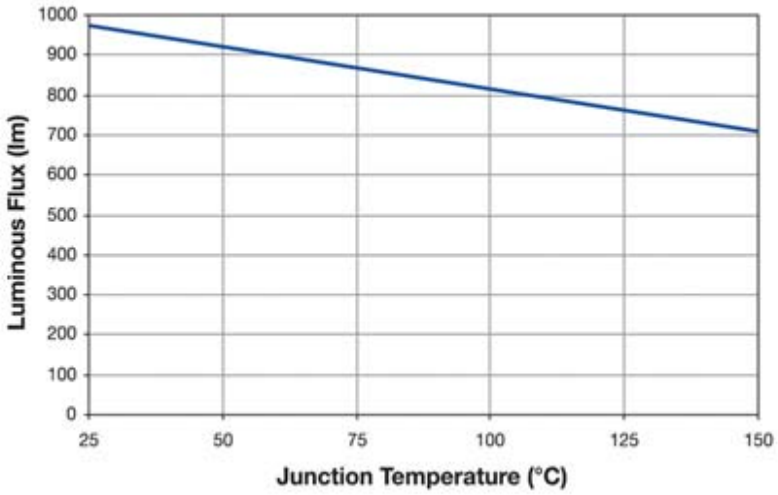


Timing Impact

■ Define Reference (True) value

- ➢ **Steady-State or Transient State?** (Electrically or Thermally)

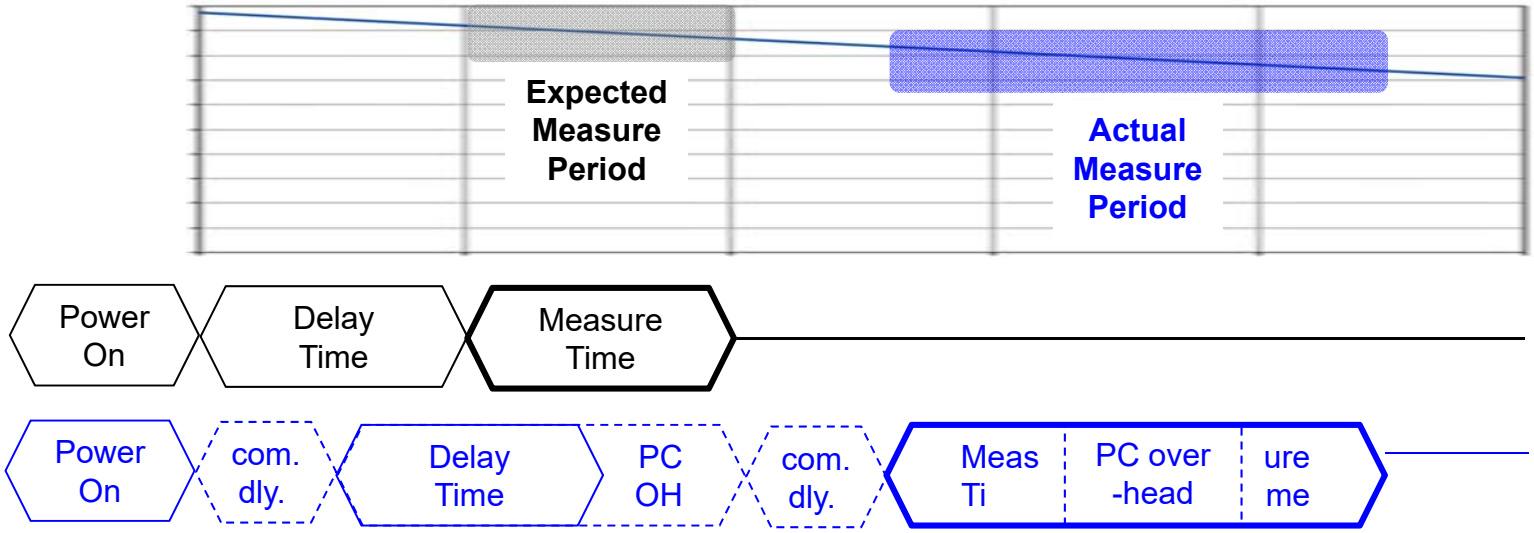




- ◆ ***Make sure you are comparing readings under same conditions***
  - **Delay (stable, settling) time**
  - **Measure (aperture) time**

Timing Impact

■ Is Your Delay Time and/or Measurement Time Correct or Same Every Time?



◆ *When DUT Characteristic Is Changing over Time ->*

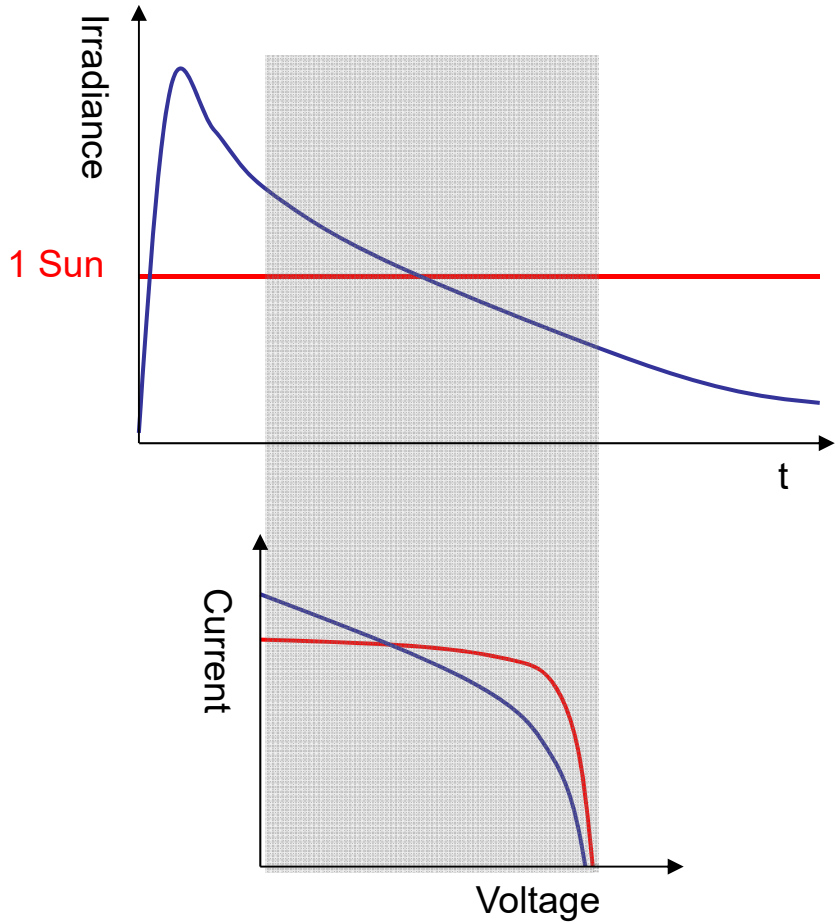
- **PC Based System Can't Provide Repetitive Result!**
- ***Hardware Sequencer Is Essential!***

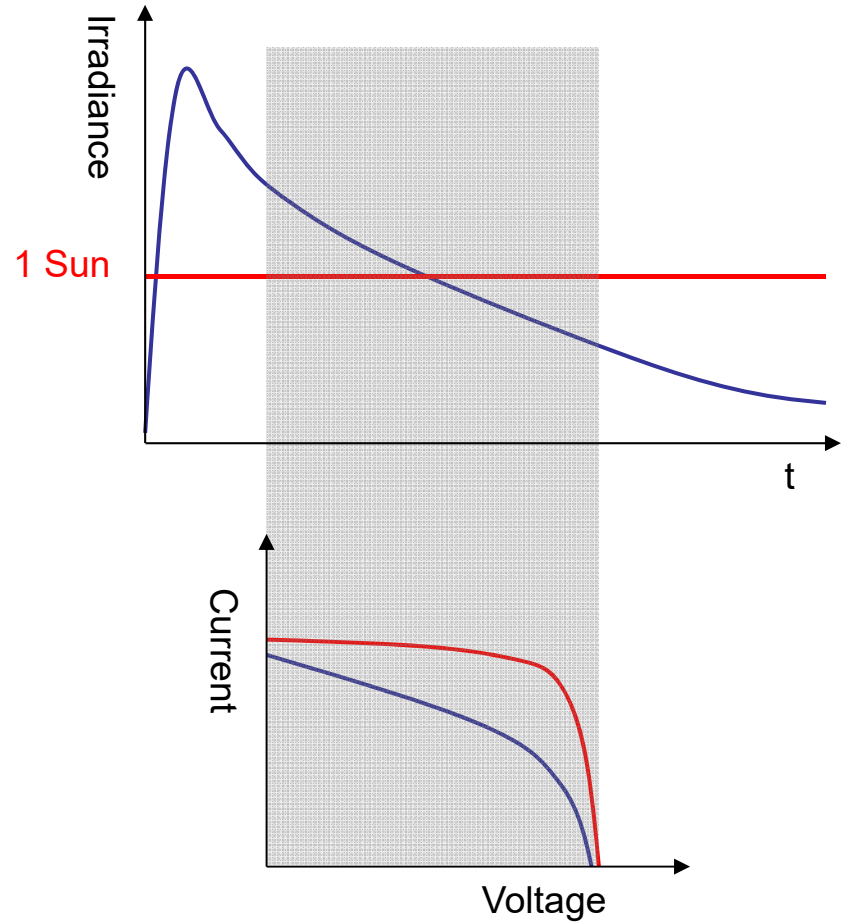
Simultaneous Measurement

I-V Curve @ 1 Sun

Non-Simultaneous Flash Simulation

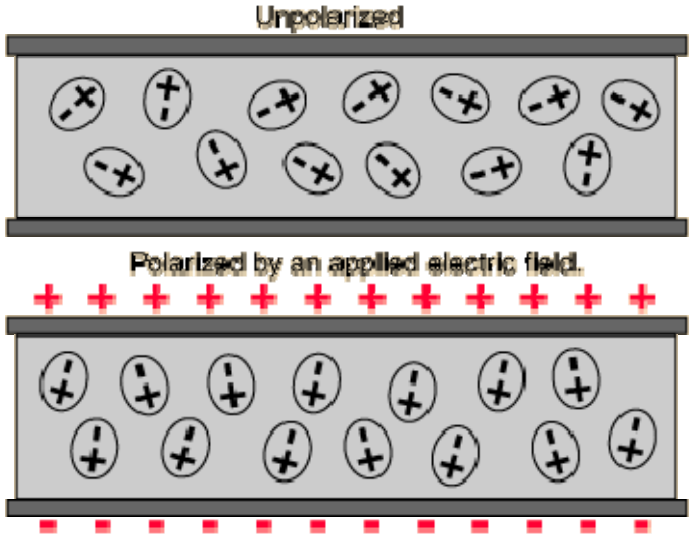
Corrected I-V Curve by Irradiance Monitor

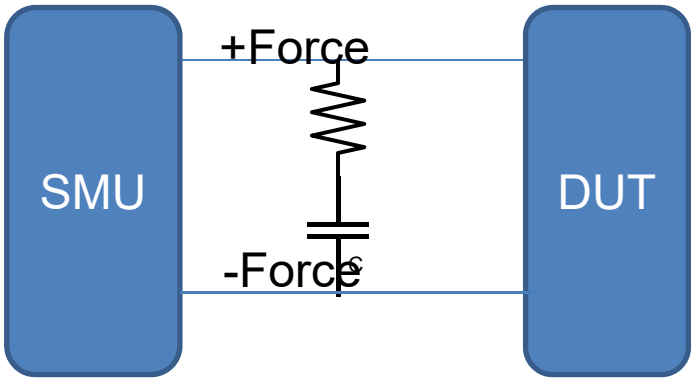




Dielectric Absorption

- All insulation material have some amount of dielectric absorption.
- The polar molecules in the insulation try to align with the electric field. The energy needed to align these molecules is seen as current (DA) from the SMU.
- DA in the insulation between SMU and DUT, can be modeled as a resistor in series with a capacitor.
- Until the capacitor is charged, the SMU will measure the DUT current + DA current.
- The DA current will ***cause an error*** to the DUTs measure current value. the only option to accurate DUT current measure is ***wait***, ***delaying throughput.***

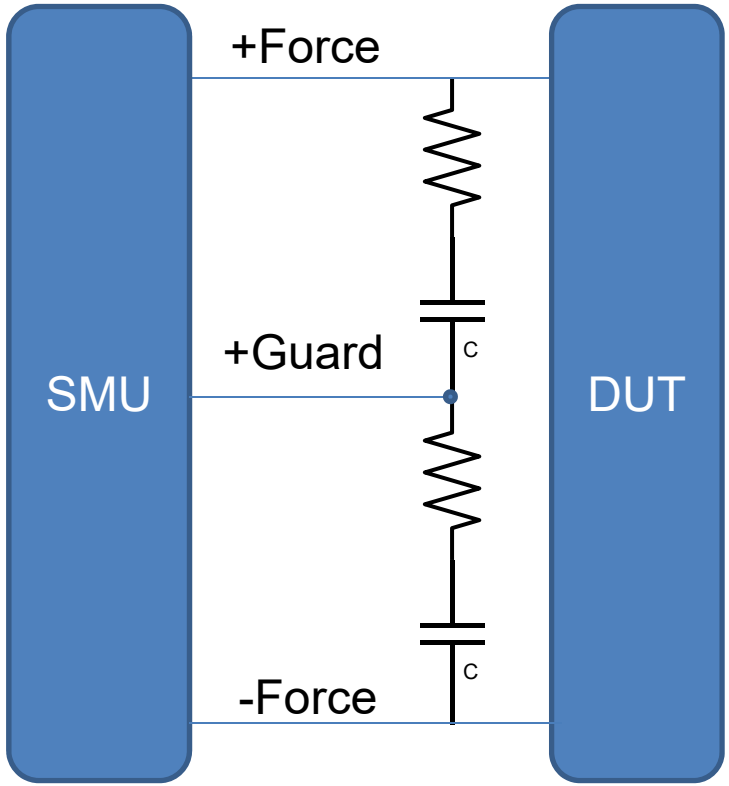




Dielectric Absorption

Solution !

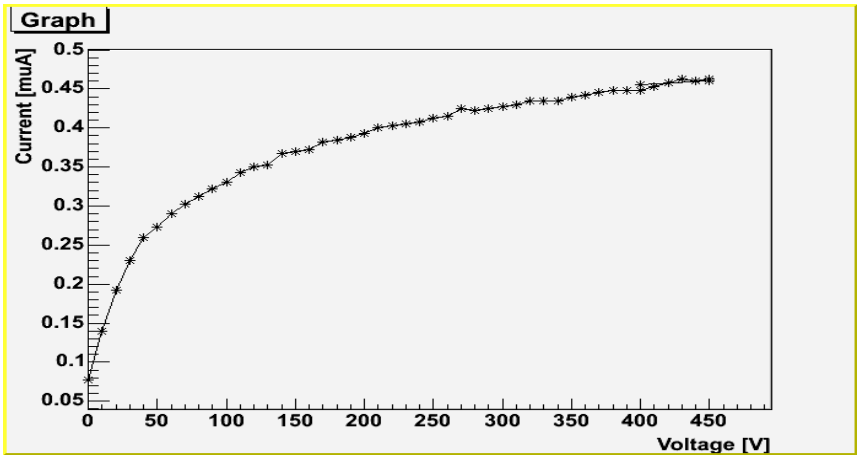
- The +Guard driven by the SMU is at the same voltage as the +Force, so there is no electric field across the insulation material.
- The insulation between +Guard and –Force still has the DA problem. But the current from the +Guard is not measured, and not part of the DUT current.
- ***Using the Guarded connection*** technique allows the SMU to measure the DUT current much ***faster and more accurate***.

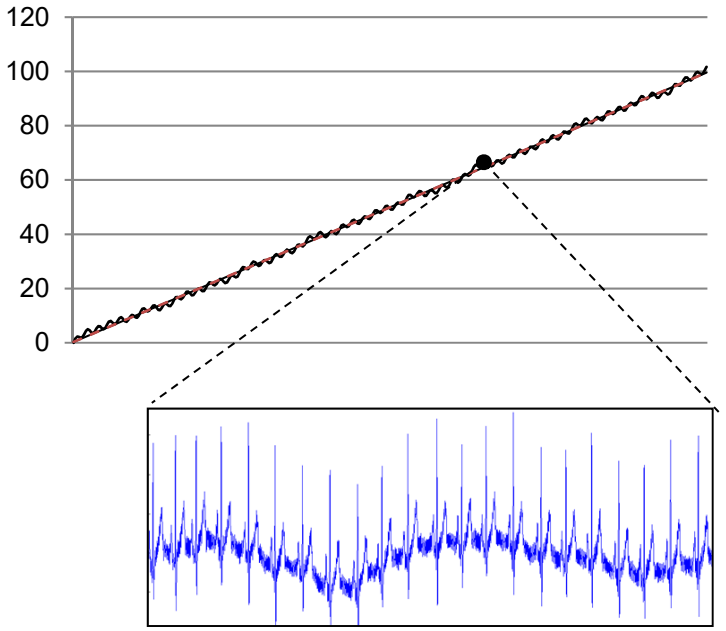


Noise Floor

■ Output Noise

- High output noise from SMU will exhibit noise signal not caused by DUT or worse - trigger unwanted response.
- Most of the influence can be averaged out by giving longer aperture time.
- However, longer aperture time means slower test speed.
- Using ***low noise SMU may help to speed up your test***.

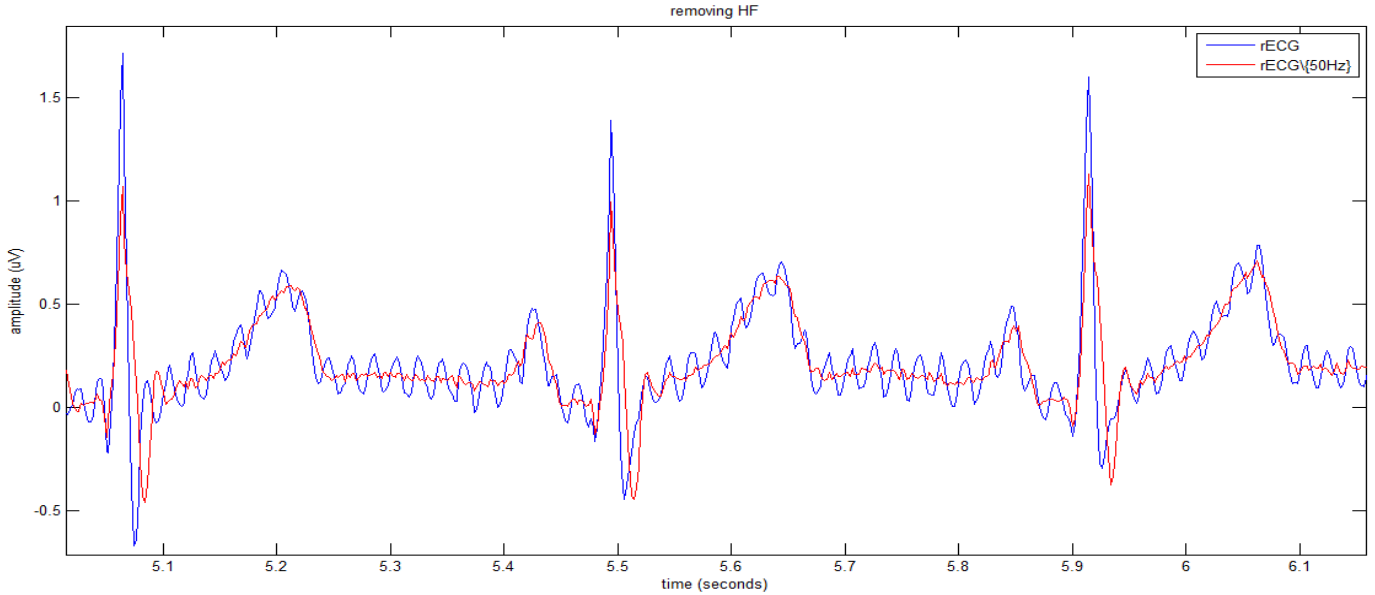




Noise Floor

■ Power Line Frequency Noise

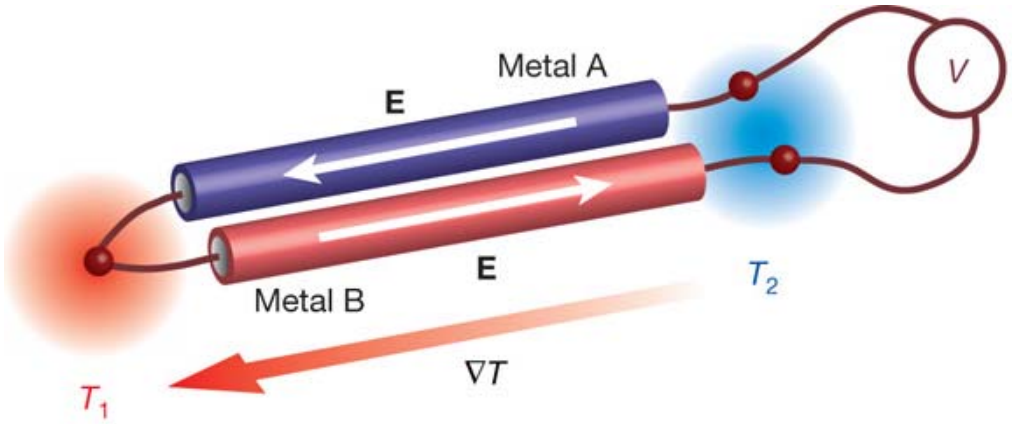
◆ Power Line Frequency Noise (Low Frequency Noise) is very hard to filter without affecting output slew rate.



◆ ***Set aperture time equal to integer number of PLC*** (Power Line Cycle) may help greatly to improve measurement accuracy. (1PLC = 20mS @ 50Hz)

■ Connector

- If the path from the SMU to the DUT has junctions of dissimilar metals, errors in accuracy will occur.
- Lead-tin solder to copper PCB trace has thermoelectric EMF of 4uV/degC
- **Minimizing dissimilar metal connectors** between SMU to DUT to decrease errors.
- Or, ***thermally insulate around these junctions***, so that both side of the junction is at the same temperature



Path to DUT

■ Relay

Mechanical relays between the SMU and DUT add errors to both current and voltage.

Voltage errors

- Voltage error is caused by thermal EMF.
- Inside relays, some ferromagnetic material is used with the electromagnetic field to actuate the contact.
- Minimize voltage errors by ***selecting a low thermal EMF relay***. However , low thermal EMF relays, still produce errors of 5uV to .5uV.

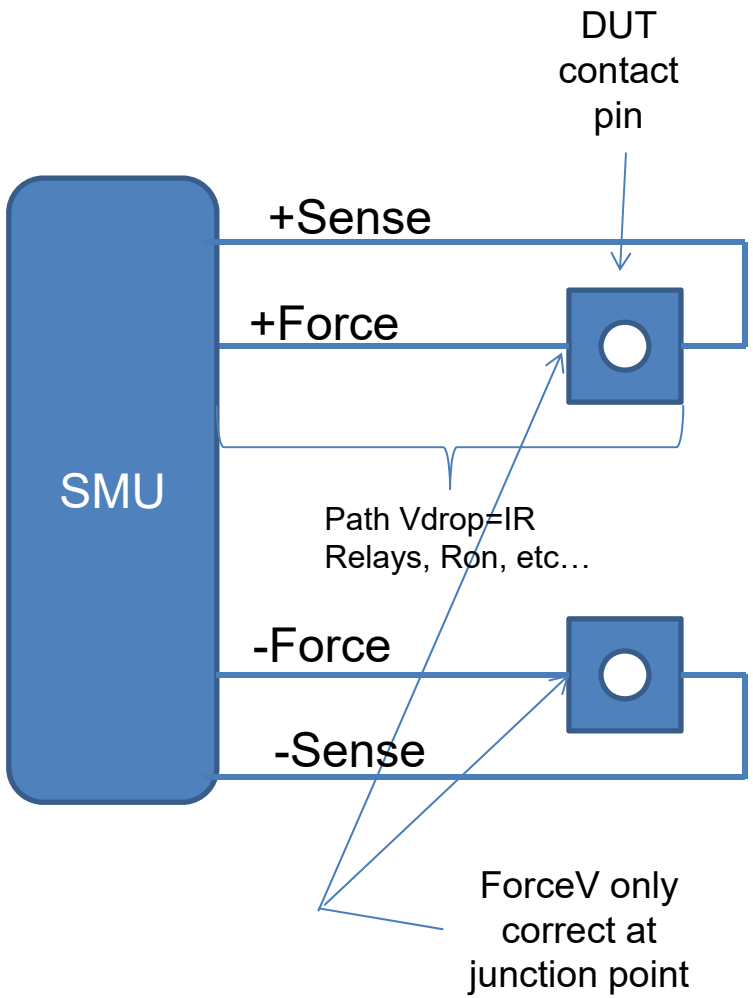
Current errors

- Relays have insulation material as their mechanical structure.
- This insulation has the DA problem, mentioned earlier as well as a pure resistive component.
- The resistance of the relay isolation adds the DUT current, causing errors in current measure.

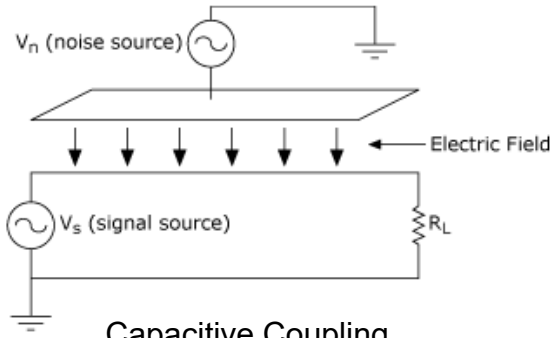
Path to DUT

IR Drop

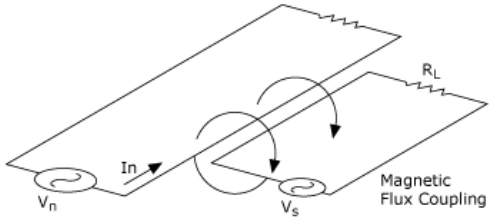
- The path between the SMU and DUT has a voltage loss dependent upon current flow to DUT.
- The path resistance x current = voltage drop along the path.
- ***Proper use of the +/- Sense lines*** (connect to DUT) will eliminate the voltage drop error.



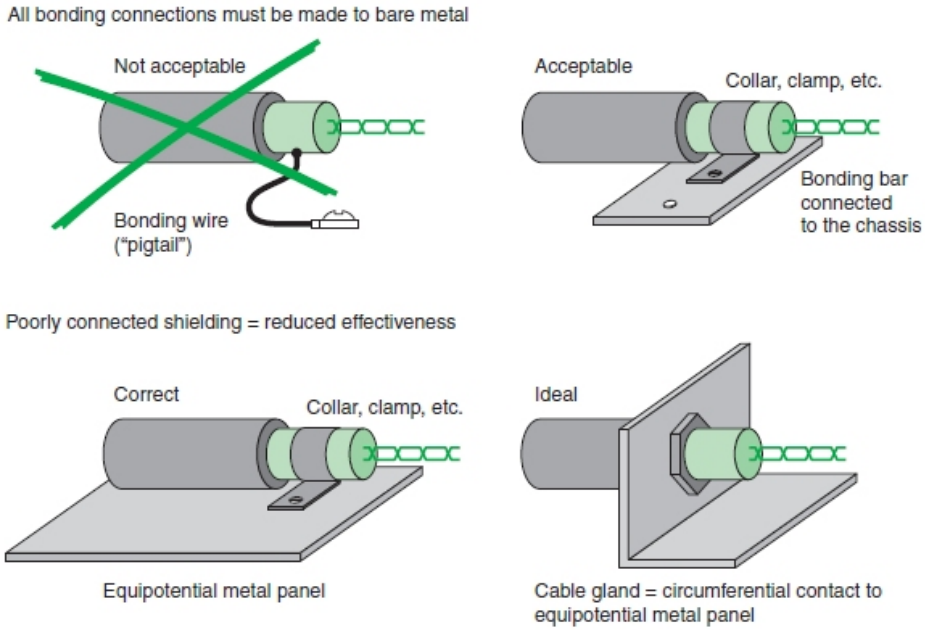
■ Ambient Noise Interference



Capacitive Coupling



Inductive Coupling



- ***Proper shielding*** is important to reduce interference induced from ambient noise source

Capacitive Loads

- Measuring low currents on high capacitance loads requires long settling time.
- To force 1V across a 1uF load on a 1uA range, and measure current to an 18bit value. We must wait ln(2^18) time constants =12.48 time constants for the voltage across the 1uF to reach 1V. (within 18bit accuracy)
- 1uA range measurements are performed by measuring a voltage across a For a 1uA, a 1Mohm resistor is used as current shunt.
- 1 time constant = 1Mohm * 1uF = 1 second
- To measure the current to 18bit accuracy, we need to wait settle time for 12.48x1second=12.48 seconds.
- ***To "precharge" the capacitor can greatly increase throughput!***
- ***Some Chroma SMUs*** have the ability to ***"precharge" the capacitor by parallel higher current range*** for a programmable amount of time. For above example, we can drive the voltage to 1V across the 1uF load in < 1usec.

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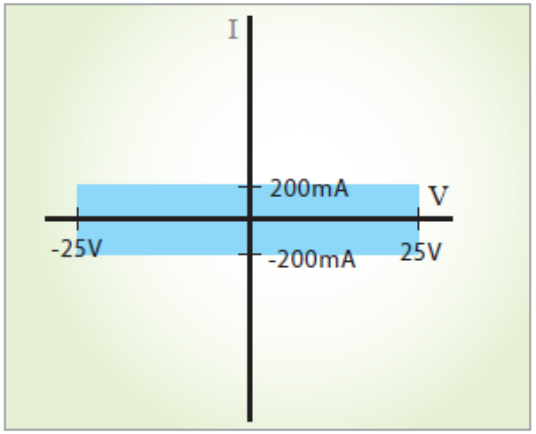
Chroma PXI/PXIe SMU

- Programmable force voltage & current
- High output slew rate
- High precision voltage/ current measurement through guarding
- High measurement sampling rate (100k s/S)
- Isolated floating output
- Remote sensing & Guarding line
- Hardware sequencer for fast and precision output profile
- Low output noise; Near Zero stability
- Precharge capability
- Synchronous between channels
- Labview / LabWindows driver
- Versatile Soft Front Panel

Chroma PXI/PXIe SMU



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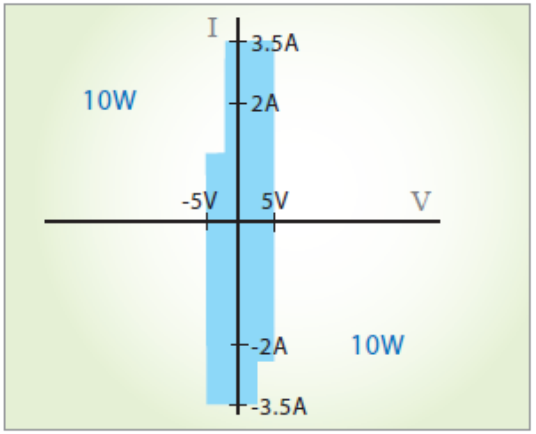

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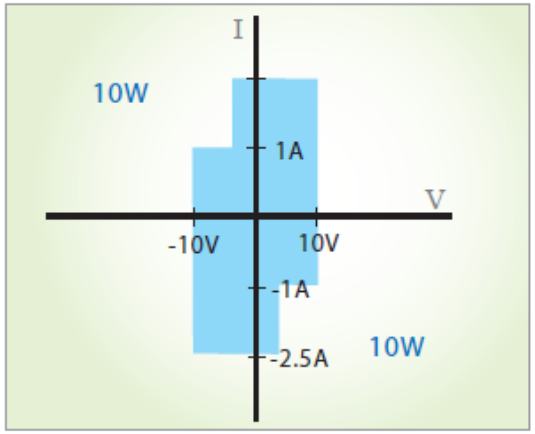

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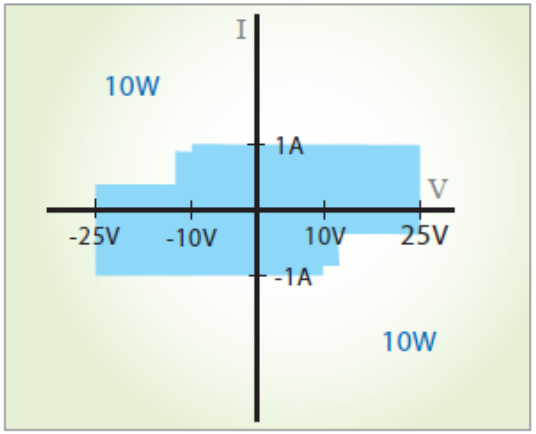

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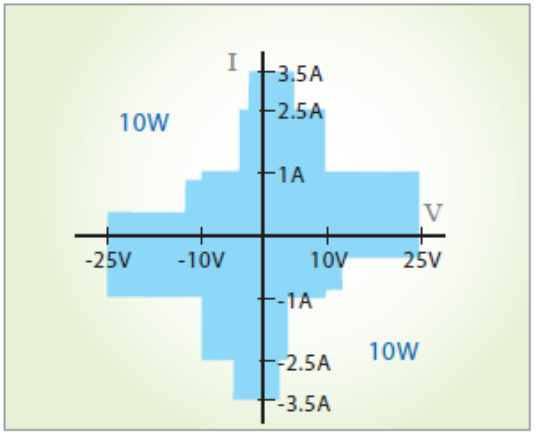

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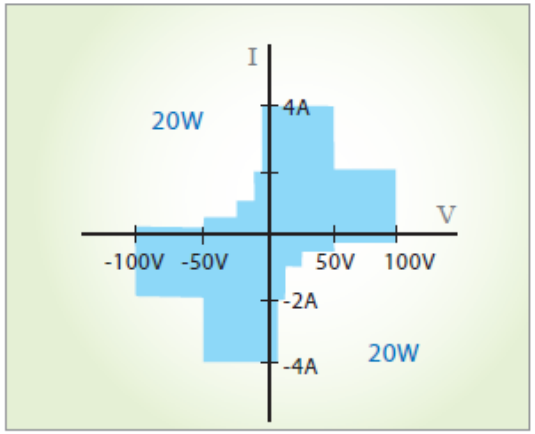

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Chroma PXIe DPS

What is DPS (Device Power Supply)?

- Device Power Supply is specially designed power supply used for semiconductor IC testing!

A good DPS has to be :

- High output slew rate to meeting test speed requirement
- Equip Hardware Sequencer
- High measurement sampling rate
- Hign measurement accuracy

Chroma PXIe DPS

- Channels per module : 2-6 depends on power & models
- Low output noise
- High programming / measurement speed
- High programming / measurement resolution (by multiple ranges)
- Simultaneous voltage, current & high accuracy measurement
- Measurement log for measured data
- Programmable resistor
- Hardware Sequencer
- LabView/LabWindows, C# drivers
- Softpanel GUI

Chroma PXIe DPS

Model Name	52314e-6-1	52312e-6-3	52316e-6-500m
Slot	1	1	1
Output Channels	4	2	6
Source Power	6Wpk (3Wcont.) x 4	18Wpk (6Wcont.) x 2	4Wpk (2Wcont.) x 6
Max. Current	1A Max (Pulse Mode)	3A Max (Pulse Mode)	500mA Max (Pulse Mode)
Input Voltage	Backplane Power		
Output Isolation	Isolated but share common LO		
Bits Resolution	20 bits for measurement ; 16 bits for programming ; 16 bit for current clamping		
Programmable Loop Bandwidth	8		
Force Voltage Ranges	±6V		
Measure Voltage Ranges	±6V		
Measure Current Ranges	1A, 100mA, 10mA, 1mA, 100uA, 10uA	3A, 1A, 100mA, 10mA,1mA, 100uA	500mA,100mA, 10mA, 1mA, 100uA, 10uA
Force Voltage Accuracy (23℃±5℃)	0.02% reading + 0.01% F.S. (Aperture Time= 2PLCs)		
Measure Voltage Accuracy (23℃±5℃)	0.02% reading + 0.01% F.S. (Aperture Time= 2PLCs)		
Measure Current (1 Year)Accuracy (23℃±5℃)	0.1% reading + 0.1% F.S. (1A) 0.05% reading + 0.05% F.S. (<1A) (Aperture Ttime= 2PLCs)		
Output Voltage Ripple & Noise (23℃±5℃)	<50mV pp 20Mhz BW Full Load		
Measurement Sampling Rate	600K Samples for both V & I		
Output Ganging	Within same DPS card (1A Range Only)		
Output Connection	4/Wire (±Force/±Sense)		
Measurement Log	32K Samples/channel		
Output Profiling	1024 Step/Per channel		
Trigger Input	Programmable 4 CH		
Trigger Output			
Master/Slave Mode	Yes		
Programmable Resistance	Yes		