How to Get the Most from Your Low Current Measurement Instruments

RE-INVENTING TEST & MEASUREMENT

THROUGH *SPEED* AND **SIMPLICITY**

Jonathan L. Tucker

Senior Marketer, Research and Education Business

and

Sensitive Measurements Product Line Manager

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Presentation Overview

- Modeling the low current measurement system
- Defining theoretical current noise limits
- Controlling sources of low current measurement error
- Low current measurement using source-measure units (SMUs)

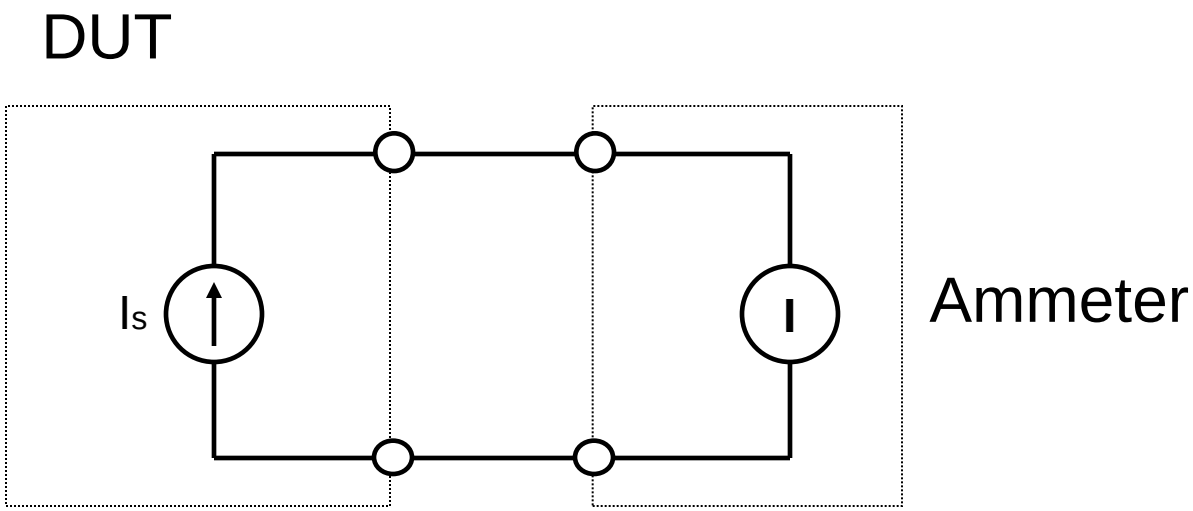
What Limits Your Results?

- The material or device under test [DUT] itself?
- The connections between the DUT and instruments [including cables, fixtures, switching]?
- The measuring instrument?
- The measurement technique?

ALL of these things

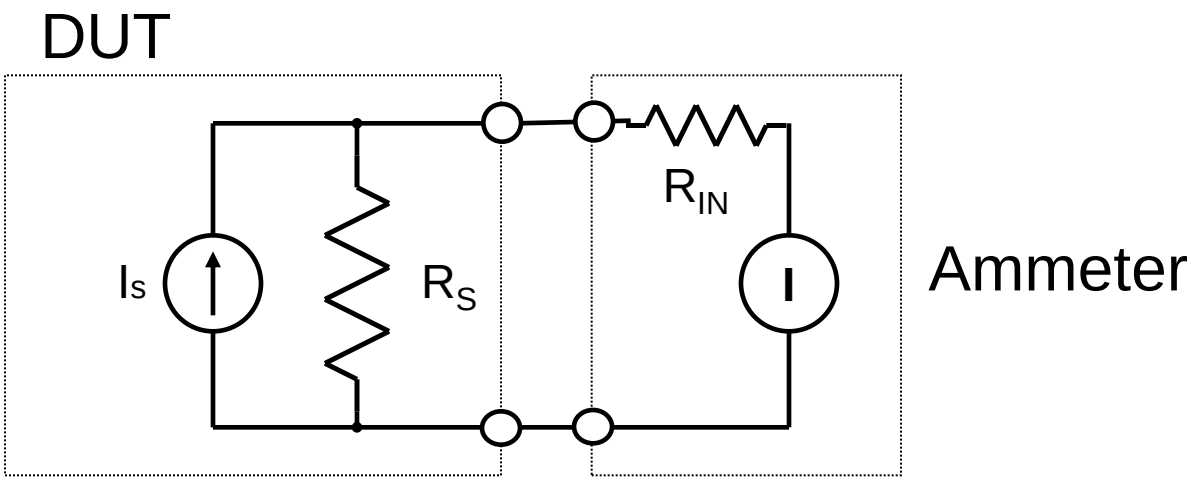
will affect your results!

Current Measurement Goal



Goal: $I = I_s$

Current Measurement Problems



Three main problems:

1. Source is not ideal, I_s is dependent upon load
2. Ammeter is not ideal, it is not an absolute short
3. Need to control common sources of error

Common Error Sources

- Theoretical limitations
- Source resistance limitations
- Triboelectric effects
- Contamination effects
- Leakage currents

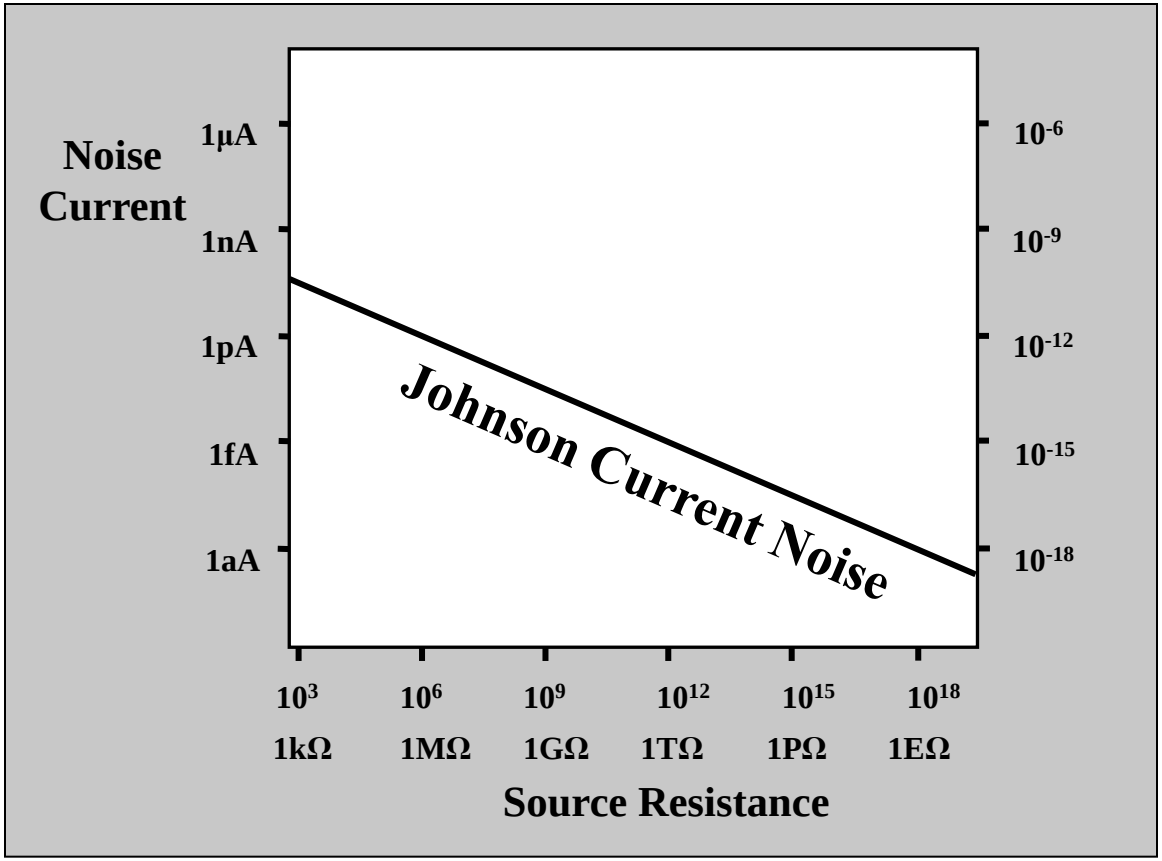
Johnson Current Noise

The R_s provides a fundamental limit to how well you can resolve I_s:

$$I_J = V_J/R_s = \frac{\sqrt{4kTBR_s}}{R_s} = \sqrt{\frac{4kTB}{R_s}}$$

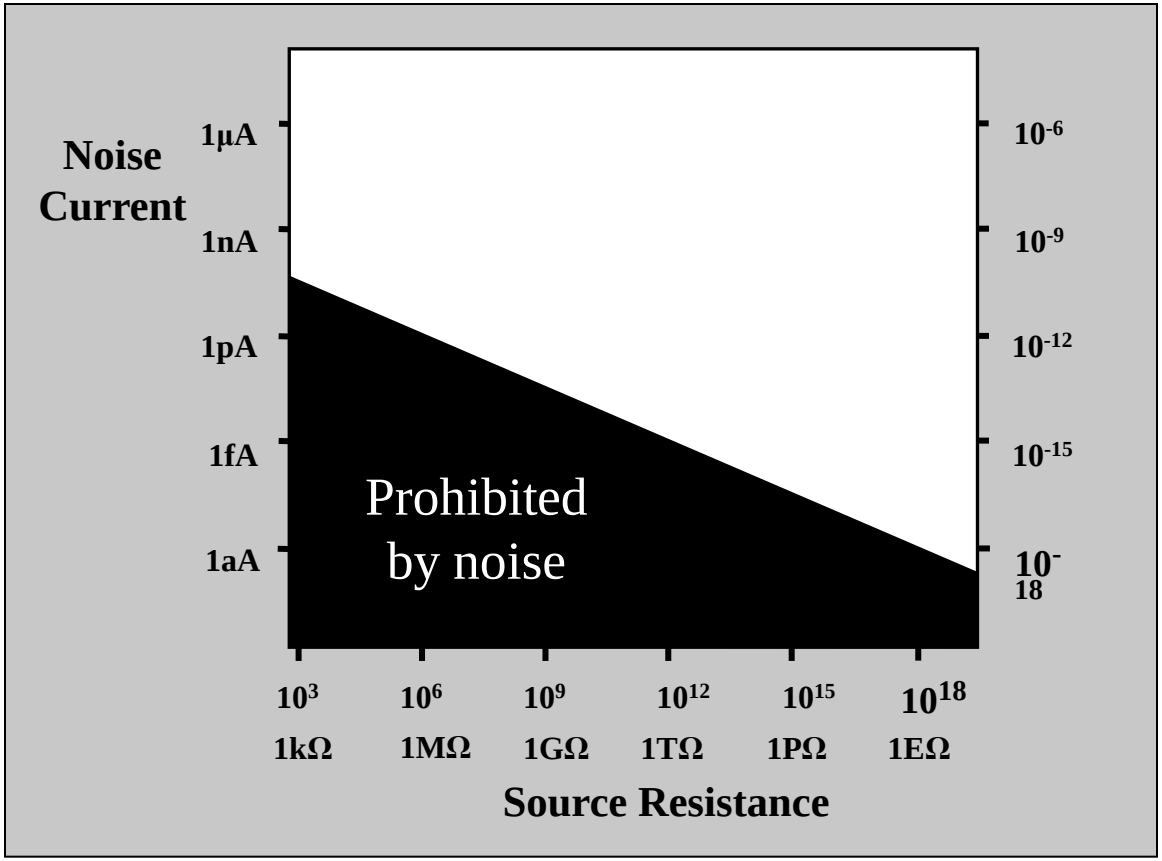
k - Boltzmann's constant: 1.38 x 10^{-23} J/K
T - Absolute temperature of the source
B - Noise bandwidth in hertz
R_S - Resistance of the source in Ohms

Theoretical Limits of Current Measurement



p-p noise taken at 3Hz, 300K

Theoretical Limits of Current Measurement



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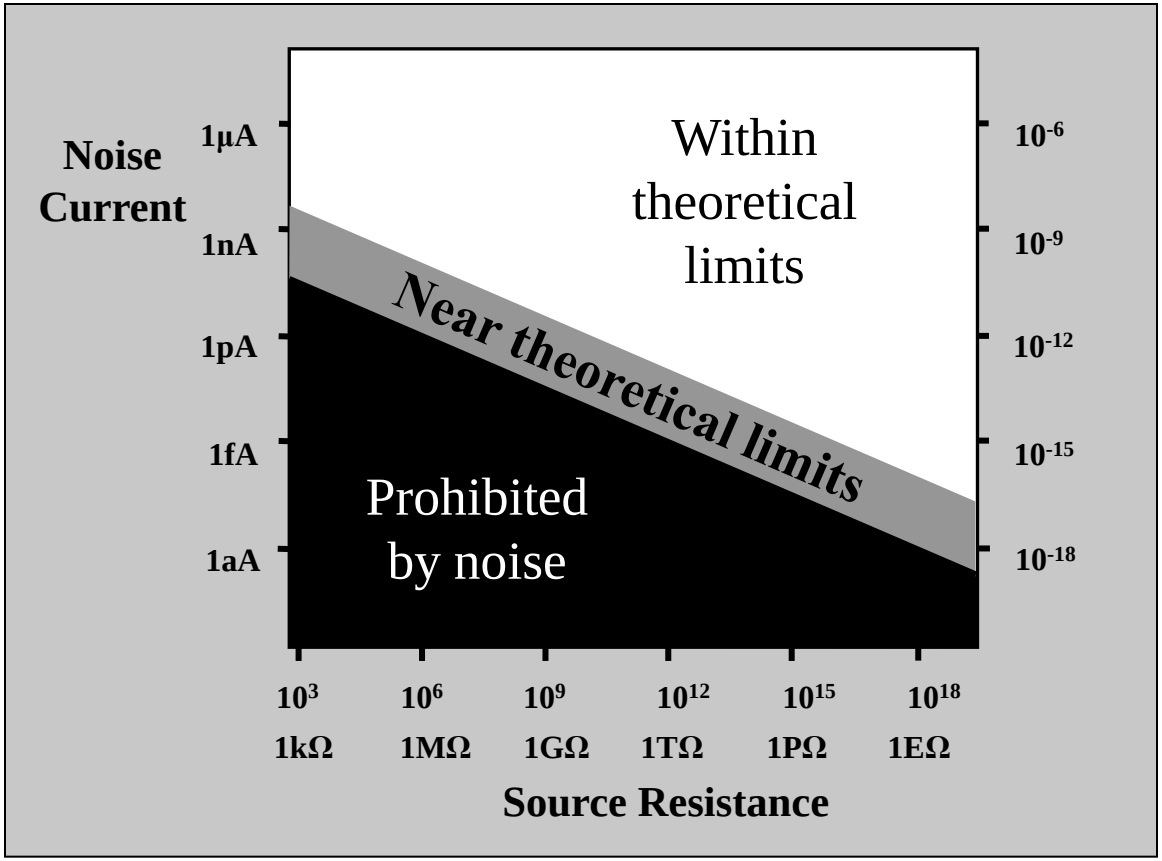
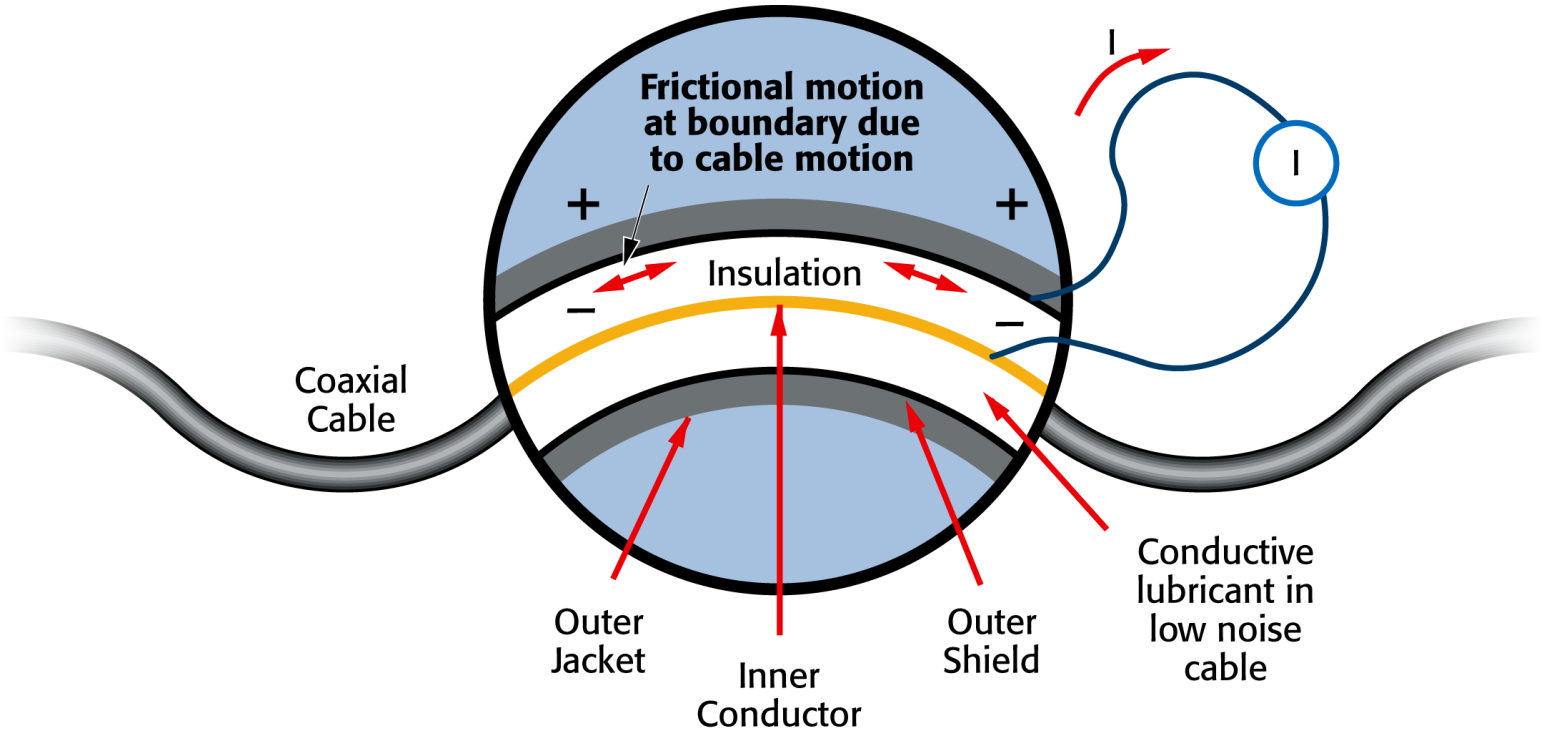


p-p noise taken at 3Hz, 300K

Triboelectric Effect

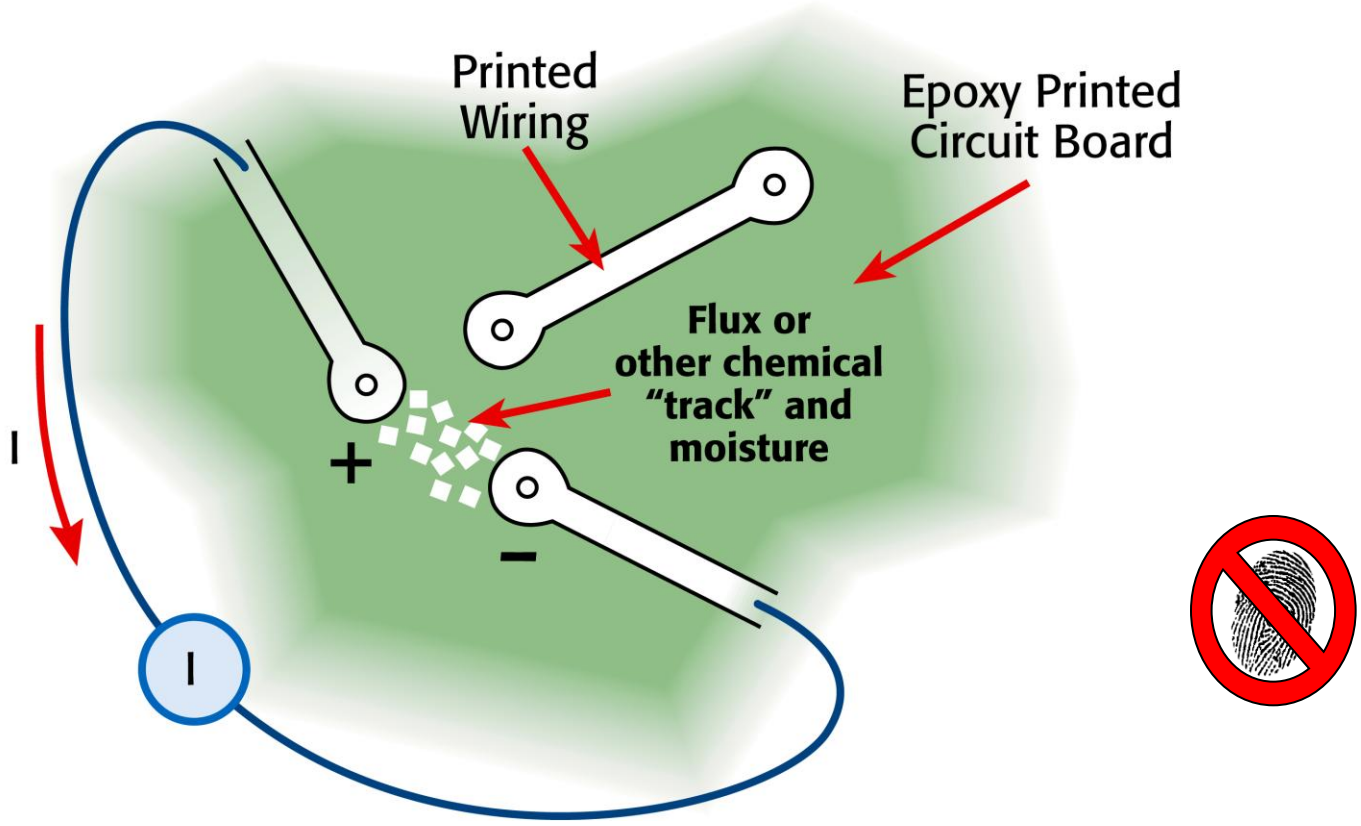


Noise current can be tens of nA

Reducing Triboelectric Effect Noise

- Use low noise cable
- Minimize cable length – get measurement close to source
- Isolate measurement from vibration
- Tape loose measurement cable to stable surface
- If 10nA of noise won't affect your results, don't need to worry about this

Contamination Effect



Noise current can be tens of nA

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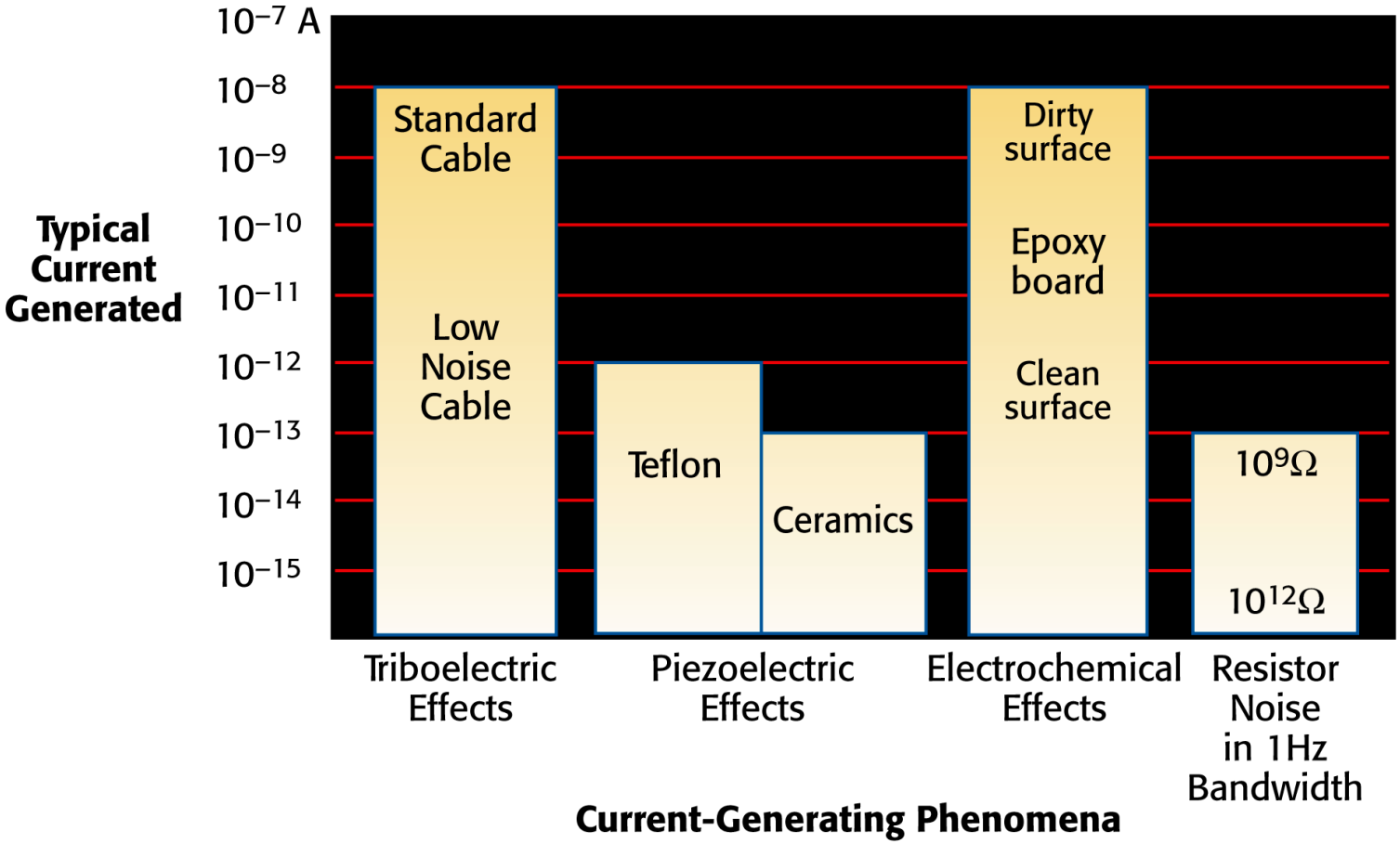
Minimizing Contamination Effects

- Use air as insulator when feasible
- Avoid touching insulators surrounding sensitive current nodes or use gloves
- Use as little flux as possible when soldering
- Clean around soldered regions with virgin solvent and clean swabs
- Be especially careful if circuit will operate in high humidity environment
- Increasing levels of care can reduce it to fA levels

Typical Magnitudes of Generated Currents



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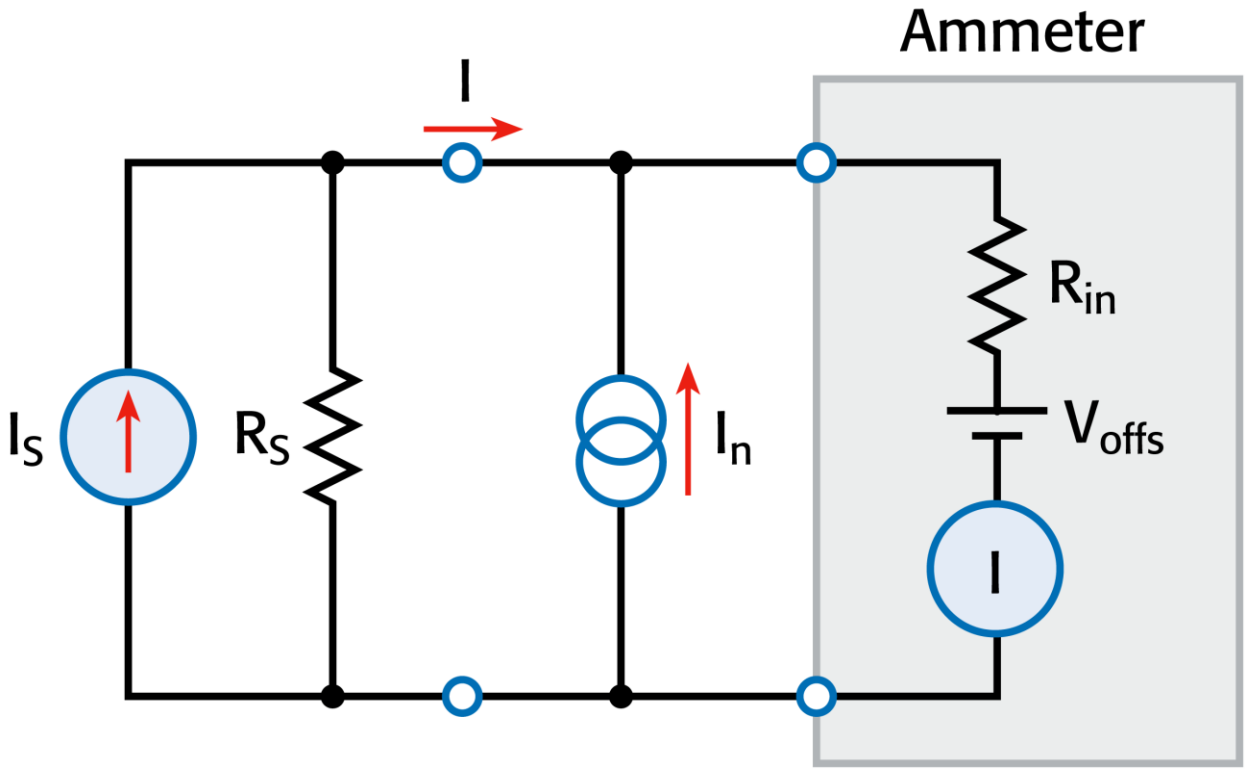
… and Then There is the Connection

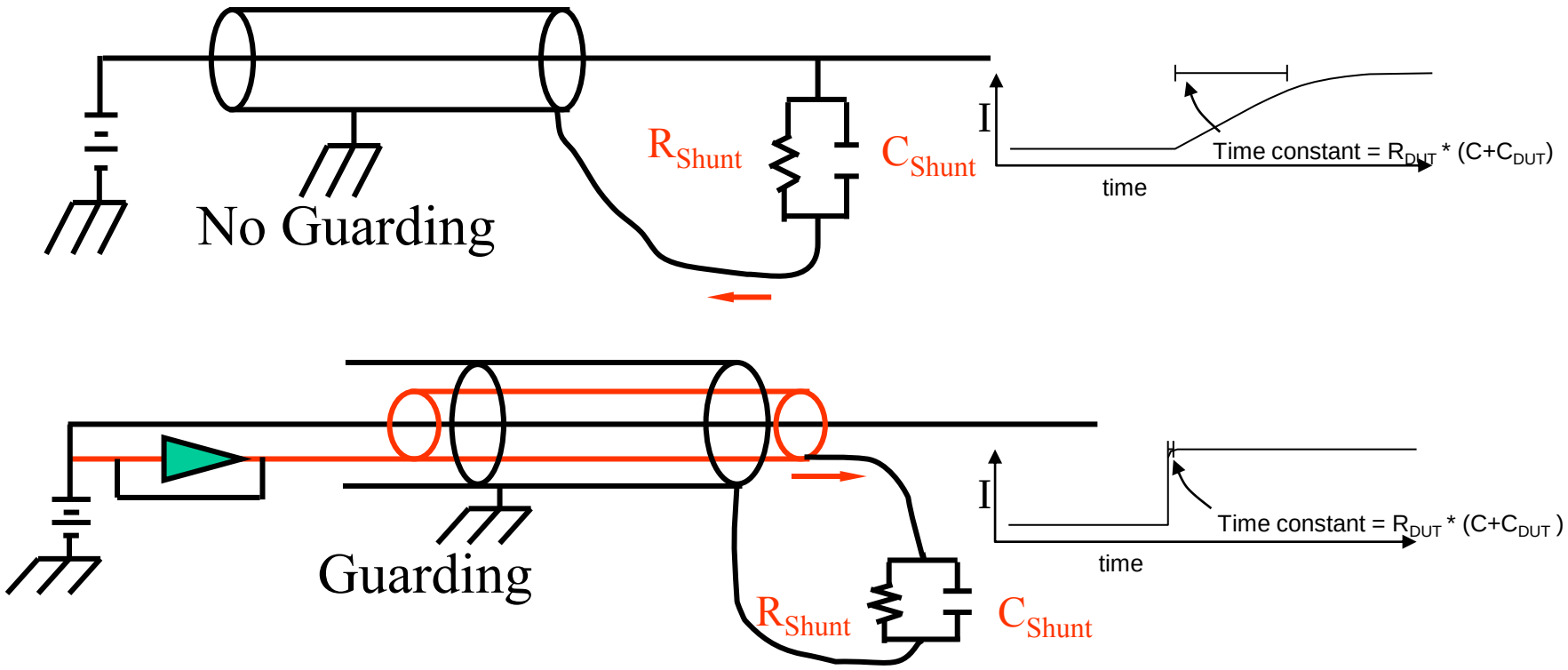


Leakage Current

- **Leakage currents are generated by resistance paths between the measurement circuit and nearby voltage sources.**
- **Leakage currents can be reduced by:**
  - Using good quality insulators (such as Teflon®, polyethylene) in the test circuit.
  - Reducing humidity in the test lab.
  - Using guarding technique

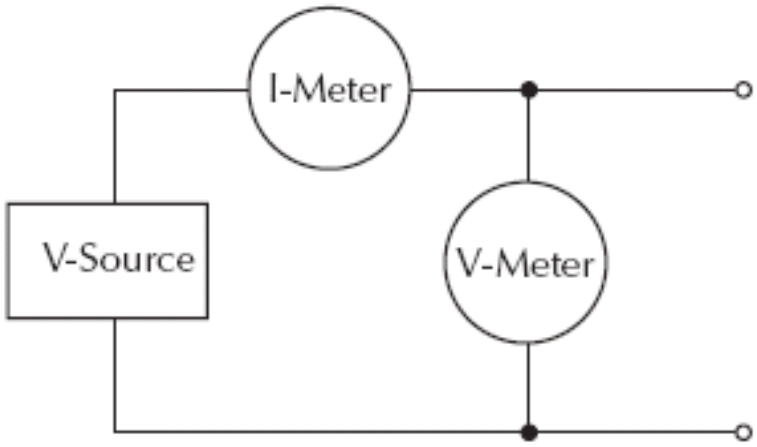
Cables and Connections

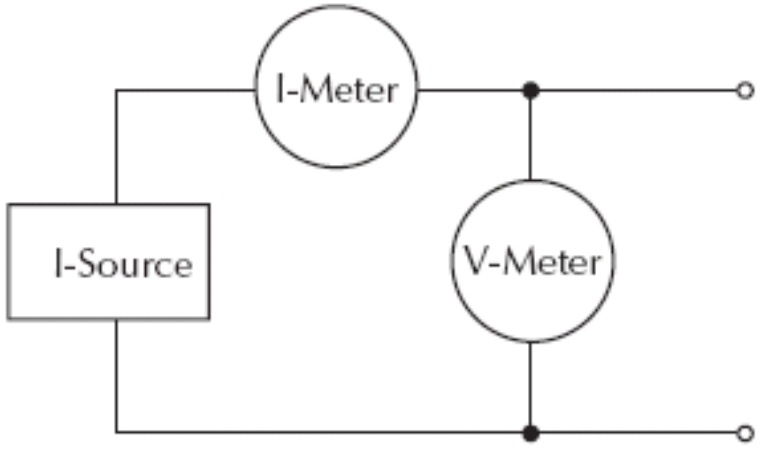
Cable leakage issues require guarding to eliminate parasitic capacitances.



Source-Measure Units

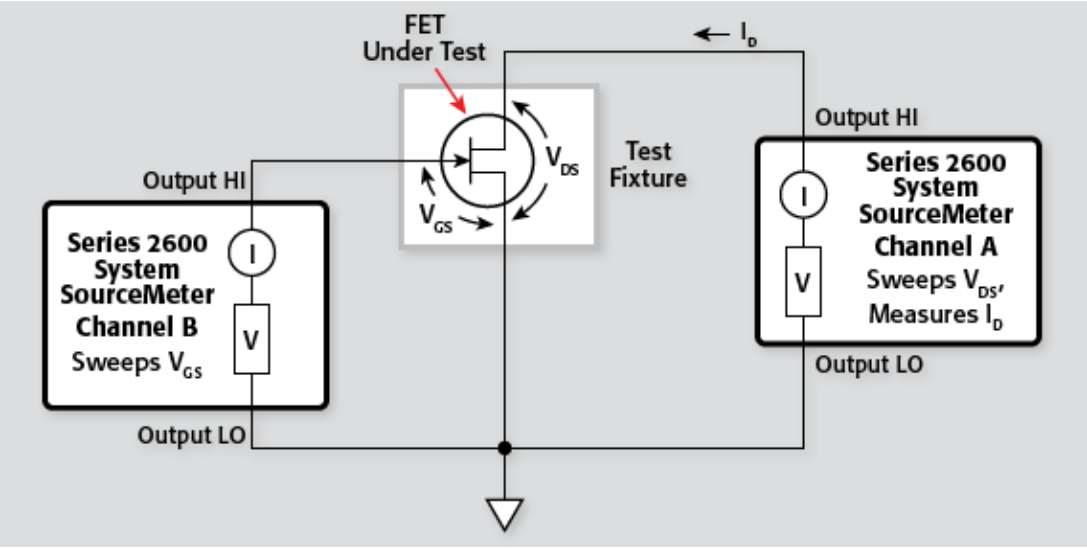
- **Combine source and measure in a single package**
  - Some compromise in flexibility; must source and measure in the same part of the circuit
- **"Swiss army knife" of instrumentation**
  - Voltage source, current source, voltmeter, ammeter, and ohmmeter





Common-Source FET Characterization

- One of the more common FET tests involving family of curves is common-source characteristics.
- Two SMU channels are required for the tests.
- For low current tests (<1mA), triax cables are recommended to make instrument-to-test fixture connections.



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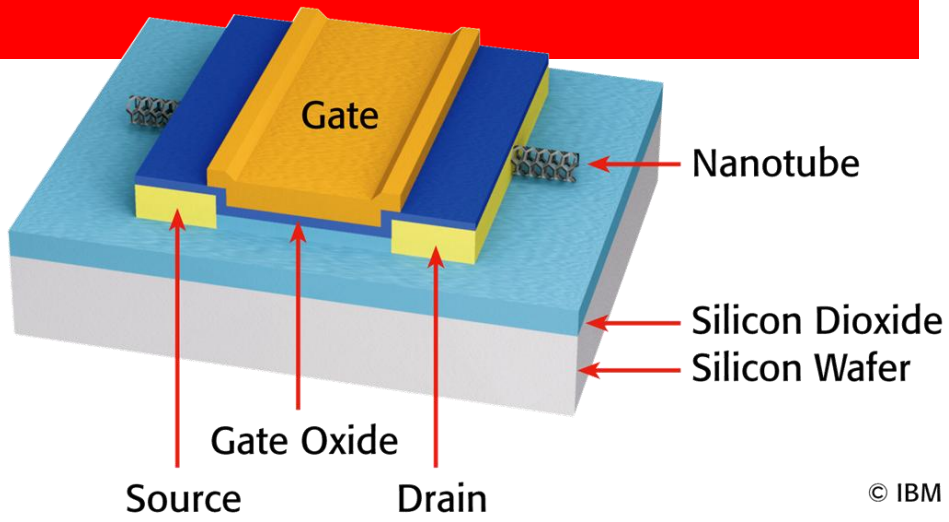
Carbon Nanotube Electronics Characterization

- **Application:**
  - IV Characterization on CNT-based Electronics
- **Key Measurement Requirements:**
  - Low current censitivity
- **End Use Applications:**
  - Smaller consumer electronics
  - Low power consumption devices



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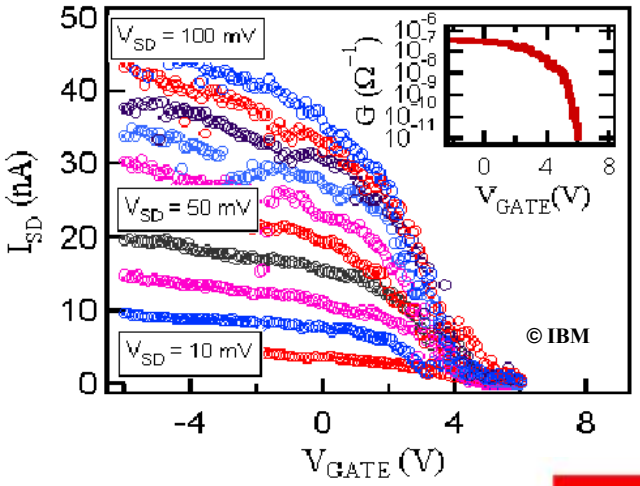

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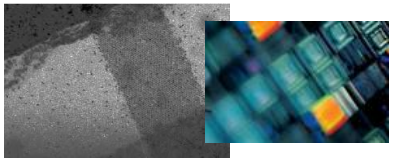
Keithley's Series 2600A SourceMeter® Instruments: Designed to Meet Demanding Applications

I-V functional test and characterization of a wide range of applications:

- Semiconductor device testing
  - Wafer level reliability
  - Low cost semiconductor device characterization
  - Wafer sort
- Nanotech research
  - Low-power characterization
- Low current component testing
  - Optoelectronic devices
  - Sensors
  - Dielectric characterization
- Research and education lab use
  - Materials testing
  - Hall effect and Van der Pauw measurements

Multiple instruments in one:

- SMU
- DMM
- Precision Bias Source
- Low Frequency Pulse Generator
- Arbitrary Waveform Generator



Test at the wafer, device, and/or packaged part level

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Newest Members of the Series 2600A SourceMeter Family Models 2635A and 2636A Low Current Instruments

- Single and dual channel versions
- 1fA measurement resolution

Triax connectors with flexible grounding scheme

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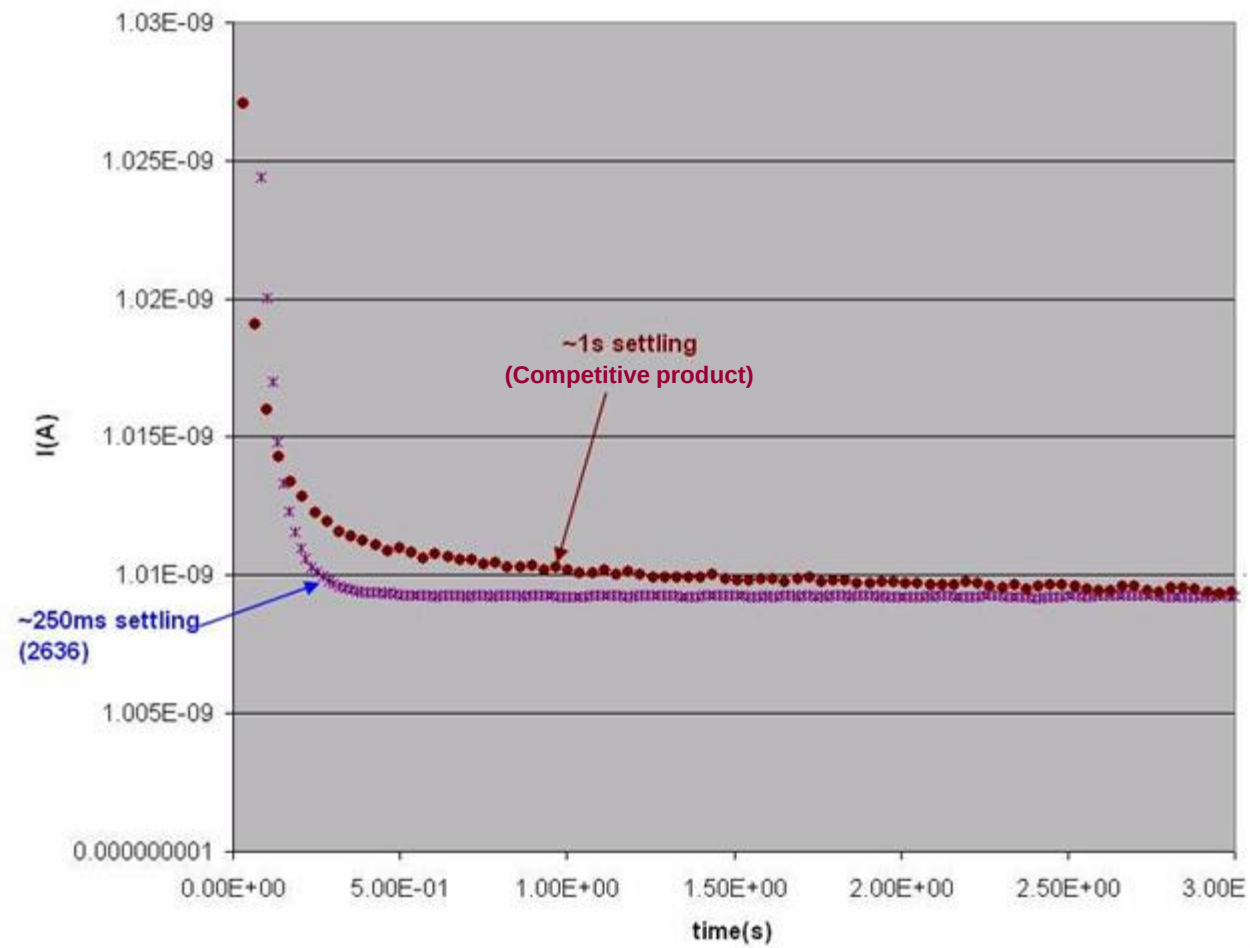
Model 2636A Enables 4x Faster Low Current Measurements



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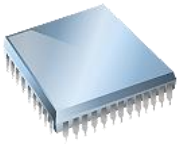
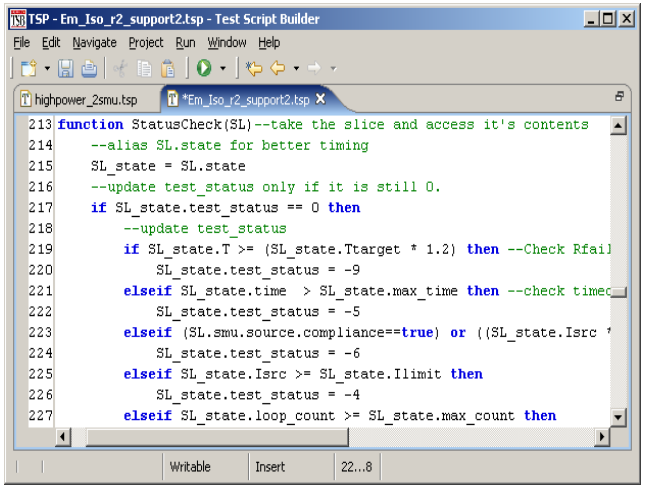
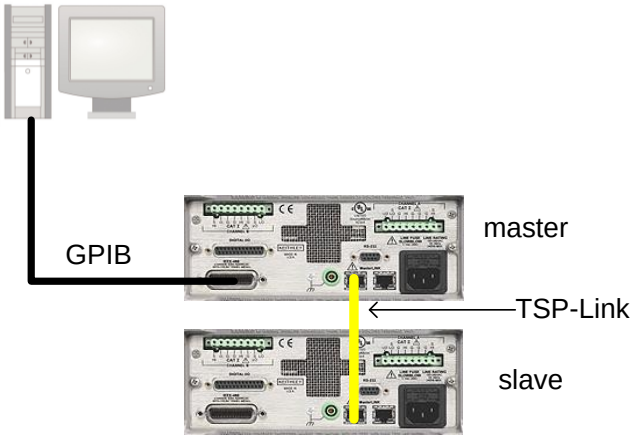
TSP® - A Revolutionary Technology that Brings PC-like Functionality to Test Instruments

Components of TSP Technology

1. Powerful Processor
2. Test Script Language – Optimize & Customize the instrument
3. TSP-Link® - for easily scaleable system with no mainframe







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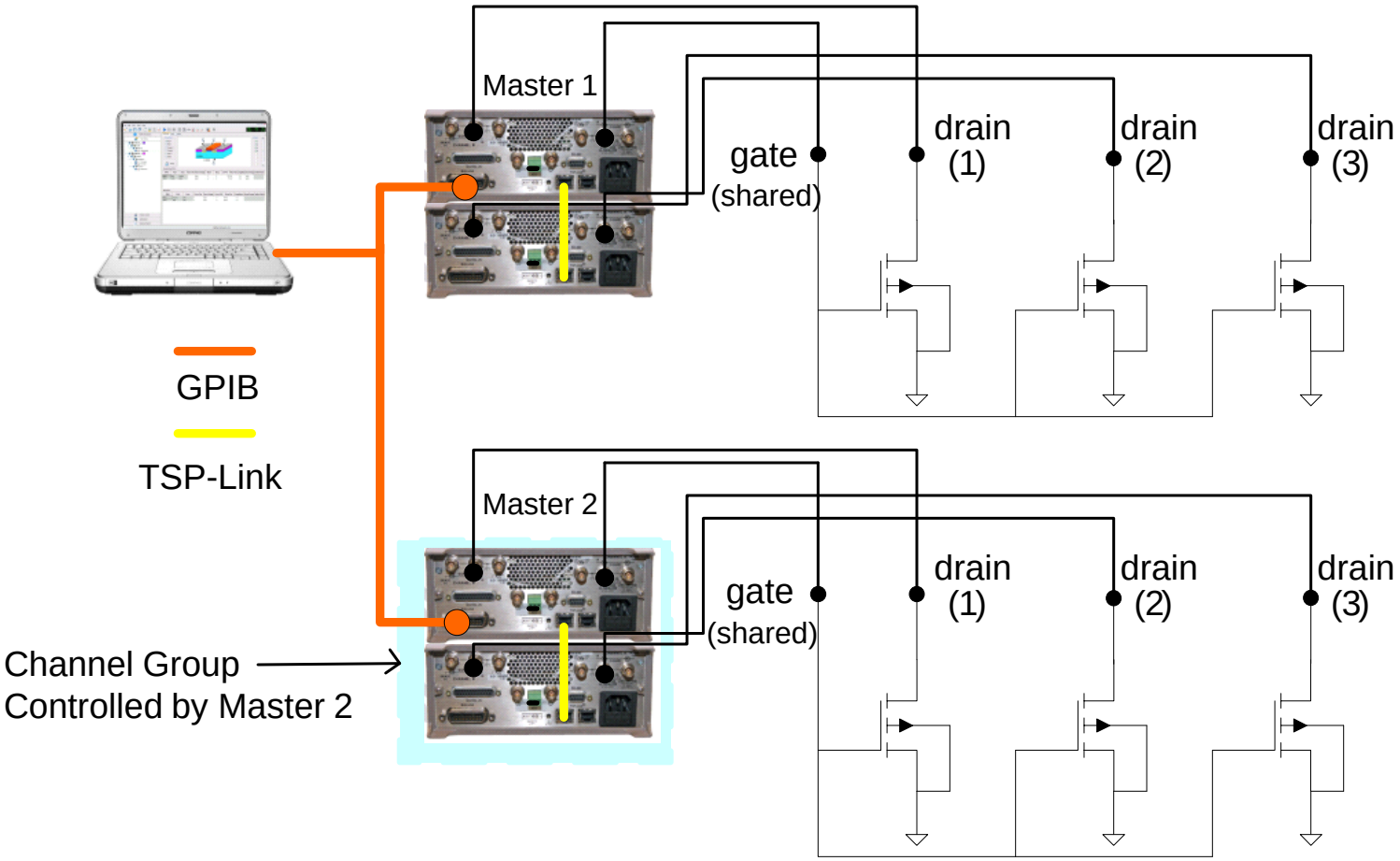
Example Configuration: NBTI Parallel Test System for Shared Gate FETS with 2 Masters (4-SMUs per master)



Unmatched Flexibility and Scalability Ensures Data Correlation Throughout the Process

Scalability Enabled by TSP and TSP-Link

Benchtop Characterization Systems
(Research and Development)

Integrated Test Systems
(Semi Labs)

Compact Multi-channel Test Systems
(Production Test)

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Summary

- Control sources of low current measurement error
  - Know your source resistance limitations as much as possible.
  - Take care of relevant current noise generators in cable and insulators. Use Triax cable if measuring below 100nA.
  - Avoid contamination. Use proper handling techniques.

- SourceMeter architecture provides multiple instruments in one
  - *Models 2635A/2636A offers the industry's fastest low current measurement capability for demanding test applications.*
  - A highly integrated automated test solution at half the cost of ownership.
  - TSP-Link allows multiple System SourceMeter Instruments to be controlled as a single unit.

Contact Keithley with Your Questions

Speaker: Jonathan L. Tucker

Senior Marketer, Research and Education Business

Sensitive Measurements Product Line Manager

Email: jtucker@keithley.com

Worldwide Headquarters Within the USA: +1-888-KEITHLEY Outside the USA: +1-440-248-0400 Email: applications@keithley.com Additional offices: www.keithley.com	Europe: Germany: (+49) 89 849 307 40 Great Britain: (+44) 118 929 7500 Far East: China: (+86) 10-822 55 011 Japan: (+81) 3-5733-7555 Korea: (+82) 2-574-7778 Taiwan: (+886) 3-572-9077

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