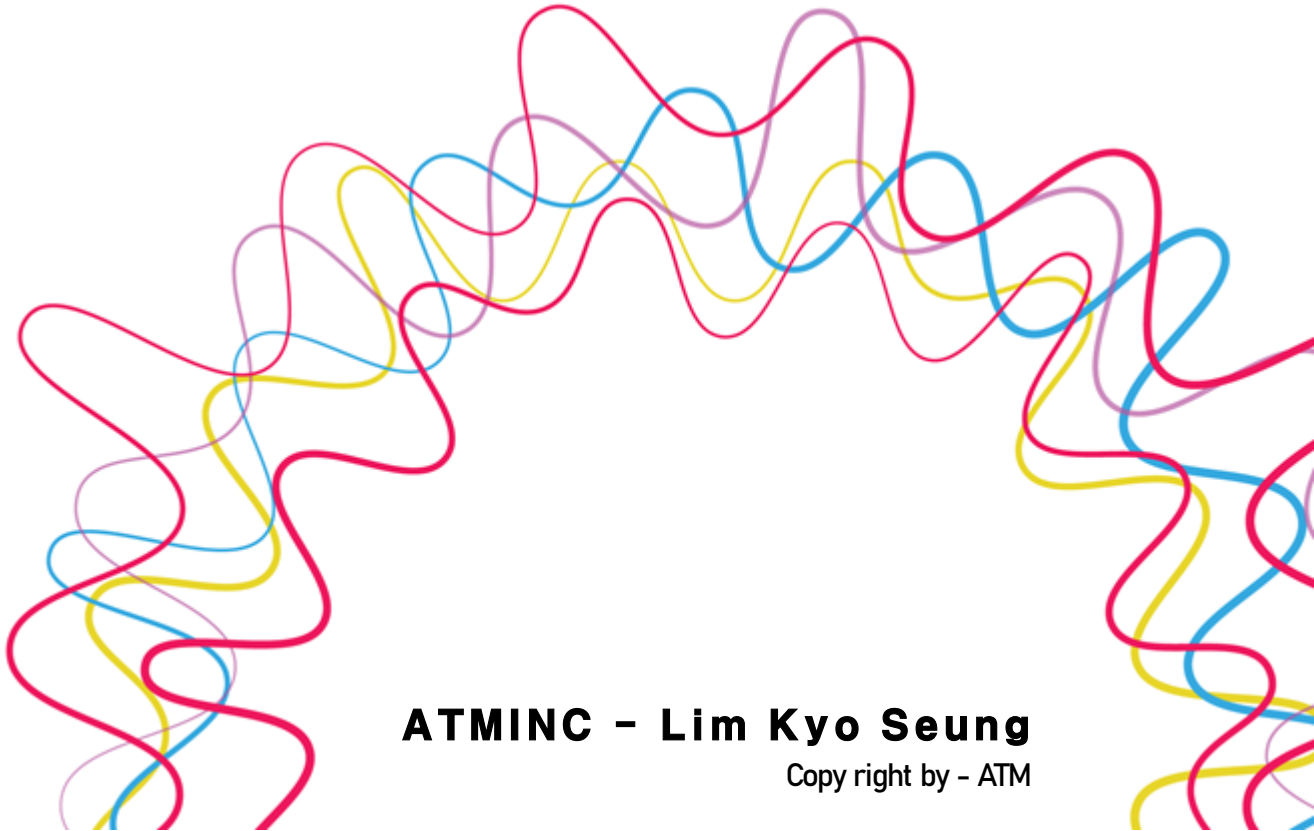
ATM INC 에이티엠

KEYSIGHT TECHNOLOGIES
Authorized Distributor

Fundamentals of precision current–voltage measurement



ATMINC - Lim Kyo Seung

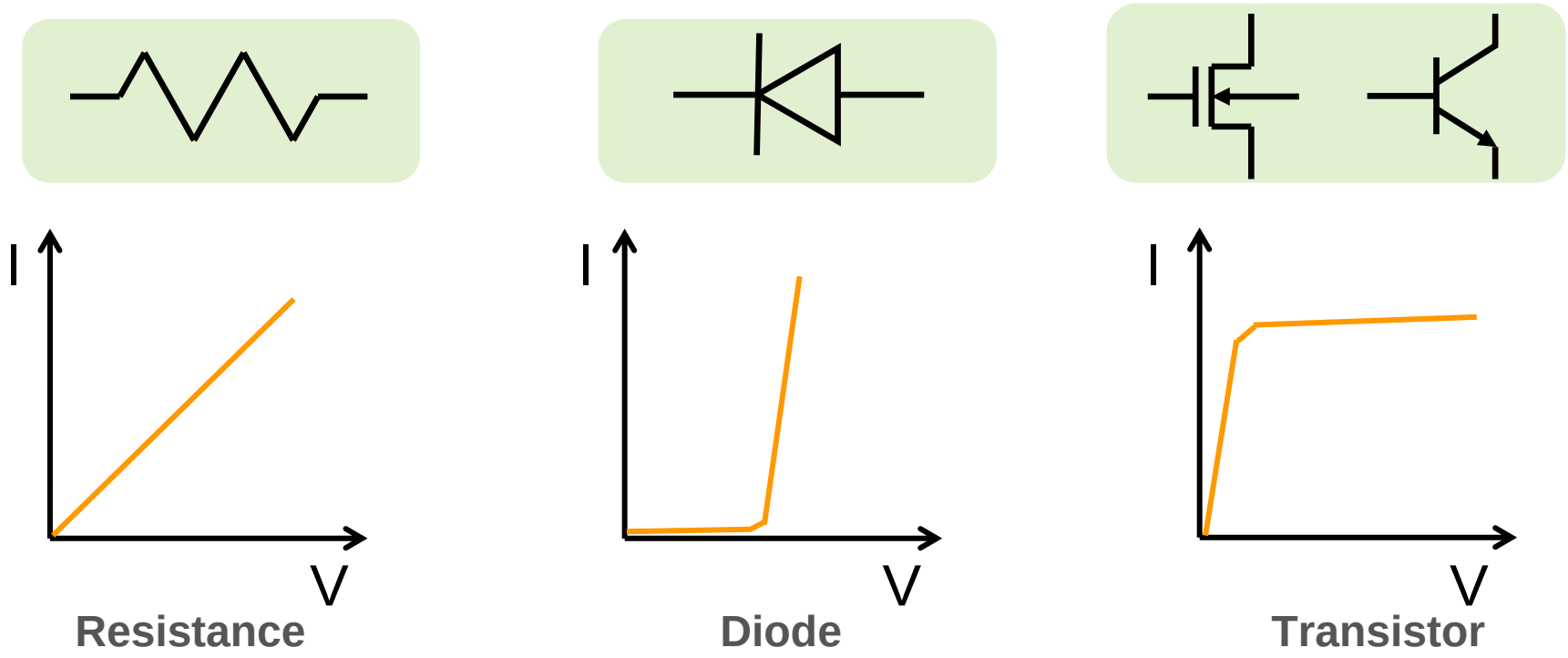
Agenda

1. What is Current-Voltage(IV) measurement?
2. What are Parameters on IV measurement?
3. Conventional measurement setup & problems
4. Introduction of SMU
5. Tips for accurate IV measurement
6. Keysight IV Measurement solution line-up

1. What is Current-Voltage(IV) measurement?

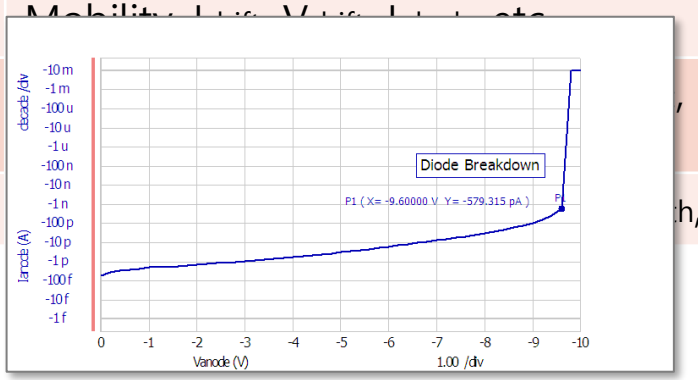
A task to obtain the current vs. voltage or resistance characteristics

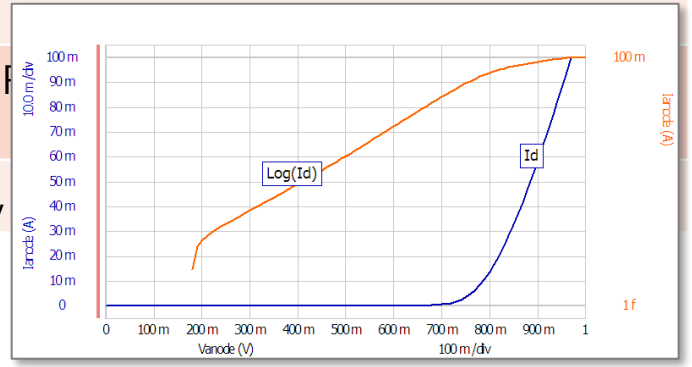
Examples:



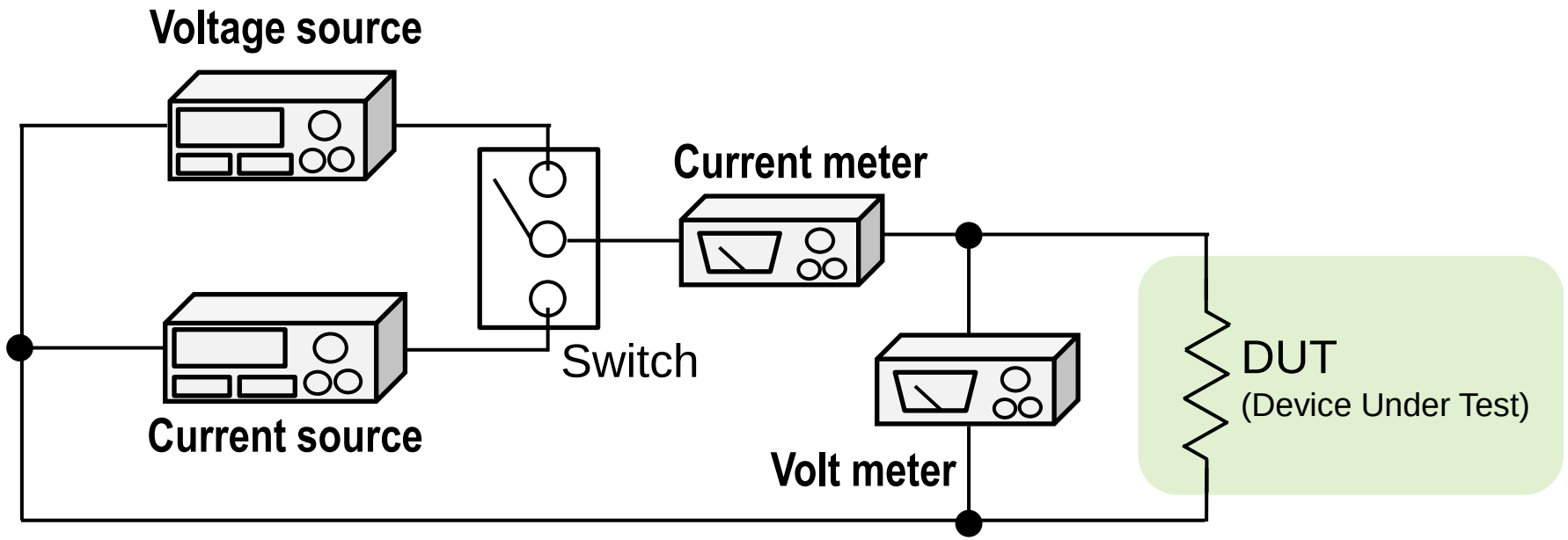
2. What are Parameters on IV measurement?

Device Type	Key Parameters
Resistance	R, R(T), R_{sheet}, R_{ave}, R_{ds}, R_{on}, R_{off} etc
Diode	BV, I_s, I_{fwd}, I_{off}, R_s, Delta I, etc
Transistor (BJT)	BV_{cbo}, BV_{cei}, BV_{ceo}, BV_{ebo}, h_{fe}, I_b, I_c, I_{on}, I_{off}, V_b, V_c, etc
Transistor (MOS)	BV_{dss}, BV_{gso}, BV_{gb}, I_d, I_g, I_{on}, I_{off}, I_{sub}, gm, gmMax, V_d, V_g, V_s, V_{sub}, V_{th}, etc
Memory	I_d, I_{dmax}, Retention time, V_{erace}, V_{write}, $V_{thinitial}$, $V_{theraced}$, $V_{thshift}$,
Reliability	Delta I, Delta V, Delta R, Failure time, I_{cpmax}, N_{ss}, V_{bd}, V_{thmin}, V_{thmax}, etc
CNT/Nanotech	Delta V, Diff R, R_{min}, R_{max}, gm, $V_{backgate}$, $I_{backgate}$, I_{dshift}, etc
Organic device	Mobility, I_shift, V_shift, I_on, etc
Solar Cell	, F
Power Device/IGBT	th,





3. Conventional measurement setup & problems

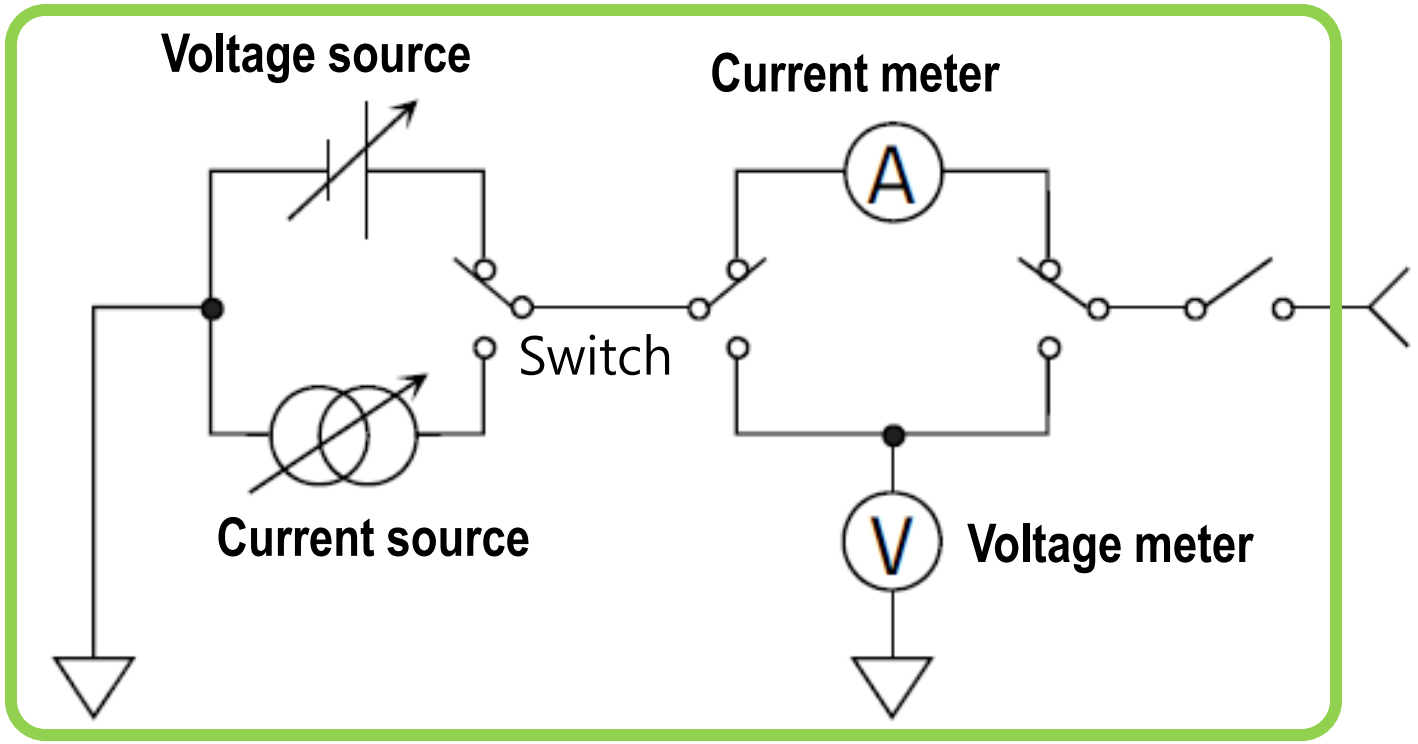


Problems

- Difficult to control and synchronize multiple instruments
- Complex cabling & setup
- Difficult to obtain good measurement performance

4. Introduction of SMU

- **Five functions are integrated on one board.**



4. Introduction of SMU

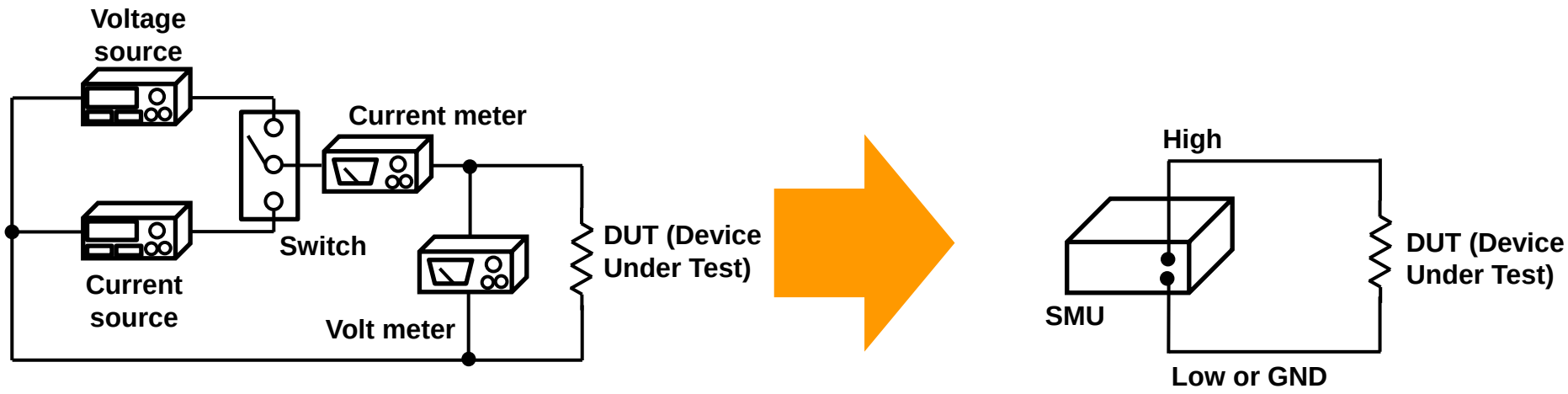
Feature & Benefit of SMU

Feature	Benefit
Five functions on one board	Simple measurement setup and cabling with resource synchronization
	Better measurement performance than conventional equipment
Guard technology	Ultra low current measurement down to fA
Auto ranging function	Wide current/voltage measurement coverage with the best resolution
I/V limit (compliance) function	Protect devices from damage caused by excessive vol tage or current.

4-1. Feature & Benefit of SMU

- **Simple measurement setup and cabling with resource synchronization**
- **Better measurement performance than conventional equipment**

An SMU reduces the number of instruments and messy wiring, and provides simple operations.

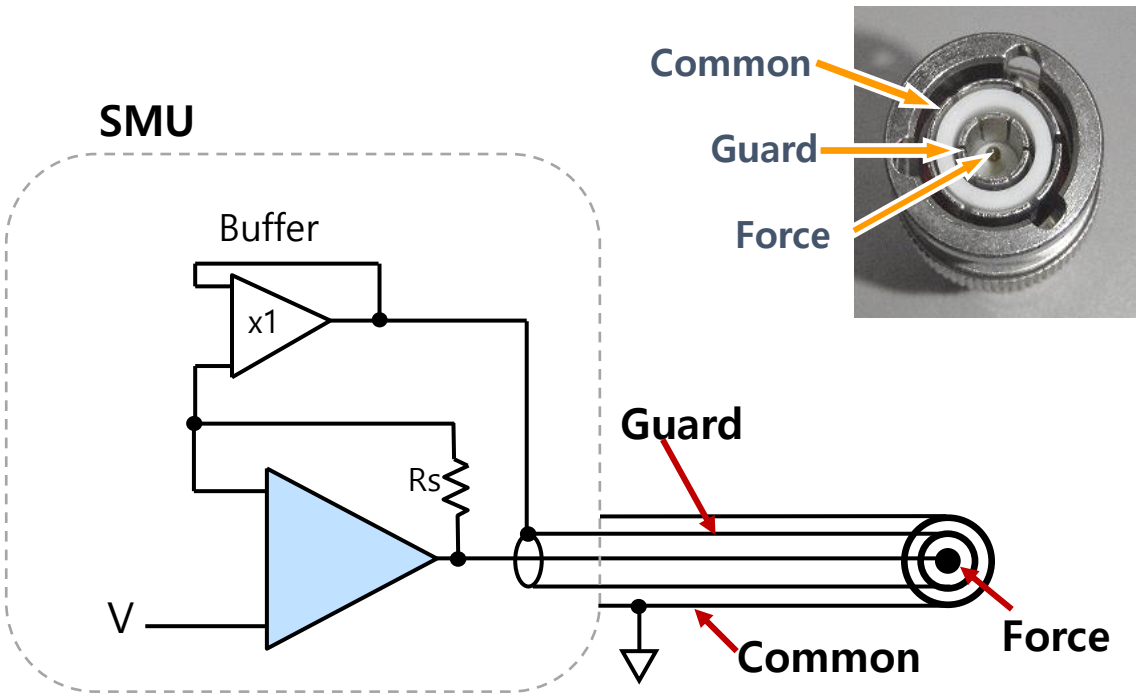


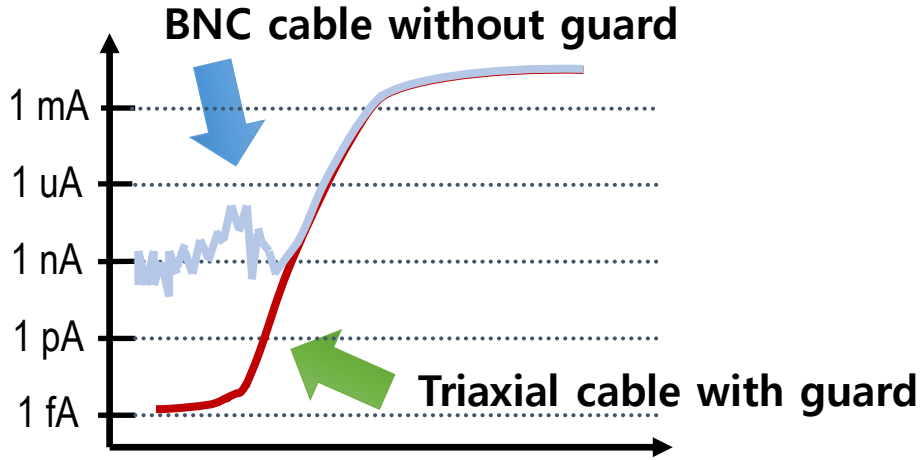
Conventional setup

Simplified setup by using SMU

4-2. Feature & Benefit of SMU

- **Guard Technology for low current measurement**





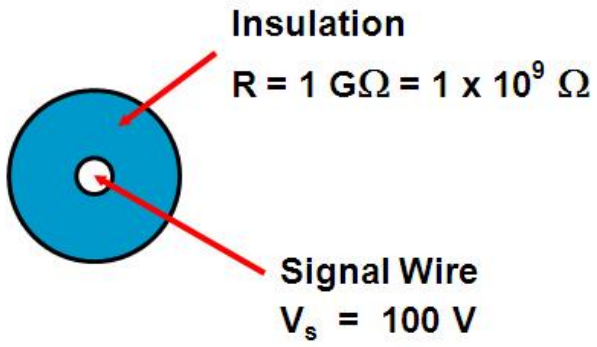
Guard Voltage = Force voltage

No leakage current!

4-2. Feature & Benefit of SMU

- **Guard Technology for low current measurement**

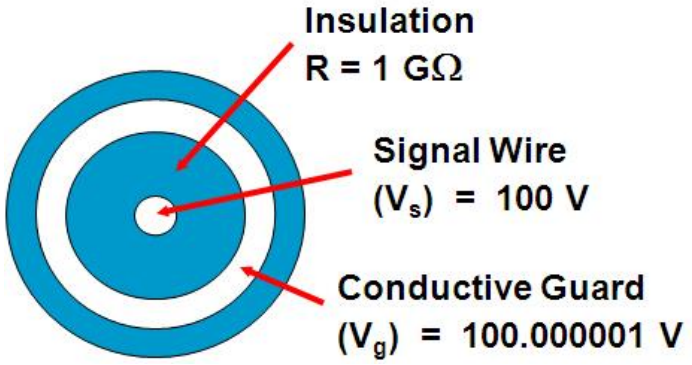
BNC (Coaxial) Cable:



Leakage Current:

$$\frac{100\ V}{1 \times 10^9 \Omega} = 100\ nA$$

Triaxial Cable:



Leakage Current:

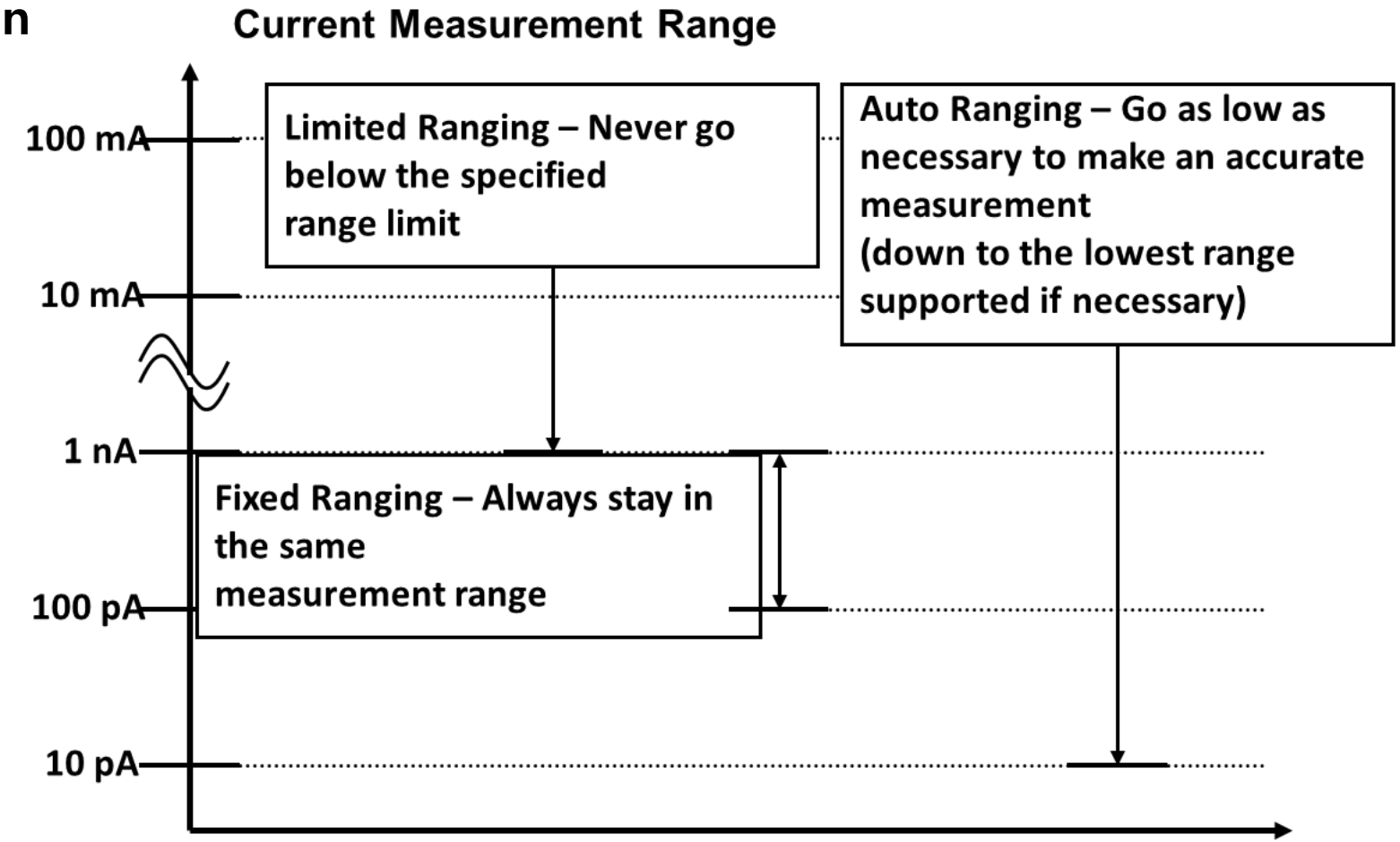
$$\frac{(100.000001\ V - 100\ V)}{1 \times 10^9 \Omega} = 1\ fA$$

Triaxial cable reduces leakage current by a factor of 100,000,000.

4-3. Feature & Benefit of SMU

Auto ranging function

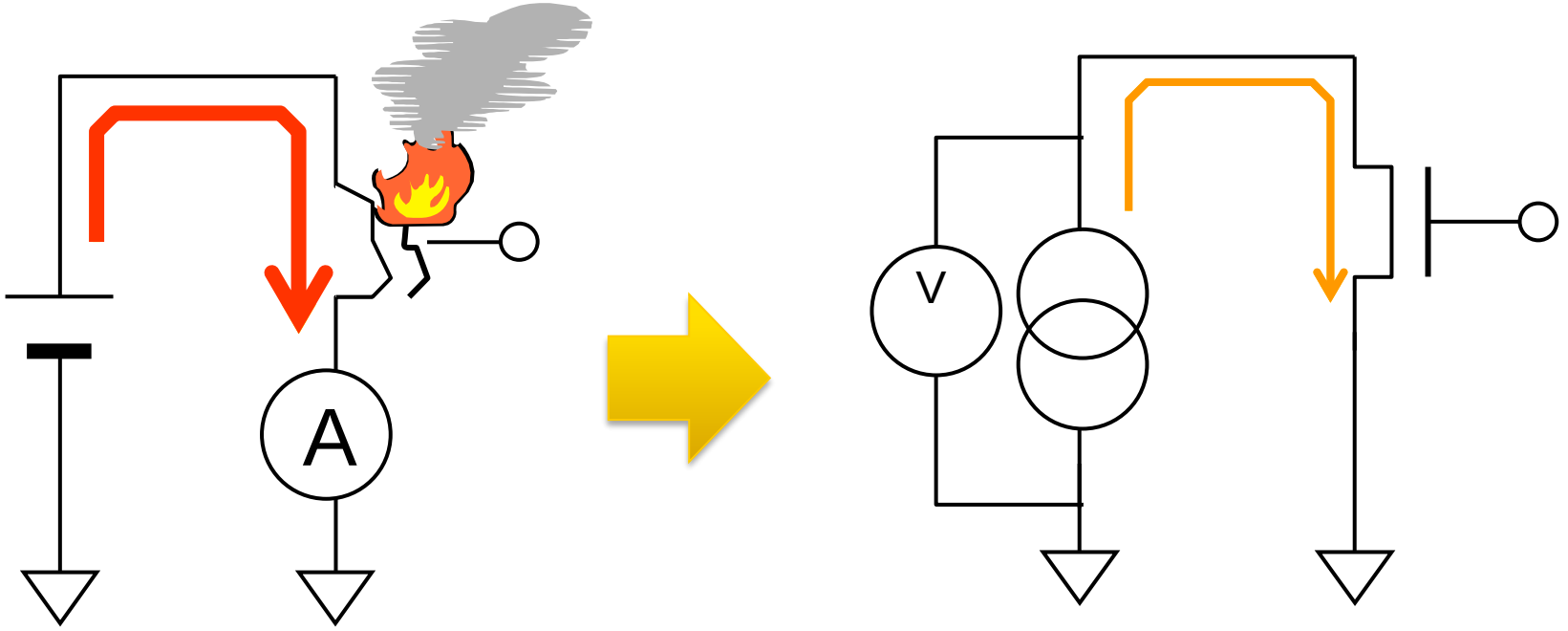
- Auto Range
- Limited Range
- Fixed Range



4-4. Feature & Benefit of SMU

I/V limit (Compliance) function

Limit (Compliance) protects your devices from excessive voltage or current

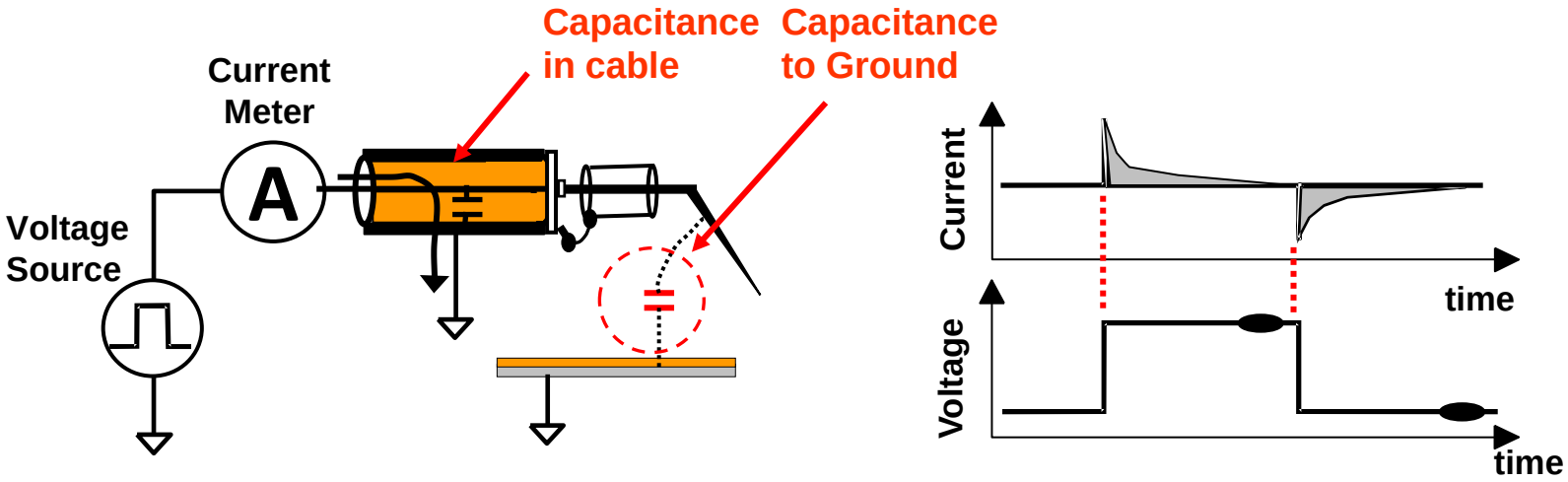


Conventional setup
(No current / voltage limit)

SMU
(with current / voltage limit)

5-1. Tips for accurate IV measurement

Wait Time to reduce Dielectric Absorption



What is dielectric absorption

- Dielectric absorption appears as an unstable slow change or setting leakage current when the applied voltage is changed.

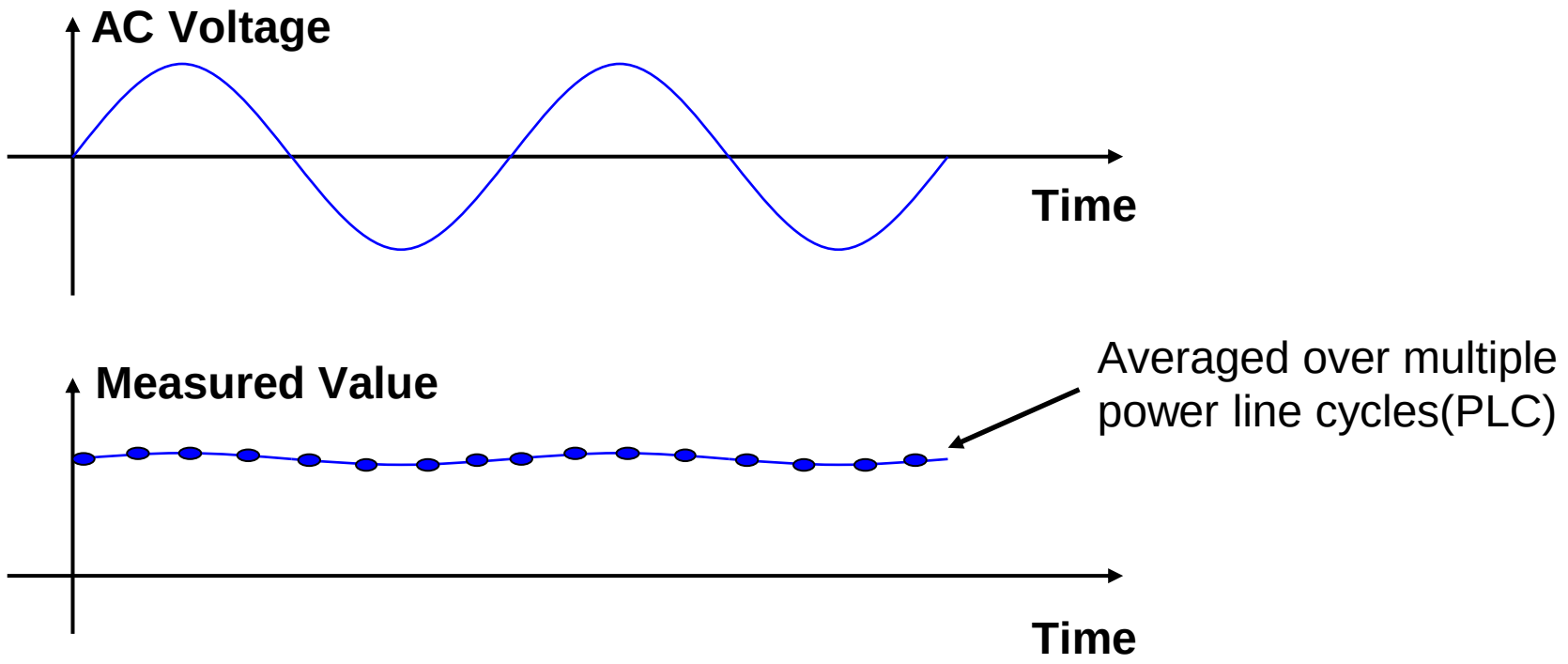
How to minimize its effect:

- Keep guard connections as close as to DUT
- Minimize capacitive coupling
- Insert appropriate “Wait Time”.

(B1500A & B1505A set suitable timing parameters automatically)

5-2. Tips for accurate IV measurement

Effect of Averaging



Integration **DOES NOT** have any effect on the measurement resolution.

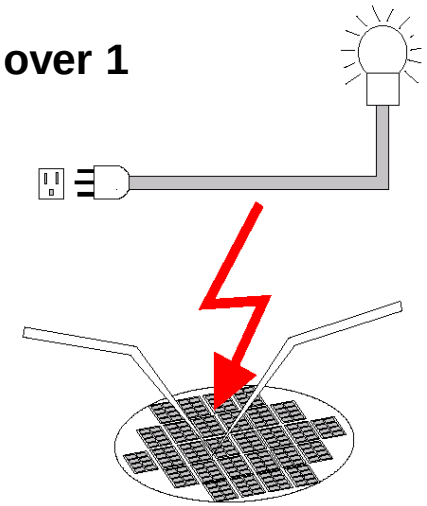
5-2. Tips for accurate IV measurement

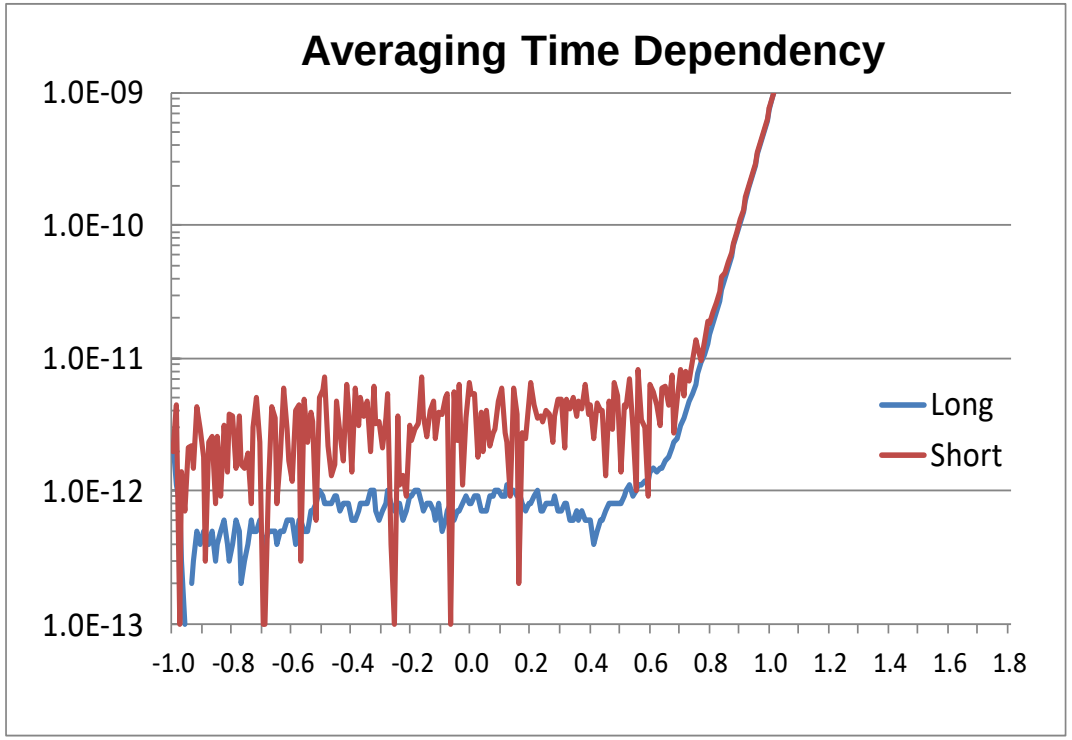
Effect of Averaging

Averaging = Integration time or Aperture time
Longer averaging time makes better repeatability / lower noise

Power line is one of the largest noise factor which shows a wide band noise spectrum.

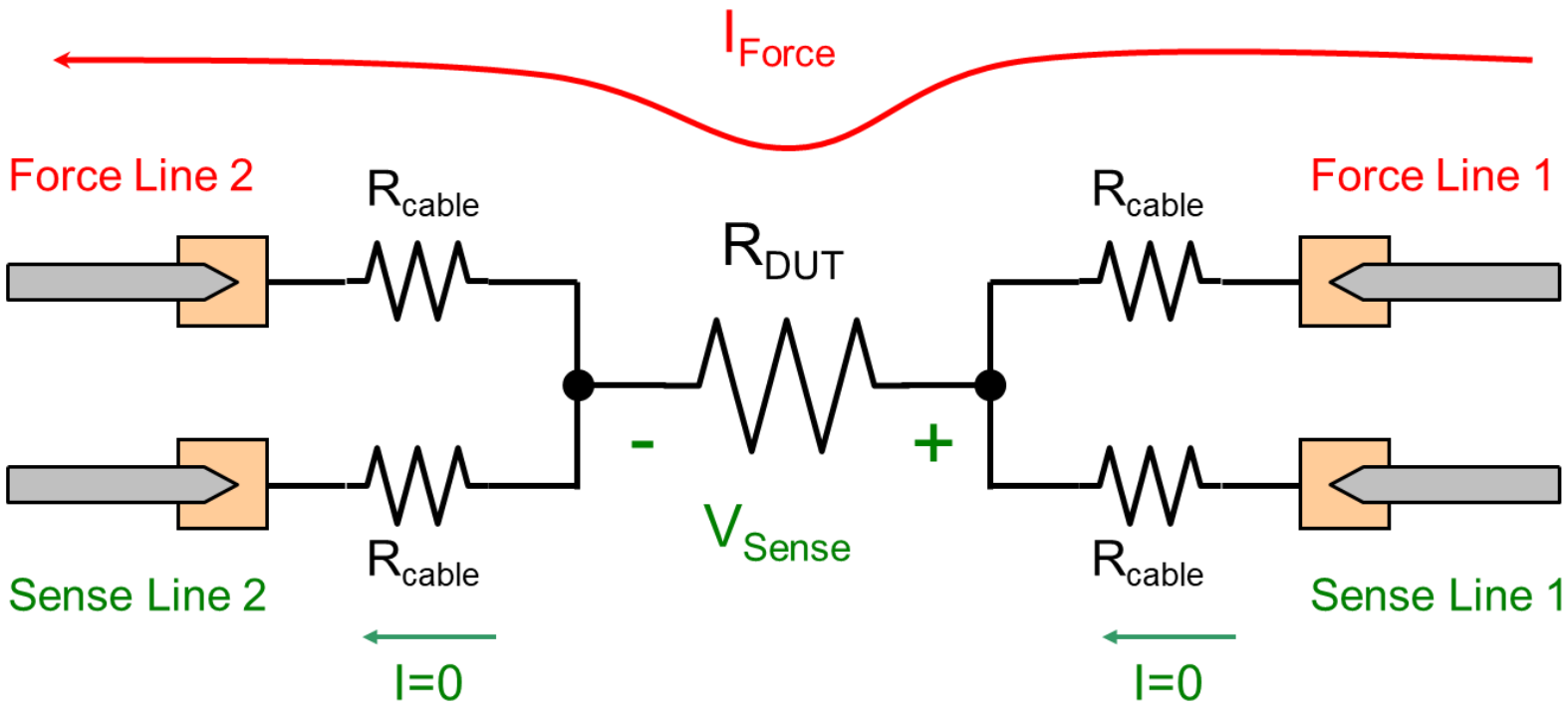
Power line noise can be reduced by over 1 PLC (Power Line Cycle) averaging.





5-3. Tips for accurate IV measurement

Kelvin (4-Wire) Measurement



→ Eliminate cable resistance from the measurement

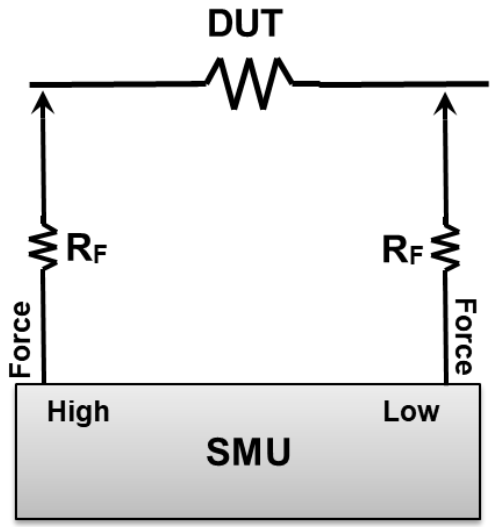
5-3. Tips for accurate IV measurement

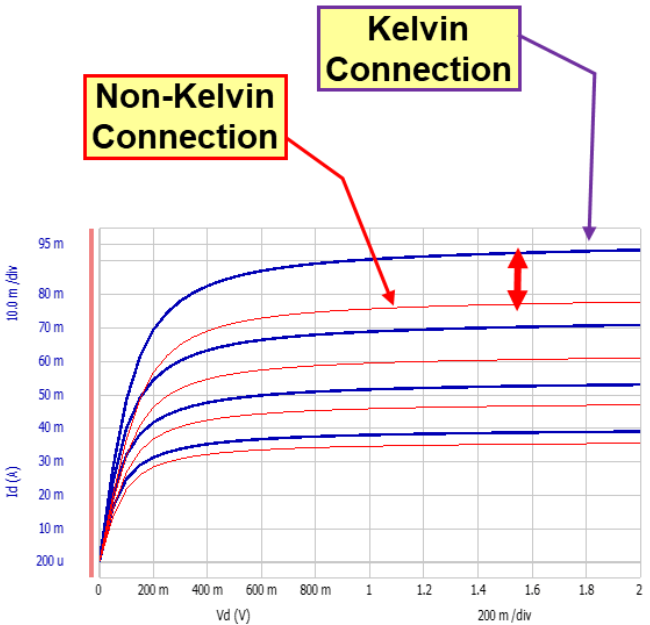
Kelvin (4-Wire) Measurement

Kelvin (4-Wire) connection is effective for low voltage/resistance measurement

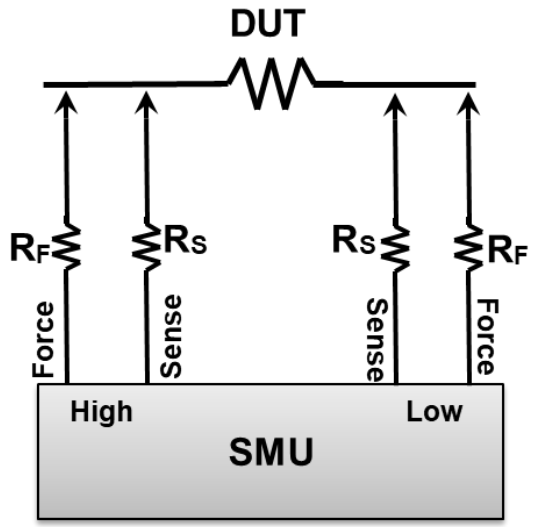
The error from the connection cable resistance and the contact resistance on the pads of DUT can be eliminated.

Non-Kelvin Connection





Kelvin Connection

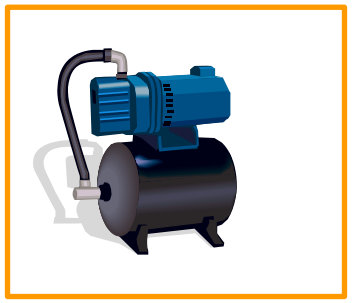


Id-Vd curve on MOSFET

5-5. Tips for accurate IV measurement

Environment consideration

Keep away from noise sources from your test environment

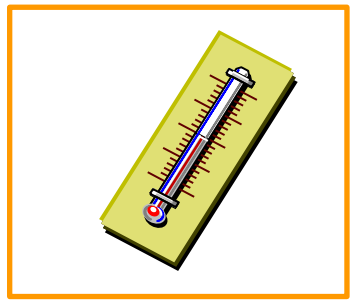


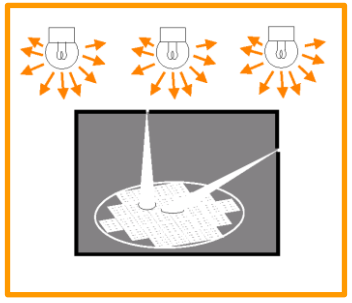
Vibration

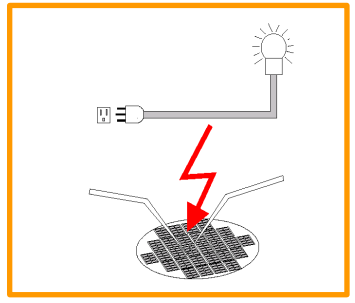
Use Anti-vibration table

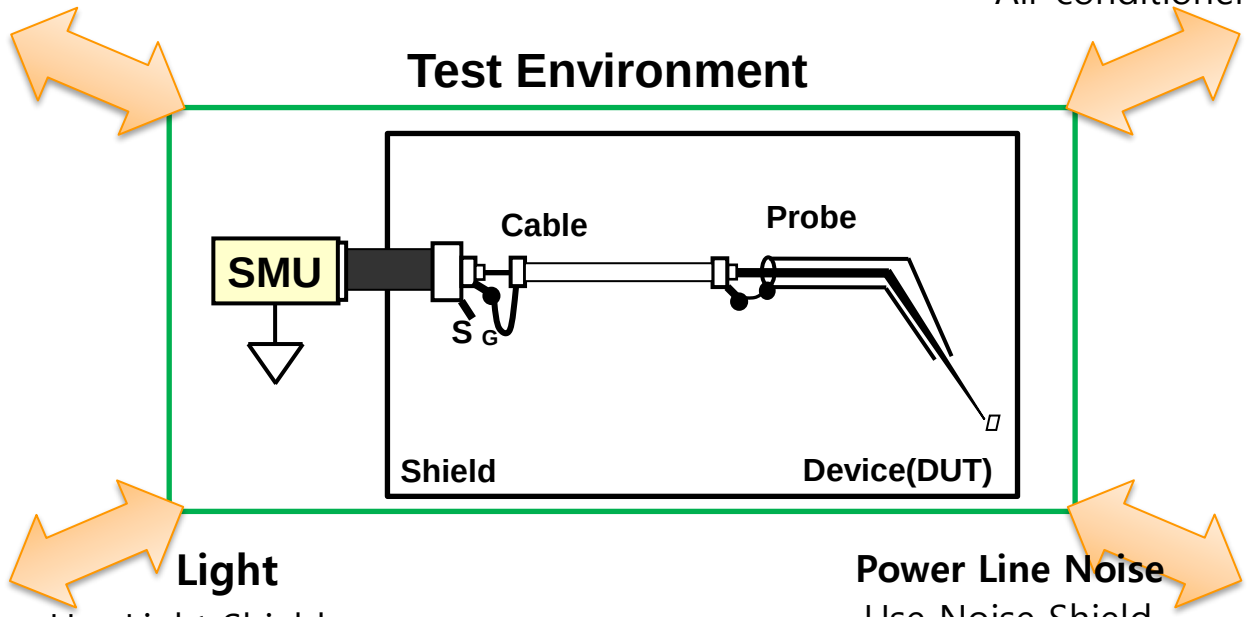
Temperature

Temperature control
Air conditioner









Light

Use Light Shield

Power Line Noise

Use Noise Shield

6. SMU Line up

Precision bench-top instrument

Each Series is optimized for current-voltage source & measurement

PRECISION Source

B2960A Series

Low Noise Power Source

PRECISION Source & Measure

B2900A Series

Source/Measure Units

PRECISION Measure

B2980A Series

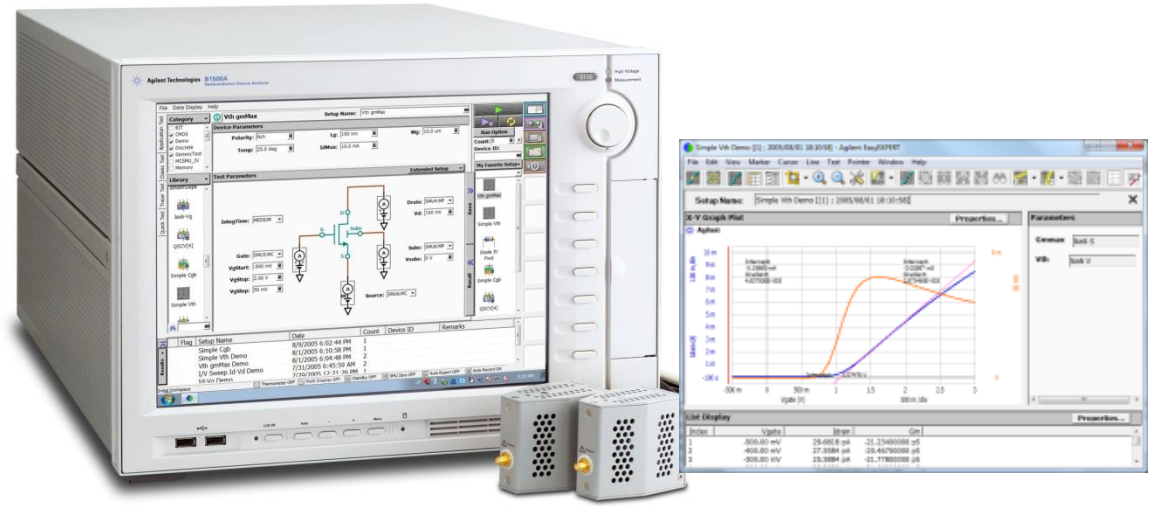
Femto/Picoammeter Electrometer/ High Resistance Meter

6. SMU Line up

Keysight Precision IV Measurement Solution

Keysight B2900A
Bench top SMU series

10 fA to 10.5 A / 0.1 uV to 210V



Keysight B1500A
Semiconductor Device Analyzer

0.1 fA to 1 A / 0.5 uV to 200 V

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Thank you.