Wide Band Gap Power Device Evaluation Challenges and Technologies

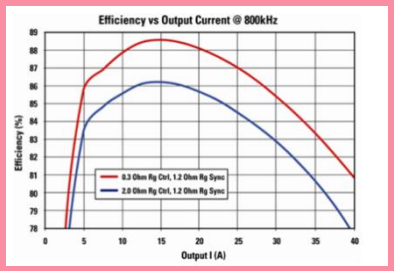
November 2016

Ryo Takeda
Solution Architect
Keysight Technologies

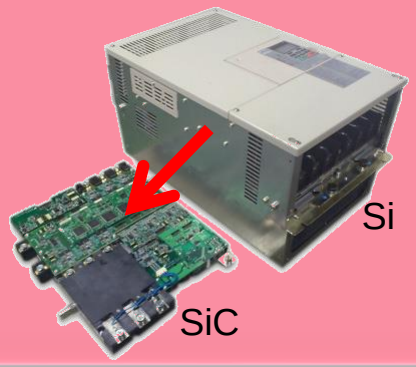
KEYSIGHT TECHNOLOGIES

Application Requirements from Modern Power Electronics

Improved conversion efficiency



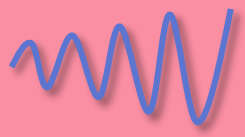
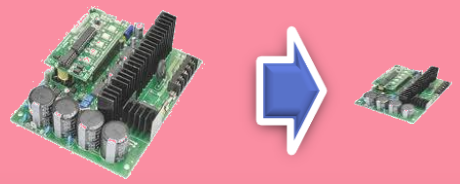
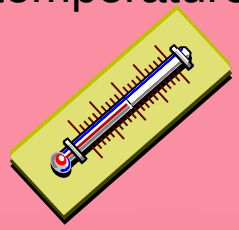
Volume and weight reduction



Motor drive system
Presented by
Yaskawa Electric
Corp.

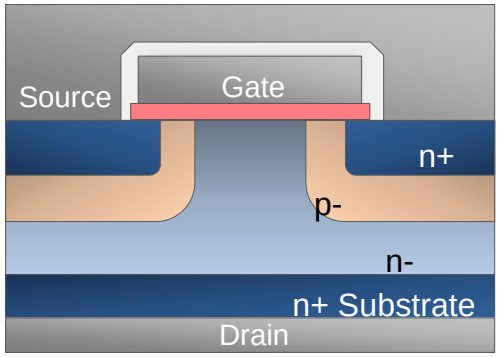
Use in harsh environments

Why Use Wide Band Gap (WBG) Semiconductors

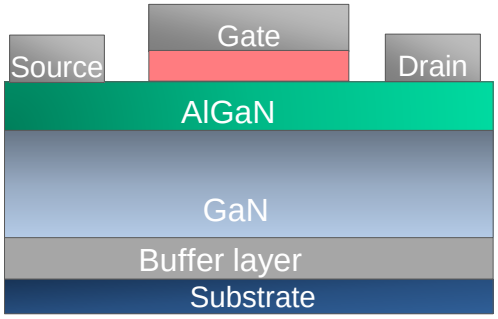
WBG properties	Benefits
Lower power loss 	Better conversion efficiency = Smaller / Lighter cooling system 
Higher frequency operation 	Smaller passive circuit components 
Higher temperature operation 	Smaller / Lighter / Sealed cooling system for harsh environment use, (e.g. excavator use) 

Expected Application Map for SiC/GaN

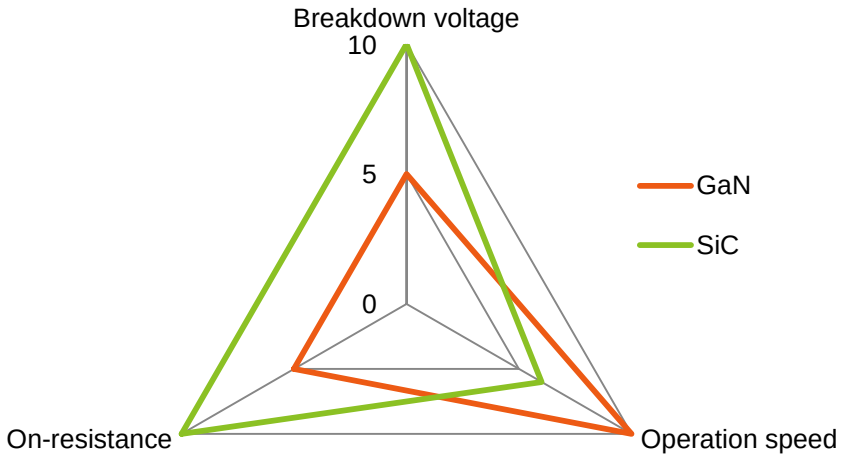
- SiC: Suitable for very high power (high current / high voltage) application
- GaN: Suitable for middle range power application



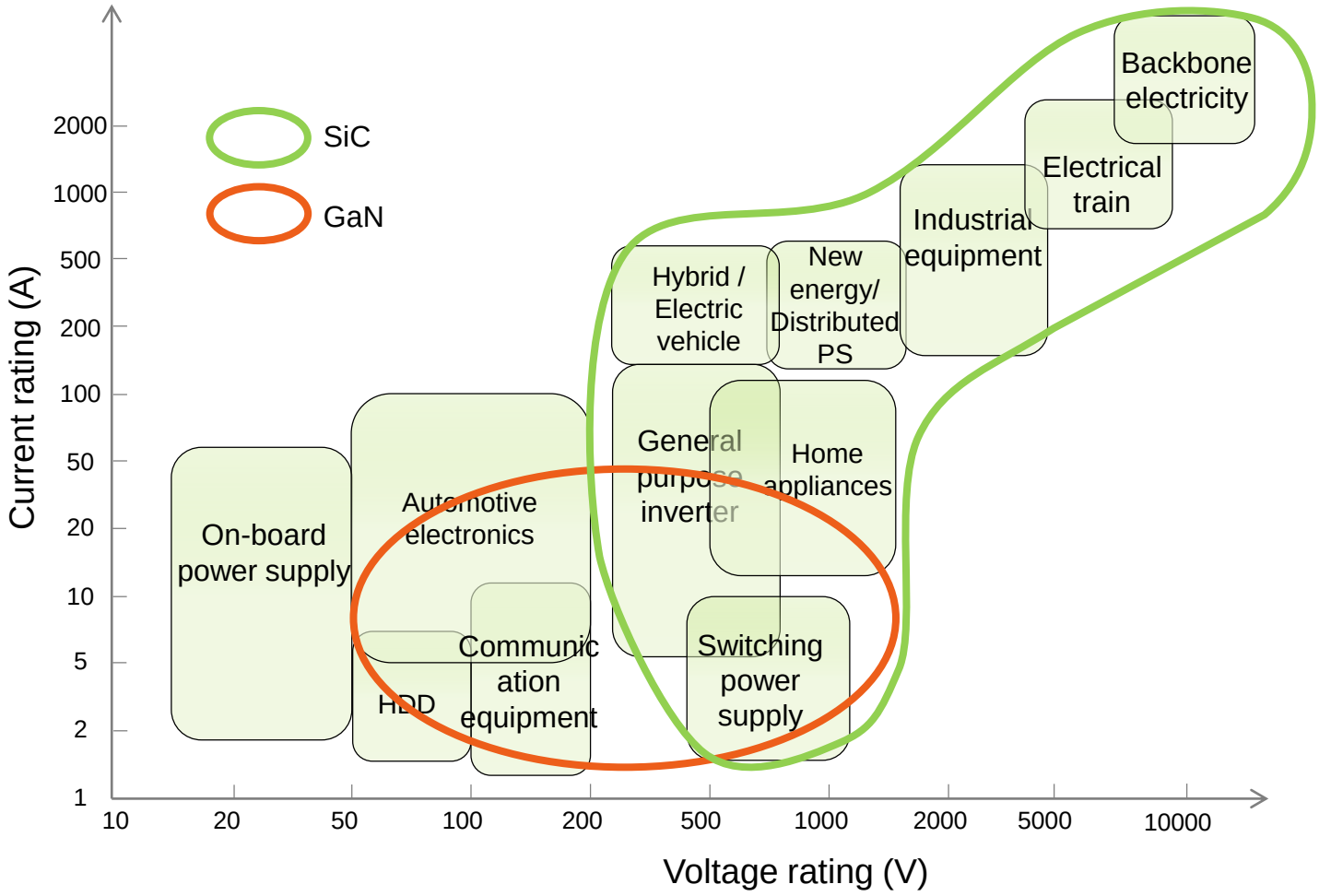
SiC: Vertical



GaN: Lateral



Expected Application Map for SiC/GaN



Critical Evaluation Items for SiC/GaN

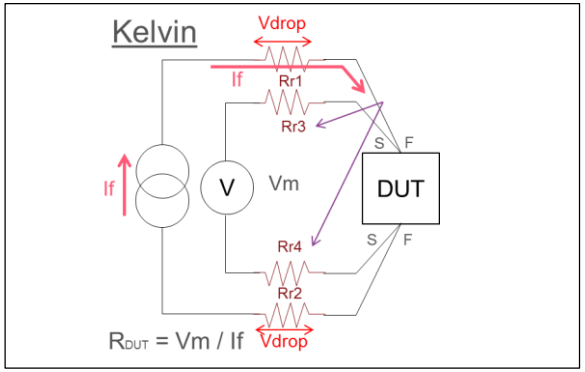
- High Current
  - High current is often used in actual operation in many applications
  - Ron becomes smaller and therefore high current is mandatory for accurate Ron evaluation. Ron is important to calculate conduction loss.
- High Voltage ⇦ Especially important for SiC
  - Basic parameter but one of the most important parameters from reliability perspective
- Temperature dependency ⇦ Especially important for SiC
  - Various power electronics products are used in harsh environment
- Capacitance (Ciss, Coss, Crss, Rg, Normally-on device) ⇦ Especially important for GaN
  - Critical parameters for switching performance
  - Important to estimate power losses such as output capacitance loss, etc.
- Gate Charge
  - Critical parameter for switching performance and gate drive circuit design
  - Important to estimate switching loss
- Reliability
  - Long term reliability is one of the main concerns when adopting new/emerging devices

Challenges in SiC/GaN Device Evaluation

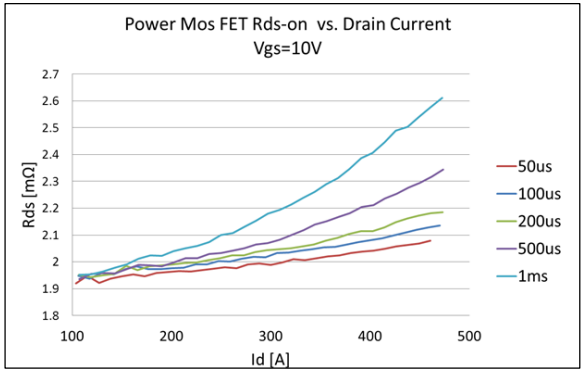
- Lack of Standard Solution
  - How many hours have you invested in isolating your test problems?
  - Device manufacturers also suffer the lack of reference measurement equipment
  - Device users have no easy way to make accurate device evaluation
- High Voltage / High Current
  - Accuracy is questionable without having a well thought test circuit and NIST traceable standard
- Temperature dependency
  - Long cable extension from test equipment to thermostatic chamber results in:
  - 1) current reduction, 2) oscillation, and 3) deteriorated accuracy
- Capacitance (Ciss, Coss, Crss, Rg & Normally-on)
  - Complicated connections and special techniques result in many measurement problems
- Gate Charge
  - Difficult to construct a test system with good accuracy and safety
- Intuitive and Standard User Interface
  - Anybody should be able to conduct device evaluation without training

High Current / High Voltage

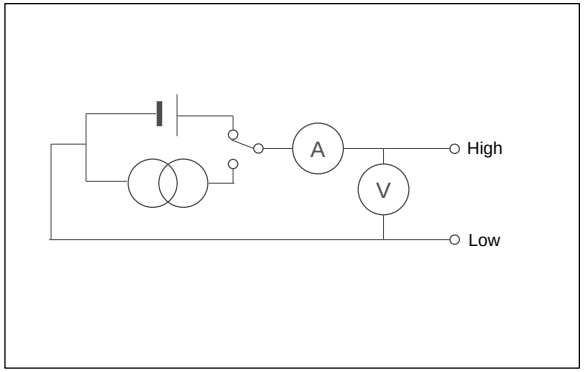
Many factors to take into account for accurate high power test



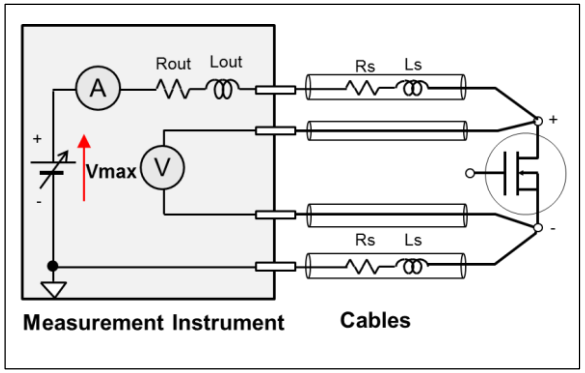
Appropriate test circuitry



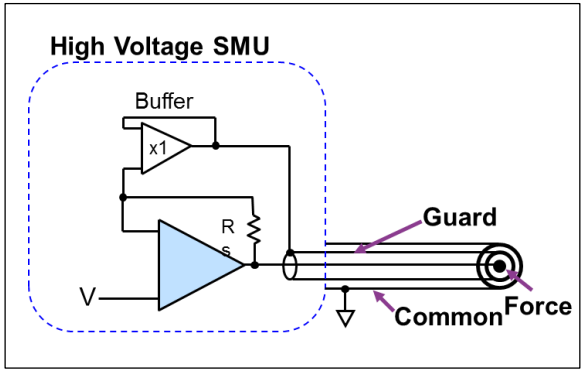
Fast pulse to avoid self heating



Both voltage & current sources



Short, low L and low R cables for high current & fast rise time



Guarding for low leakage at high voltage test

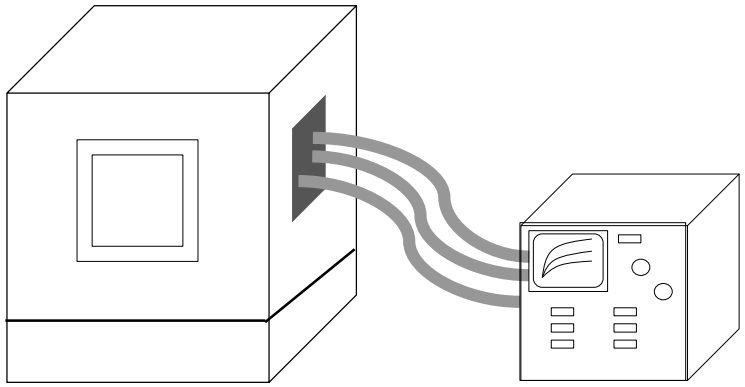
Traceability to international standard

Standard solution with NIST traceability is required in all aspects of the power electronics industry.

Issues with Temperature Dependency Test using Thermostatic Chamber

- Time consuming set up / measurement
  - Extremely slow test throughput. Only a few tests performed a day

- Long cable causes several issues
  - Lowered maximum current
  - Deteriorated accuracy
  - High risk of oscillation

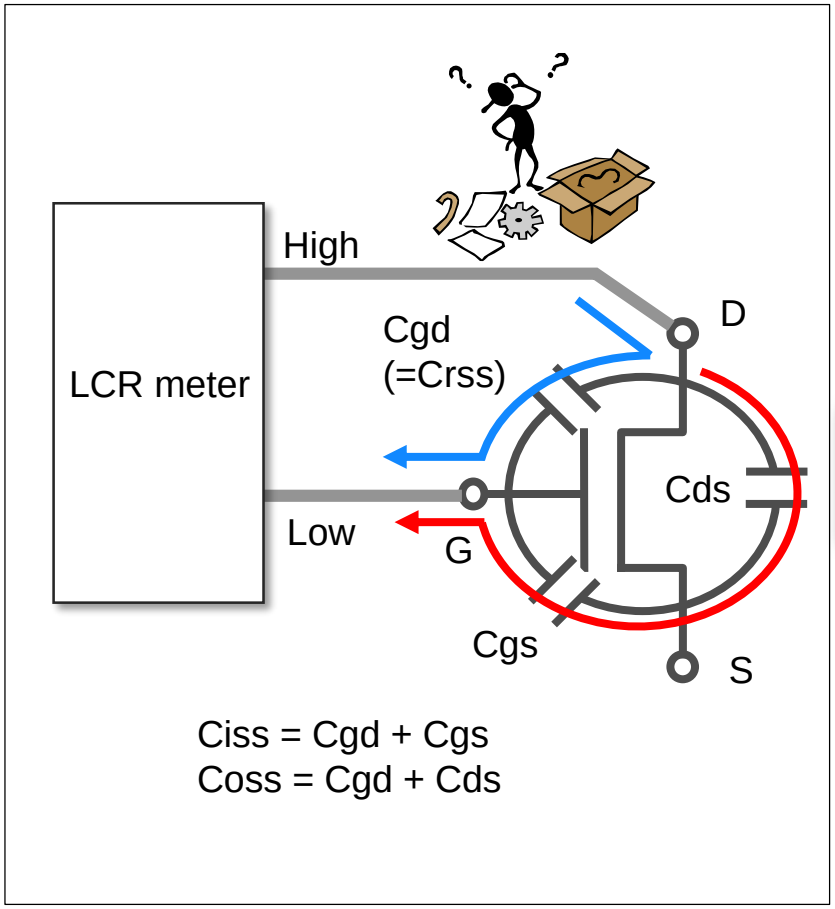


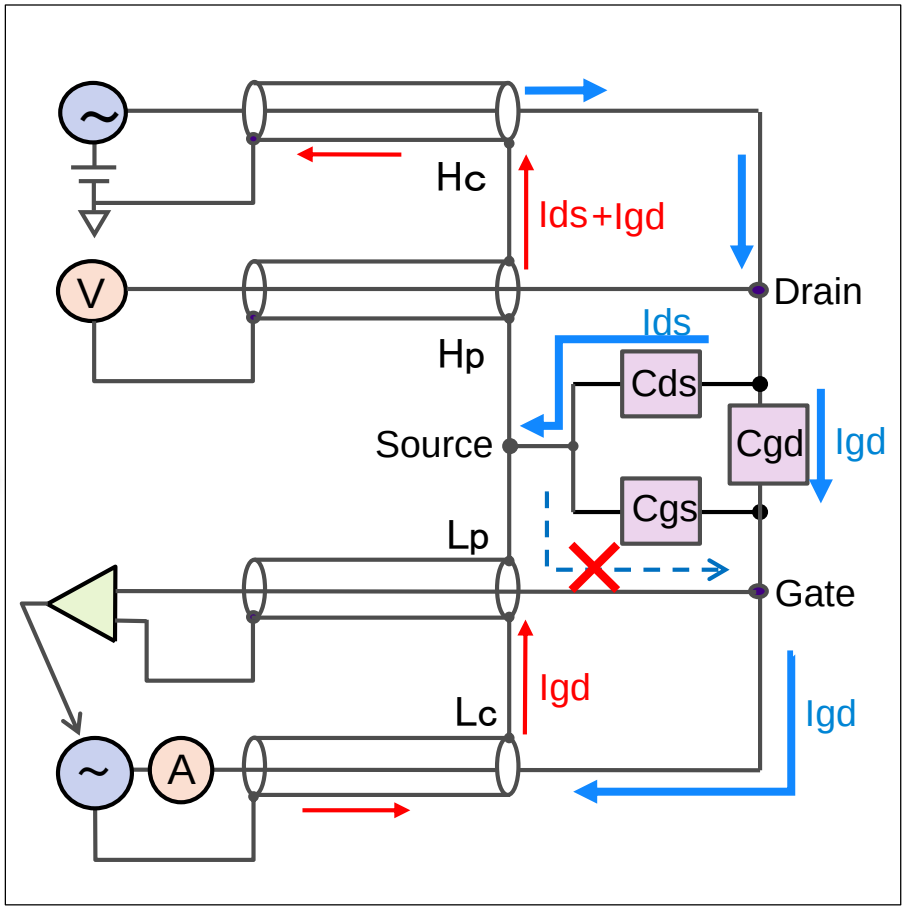
Thermostatic chamber Measurement equipment

Although the temperature dependent test is important most people don't perform it due to problematic measurement and long test time. Fast and accurate thermal test equipment is necessary across the entire power electronics industry.

Issues Associated with Capacitance Measurement (1)

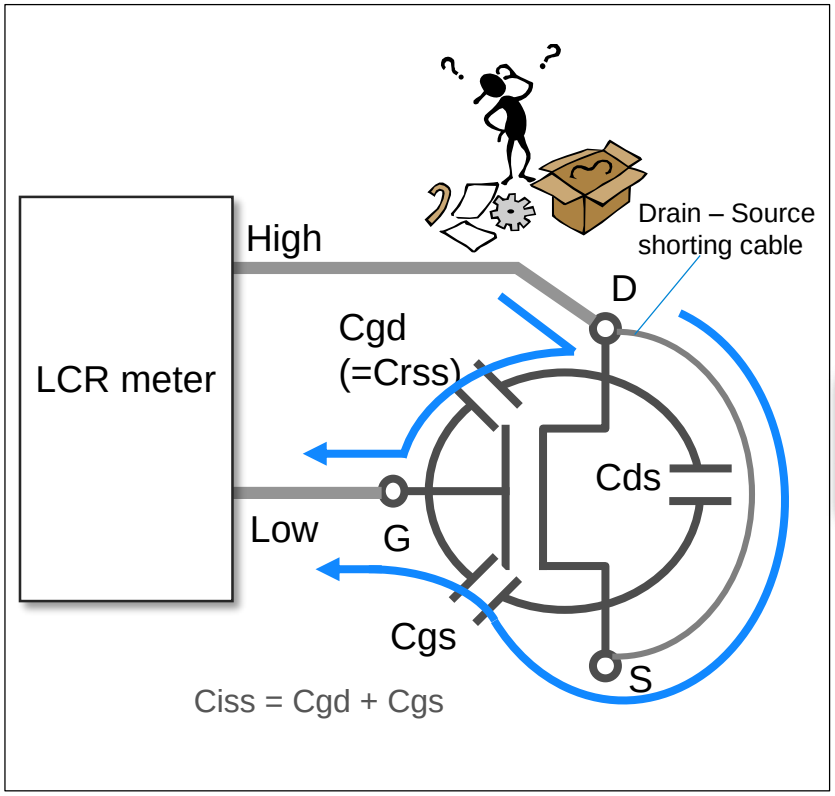
Measuring Crss?

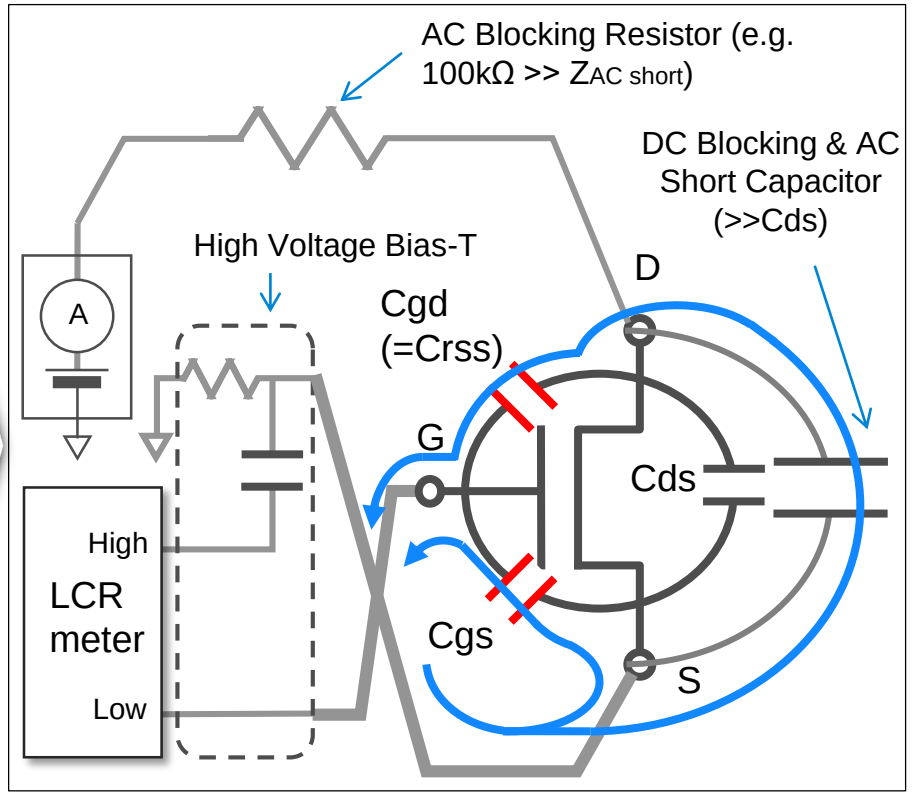




Issues Associated with Capacitance Measurement (2)

Measuring Ciss with high voltage bias?





Complicated test circuit with manual connection changes make the capacitance test challenging and result in human errors, an industrial solution is required for users of power devices.

Issues with Gate Charge Measurement

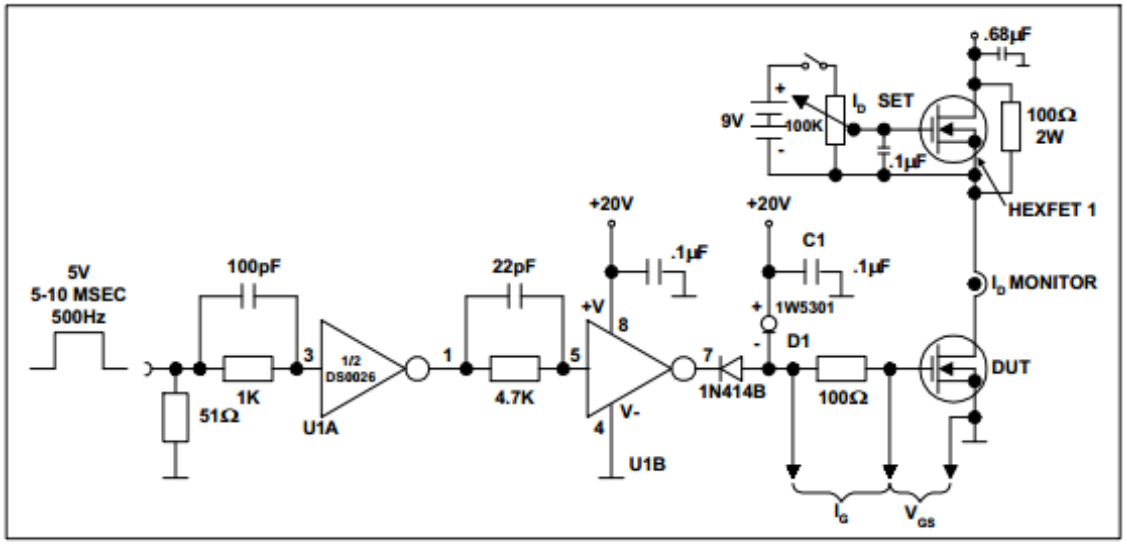


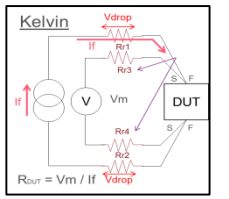
Figure 1. HEXFET POWER MOSFET Gate Charge Circuit. Courtesy of International Rectifier

1. Difficult to prepare a power source at drain that has enough simultaneous current and voltage capacity. Using a capacitor is a solution. However, it has safety issues.
2. Difficult to prepare a constant current source which has small enough current to allow slow gate charge accumulation for accurate sampling.
3. Device is likely to be destroyed by measuring at up to rated current with high voltage bias.

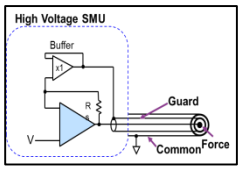
Designing a safe and accurate test system is difficult, an industrial solution is required for users of power devices.

Standard Solution Example

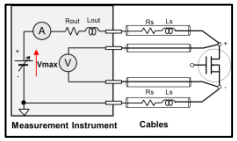
Keysight B1506A Power Device Analyzer



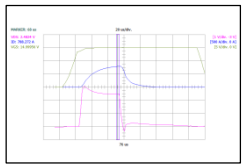
Kelvin connection

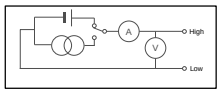


Guarding



Low L, R cables

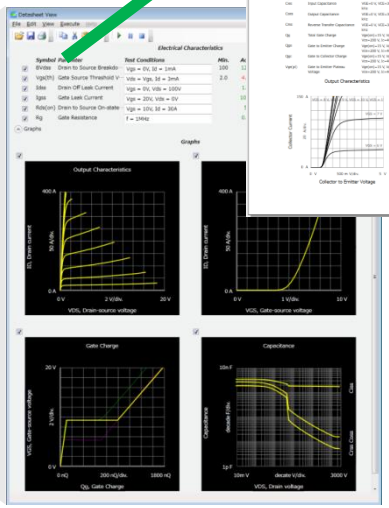

Fast pulses

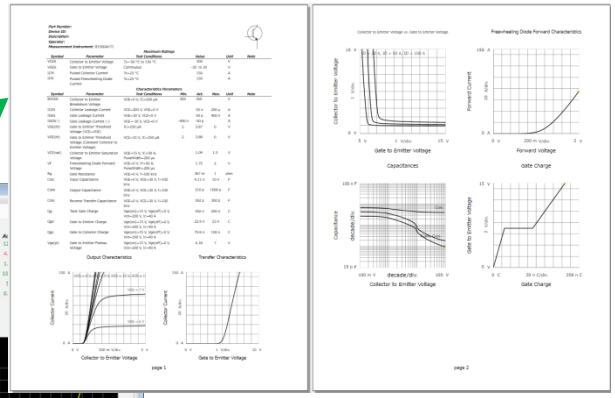


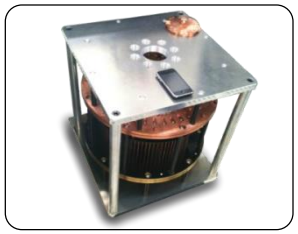
SMU technology

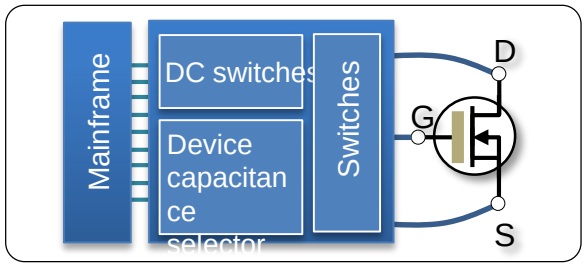
Critical power device test technologies


B1506A


Datasheet format Software I/F


Datasheet format report


NIST traceability



Full automation through IV, CV switches

key points

- To cover critical power device test technologies when building test system or test instrument
- To make the instrument NIST traceable in order to deploy the test system to different locations. Calibration standard must be built first to make it happen.
- Switching matrix that change the test resources connected to DUT is necessary to make the automated and reliable test system. For FET capacitance test, the matrix should include DC blocking capacitor and AC blocking resistor.
- User interface should be easy enough. One example is to simulate datasheet, which is friendly to device manufacturer and device users.

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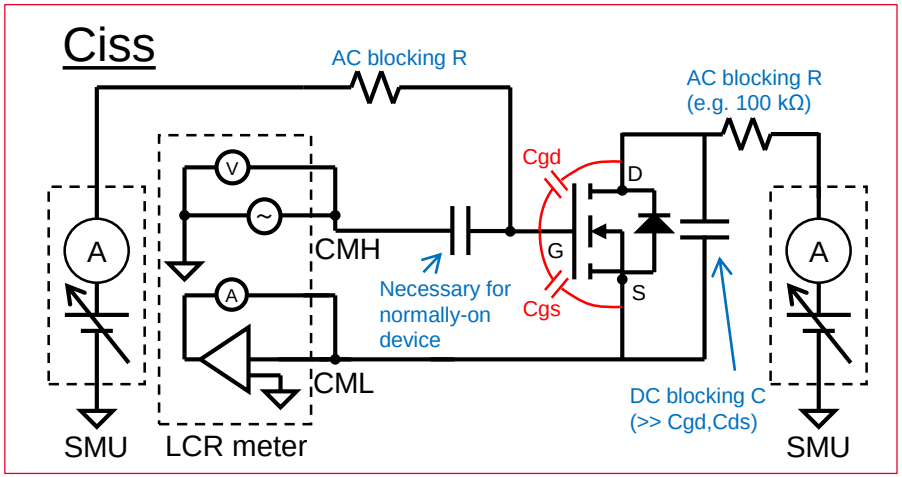
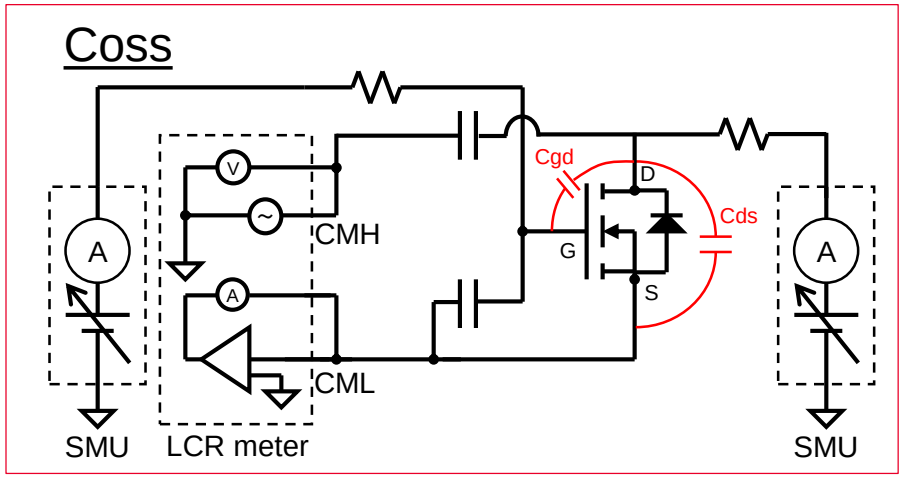
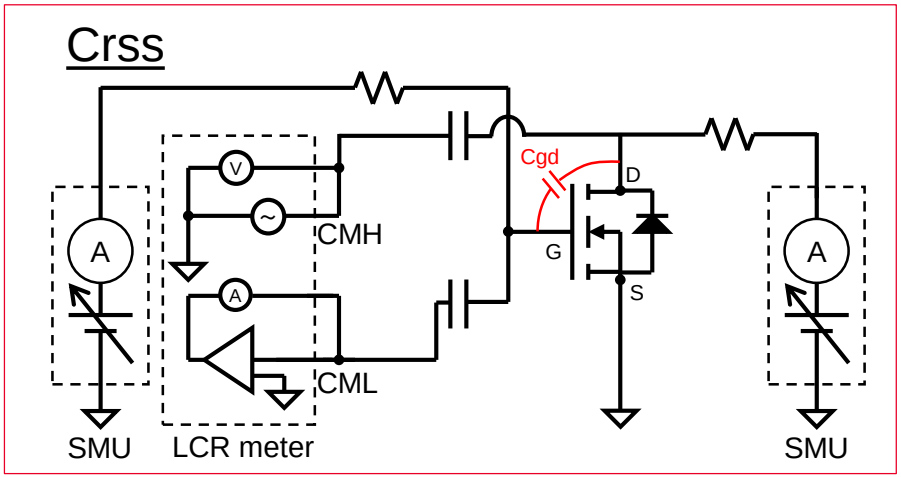
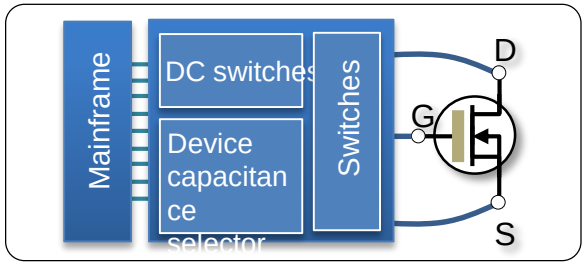
3 Terminal FET Capacitance Measurement

Circuit Diagrams

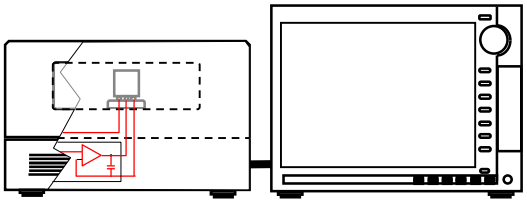








Fully Automatic Temperature Dependency Test Example

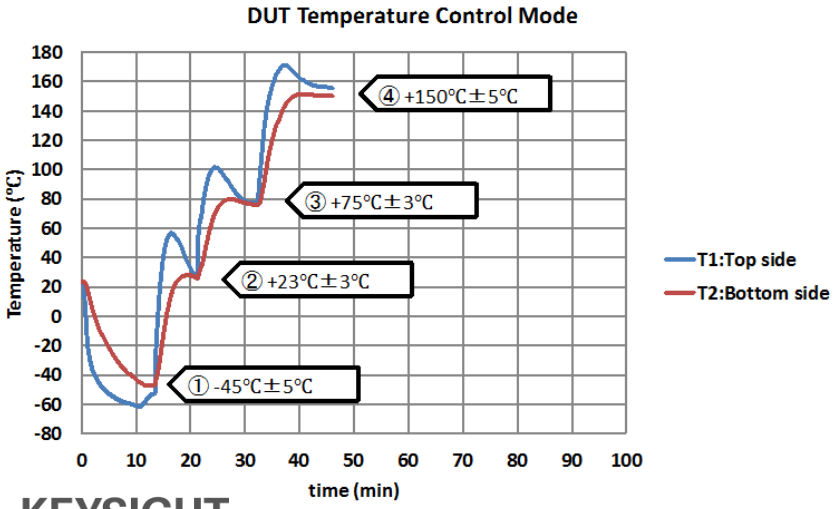


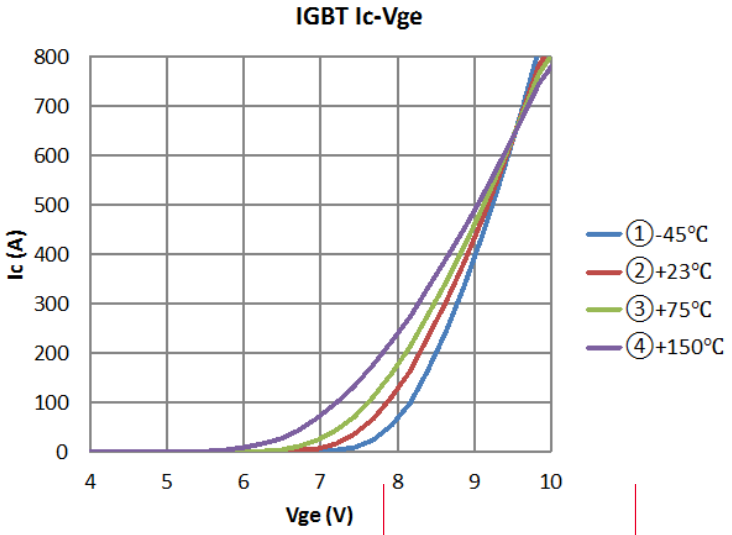
key points

- To bring test resource (i.e. current amplifier in a test fixture) near DUT in order to reduce cable inductance and therefore maximize current and reduce the chance of oscillation
- To use thermal equipment that can be controlled via computer.
- To avoid condensation in the fixture when cooling DUT

With Thermostream
(-50°C to +220°C)

With hot plate
(Room temp to +250°C)





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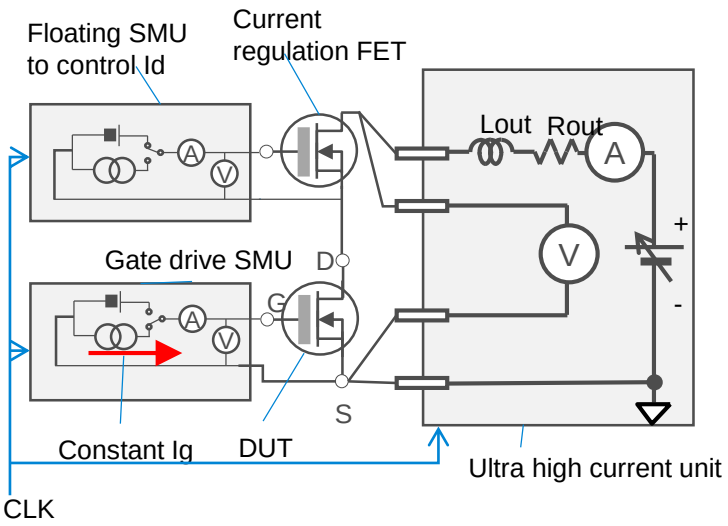
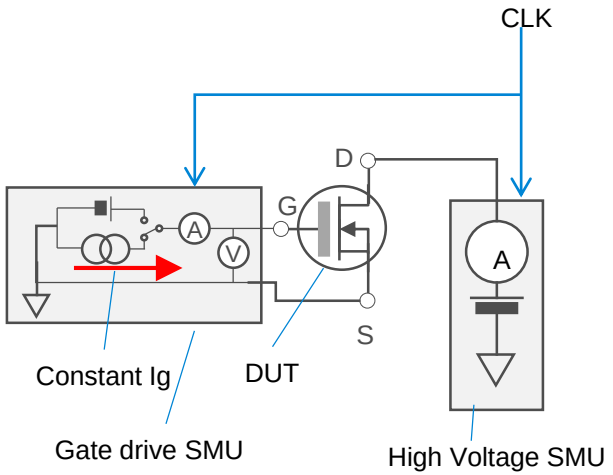
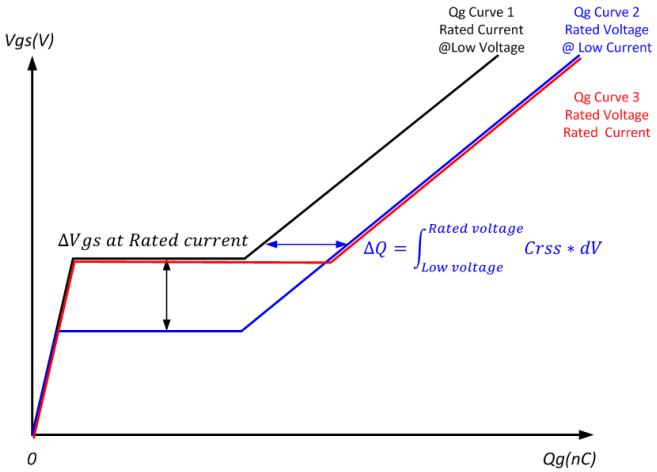
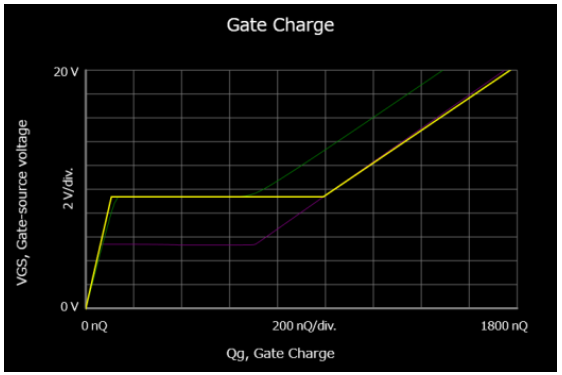
Novel Qg Measurement Method







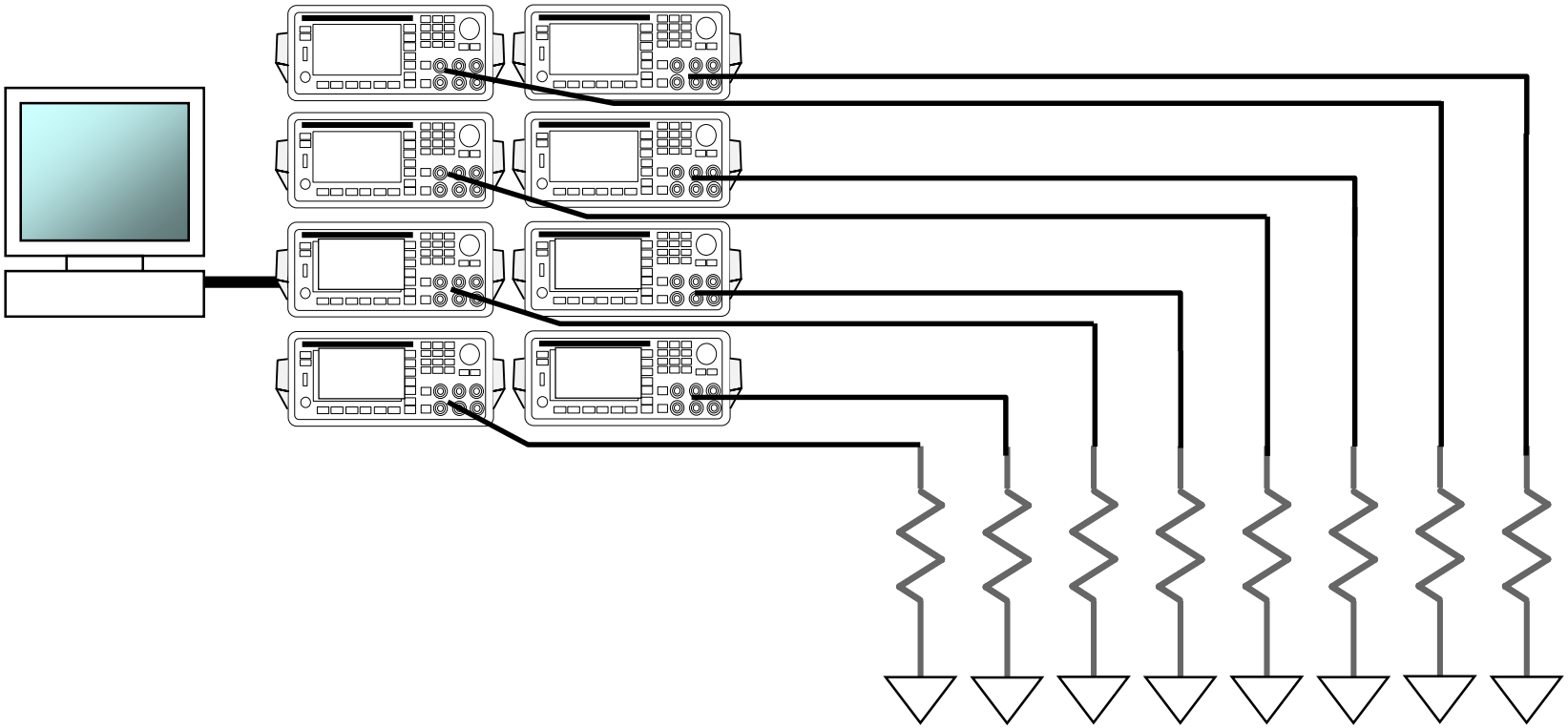


key points

- To separate Qg measurement into two, 1) high voltage low current measurement and 2) low voltage high current measurement
- To regulate maximum current with another FET
- To use SMU in order to apply precise current to the gate
- Fast sampling to monitor gate voltage and drain current changes

Reliability Test System Concept

- Choose instrument that has enough voltage or current range for reliability testing
- Use multiple instruments in order to give stress to multiple devices simultaneously



Summary

- Wide Band Gap devices brings about new measurement challenges
  - High voltage
  - High current (Accurate Ron)
  - Temperature dependency
  - Capacitances & Rg
  - Gate charge

- A standard solution is necessary across the entire power electronics industry
  - Consistent test results in any location every time
  - Everyone should make evaluation without having product training

- Keysight provides a product that fills the gap