



# Wide Bandgap characteristics and test concept

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# Agenda

## 1. About WBG

- What is WBG ?
- Applications

## 2. WBG Test

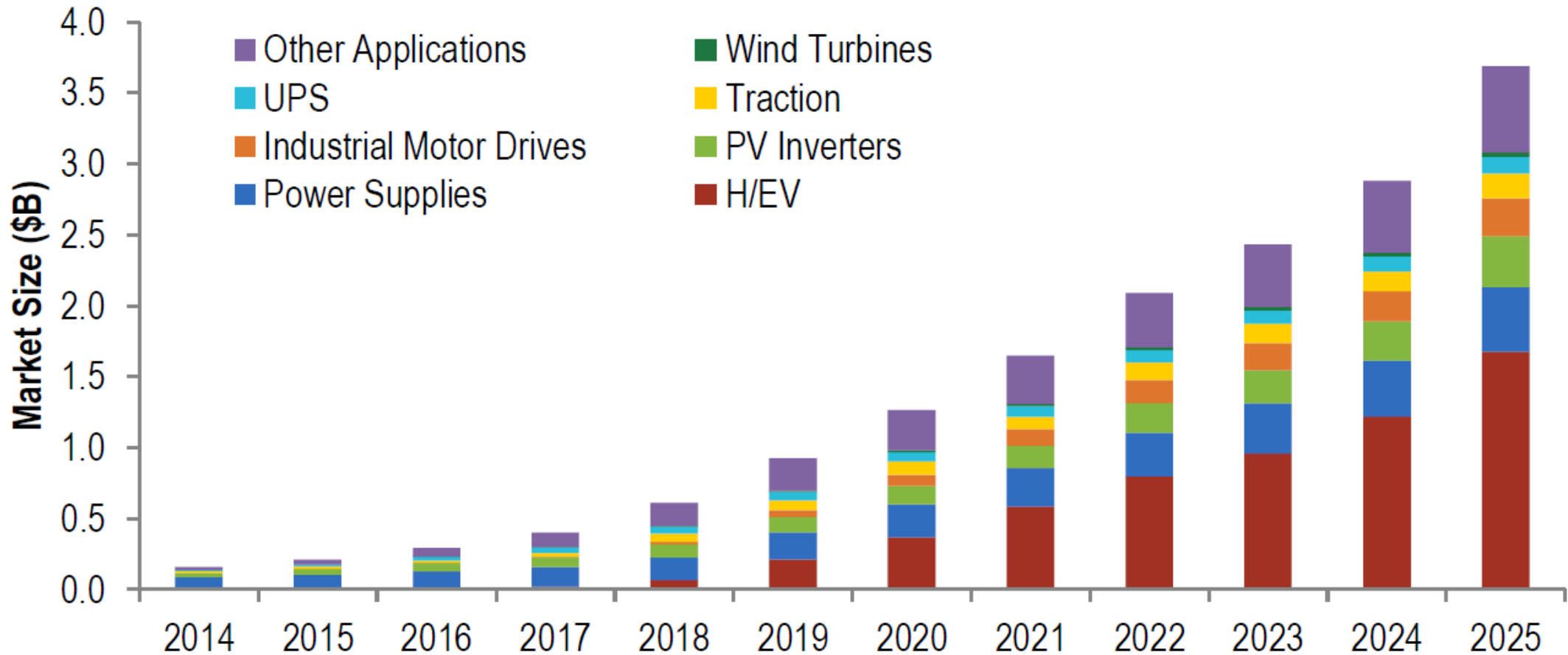
- Test configuration & parameters

## 3. Tektronix Suggestions

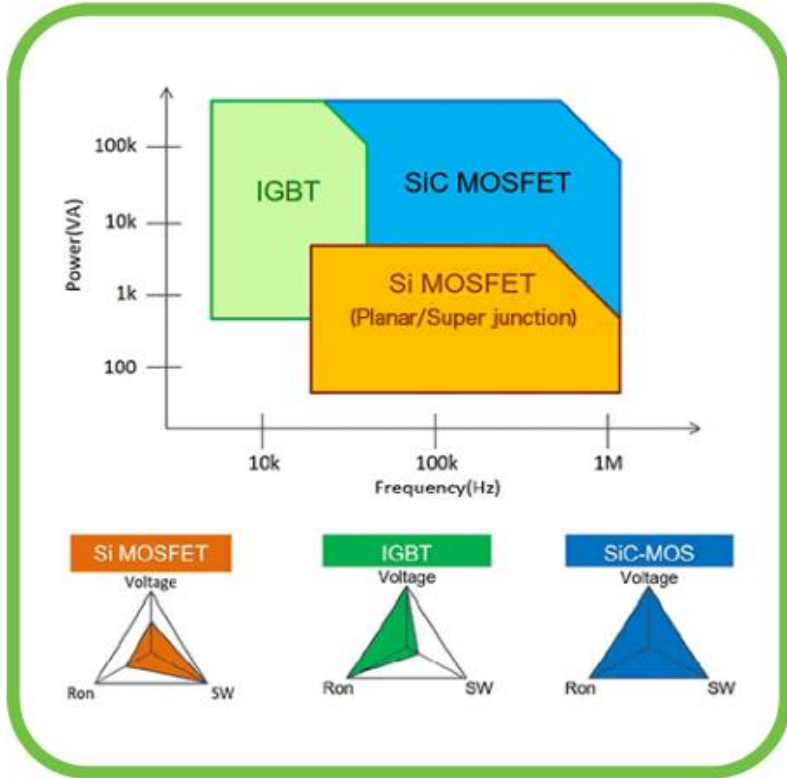
# About Wide Bandgap



# Wide Bandgap market



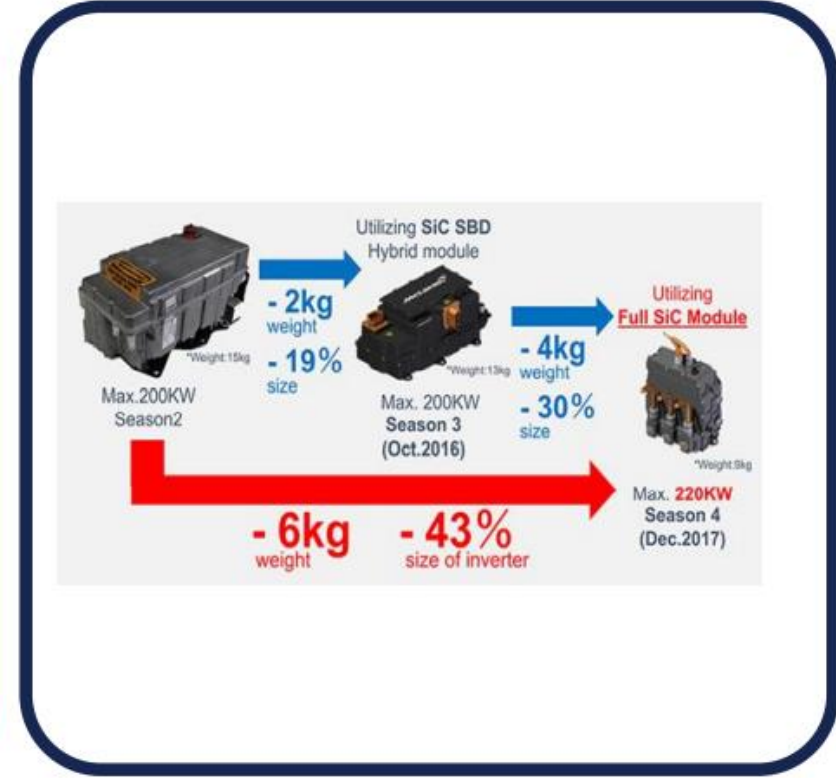
# Why Wide Bandgap ?



**Higher Power Levels  
Faster Switching speeds**



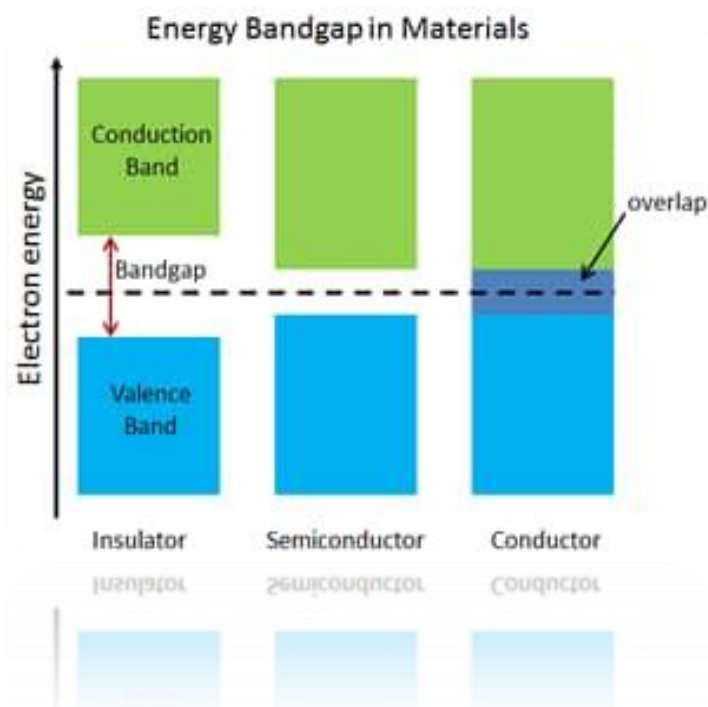
**Lower Switching Losses**



**Smaller Form Factor**

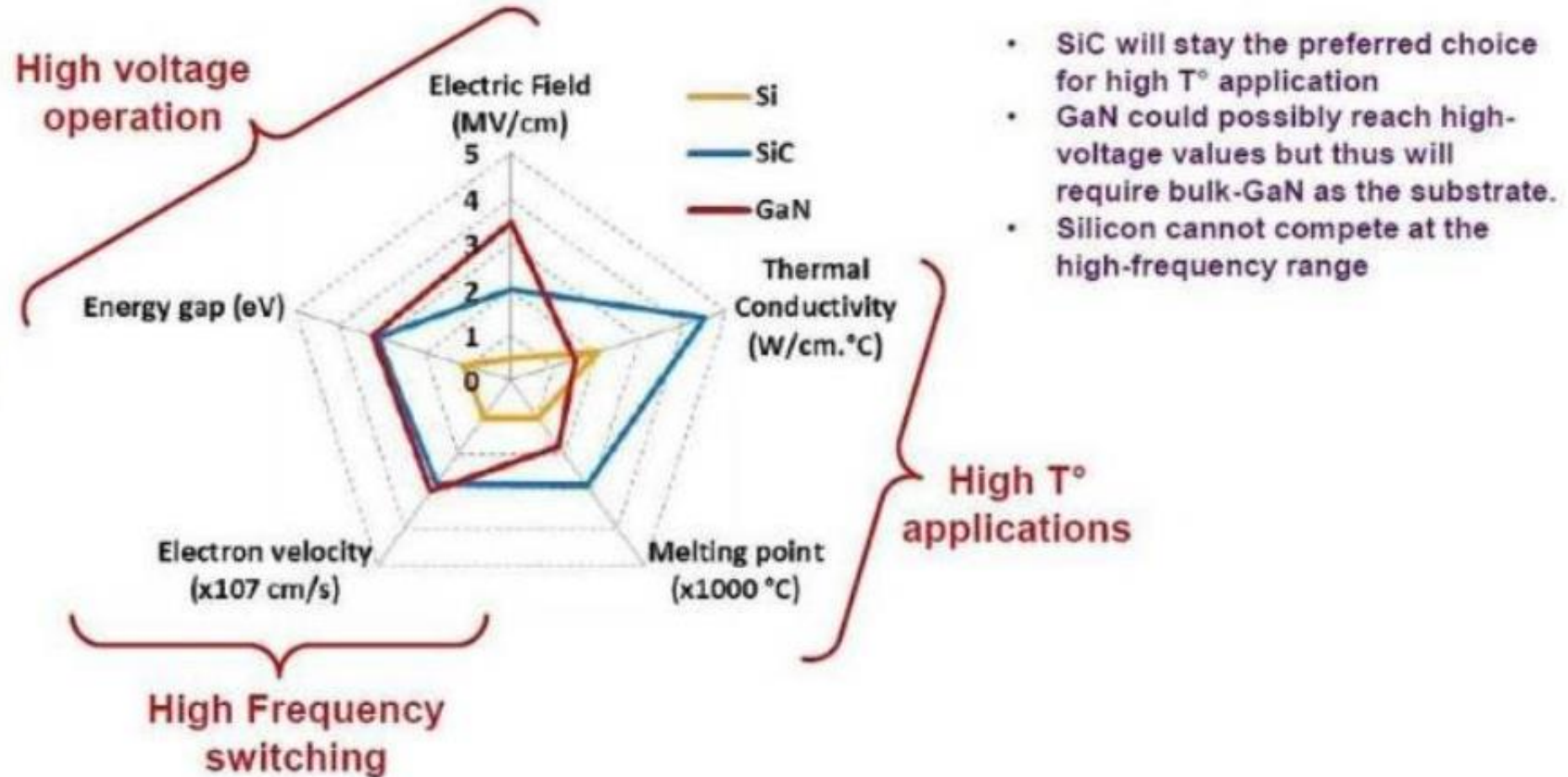
# What is Wide Bandgap ?

- Wide bandgap semiconductors are materials that possess bandgaps significantly greater than those of silicon.



- This will enable devices to operate at :
  - Higher voltage
  - Higher temperature
  - Higher frequency

# Theory of Wide Bandgap



Comparison of the figures of merit of Si, SiC and GaN [Source: Yole Développement]

# Theory of Wide Bandgap

Material	Electric Field (MV/cm)	Vsat $10^7$ (cm/s)
Si	0.3	1.0
SiC	2.0	2.0
GaN	3.3	2.5
C	5.6	2.7

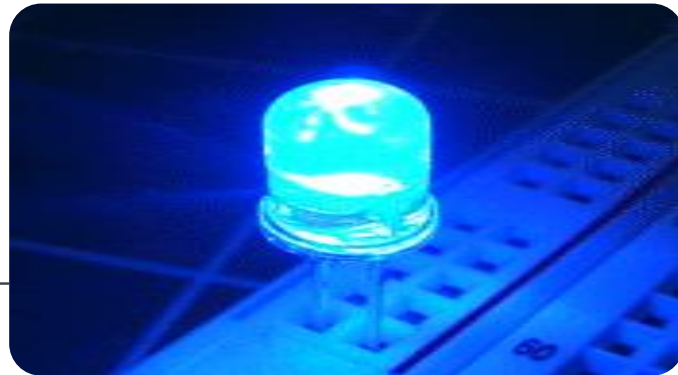
Material	Thermal Conductivity k(W/cm °C)
Si	1.5
SiC	4.5
GaN	1.3
C	20

- **Higher Electric field and higher Vsat (saturation velocity) :**
  - Higher Voltage rating
  - Increased drain current
  - Better on-state performance
  - Improved switching
- **Higher Thermal conductivity enables :**
  - Higher power density
  - Better reliability
  - Higher temperature capability

# What is Wide Bandgap ?

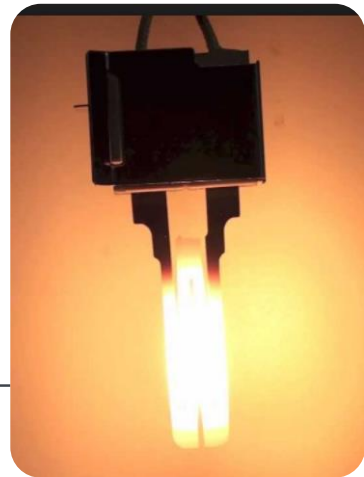
## GaN (Gallium Nitride)

- Gallium + Nitride
- Used in RF, LED ...
- Some properties ;
  - high electron mobility
  - allow small form-factors

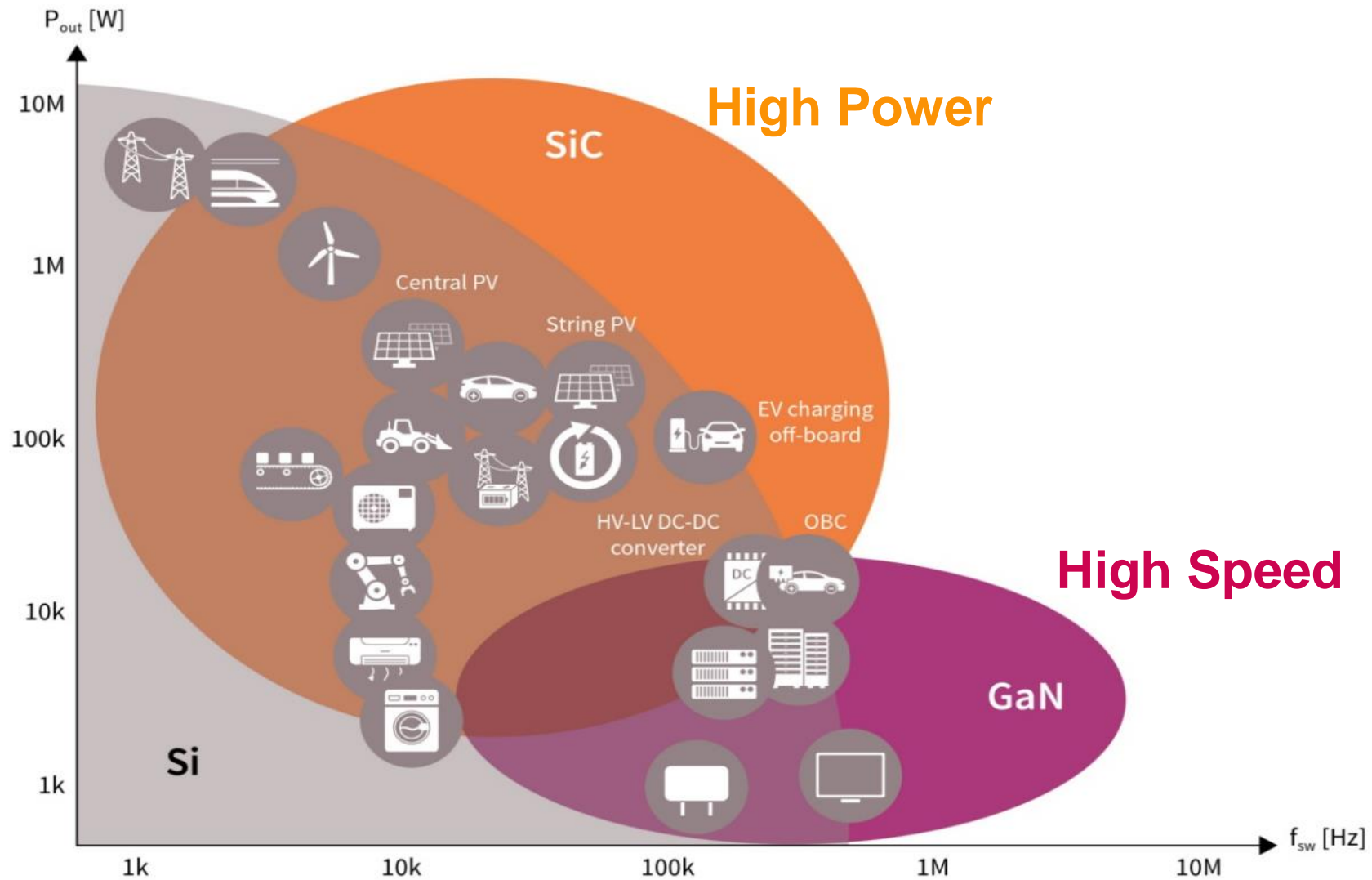


## SiC (Silicon Carbide)

- Silicon + Carbon
- Used in Automotive ...
- Some properties ;
  - high strength
  - hardness
  - high thermal conductivity



# Applications



# Wide Bandgap Test



# Test Configuration

· 2600-PCT-4B

· 4200A

With integrated clarius software

ACS Basic software @PC



2636B  
SMU 1,2 & TSP Node : 1

2657A  
SMU 3 & TSP Node : 2

2651A  
SMU 4 & TSP Node : 3

8010 Test Fixture



SMU + CVU + PMU

# Test parameters - GaN

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Static characteristics</b>						
$V_{GS(th)}$	gate-source threshold voltage	$I_D = 1 \text{ mA}; V_{DS}=V_{GS}; T_J = 25 \text{ }^\circ\text{C}$	3.4	3.9	4.5	V
		$I_D = 1 \text{ mA}; V_{DS}=V_{GS}; T_J = 175 \text{ }^\circ\text{C}; \text{Fig. 9}$	2.2	-	-	V
		$I_D = 1 \text{ mA}; V_{DS}=V_{GS}; T_J = -55 \text{ }^\circ\text{C}; \text{Fig. 9}$	-	-	5.2	V
$I_{DSS}$	drain leakage current	$V_{DS} = 650 \text{ V}; V_{GS} = 0 \text{ V}; T_J = 25 \text{ }^\circ\text{C}$	-	2	25	$\mu\text{A}$
		$V_{DS} = 650 \text{ V}; V_{GS} = 0 \text{ V}; T_J = 175 \text{ }^\circ\text{C}$	-	25	-	$\mu\text{A}$
$I_{GSS}$	gate leakage current	$V_{GS} = -20 \text{ V}; V_{DS} = 0 \text{ V}; T_J = 25 \text{ }^\circ\text{C}$	-	10	100	nA
		$V_{GS} = 20 \text{ V}; V_{DS} = 0 \text{ V}; T_J = 25 \text{ }^\circ\text{C}$	-	10	100	nA
$R_{Dson}$	drain-source on-state resistance	$V_{GS} = 10 \text{ V}; I_D = 25 \text{ A}; T_J = 25 \text{ }^\circ\text{C}$	-	50	60	m $\Omega$
		$V_{GS} = 10 \text{ V}; I_D = 25 \text{ A}; T_J = 175 \text{ }^\circ\text{C}; \text{Fig. 10}$	-	120	-	m $\Omega$
$R_G$	gate resistance	$f = 1 \text{ MHz}$	-	2.3	-	$\Omega$

<b>Dynamic characteristics</b>						
$Q_{G(tot)}$	total gate charge	$I_D = 25 \text{ A}; V_{DS} = 400 \text{ V}; V_{GS} = 10 \text{ V}; T_J = 25 \text{ }^\circ\text{C}$	-	15	-	nC
$Q_{GS}$	gate-source charge		-	6	-	nC
$Q_{GD}$	gate-drain charge		-	4	-	nC
$C_{iss}$	input capacitance	$V_{DS} = 400 \text{ V}; V_{GS} = 0 \text{ V}; f = 1 \text{ MHz}; T_J = 25 \text{ }^\circ\text{C}; \text{Fig. 11}$	-	1000	-	pF
$C_{oss}$	output capacitance		-	130	-	pF
$C_{rss}$	reverse transfer capacitance		-	8	-	pF
$C_{o(er)}$	effective output capacitance, energy related	$0 \text{ V} \leq V_{DS} \leq 400 \text{ V}; V_{GS} = 0 \text{ V}; T_J = 25 \text{ }^\circ\text{C}; \text{Fig. 12}$	-	190	-	pF
$C_{o(tr)}$	effective output capacitance, time related	$0 \text{ V} \leq V_{DS} \leq 400 \text{ V}; V_{GS} = 0 \text{ V}; T_J = 25 \text{ }^\circ\text{C}$	-	310	-	pF
$t_{d(on)}$	turn-on delay time	$V_{DS} = 400 \text{ V}; R_L = 16 \text{ } \Omega; V_{GS} = 12 \text{ V}; R_{G(ext)} = 40 \text{ } \Omega$	-	57	-	ns
$t_r$	rise time		-	10	-	ns
$t_{d(off)}$	turn-off delay time		-	88	-	ns
$t_f$	fall time		-	11	-	ns
$Q_{oss}$	output charge	$V_{GS} = 0 \text{ V}; V_{DS} = 400 \text{ V}$	-	125	-	nC
<b>Source-drain diode</b>						
$V_{SD}$	source-drain voltage	$I_S = 25 \text{ A}; V_{GS} = 0 \text{ V}; T_J = 25 \text{ }^\circ\text{C}; \text{Fig. 13}$	-	1.9	-	V
		$I_S = 12.5 \text{ A}; V_{GS} = 0 \text{ V}; T_J = 25 \text{ }^\circ\text{C}$	-	1.35	-	V
$t_{rr}$	reverse recovery time	$I_S = 25 \text{ A}; di_S/dt = -1000 \text{ A}/\mu\text{s}; V_{GS} = 0 \text{ V}; V_{DS} = 400 \text{ V}; \text{Fig. 14}$	-	54	-	ns
$Q_r$	recovered charge		-	125	-	nC

<https://assets.nexperia.com/documents/data-sheet/GAN063-650WSA.pdf>

# Test parameters - IGBT

## ELECTRICAL CHARACTERISTICS (T<sub>J</sub> = 25°C unless otherwise noted)

Parameter	Test Conditions	Symbol	Min	Typ	Max	Unit
<b>OFF CHARACTERISTICS</b>						
Collector-emitter breakdown voltage, gate-emitter short-circuited	V <sub>GE</sub> = 0 V, I <sub>C</sub> = 1 mA	BV <sub>CES</sub>	650	-	-	V
Temperature Coefficient of Breakdown Voltage	V <sub>GE</sub> = 0 V, I <sub>C</sub> = 1 mA	$\frac{\Delta BV_{CES}}{\Delta T_J}$	-	0.6	-	V/°C
Collector-emitter cut-off current, gate-emitter short-circuited	V <sub>GE</sub> = 0 V, V <sub>CE</sub> = 650 V	I <sub>CES</sub>	-	-	250	μA
Gate leakage current, collector-emitter short-circuited	V <sub>GE</sub> = 20 V, V <sub>CE</sub> = 0 V	I <sub>GES</sub>	-	-	±400	nA
<b>ON CHARACTERISTICS</b>						
Gate-emitter threshold voltage	V <sub>GE</sub> = V <sub>CE</sub> , I <sub>C</sub> = 50 mA	V <sub>GE(th)</sub>	3.4	4.9	6.4	V
Collector-emitter saturation voltage	V <sub>GE</sub> = 15 V, I <sub>C</sub> = 50 A V <sub>GE</sub> = 15 V, I <sub>C</sub> = 50 A, T <sub>J</sub> = 175°C	V <sub>CE(sat)</sub>	-	1.6 1.95	2.1	V

## DYNAMIC CHARACTERISTICS

Input capacitance	V <sub>CE</sub> = 30 V, V <sub>GE</sub> = 0 V, f = 1 MHz	C <sub>ies</sub>	-	3209	-	pF
Output capacitance		C <sub>oes</sub>	-	42	-	
Reverse transfer capacitance		C <sub>res</sub>	-	12	-	
Gate charge total	V <sub>CE</sub> = 400 V, I <sub>C</sub> = 50 A, V <sub>GE</sub> = 15 V	Q <sub>g</sub>	-	99	-	nC
Gate-to-emitter charge		Q <sub>ge</sub>	-	17	-	
Gate-to-collector charge		Q <sub>gc</sub>	-	23	-	

## SWITCHING CHARACTERISTICS, INDUCTIVE LOAD

Turn-on delay time	T <sub>C</sub> = 25°C, V <sub>CC</sub> = 400 V, I <sub>C</sub> = 25 A, R <sub>G</sub> = 4.7 Ω, V <sub>GE</sub> = 15 V, Inductive Load, FWD: AFGHL50T65SQD	t <sub>d(on)</sub>	-	19	-	ns	
Rise time		t <sub>r</sub>	-	11	-		
Turn-off delay time		t <sub>d(off)</sub>	-	87	-		
Fall time			t <sub>f</sub>	-	5	-	mJ
Turn-on switching loss		E <sub>on</sub>	-	0.35	-		
Turn-off switching loss		E <sub>off</sub>	-	0.12	-		
Total switching loss		E <sub>ts</sub>	-	0.47	-		
Turn-on delay time		T <sub>C</sub> = 25°C, V <sub>CC</sub> = 400 V, I <sub>C</sub> = 50 A, R <sub>G</sub> = 4.7 Ω, V <sub>GE</sub> = 15 V, Inductive Load, FWD: AFGHL50T65SQD	t <sub>d(on)</sub>	-	20	-	ns
Rise time			t <sub>r</sub>	-	28	-	
Turn-off delay time	t <sub>d(off)</sub>		-	81	-		
Fall time			t <sub>f</sub>	-	36	-	mJ
Turn-on switching loss	E <sub>on</sub>		-	0.95	-		
Turn-off switching loss	E <sub>off</sub>		-	0.46	-		
Total switching loss	E <sub>ts</sub>		-	1.41	-		

<https://www.onsemi.com/pdf/datasheet/afghl50t65sq-d.pdf>

# BVces

## Test condition

Definition Data Status

Mode

DC Only

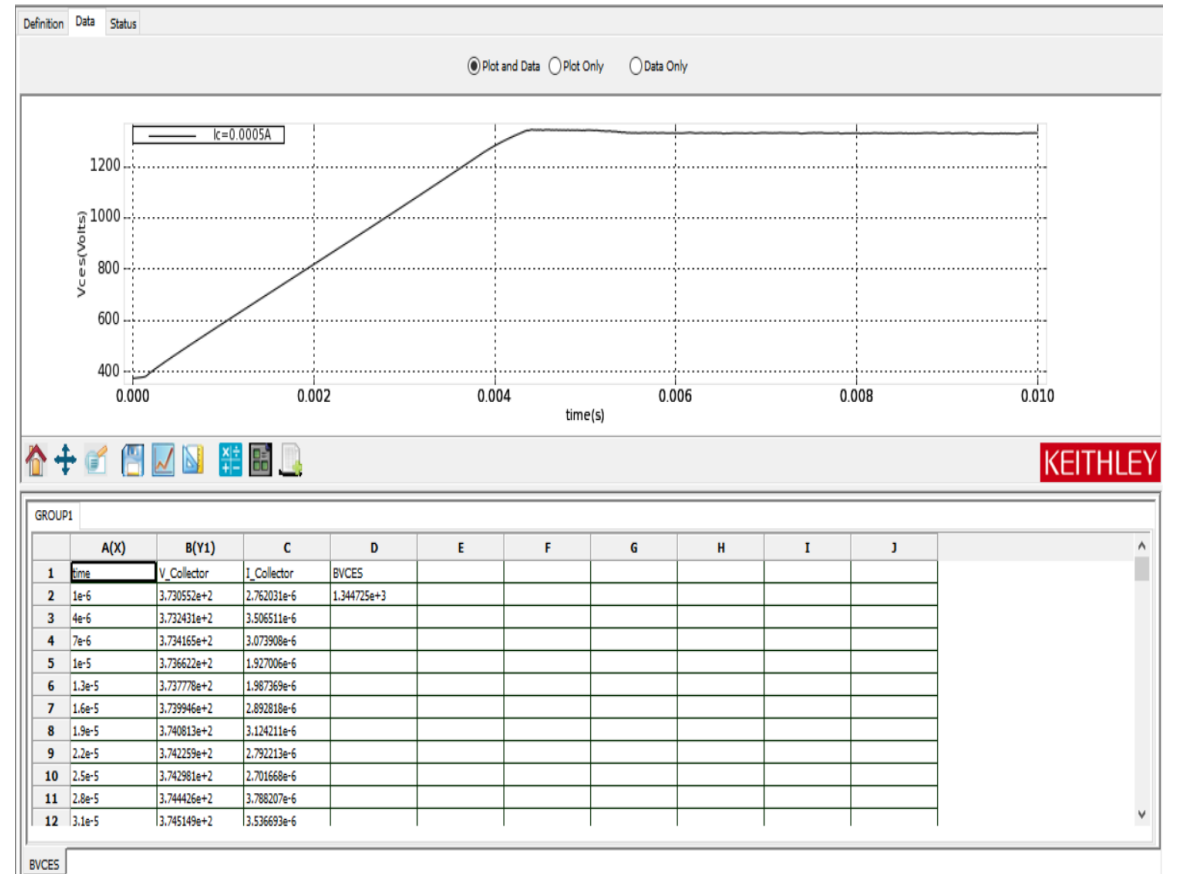
Pulse Available

Timing

Stop on Compliance

Device Num	SMU	Pad	Function	Force Mode	Source	Measure	Compliance	Meas.Range	Advanced
1	SMU3	Collector	Bias I	Pulse Timing 1	[0.001, 0]	I+V	1500.0	1.5kV	...
	SMU2	Gate	GND						

## Test result



# Ices & Iges

Test condition

Definition Data Status

Mode

DC Only

Pulse Available

Timing

Stop on Compliance

Device Num SMU

1	SMU3
	SMU2

Definition Data Status

Mode

DC Only

Pulse Available

Timing

Stop on Compliance

Device Num SMU Pad Function Force Mode Source Measure Compliance Meas.Range Advanced

1	SMU3	Collector	GND						
	SMU2	Gate	Bias V	DC	20.0	I+V	0.001	auto	...

Test result

Definition Data Status

Plot and Data  Plot Only  Data Only

$\times 1e-8$

I\_Collector

time

Y1: Collector

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GROUP1

	A(X)	B	C(Y1)	D	E	F	G	H	I	J
1	time	V_Collector	I_Collector	VCES	ICES					
2	1.00001e-1	1.200502e+3	5.960354e-8	1.200503e+3	5.908252e-8					
3	1.35073e-1	1.200501e+3	5.949352e-8							
4	1.70144e-1	1.2005e+3	5.942632e-8							
5	2.05215e-1	1.2005e+3	5.936133e-8							
6	2.40286e-1	1.200503e+3	5.931169e-8							
7	2.75358e-1	1.200502e+3	5.92624e-8							
8	3.1043e-1	1.200505e+3	5.924364e-8							
9	3.45502e-1	1.200504e+3	5.921588e-8							
10	3.80574e-1	1.200504e+3	5.91959e-8							
11	4.15646e-1	1.200505e+3	5.91782e-8							
12	4.50717e-1	1.200504e+3	5.916522e-8							

# ■ Vge(th)

## Test condition

Device Num	SMU	Pad	Function	Force Mode	Source	Measure	Compliance	Meas.Range	Advanced
1	SMU3	Collector	Sweep V	DC	Linear:[3, 7, 401, 0, 0.01]	I+V	0.12	1.20mA	...
	SMU2	Gate	Sweep V	DC	Linear:[3, 7, 401, 0, 0.01]	V	0.1		...

$V_{ge(th)} = AT(V\_Gate, FINDLIN(I\_Collector, 0.00085, 2))$

## Test result

GROUP1	A	B(X)	C	D(Y1)	E	F	G	H	I	J
1	Time	V_Gate	V_Collector	I_Collector	VGETH					
2	2.51e-4	3.996384	3.997899	1.699932e-5	5.813144					
3	3.0253e-2	4.009836	4.007364	2.085765e-5						
4	6.0254e-2	4.020493	4.01665	2.09791e-5						
5	9.0255e-2	4.030802	4.028258	2.125936e-5						
6	1.20256e-1	4.040585	4.037724	2.106318e-5						
7	1.50257e-1	4.048448	4.048081	2.137147e-5						
8	1.80258e-1	4.061027	4.057725	2.119397e-5						
9	2.10259e-1	4.071159	4.069155	2.136213e-5						
10	2.4026e-1	4.081817	4.077013	2.130607e-5						
11	2.70261e-1	4.090726	4.08737	2.139015e-5						
12	3.00262e-1	4.097192	4.095049	2.18666e-5						

# ■ Vce(sat)

## Test condition

Definition Data Status

Mode

DC Only

Pulse Available

Timing

Stop on Compliance

Device Num	SMU	Pad	Function	Force Mode	Source	Measure	Compliance	Meas.Range	Advanced
1	SMU4	Collector	Bias I	Pulse Timing 1	[50, 0]	I+V	10.0	20V	...
	SMU1	Gate	Bias V	Pulse Timing 2	[15, 0]	V	0.1		...

## Test result

Setup Data Status

Plot and Data  Plot Only  Data Only

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DATA

	A(X)	B(Y1)	C	D	E	F	G	H	I	J
1	Vce	Ic	error							
2	4.152521e-1	-1.424184e-3	0							
3	1.018174	4.733314e-1								
4	1.128988	9.787886e-1								
5	1.205247	1.484246								
6	1.269292	1.994152								
7	1.326189	2.482257								
8	1.386958	2.98193								
9	1.439237	3.491391								
10	1.485558	3.998628								
11	1.533624	4.476499								
12	1.583717	4.981066								

VceSAT\_MDX\_P1SS1D5T2

# Rds(on)

## Test condition

Definition Data Status

Mode  
 DC Only  
 Pulse Available

Timing

Stop on Compliance

Device Num	SMU	Pad	Function	Force Mode	Source	Measure	Compliance	Meas.Range	Advanced
1	SMU4	Drain	Sweep 1	Pulse Timing 1	Linear:[23, 27, 401, 0, 0.01, 0]	I+V	20.0	40V	...
	SMU1	Gate	Bias V	Pulse Timing 2	[10, 0]	V	0.1		...

$$RDS = V\_Drain / I\_Drain$$

$$RDS(ON) = AT(V\_Drain, FINDLIN(I\_Drain, 1.3, 2)) / AT(I\_Drain, FINDLIN(I\_Drain, 1.3, 2))$$

## Test result

Definition Data Status

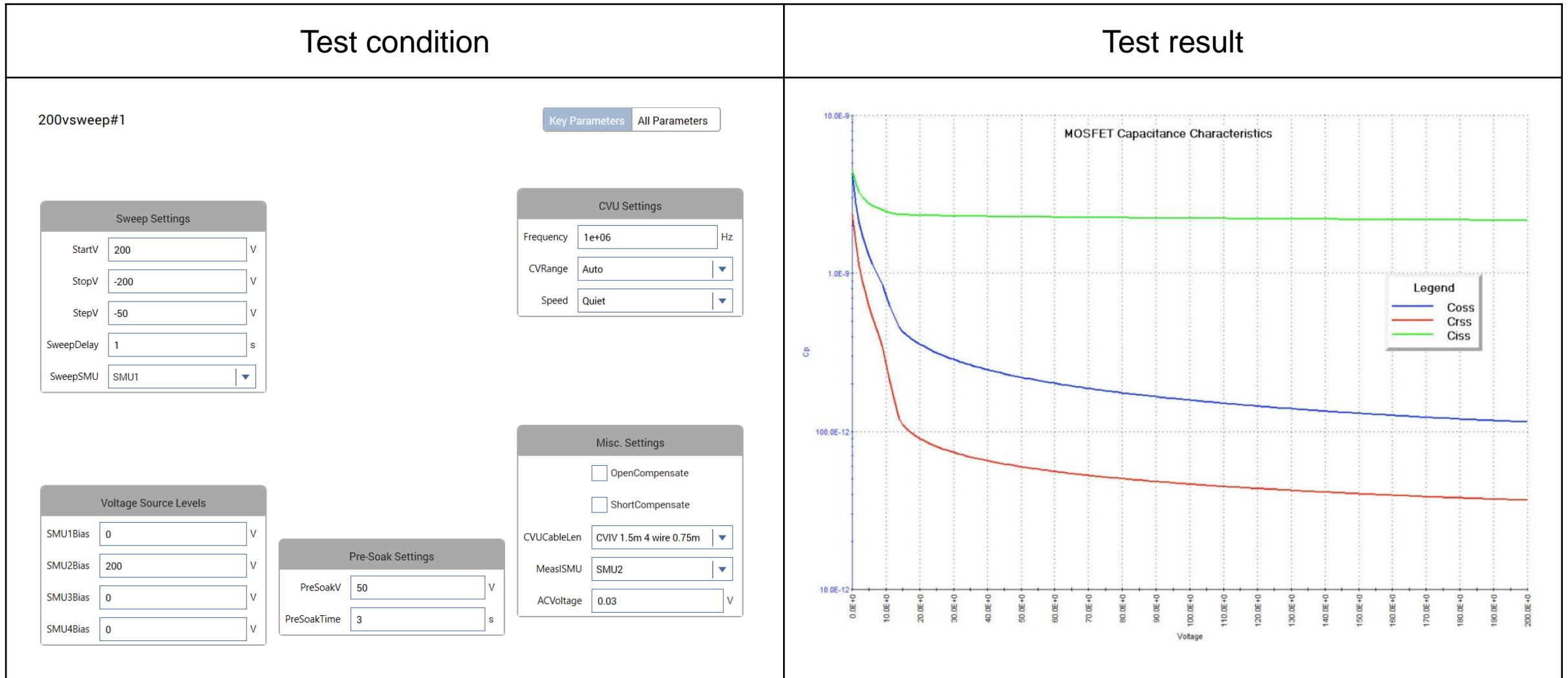
Plot and Data  Plot Only  Data Only

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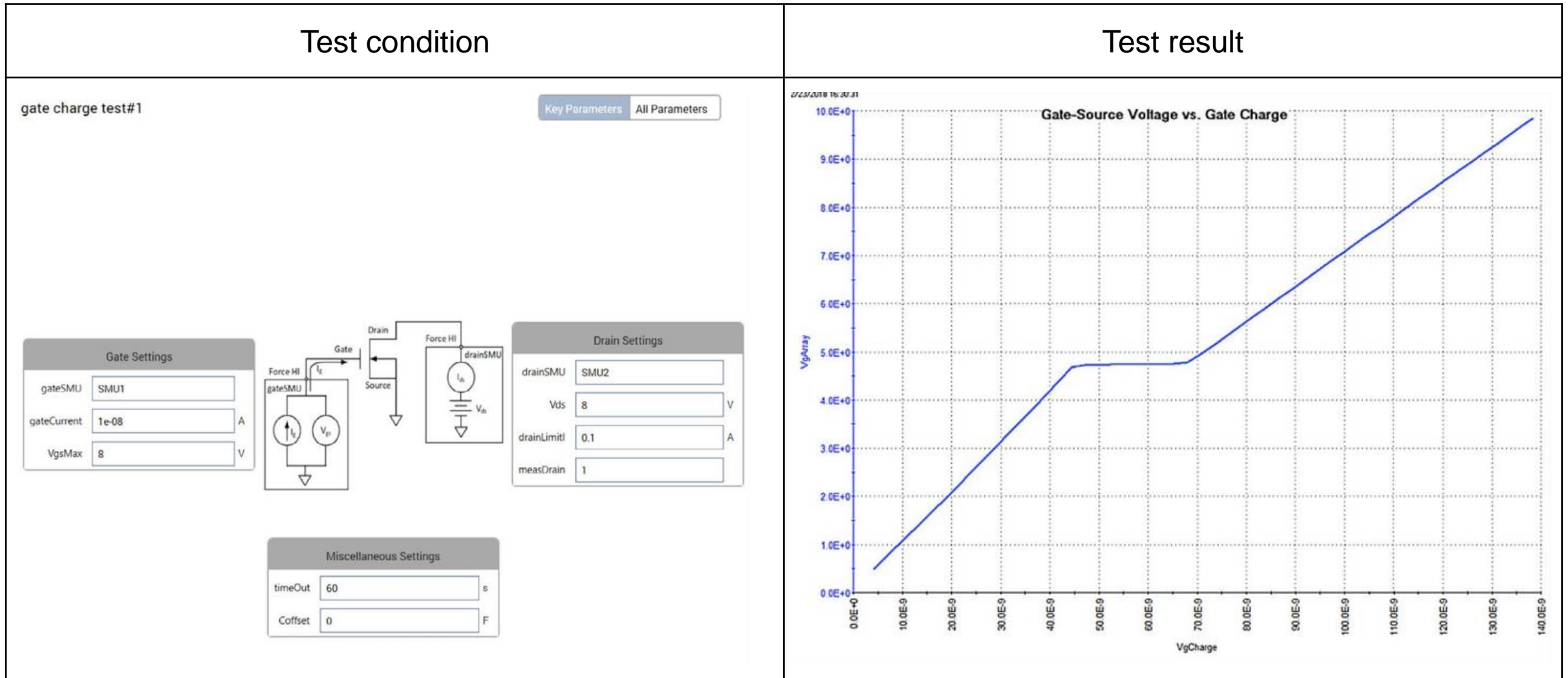
GROUP1	A	B	C(X)	D	E	F(Y1)	G	H	I	J
1	time	V_Drain	I_Drain	V_Gate	RDSON	RDS				
2	2.51e-4	1.976648	3.570774e-1	1.000029e+1	5.880302	5.53563				
3	3.0252e-2	2.540289	4.496083e-1	1.000377e+1		5.650004				
4	6.0253e-2	2.682762	4.705991e-1	1.000464e+1		5.700738				
5	9.0254e-2	2.787272	4.941602e-1	1.000319e+1		5.640423				
6	1.20255e-1	2.890591	5.09582e-1	1.000218e+1		5.672476				
7	1.50256e-1	3.002694	5.250038e-1	1.000349e+1		5.719376				
8	1.80257e-1	3.099314	5.479937e-1	1.000247e+1		5.655747				
9	2.10258e-1	3.198316	5.621304e-1	1.000247e+1		5.689633				
10	2.40259e-1	3.30625	5.796941e-1	1.000363e+1		5.703439				
11	2.7026e-1	3.4121	6.03252e-1	1.000131e+1		5.656147				
12	3.00261e-1	3.511846	6.148216e-1	1.000479e+1		5.711977				

RdsON\_P1551D4T11

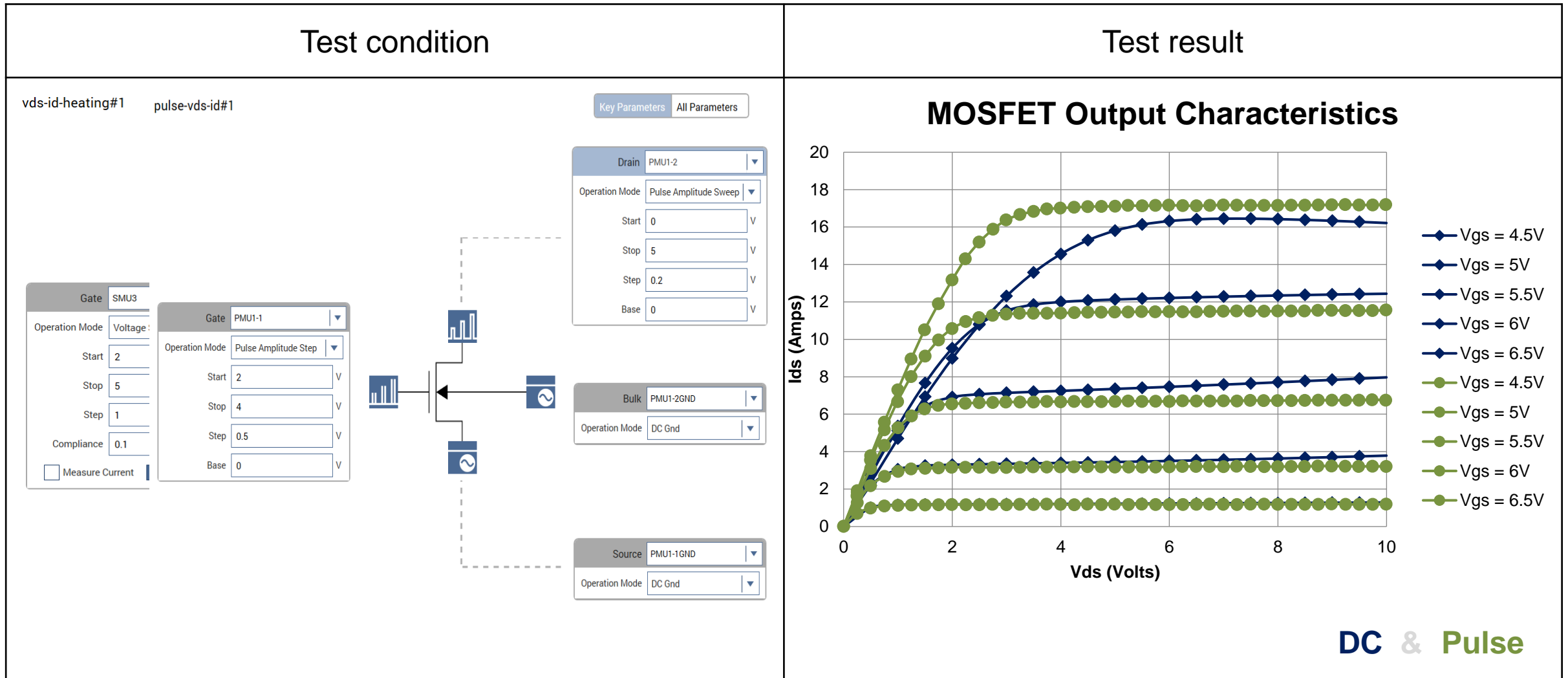
# ■ Ciss & Coss & Crss



# ■ Qg (Qgs & Qgd)



# Self-heating effect



# Tektronix Suggestions

The background is a gradient of blue and teal. It features several diagonal lines and shapes. A prominent feature is a large, light blue parallelogram with a halftone dot pattern, tilted upwards. Other solid-colored diagonal bands in various shades of blue and teal are layered over the background.

# Tektronix Suggestion

1. 2600-PCT for measuring various parameters except capacitance



# Tektronix Suggestion

## 1. 2600-PCT Spec

Model		Collector/Drain Supply		Step Generator	Auxiliary Supply
		High Voltage Mode	High Current Mode	Base/Gate supply	
Low Power	2600-PCT-1B	200V/10A	200V/10A	200V/10A	N/A
High Current	2600-PCT-2B	200V/10A	40V/50A	200V/10A	200V/10A
High Voltage	2600-PCT-3B	3KV/120mA	200V/10A	200V/10A	200V/10A
High Current and High Voltage	2600-PCT-4B	3KV/120mA	40V/50A	200V/10A	200V/10A
High Current and High Voltage	2600-PCT-4B + 2651A	3KV/120mA	40V/100A	200V/20A	200V/20A

# Tektronix Suggestion

## 1. 2600-PCT Software

Automated Characterization Suite(ACS) V1.2BASIC---ACADMIN[C:\Documents and Settings\jchenev\My Documents\my ACS projects\Agent Smith examples\jsmTrain\_5TM\_PTM]

Interactive Test Module: IdVd\_St

Project: nMOSFET

- IdVd\_StepVg
- IdVd\_BiasVg
- npnlJT
- ICVce\_BiasVb
- RESISTOR\_2T
- Sweep\_IV\_2SMU
- DCODE
- Sweep\_IdVdVd
- Sweep\_IrdVdVd
- stin
- tm\_ptm
- tm\_ptm\_2
- tm\_ptm\_3
- tm\_ptm\_1

Force Func:

- Bias V
- Bias I
- Sweep V
- Sweep I
- Step V
- Step I

Timing

Device Num	SMU	Pad	Function	Force Range	Source	Measure	Compliance	Meas Range	Limits Auto
1	SMU1	Drain	Sweep V	auto	Linear [0, 14, 1]	[+V(prop)]	0.1	auto	
	SMU1	Gate	Step V	auto	[2, 5, 4]	None	0.1		

Automated Characterization Suite(ACS) V5.3(DEMO)---ACADMIN[C:\YACS\Projects\TEST]

ITM: IdVg (26xx SMU)

Wafer Description

Test Setup

Patterns

- Pattern\_1
- SUBSITE1
- DIODE\_26
- TRVR
- OFFSET
- nMOSFET\_26
- IdVg
- IdVd
- IdVd2
- IdVd\_pulse

Definition Data Status

Plot and Data Plot Only Data Only

IDVG Transfer Curve

Y1: Drain (A)

Y1: FIT\_GM

Y2: GM1 (S)

V\_Gate (V)

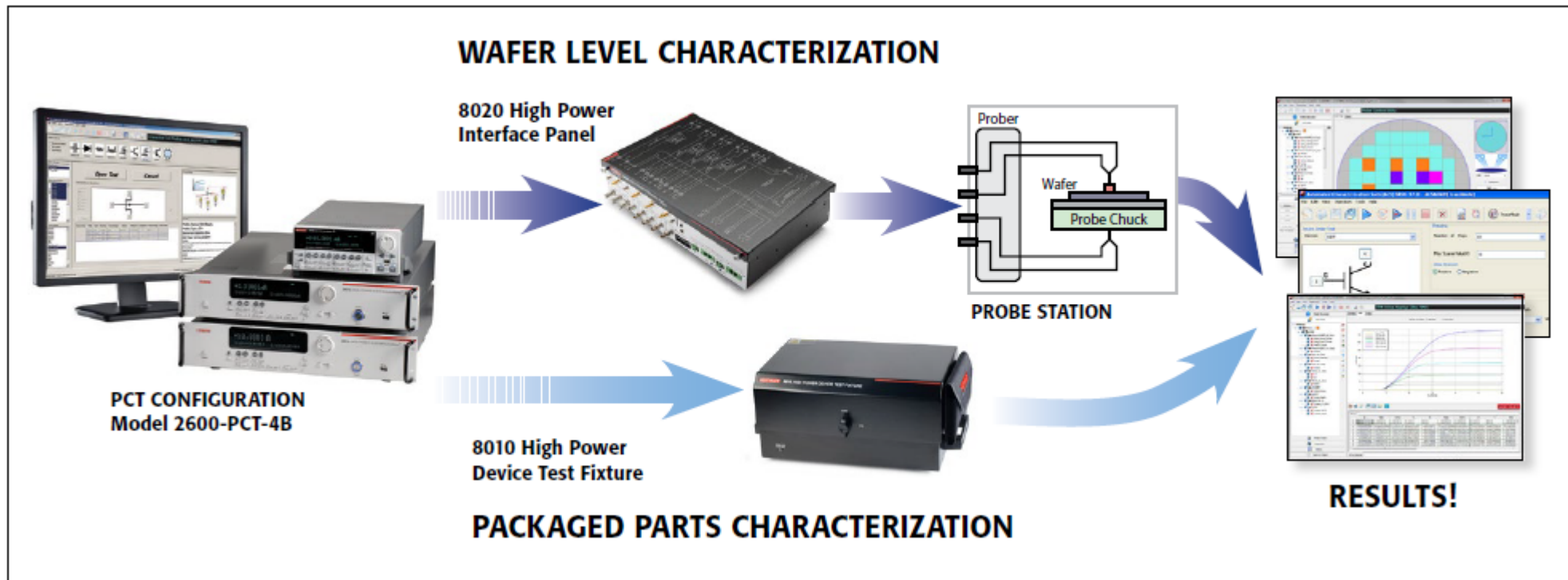
GROUP1	A(X)	B(Y1)	C(Y2)	D	E	F(Y1)	G
1	V_Gate	I_Drain	GM1	POS_GM	X_GM	FIT_GM	VT_GM
2	0	1.69515605979e-12	#REF	3.3e+1	1.55	-1.20938559121e-3	1.30670334398
3	5e-2	6.72340384322e-13	-2.04563135094e-11			-1.16310938029e-3	
4	1e-1	8.23736207283e-13	3.02791645923e-12			-1.11683316936e-3	
5	1.5e-1	8.72611987009e-13	9.77515594511e-13			-1.07056958444e-3	
6	2e-1	1.82151797854e-12	1.89781198569e-11			+1.02428074752e-3	
7	2.5e-1	3.97682190997e-12	4.31060786024e-11			-9.78004536591e-4	
8	3e-1	8.75234607012e-12	9.55104832029e-11			-9.31728325668e-4	
9	3.5e-1	1.78873530571e-11	1.82700139739e-10			-8.85452114744e-4	

Automated Characterization Suite

Keithley Instruments, Inc.

# Tektronix Suggestion

## 1. 2600-PCT Setup



# Tektronix Suggestion

## 2. 4200A for measuring capacitance and pulse IV



# Tektronix Suggestion

## 2. 4200A Spec

Modules	Description	Key Measurements	Range
4200-SMU 4201-SMU	Medium power Source Measure Unit	<ul style="list-style-type: none"> <li>DC I-V</li> <li>VLF C-V (Very low frequency C-V)</li> <li>QSCV</li> </ul>	$\pm 100$ mA, $\pm 210$ V
4210-SMU 4211-SMU	High power Source Measure Unit		$\pm 1$ A, $\pm 210$ V
4200-PA	Remote Preamplifier Module		Extends current ranges for all SMU's
4215-CVU	Capacitance-Voltage Unit	<ul style="list-style-type: none"> <li>AC Impedance</li> <li>C-V, C-f, C-t</li> </ul>	1 kHz – 10 MHz $\pm 30$ V built-in DC bias (60 V differential) $\pm 210$ V DC bias with SMU's
4200A-CVIV	I-V/C-V Multi-Switch Module	DC I-V and C-V with automatic switching	-
4225-PMU	Ultra-Fast Pulse Measure Unit	<ul style="list-style-type: none"> <li>Pulsed I-V</li> <li>SegmentARB® multi-level pulsing</li> <li>Transient Waveform Capture</li> </ul>	$\pm 40$ V (80 V p-p), $\pm 800$ mA 200 M Sa/s simultaneous I and V measure 2048 unique segments 20 ns PW source only 60 ns PW source/measure
4225-RPM	Remote Preamplifier/Switch Module	DC I-V, C-V, Pulsed I-V with automatic switching	Extends current range of 4225-PMU unit
4220-PGU	High Voltage Pulse Generator Unit	<ul style="list-style-type: none"> <li>Pulsed voltage source</li> <li>SegmentARB® multi-level pulsing</li> </ul>	$\pm 40$ V (80 V p-p) 2048 unique segments

# Tektronix Suggestion

## 2. 4200A features

- Integrated parameter analyzer that reduces characterization complexity, troubleshooting and test set up time.
- Fully characterize a device, material or process
  - DC I-V Source Measure Units (SMU)
  - AC Impedance Capacitance-Voltage Unit (CVU)
  - Pulsed I-V Pulse Measure Unit (PMU)
- Industry's easiest methods to switch between I-V, C-V and Pulsed I-V measurements
- Jumpstart testing with over 250 user-modifiable, searchable application tests
  - No complex programming required
- Industry's first instrument with built-in measurement videos
  - "YouTube-like" experience
  - Get answers faster and investigate unexpected results more quickly

# Tektronix Suggestion

## 2. 4200A Software

The screenshot shows the Tektronix 4200A software interface for configuring a MOSFET test. The main window is titled "default - Clarius - [vds-id#1]". The interface is divided into several sections:

- Project:** default
- 4terminal-n-fet:** A list of test components including vds-id, vtlin, subvt, vgs-id, ig-vg, cv-nmosfet, pulse-vds-id, waveform-meas, 3terminal-npn-bjt, vce-ic, gummel, vcsat, 2-wire-resistor, res2t, pulse-resistor, and vfd.
- Gate (SMU3):** Operation Mode: Voltage Step. Start: 2 V, Stop: 5 V, Step: 1 V, Compliance: 0.1 A.  Report Current,  Report Voltage.
- Drain (SMU2):** Operation Mode: Voltage Linear Sweep. Start: 0 V, Stop: 5 V, Step: 0.1 V, Compliance: 0.1 A.  Measure Current,  Report Voltage.
- Bulk (GNDU):** Operation Mode: Ground Unit.
- Source (SMU1):** Operation Mode: Voltage Bias. Bias: 0 V, Compliance: 0.1 A.  Report Current,  Report Voltage.
- Measure Settings:** Speed: Normal,  Report Timestamps.
- Test Mode:** Mode: Sweeping, Sweep Delay: 0 s, Hold Time: 0 s.
- Formulator, Output Values, Exit Conditions:** Buttons for test execution control.
- Messages:** Model/PreAmp configuration in saved test differs from system configuration. Performing auto adjustment.

The screenshot shows the Tektronix 4200A software interface displaying test results for a MOSFET test. The main window is titled "MOSFET\_TEST - Clarius - [vds-id#1]". The interface is divided into several sections:

- Project:** MOSFET\_TEST
- Run5 Formulas List:** A table showing test results for various parameters over time.
- Graph:** A plot showing Drain current (A) versus Drain voltage (V) for Run5. The x-axis ranges from 0 to 4.000E+00 V, and the y-axis ranges from -1.000E-03 to 30.0E-03 A. The plot shows a linear relationship between Drain current and Drain voltage.
- Run History:** A list of test runs with their execution times and status.
- Messages:** Total Execution Time: 00:00:03:19.

Run	Drain(V1)	Drain(V2)	Gate(V1)	Gate(V2)	Drain(I1)	Drain(I2)	Gate(I1)	Gate(I2)	Drain(V3)	Drain(I3)
1	-1.977E-6	0.0000E+0	6.0597E-15	2.000E+0	8.31566E-9	0.0000E-3	-1.5231E-15	3.000E+0	1.2983E-6	0.0000E-3
2	6.18196E-6	1.0000E-3	5.22364E-15	2.000E+0	1.0144E-3	1.0000E-3	5.21526E-19	3.000E+0	1.3229E-3	1.0000E-3
3	1.1731E-3	2.0000E-3	5.14898E-15	2.000E+0	2.0215E-3	2.0000E-3	3.17654E-15	3.000E+0	2.9279E-3	2.0000E-3
4	1.6640E-3	3.0000E-3	5.18101E-15	2.000E+0	2.9770E-3	3.0000E-3	5.9907E-15	3.000E+0	3.8997E-3	3.0000E-3
5	2.6802E-3	4.0000E-3	5.32834E-15	2.000E+0	3.9748E-3	4.0000E-3	6.5155E-15	3.000E+0	5.1067E-3	4.0000E-3
6	2.4341E-3	5.0000E-3	6.23356E-15	2.000E+0	4.7154E-3	5.0000E-3	6.5229E-15	3.000E+0	6.2625E-3	5.0000E-3
7	2.7022E-3	6.0000E-3	4.70778E-15	2.000E+0	5.4915E-3	6.0000E-3	5.4773E-15	3.000E+0	7.4055E-3	6.0000E-3
8	2.9556E-3	7.0000E-3	4.68071E-15	2.000E+0	6.2277E-3	7.0000E-3	5.8241E-15	3.000E+0	8.4887E-3	7.0000E-3
9	3.1028E-3	8.0000E-3	4.47411E-15	2.000E+0	6.9633E-3	8.0000E-3	5.3681E-15	3.000E+0	9.5196E-3	8.0000E-3
10	3.2414E-3	9.0000E-3	3.91859E-15	2.000E+0	7.5233E-3	9.0000E-3	5.1898E-15	3.000E+0	1.0504E-2	9.0000E-3
11	3.3402E-3	1.0000E+0	4.07265E-15	2.000E+0	8.0076E-3	1.0000E+0	4.9708E-15	3.000E+0	1.1439E-2	1.0000E+0
12	3.4285E-3	1.1000E+0	3.82984E-15	2.000E+0	8.5848E-3	1.1000E+0	4.61334E-15	3.000E+0	1.2319E-2	1.1000E+0
13	3.4882E-3	1.2000E+0	3.79774E-15	2.000E+0	9.0501E-3	1.2000E+0	4.5321E-15	3.000E+0	1.3161E-2	1.2000E+0
14	3.5307E-3	1.3000E+0	3.73871E-15	2.000E+0	9.4529E-3	1.3000E+0	4.3126E-15	3.000E+0	1.3930E-2	1.3000E+0
15	3.5620E-3	1.4000E+0	3.45314E-15	2.000E+0	9.8066E-3	1.4000E+0	4.0509E-15	3.000E+0	1.4659E-2	1.4000E+0
16	3.5836E-3	1.5000E+0	3.27064E-15	2.000E+0	1.0112E-2	1.5000E+0	4.1361E-15	3.000E+0	1.5337E-2	1.5000E+0
17	3.6021E-3	1.6000E+0	2.93867E-15	2.000E+0	1.0374E-2	1.6000E+0	3.9376E-15	3.000E+0	1.5969E-2	1.6000E+0
18	3.6169E-3	1.7000E+0	3.0332E-15	2.000E+0	1.0596E-2	1.7000E+0	3.8606E-15	3.000E+0	1.6538E-2	1.7000E+0
19	3.6287E-3	1.8000E+0	2.73304E-15	2.000E+0	1.0782E-2	1.8000E+0	3.3522E-15	3.000E+0	1.7065E-2	1.8000E+0

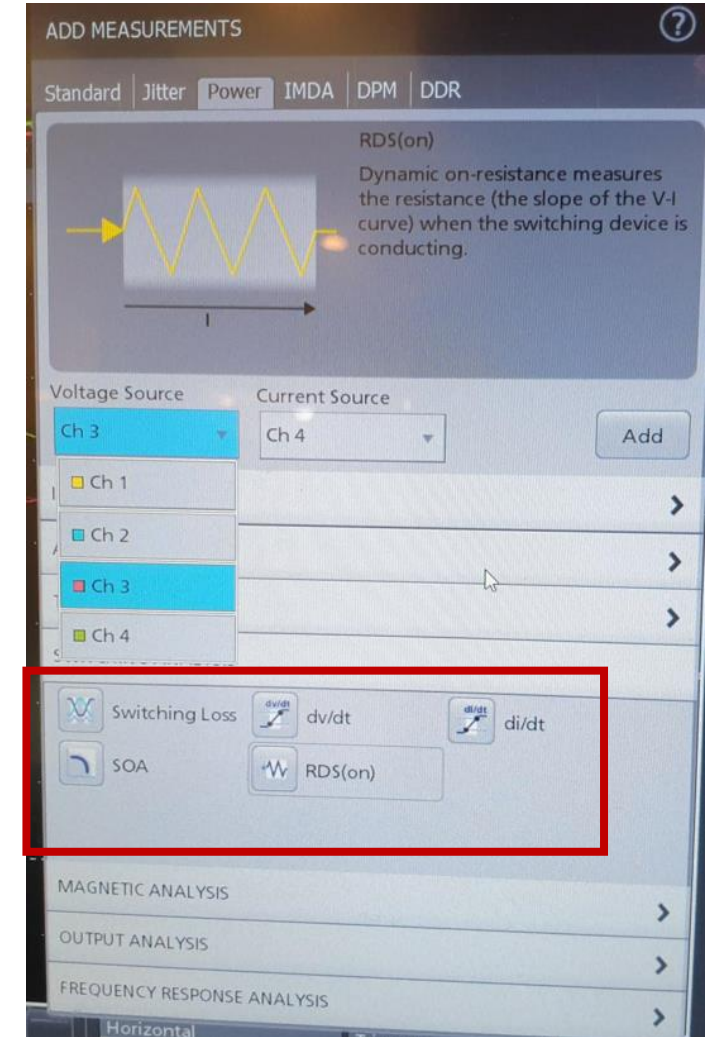
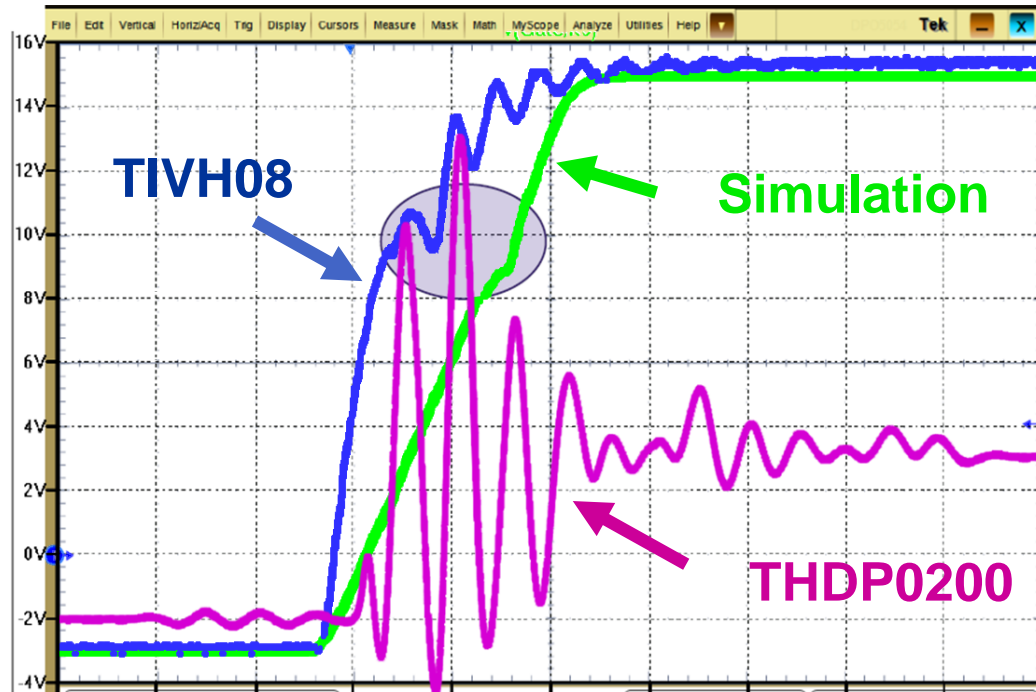
# Tektronix Suggestion

## 3. Keithley Parametric test system for measuring various parameters



# Tektronix Suggestion

## 4. Scope + IsoVu for measuring various parameters



# Summary

- Wide Bandgap Semiconductors will play a big role of power devices.
- They are smaller, faster and more efficient than Silicon Counterpart.
- For meeting this, the characterizations involve measurements for materials is needed such as conduction loss, switching loss and many other parameters.
- Tektronix/Keithley can suggest 2600-PCT, 4200A and Oscilloscope with IsoVu for test.

**Thank you !**