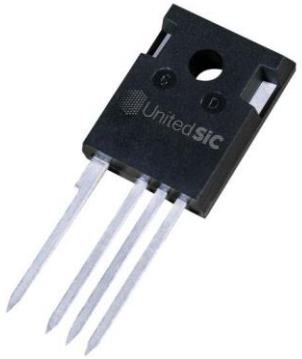
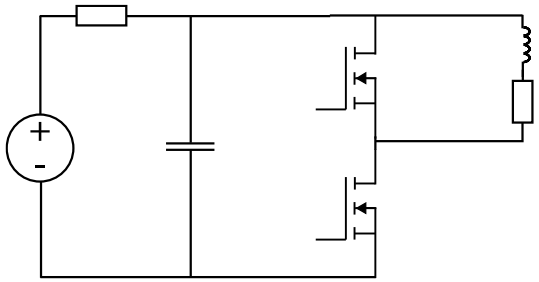
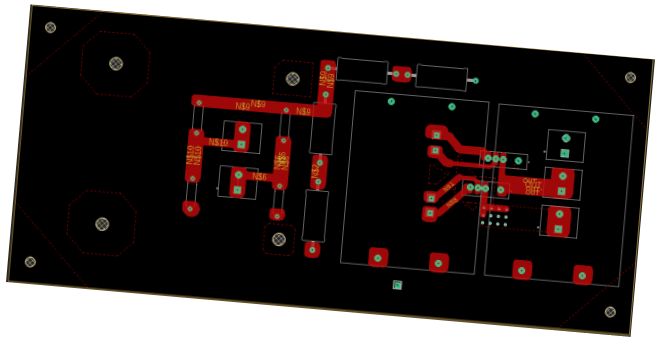
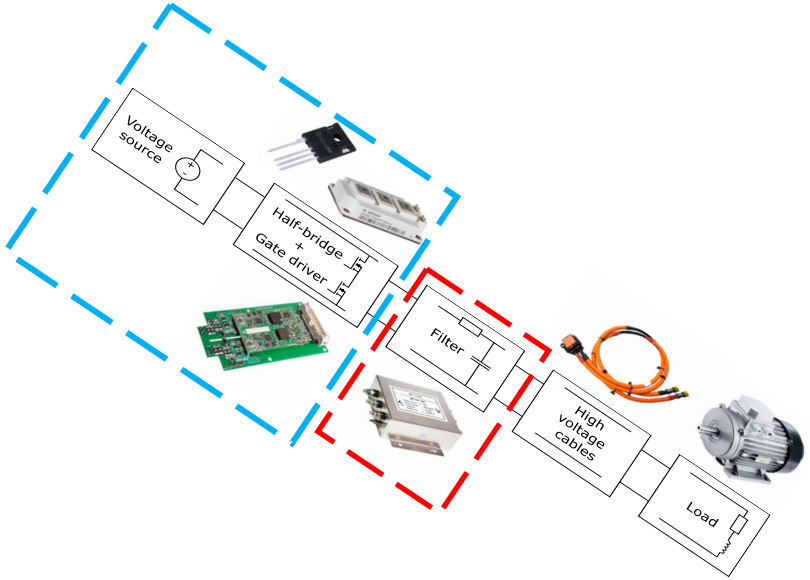






Double pulse testing

Philip Abrahamsson

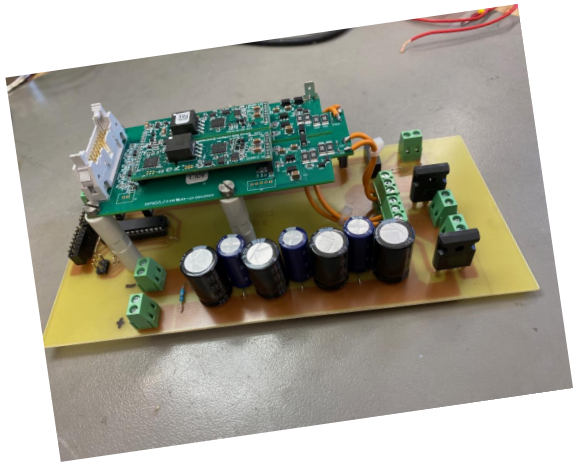


IMZ120R140M1H
CoolSiC™ 1200V SiC Trench MOSFET
Electrical Characteristics

3.3 Switching characteristics

Table 6 Switching characteristics, Inductive load [4]

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
MOSFET Characteristics, T_{vj} = 25°C						
Turn-on delay time	$t_{d(on)}$	V_{DD} = 800V, I_D = 6A, V_{GS} = 0/18V, $R_{G,ext}$ = 2Ω, L_σ = 40nH, diode: body diode at V_{GS} = 0V see Fig. E	-	5	-	ns
Rise time	t_r		-	2	-	
Turn-off delay time	$t_{d(off)}$		-	10.3	-	
Fall time	t_f		-	11.6	-	
Turn-on energy	E_{on}		-	62	-	µJ
Turn-off energy	E_{off}		-	12	-	
Total switching energy	E_{tot}		-	74	-	
Body Diode Characteristics, T_{vj} = 25°C						
Diode reverse recovery charge	Q_r	V_{DD} = 800V, I_{SD} = 6A, V_{GS} at diode = 0V, di/dt = 1000A/µs, Q_r includes also Q_c, see Fig. C	-	100	-	nC
Diode peak reverse recovery current	I_{rrm}		-	2	-	A



Other applications

Power Transistor

- It takes some time for the current and voltage to fall/rise
- Losses are generated during a switching event

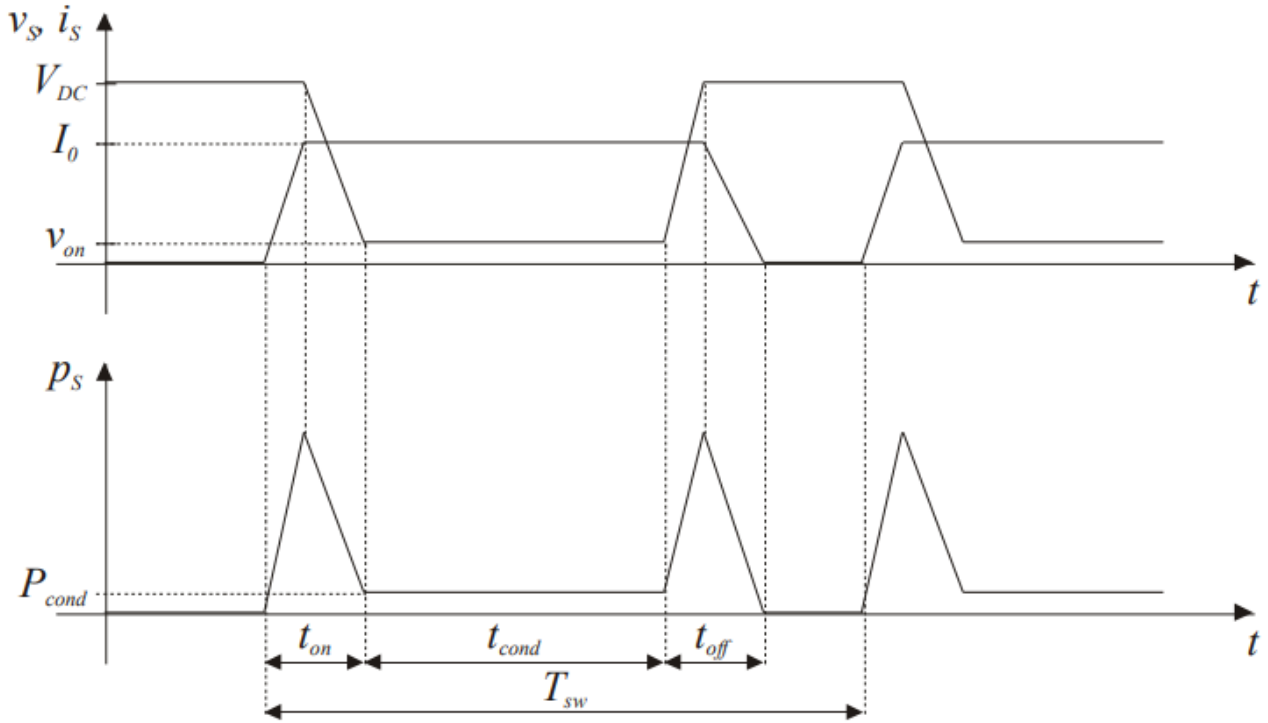


Figure 6.2: Approximate switching waveforms for the switch S.

Figure 6.2: Course compendium

Measure switching characteristics

- Measure current and voltage during turn on and off events.
- Double pulse testing

IMZ120R140M1H
CoolSiC™ 1200V SiC Trench MOSFET
Electrical Characteristics

3.3 Switching characteristics

Table 6 Switching characteristics, Inductive load [4]

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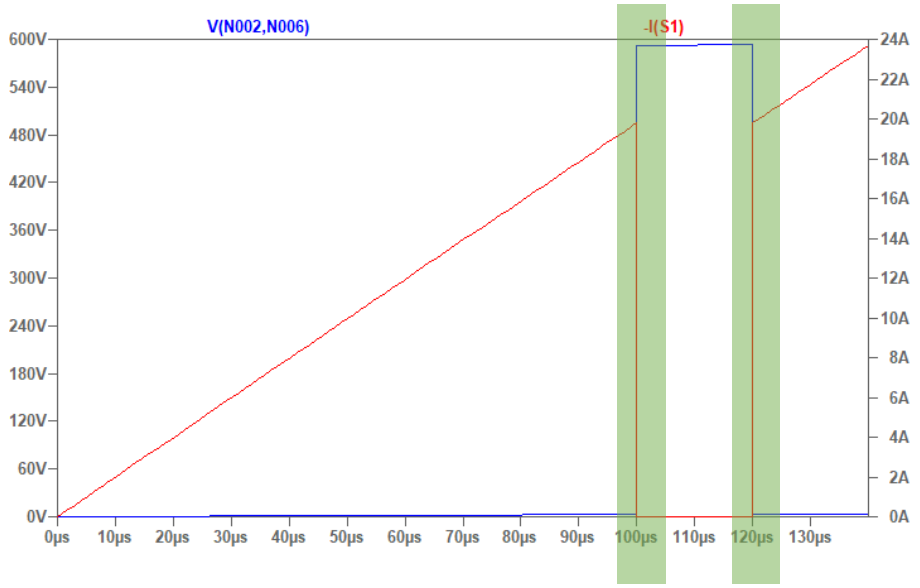
Rise time	t_r		-	2	-	
Turn-off delay time	$t_{d(off)}$		-	10.3	-	
Fall time	t_f		-	11.6	-	
Turn-on energy	E_{on}		-	62	-	µJ
Turn-off energy	E_{off}		-	12	-	
Total switching energy	E_{tot}		-	74	-	
Body Diode Characteristics, T_{vj} = 25°C						
Diode reverse recovery charge	Q_{rr}	V_{DD} = 800V, I_{SD} = 6A, V_{GS} at diode = 0V, di_f/dt = 1000A/µs, Q_{rr} includes also Q_C, see Fig. C	-	100	-	nC
Diode peak reverse recovery current	I_{rrm}		-	2	-	A



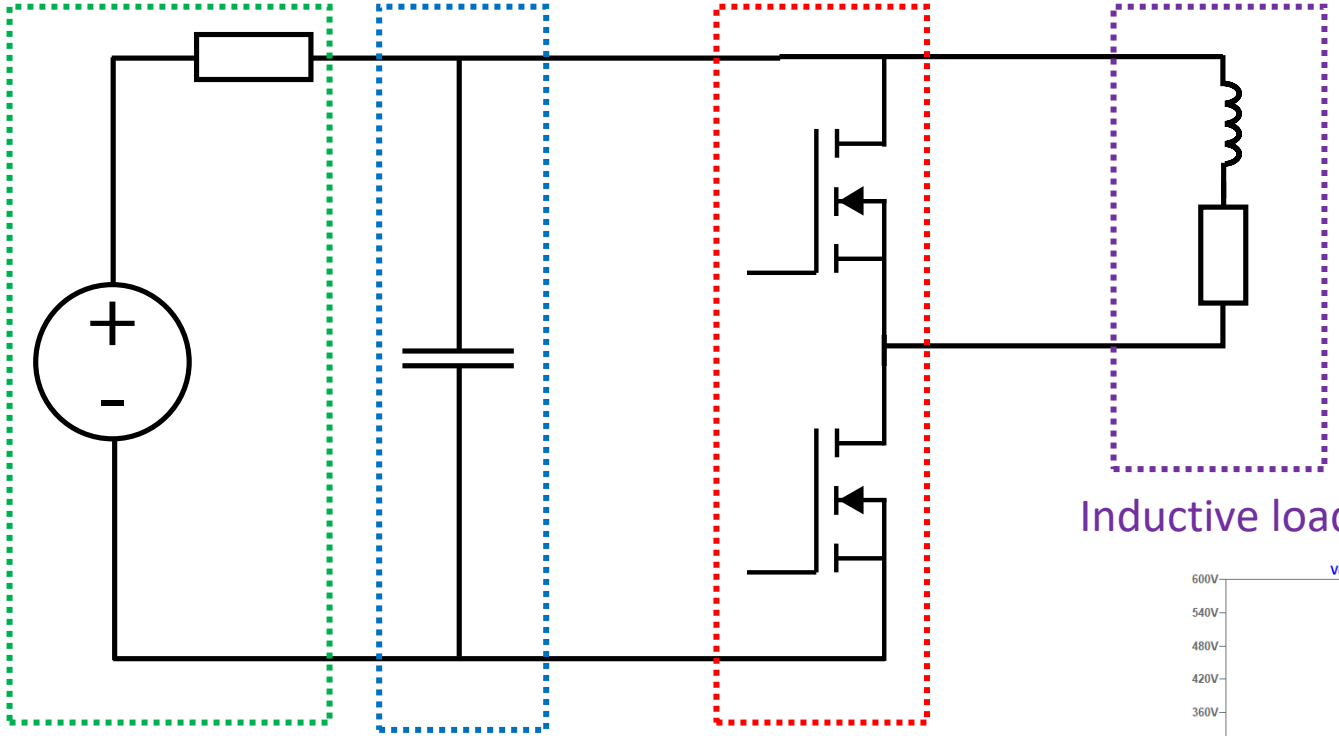
Turn off Turn on

Double pulse tester – The different parts

$E = \frac{CV^2}{2}$

$E = \frac{LI^2}{2}$

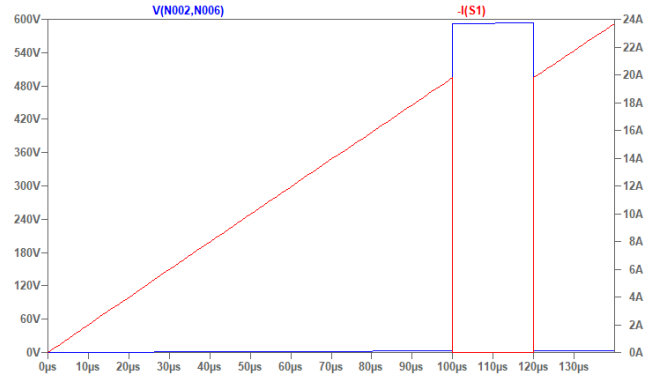
Power Supply
&
Current limiting resistor



DC-link Capacitor

Power transistors

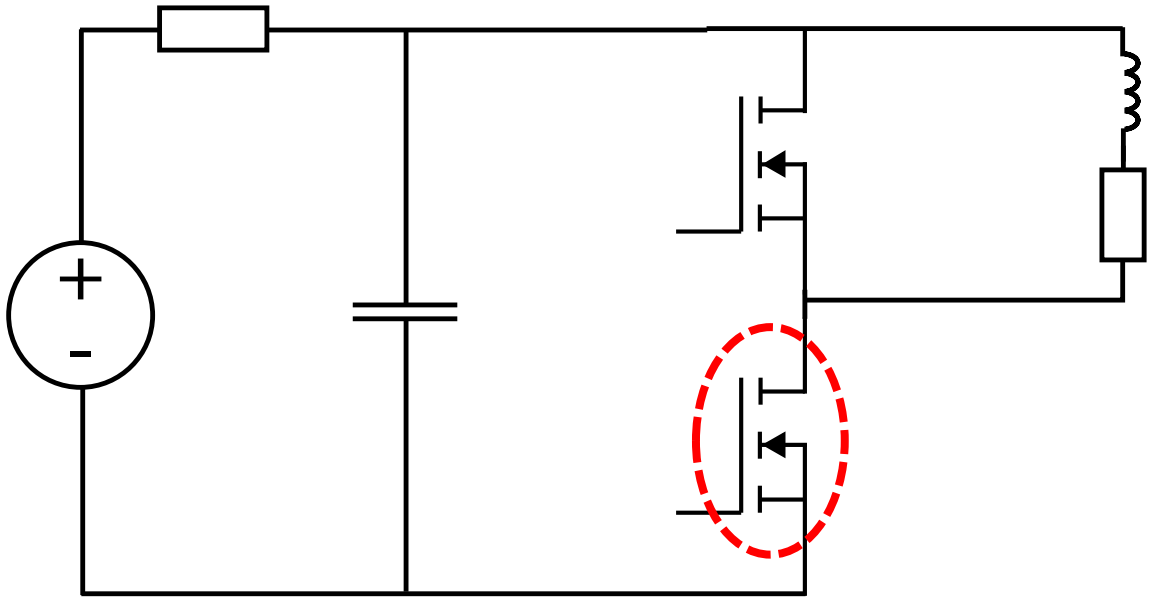
Inductive load

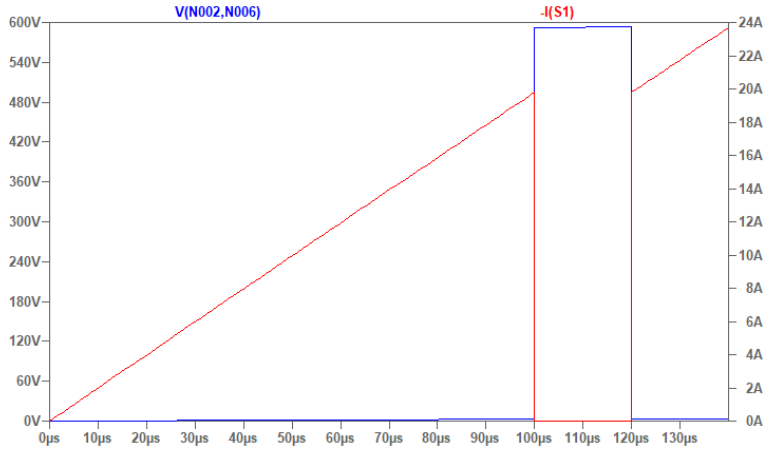


Double pulse tester – How it works

$$E = \frac{CV^2}{2}$$

$$E = \frac{LI^2}{2}$$

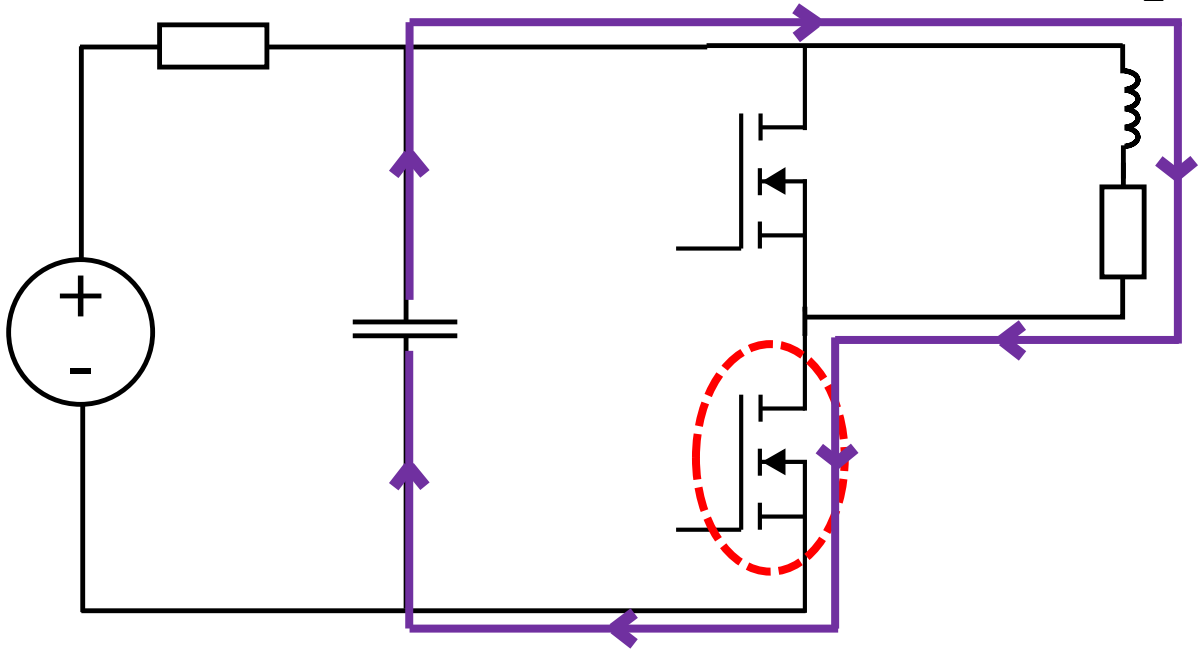


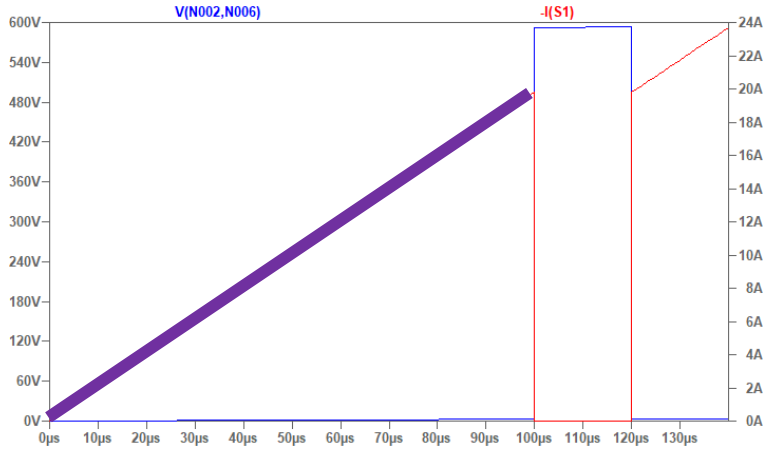


Double pulse tester – How it works

$$E = \frac{CV^2}{2}$$

$$E = \frac{LI^2}{2}$$

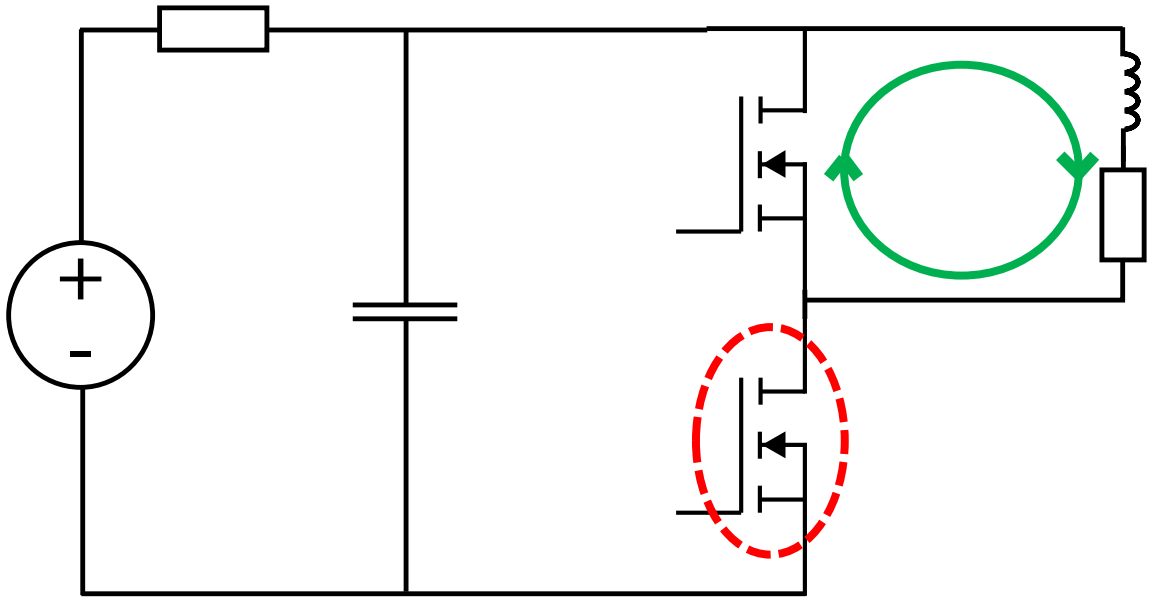


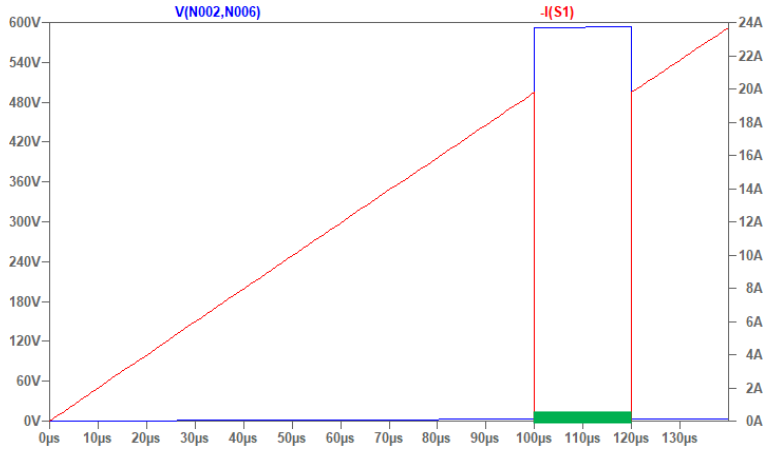


Double pulse tester – How it works

$$E = \frac{CV^2}{2}$$

$$E = \frac{LI^2}{2}$$

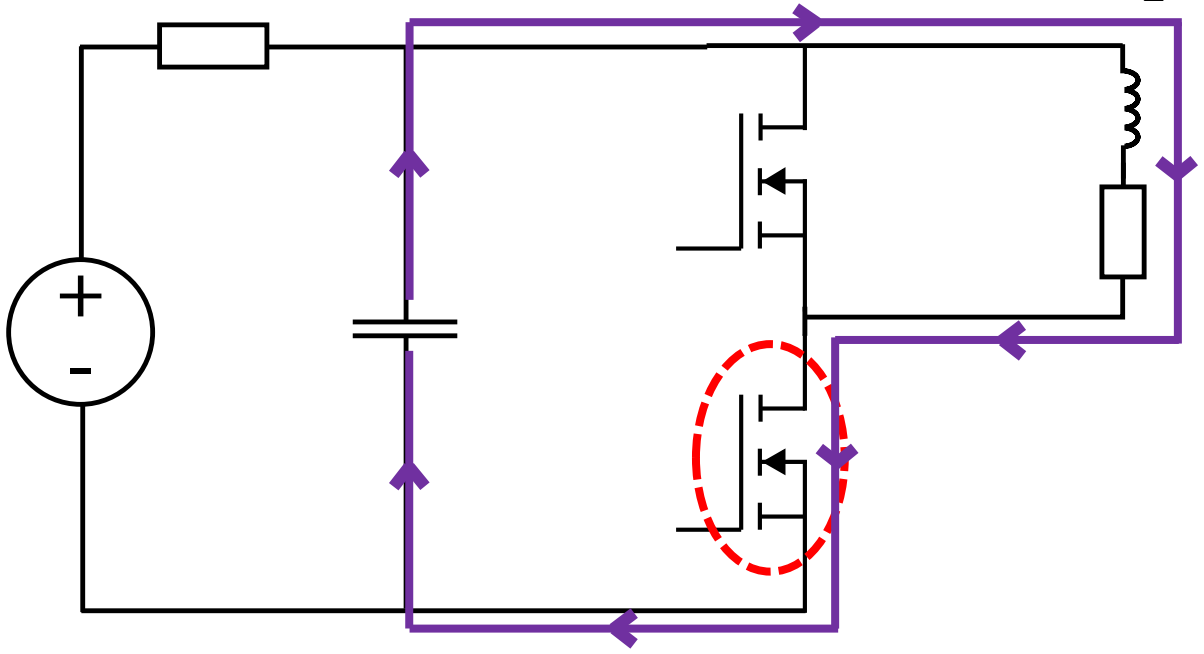


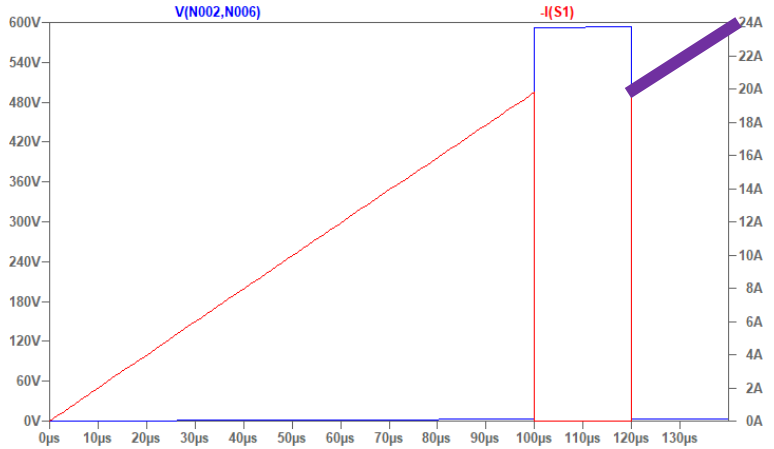


Double pulse tester – How it works

$$E = \frac{CV^2}{2}$$

$$E = \frac{LI^2}{2}$$

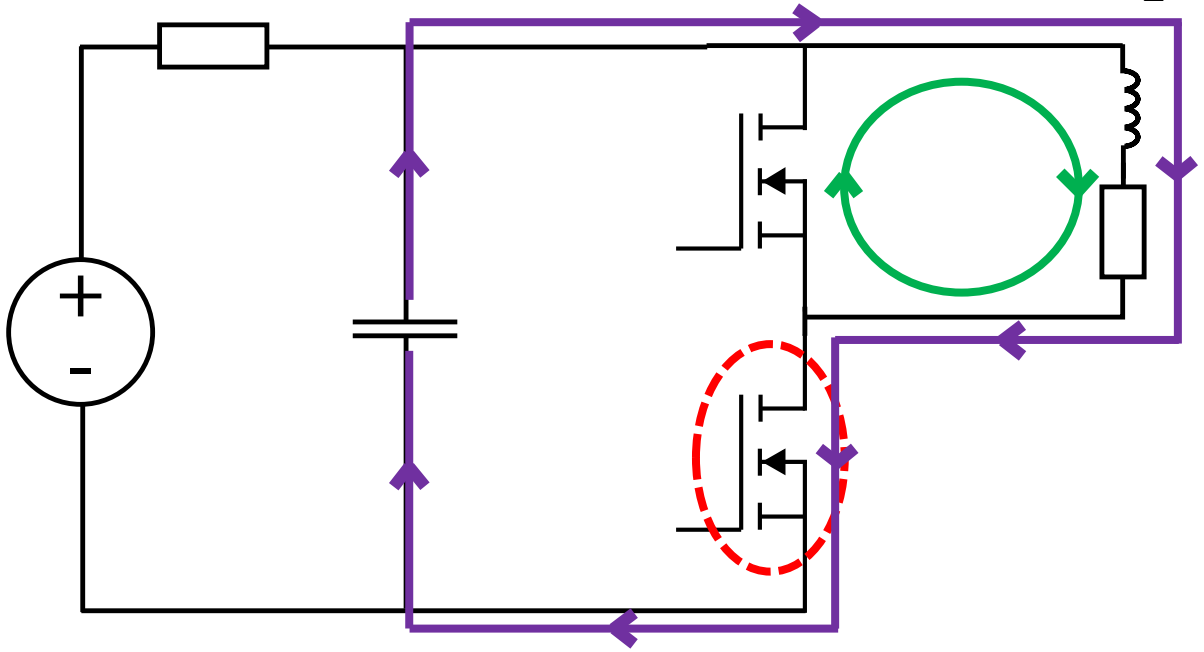


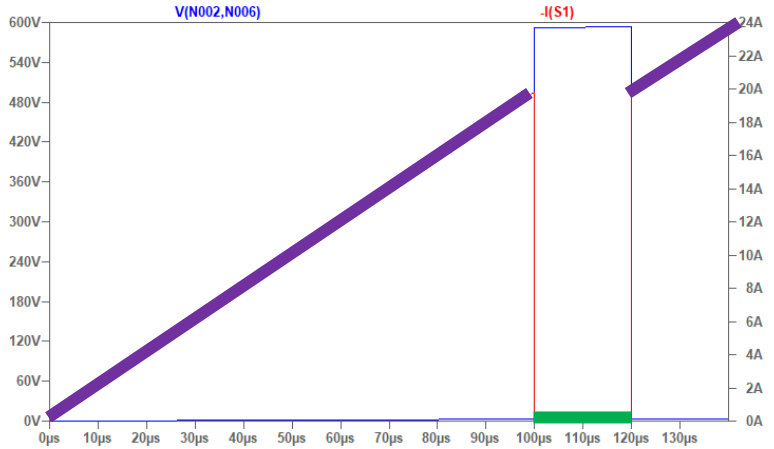


Double pulse tester – How it works

$$E = \frac{CV^2}{2}$$

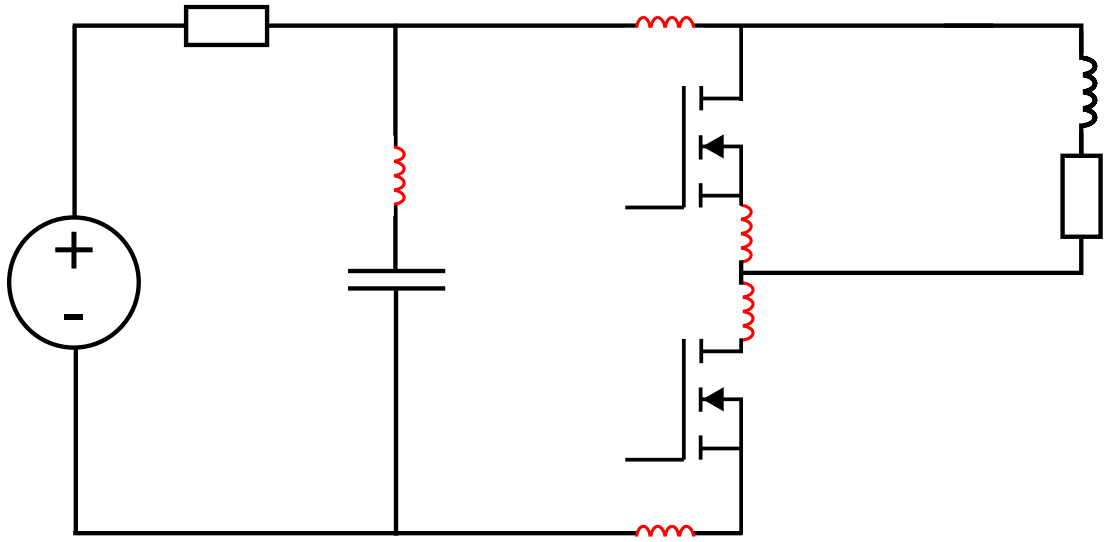
$$E = \frac{LI^2}{2}$$

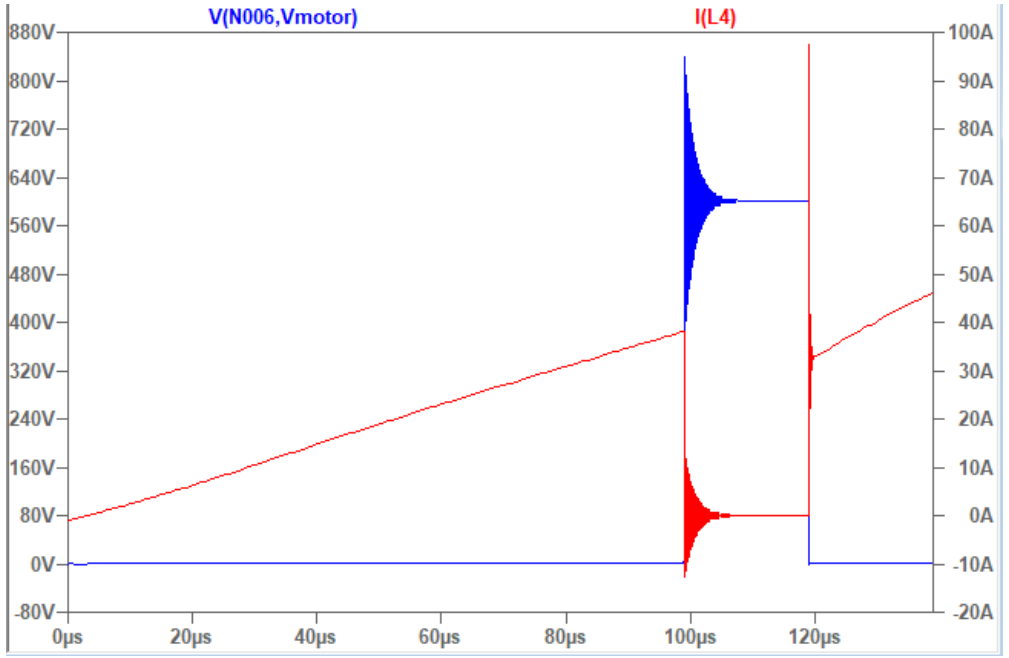




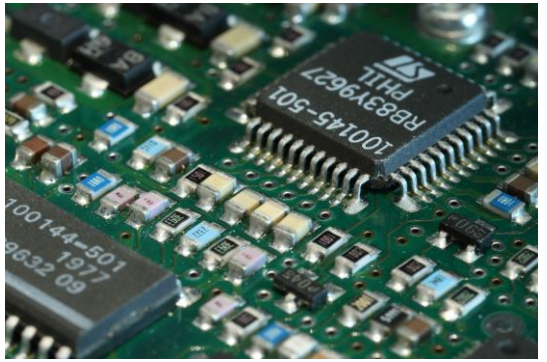
Double pulse tester – Parasitics

- Paracitics are present in any real circuit
- Non ideal switching events





PCB design



- A good PCB design can reduce stray inductance

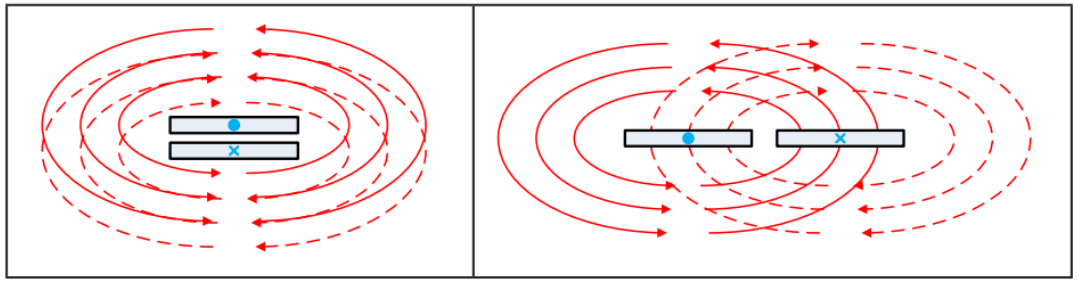


Figure 6: Parallel plate overlap

Figure 7: Coplanar plate overlap

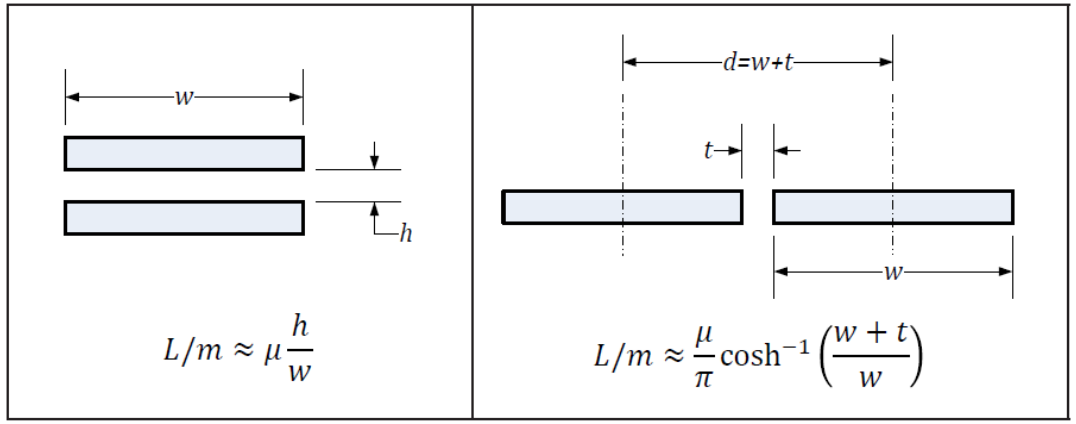
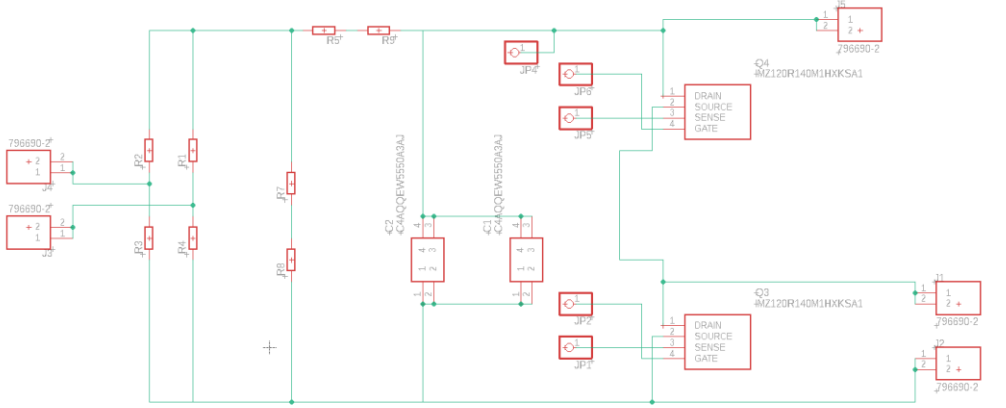


Figure 8: Parallel plate inductance approximation

Figure 9: Coplanar plate inductance approximation



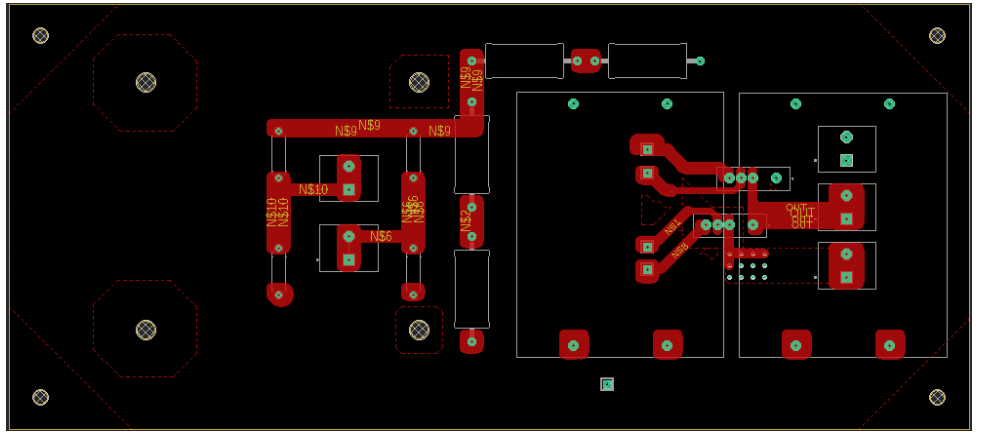
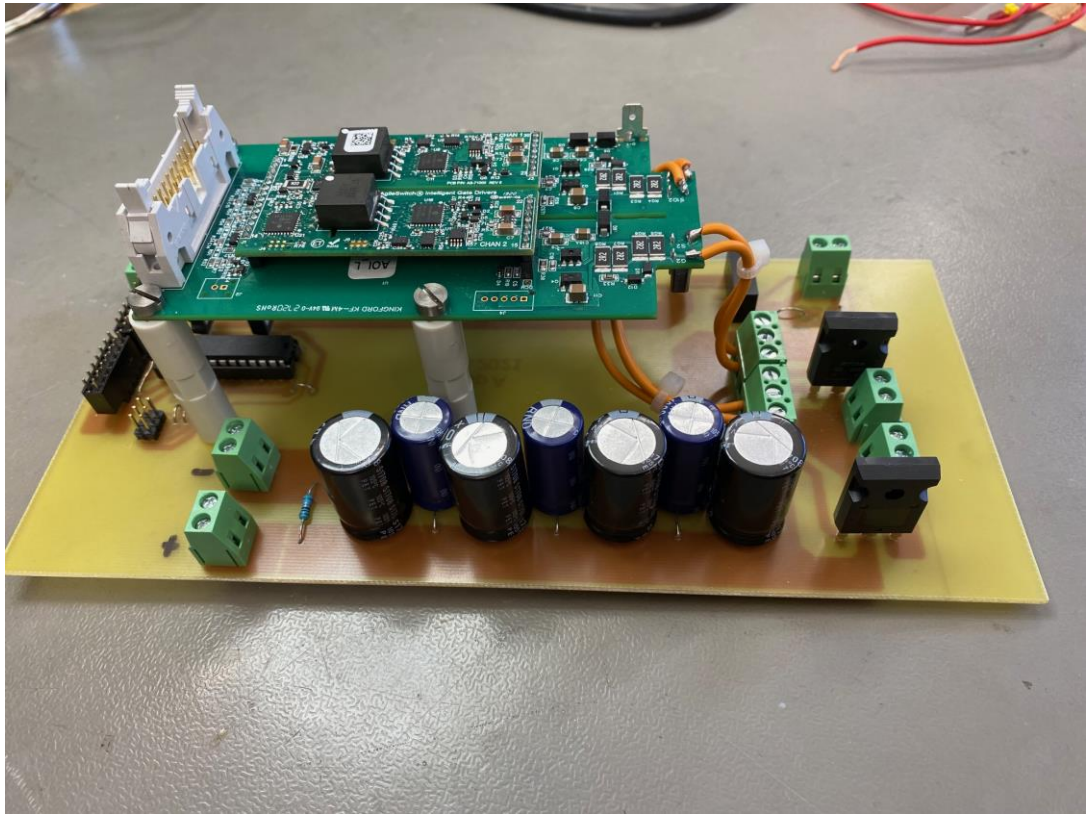


Figure 6-9: CREE, Design Considerations for Designing with Cree SiC Modules Part 2. Techniques for Minimizing Parasitic Inductance

Results - PCB

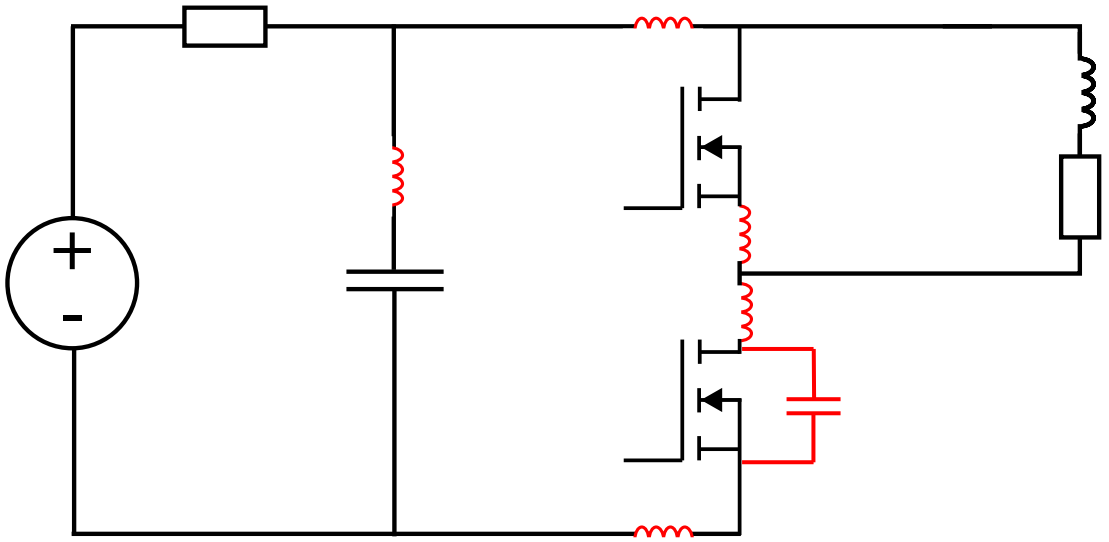


Results

- Video from the lab

Results

- Ringing is also caused by capacitance in the circuit



Results - Measurements

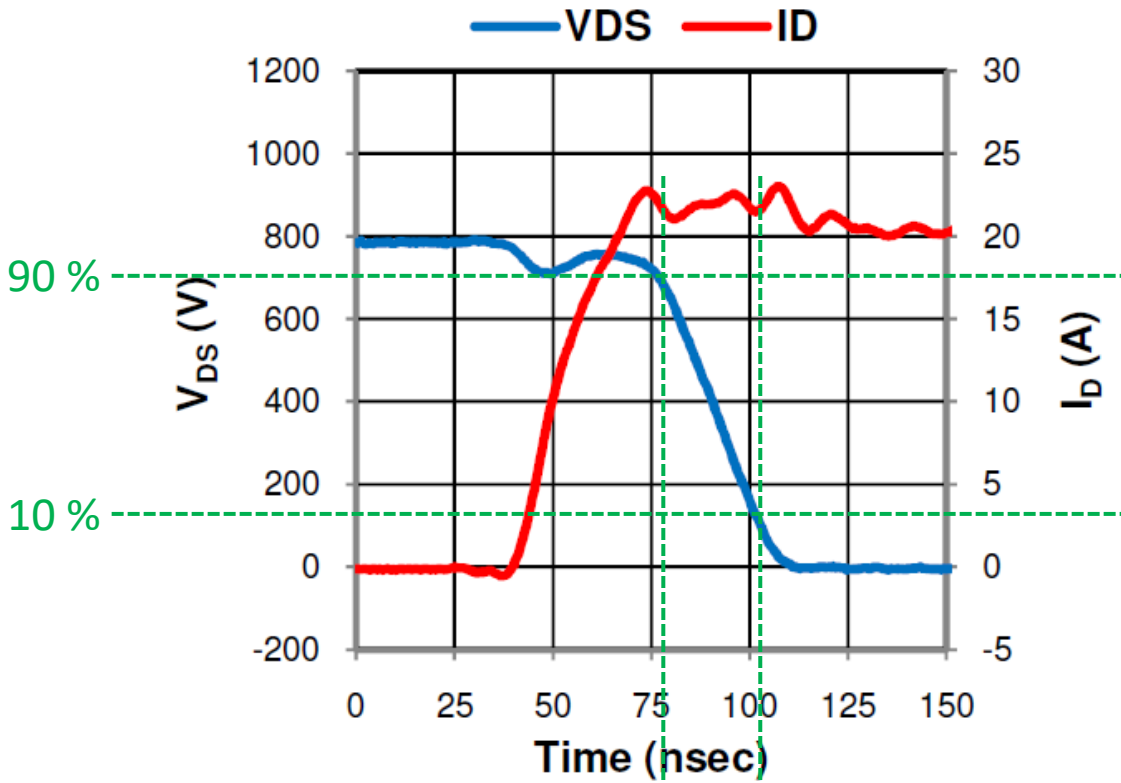


Figure 9: Turn-On Waveforms

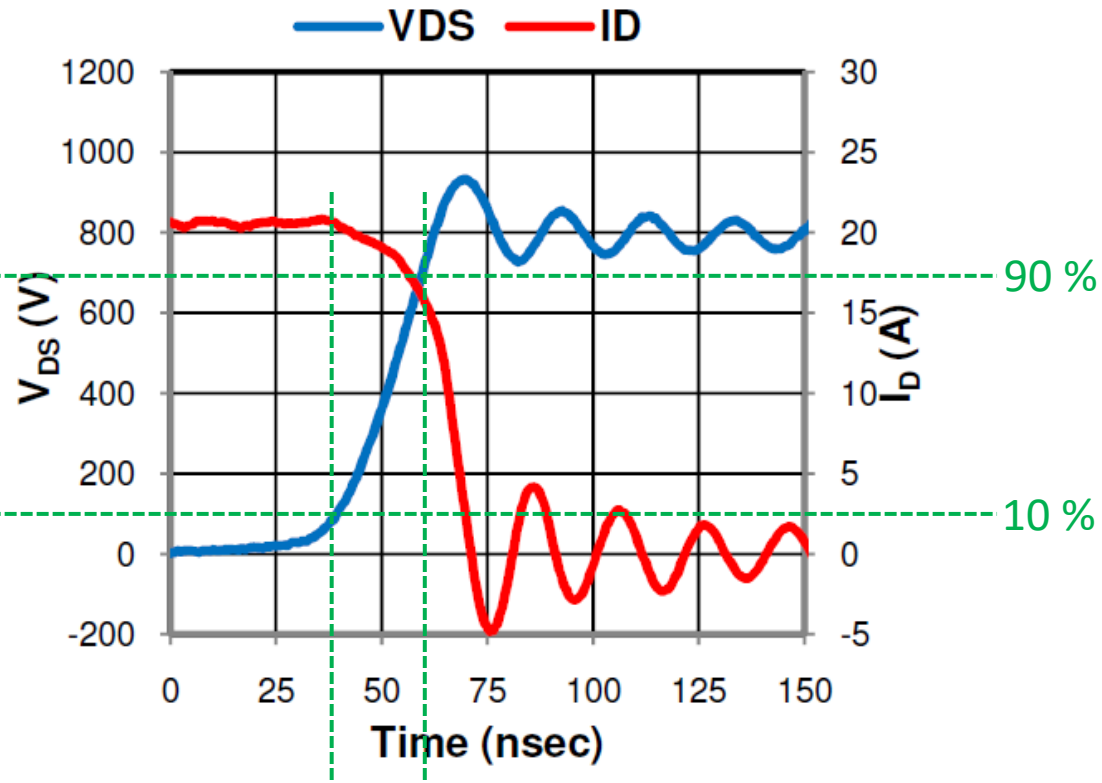


Figure 10: Turn-Off Waveforms

90 %

10 %

90 %

10 %

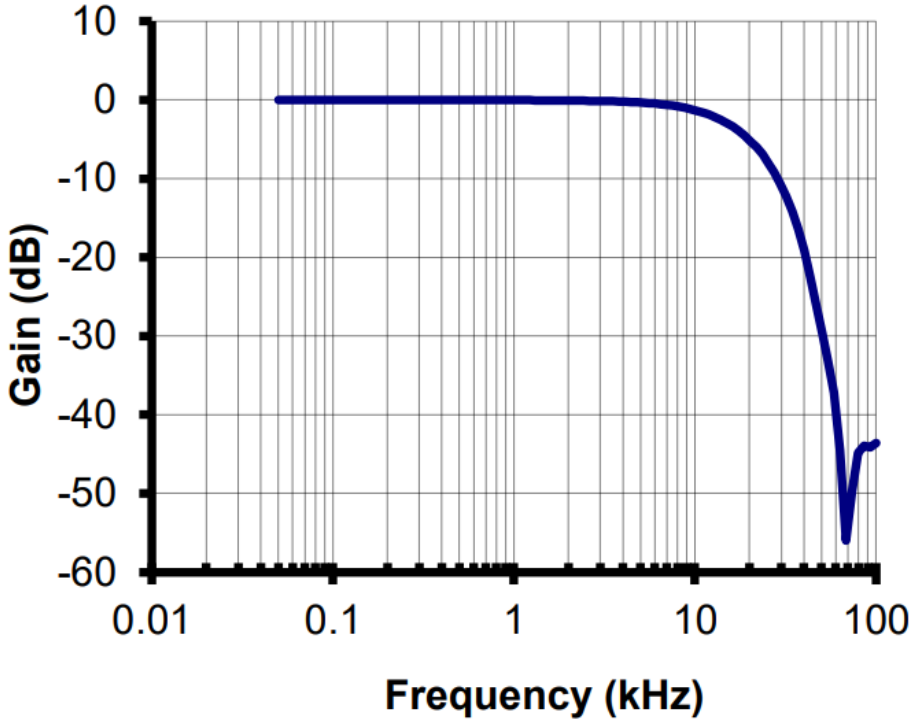
Rise time

Fall time

Figure 9-10: CREE, SiC MOSFET Double Pulse Fixture

Measurement equipment - Properties

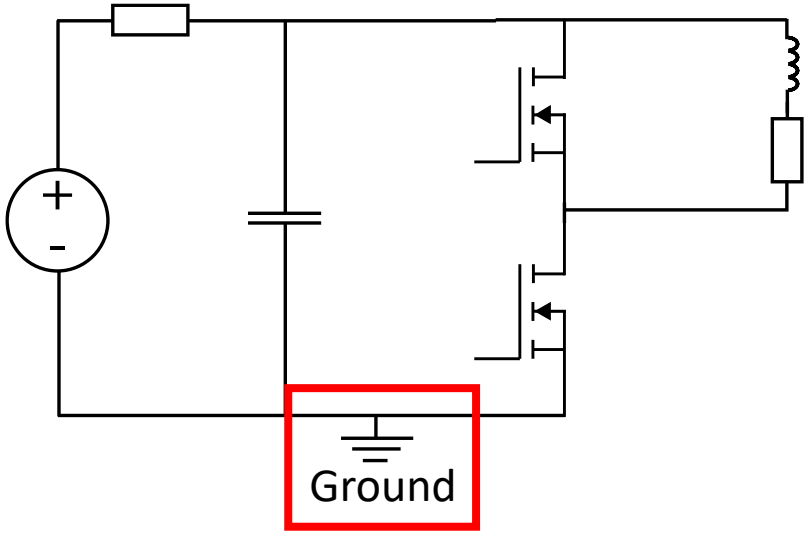
- Bandwidth
- Delay
- Accuracy



Measurement equipment – Examples of probes

Single ended

Differential

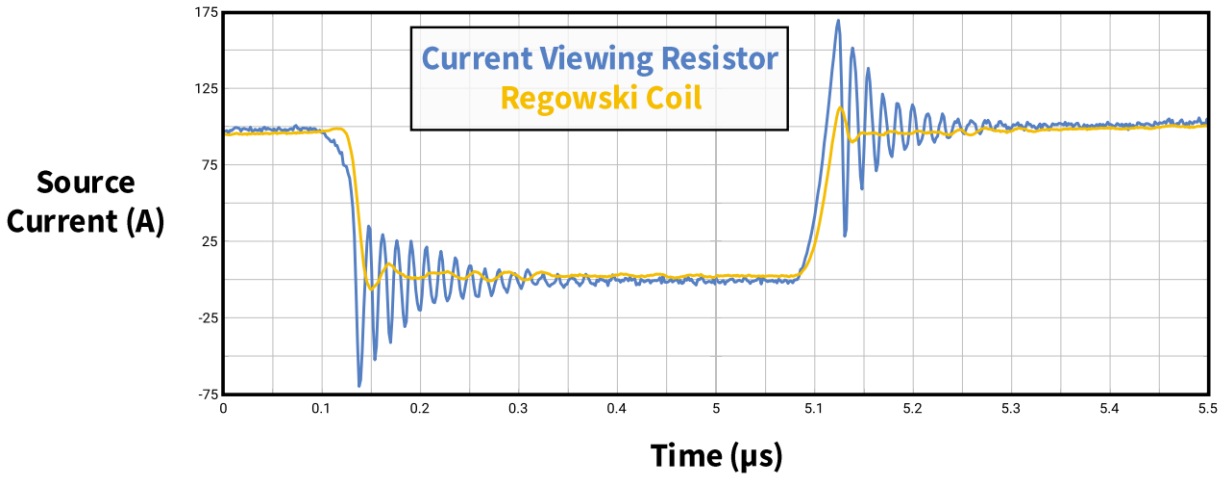


Figures: CREE, CPWR-AN45 Wolfspeed WolfPACK™ Dynamic Performance Application Note

Measurement equipment – Examples of probes

Resistor

Rogowski coil

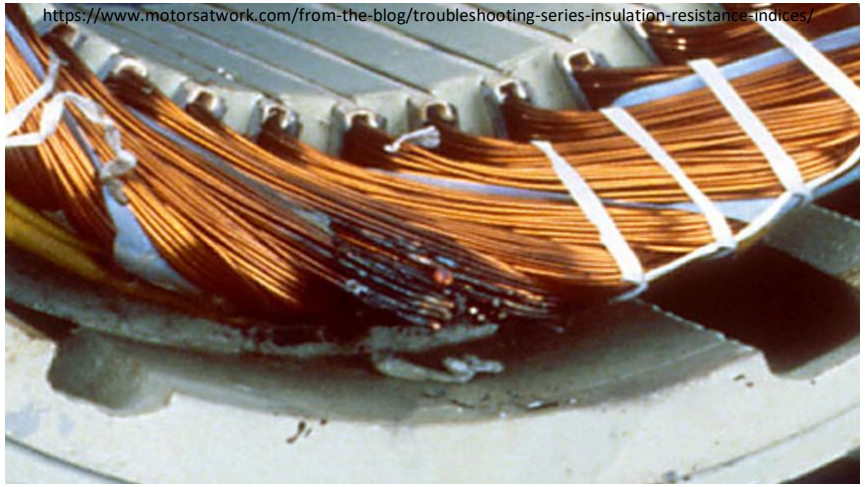


Figures: CREE, CPWR-AN45 Wolfspeed WolfPACK™ Dynamic Performance Application Note

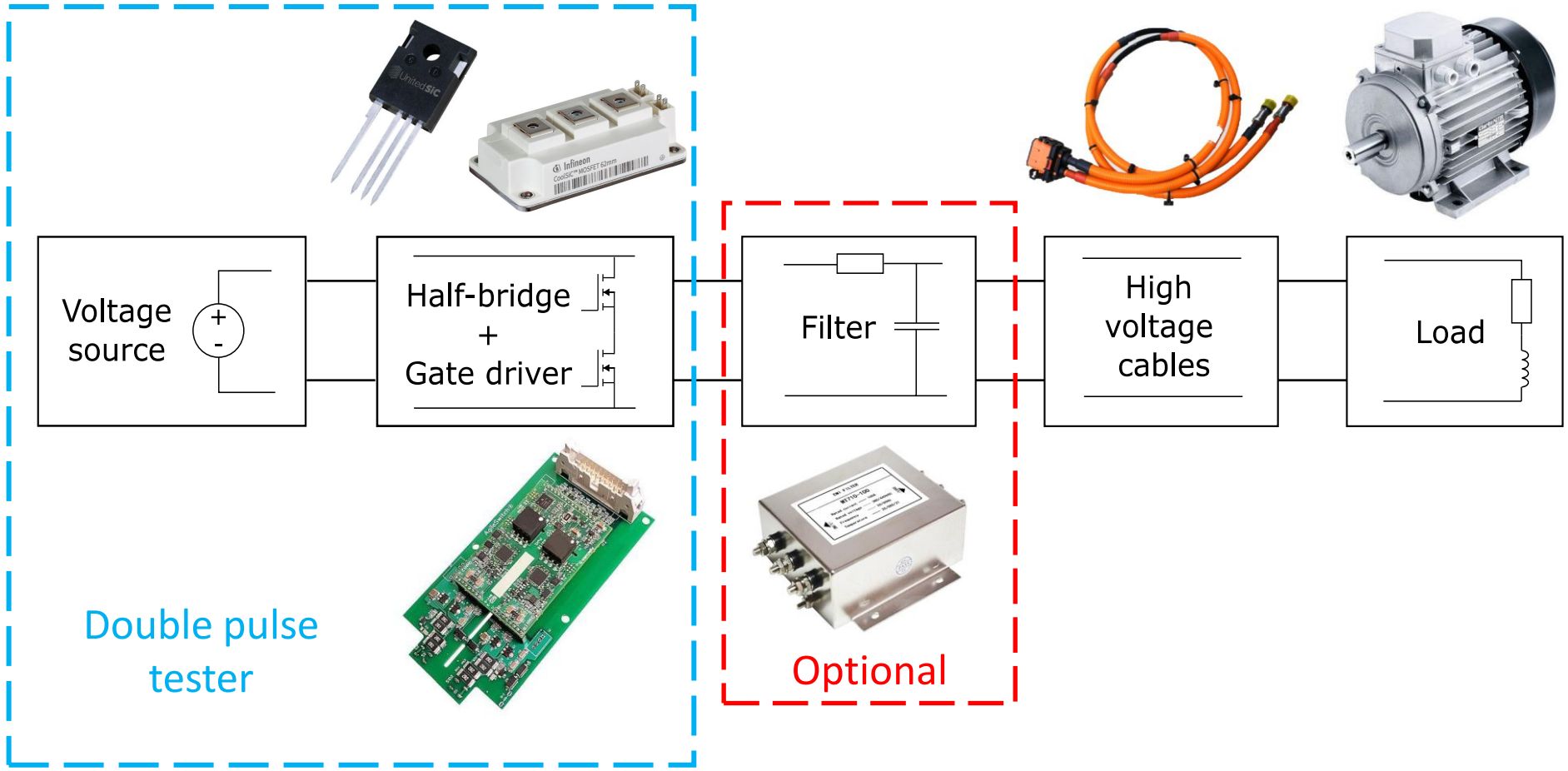
What else can the double pulse tester be used for?

Investigate how switching events effect electric insulation

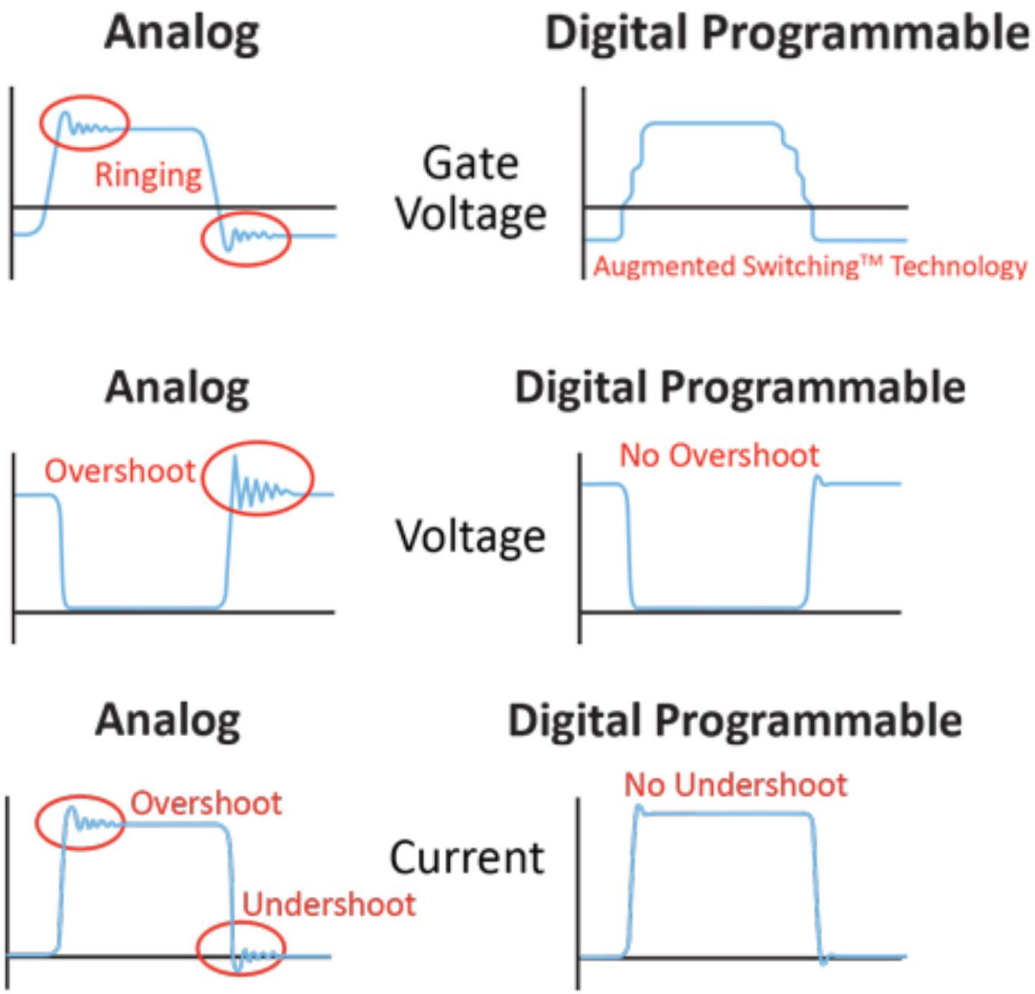
- Switching events cause high dV/dt
- High dV/dt can break down insulation in electric machines



Test of electric insulation

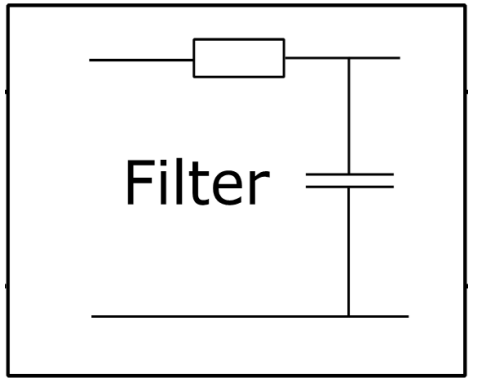


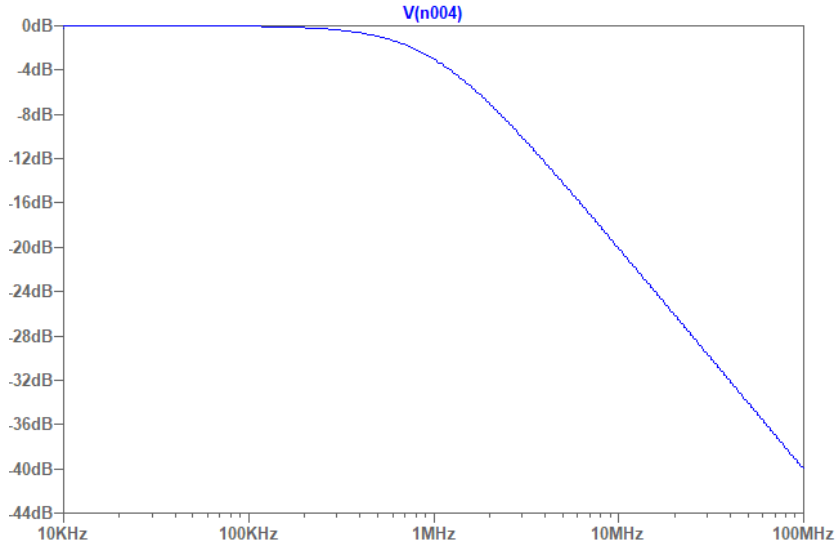
Programmable gate driver

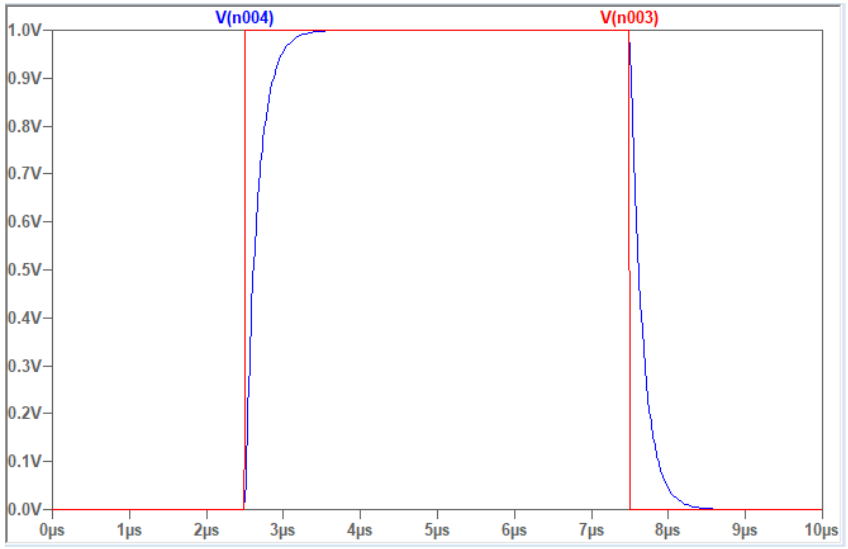


Figures: https://www.microchip.com/en-us/products/power-management/silicon-carbide-sic-devices-and-power-modules/digital-programmable-gate-drivers

Filter - Reduce dV/dt







Summary

- A double pulse tester can be used to characterize power transistors
- PCB design is important for proper switching performance
- High bandwidth is needed for the measurement equipment

Questions?