Driving Power MOSFETs

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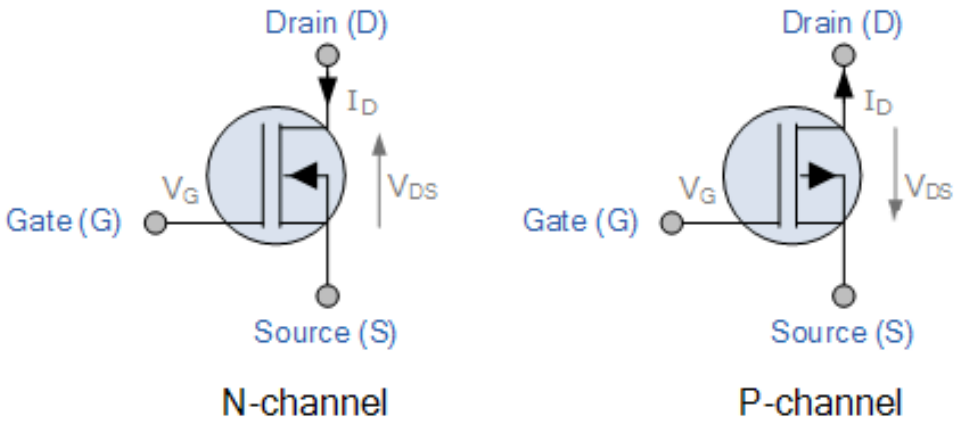
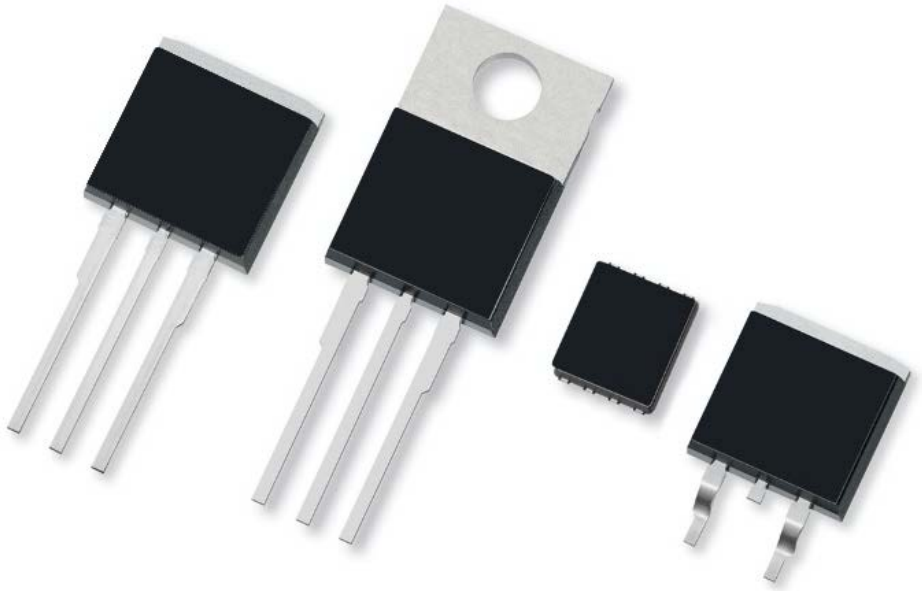
Driving Power MOSFETs

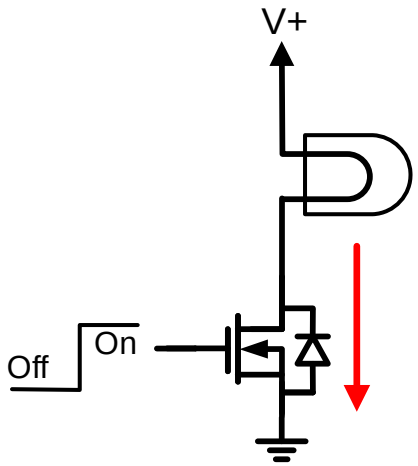
- MOSFET Basics
- Driving Loads: H-Bridges and Half-H-Bridges
- Driving the Gate
- Effects of MOSFET Switching Speed
- Conclusion

Power MOSFETs

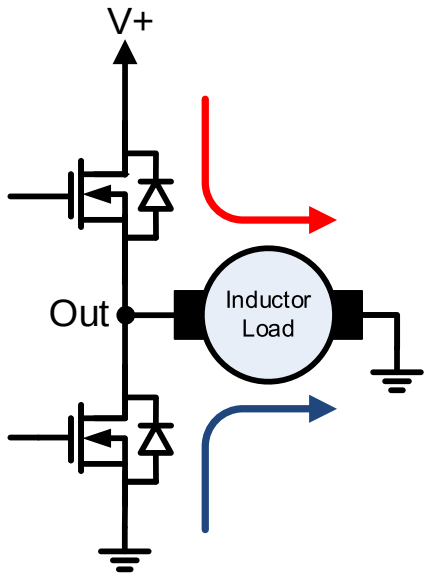




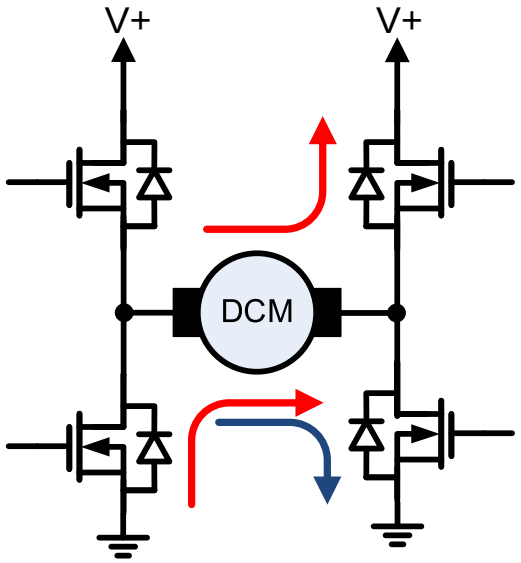
Power Drive Circuits



Low side



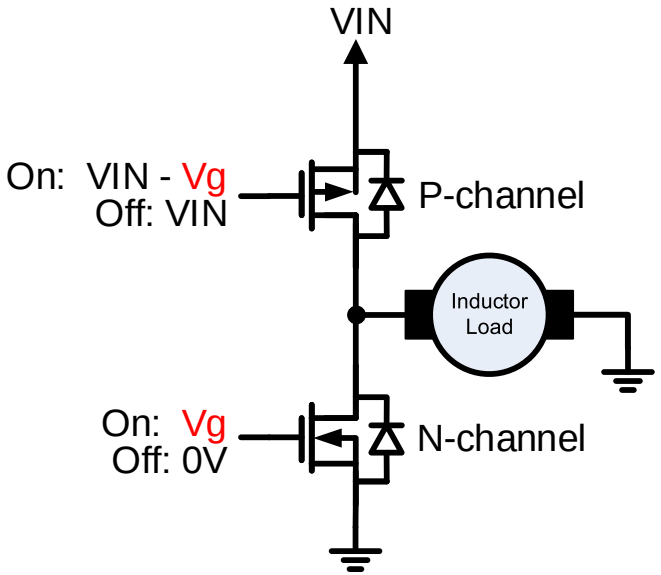
Half Bridge

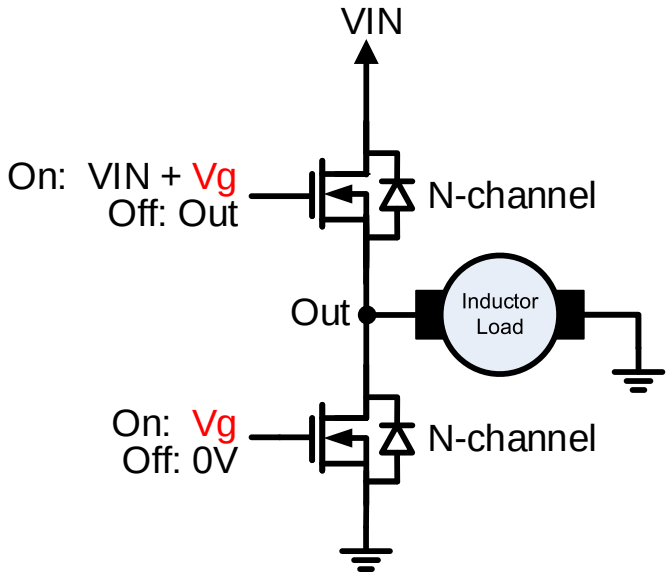


H-Bridge

Red: PWM On
Blue: PWM Off

Half Bridges: N and P

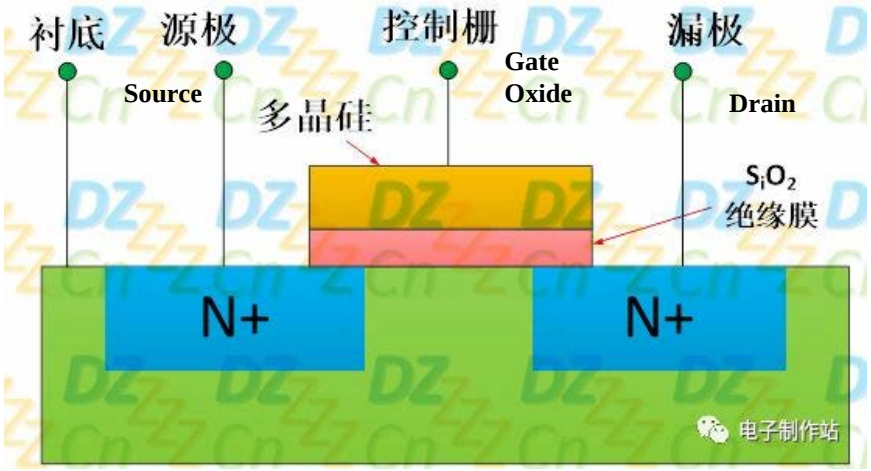


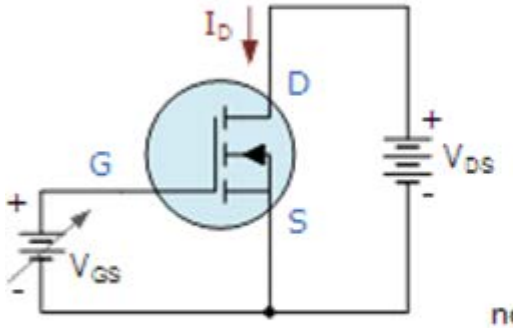


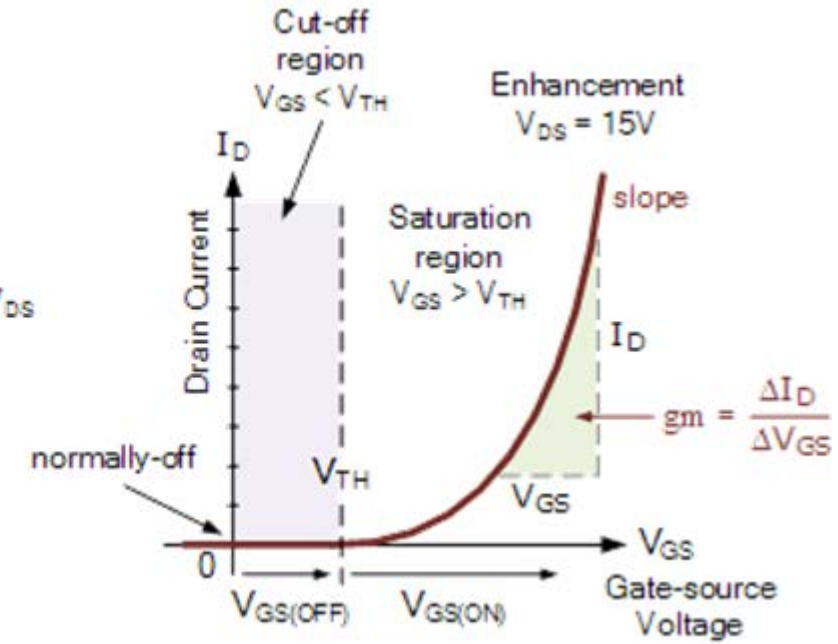
VIN – Load Supply Voltage

VG – Gate Drive Voltage

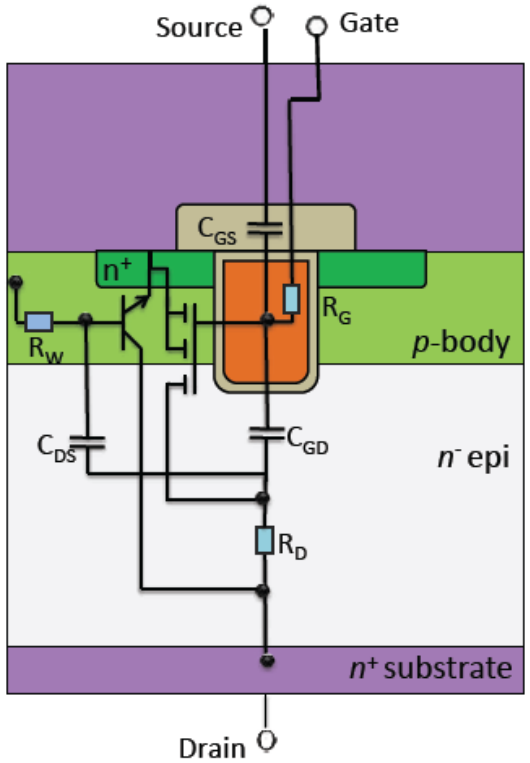
MOSFET Structure

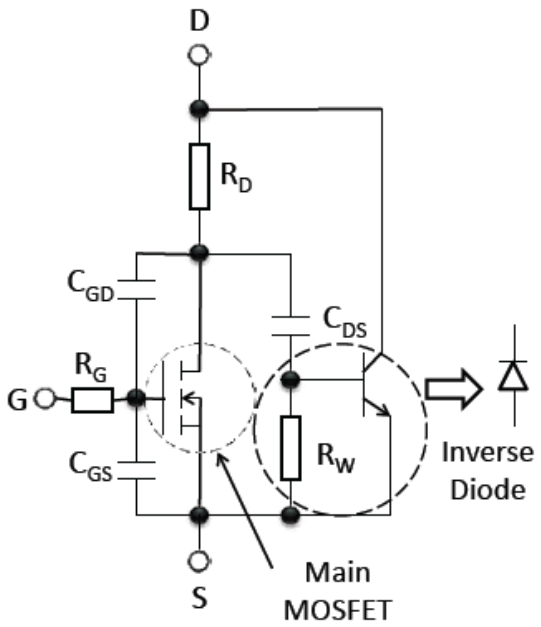






Simplified Model of an N-channel Power MOSFET





Datasheet Specs and Total Gate Charge

$1\ \text{Coulomb} = 6.28 \times 10^{18}\ \text{Electrons}$

that is:

6,280,000,000,000,000,000

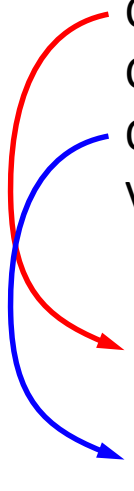
ELECTRONS

Q = CV (Charge = Capacitance x Voltage)

I = Q/t (Current = Charge / Time)

IPP015N04N

VDS	max	40.0 V
RDS (on) (@10V)		max 1.5 mΩ
ID (@25°C)	max	120.0 A
Ptot	max	250.0 W
Ciss		15000.0 pF
Coss		4000.0 pF
QG (typ @10V)		188.0 nC
VGS(th)	min / max	2.0 V / 4.0 V



C_{ISS} – Input capacitance (gate-to-source + gate-to-drain)

Q_G – Total gate charge

Driving the Gate

IPP015N04N

VDS max	40.0 V
RDS (on) (@10V)	max 1.5 mΩ
ID (@25°C) max	120.0 A
Ptot max	250.0 W
Ciss	15000.0 pF
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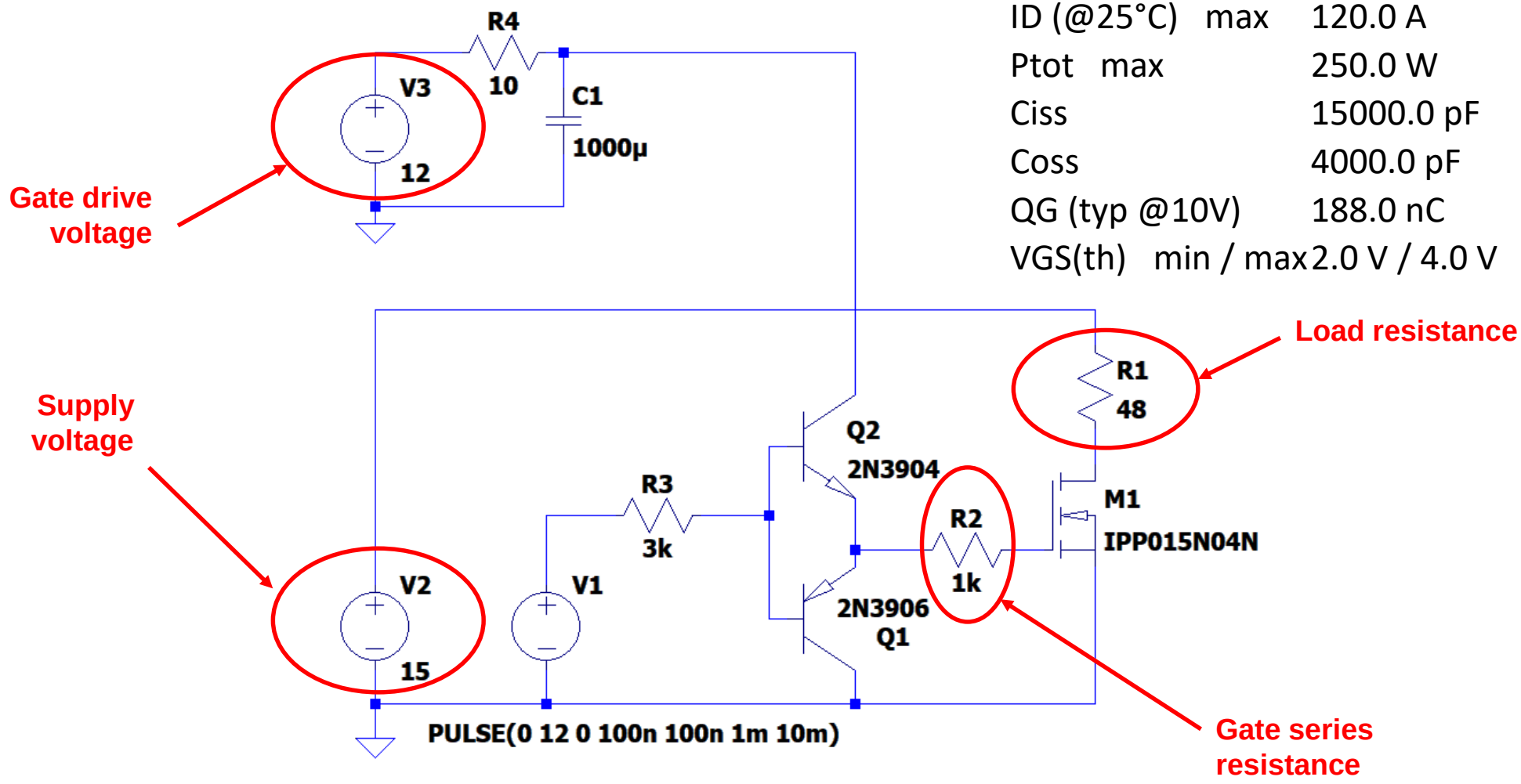
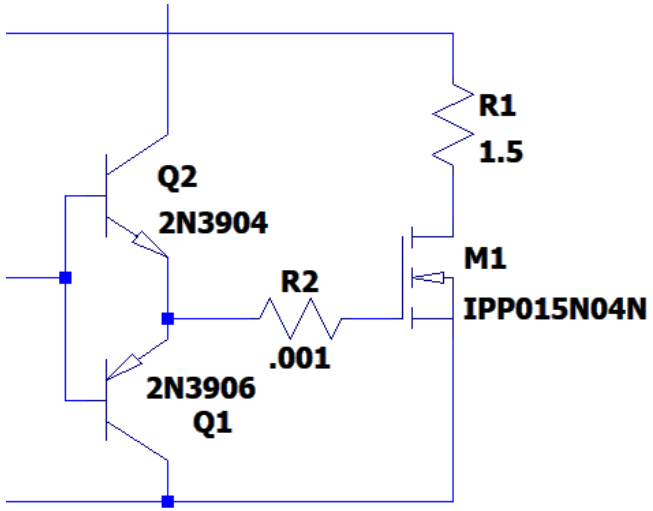
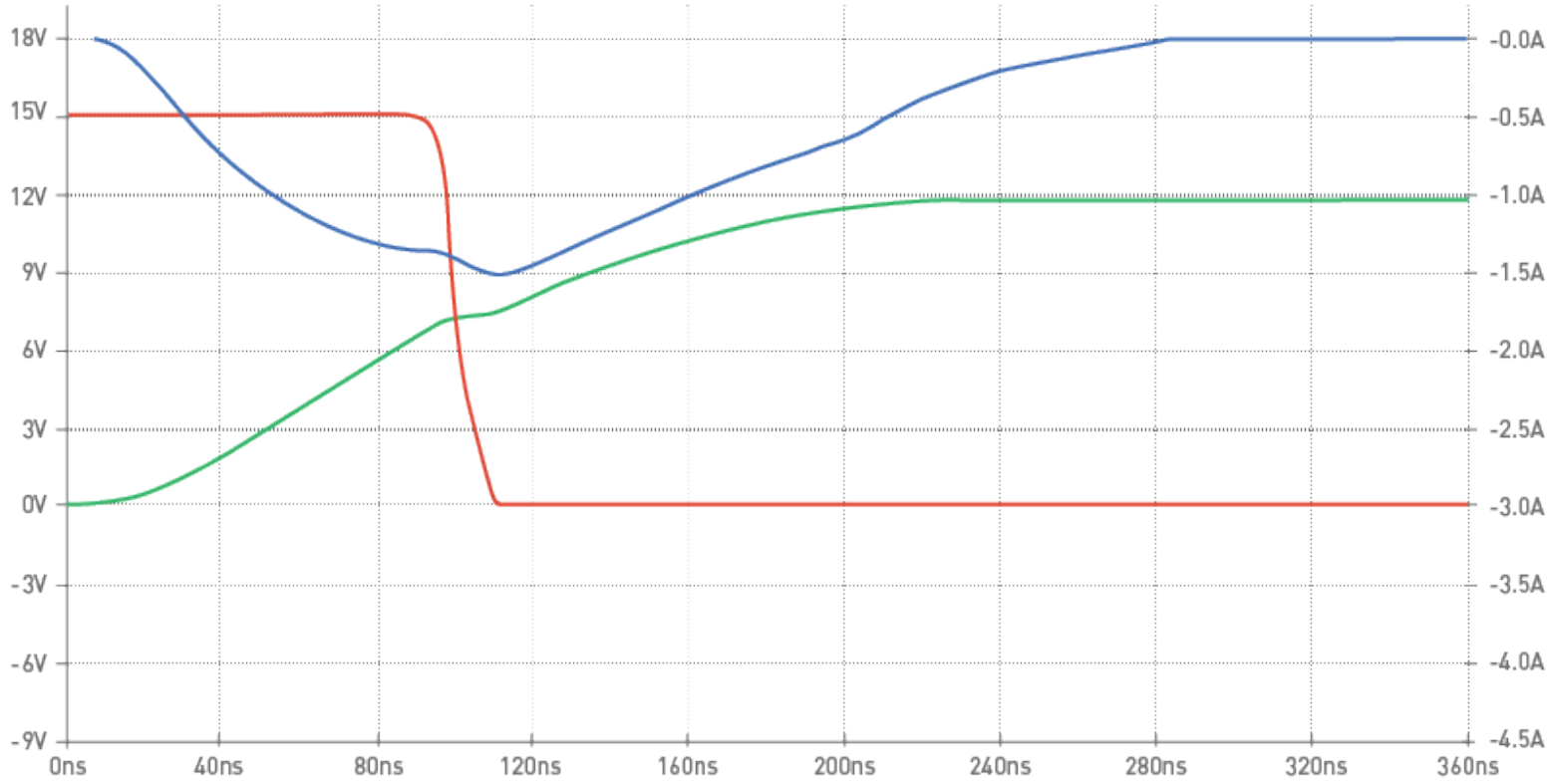


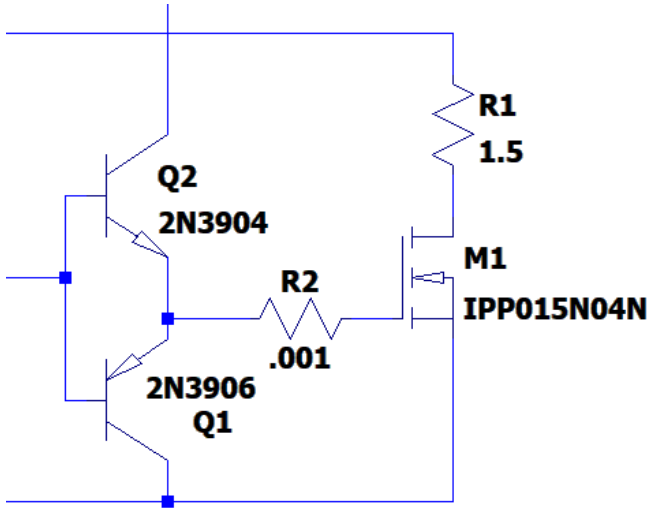
Low Resistance Gate Drive

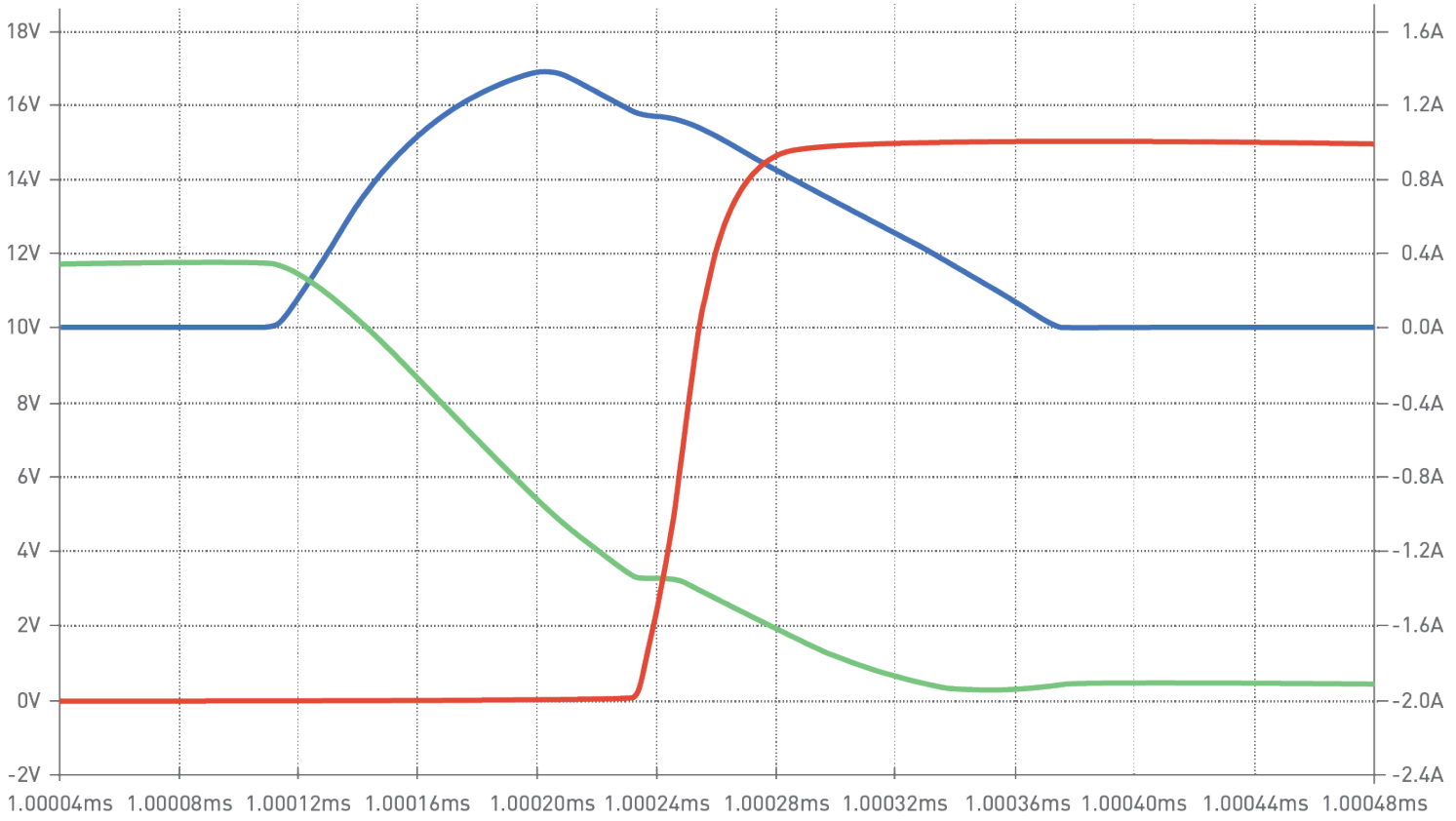




Red: Drain Voltage
Green: Gate Voltage
Blue: Gate Current

Low Resistance Gate Drive





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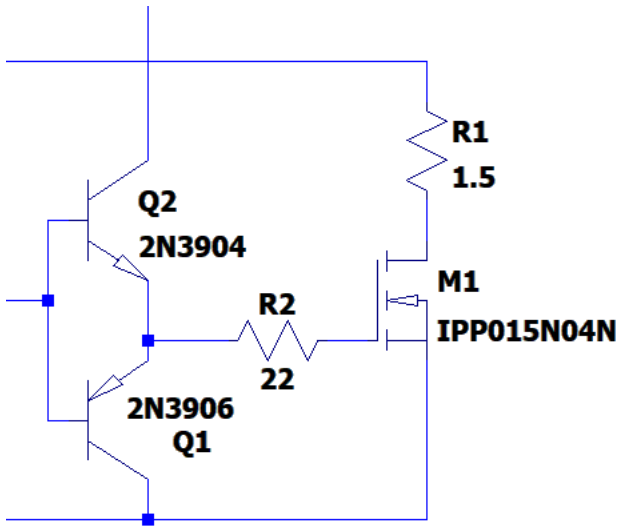
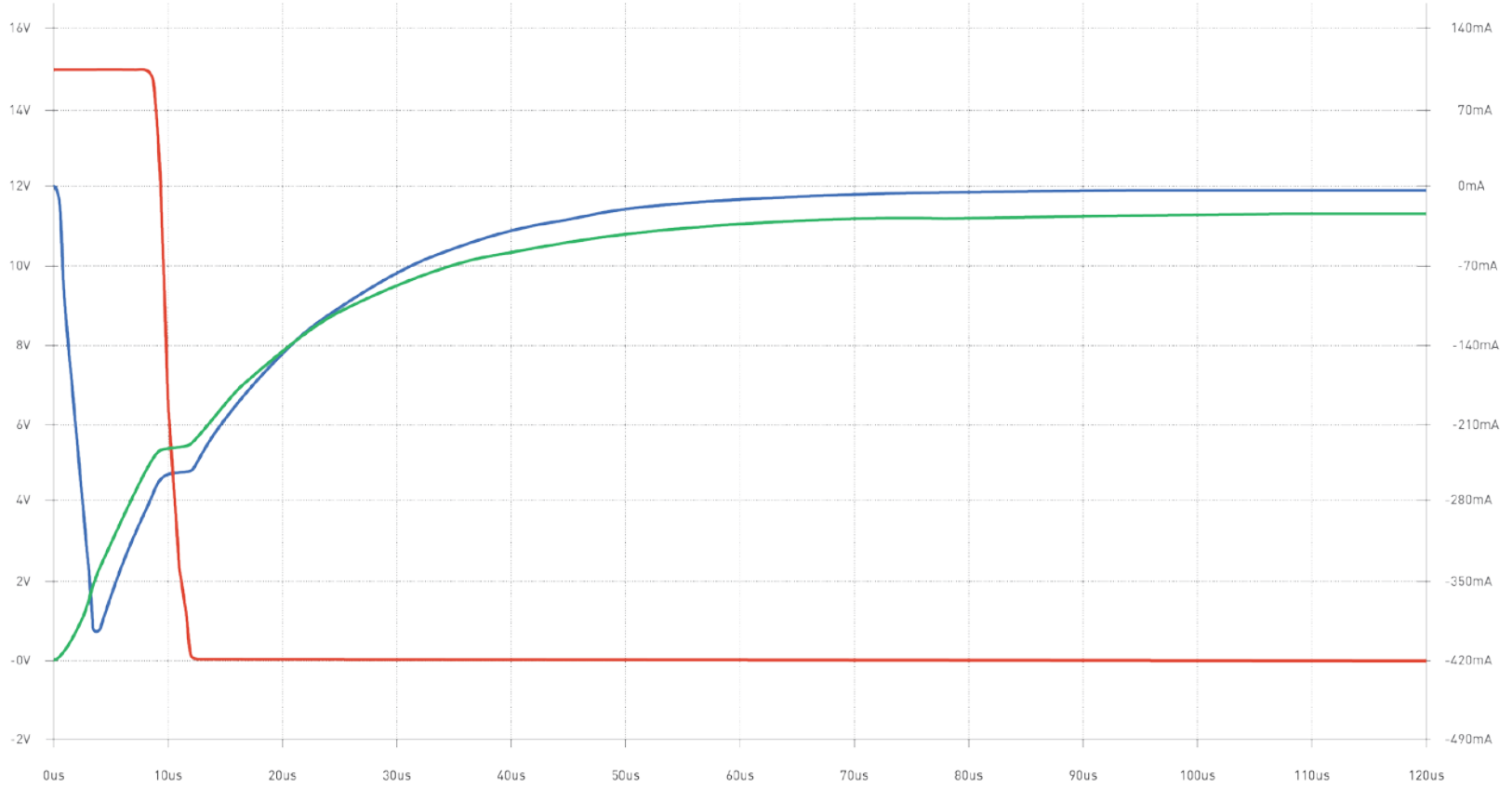
Adding Series Resistance





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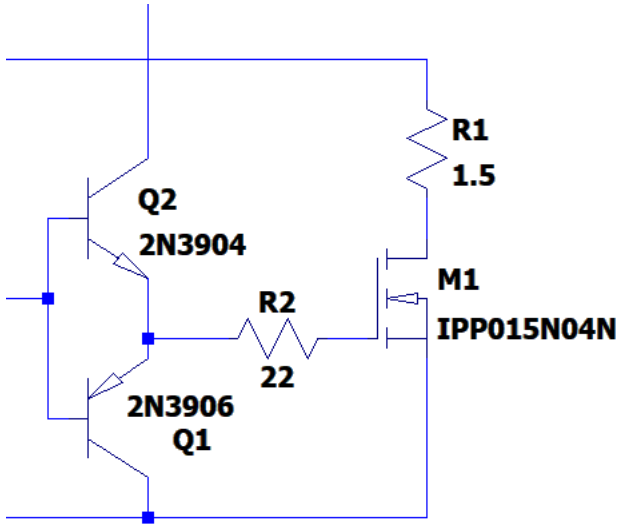

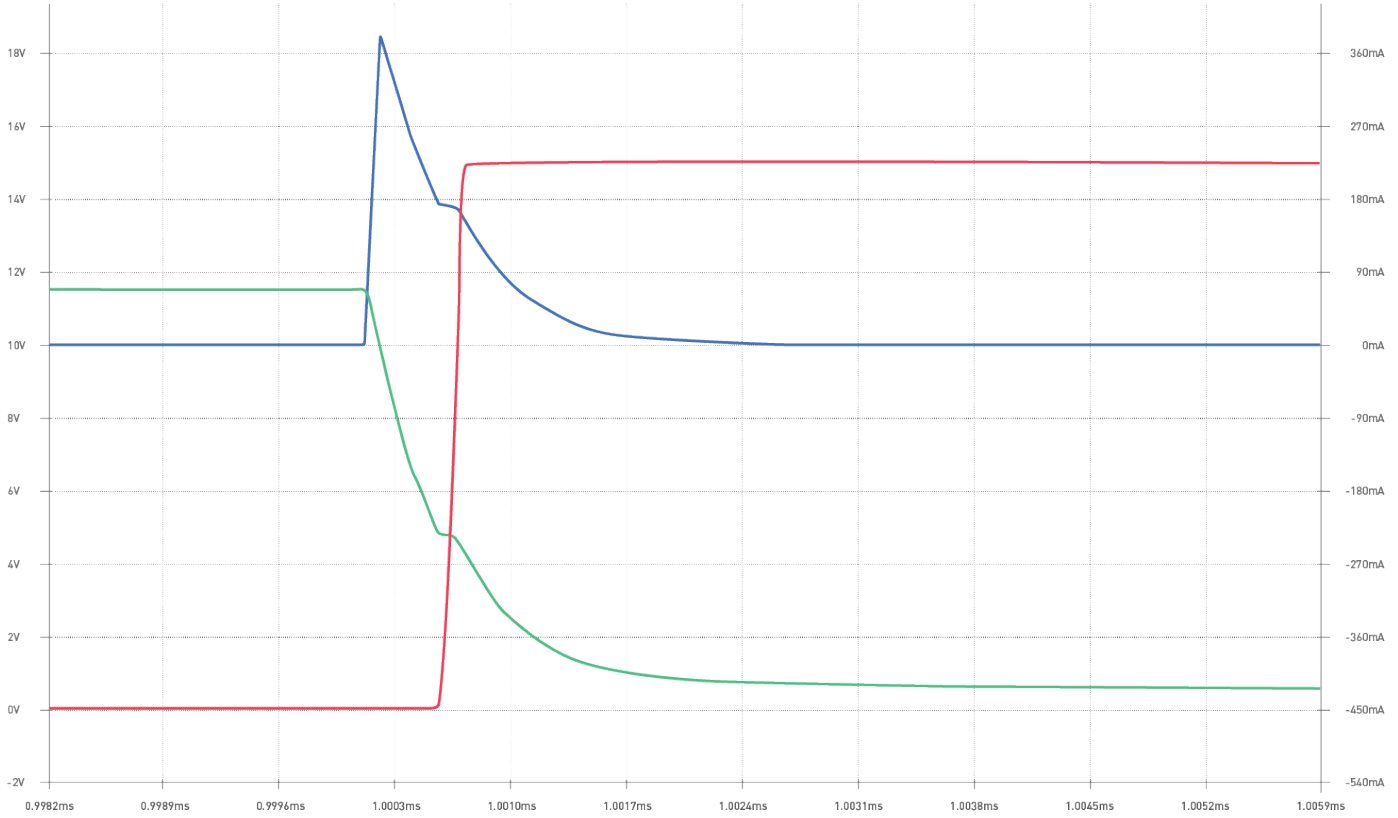

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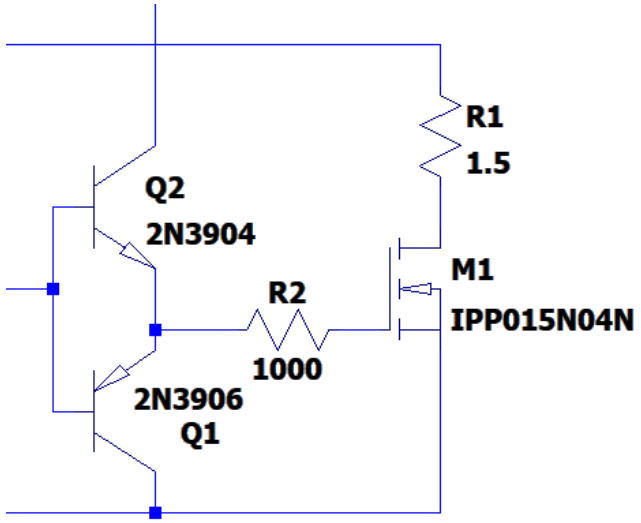
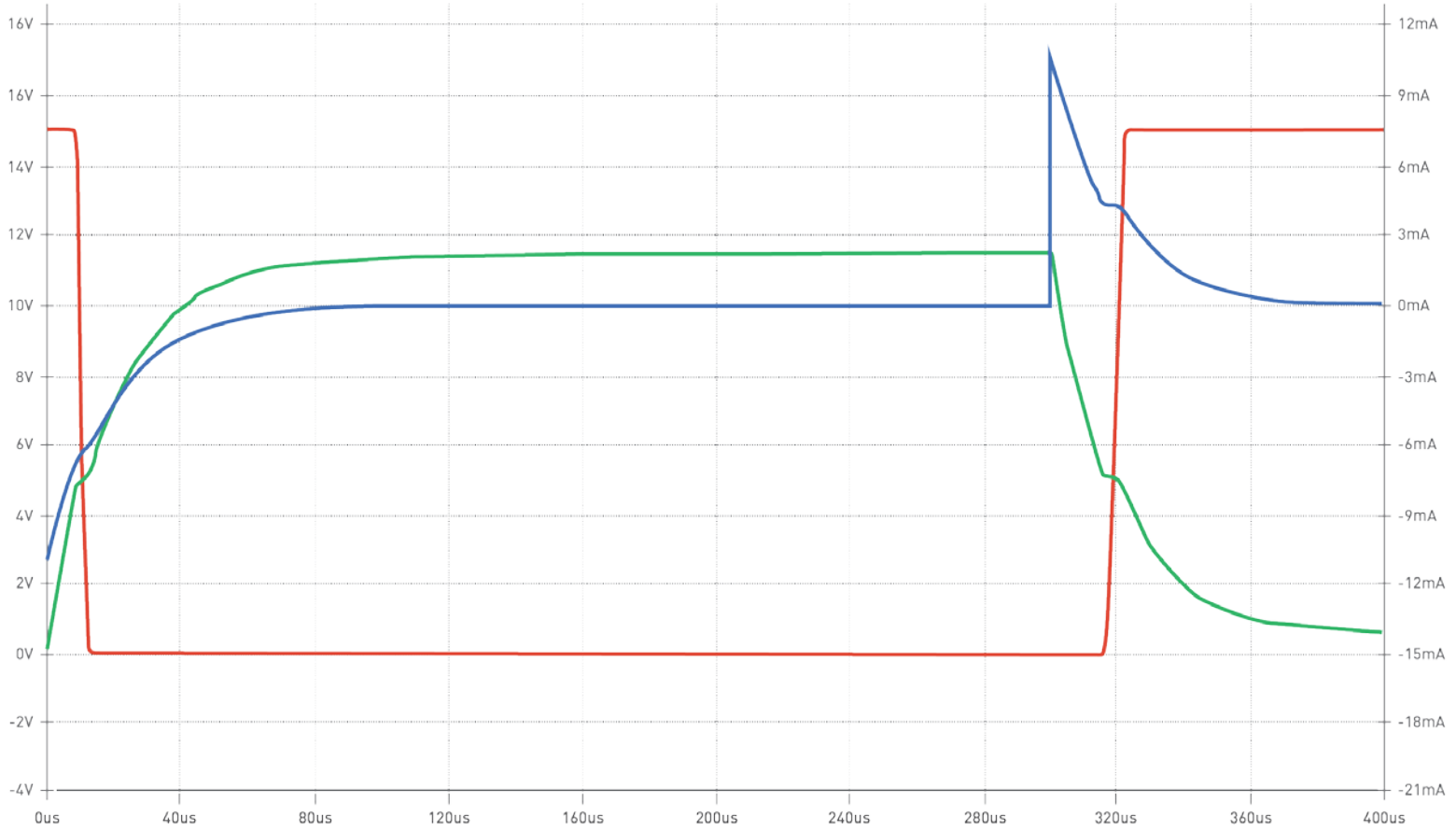
Too Much Series Resistance?





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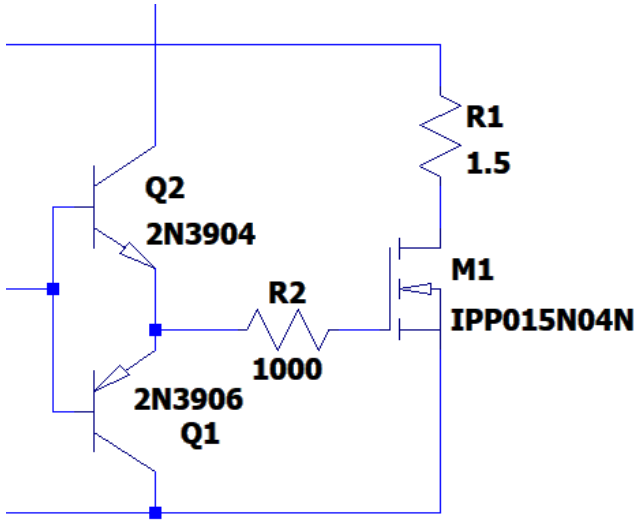

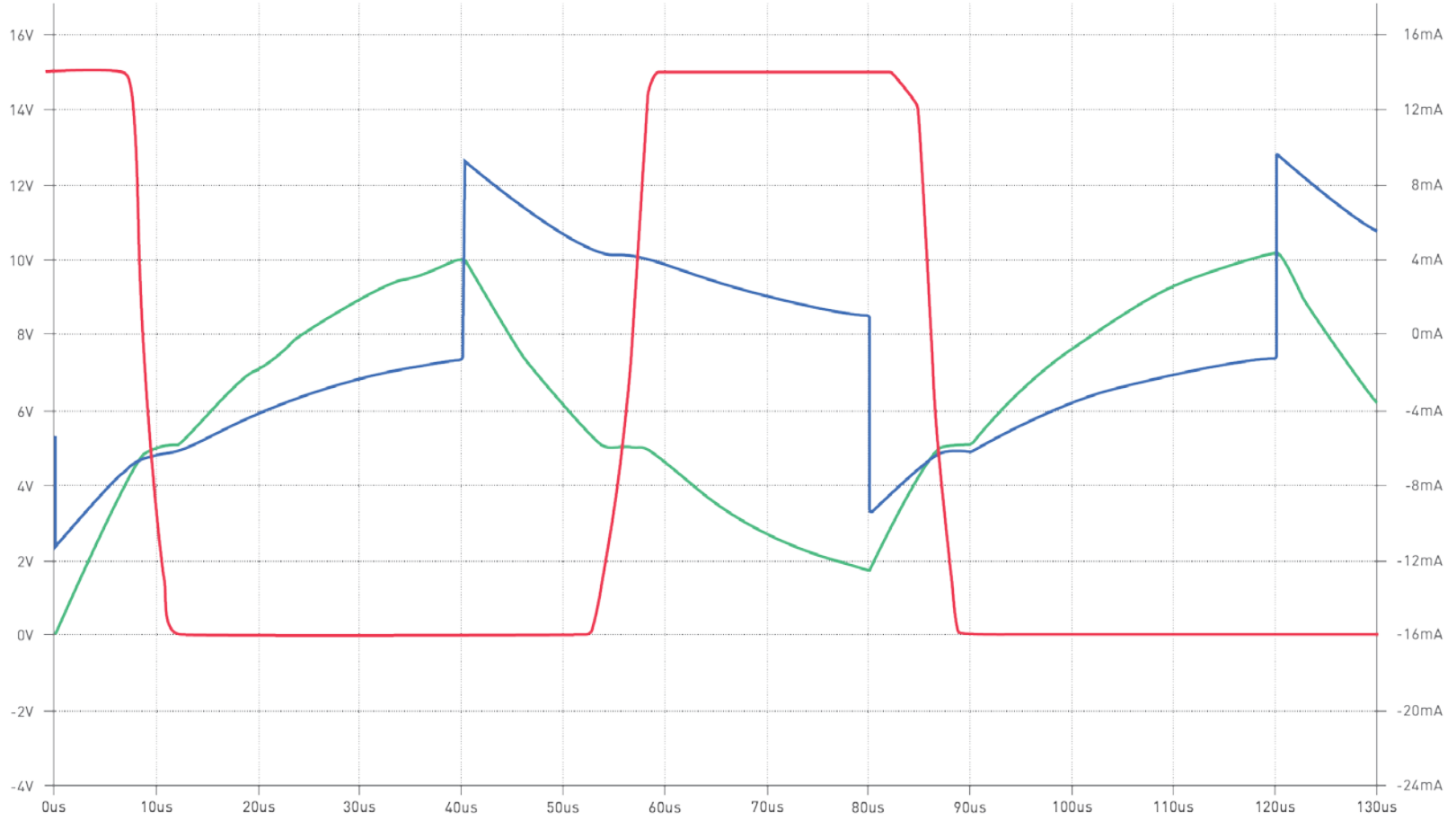

Red: Drain Voltage
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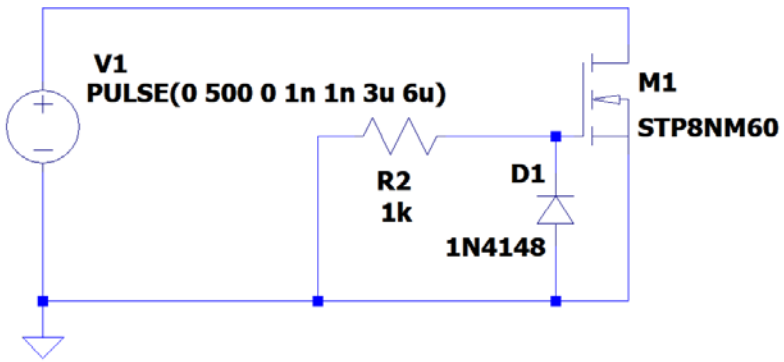
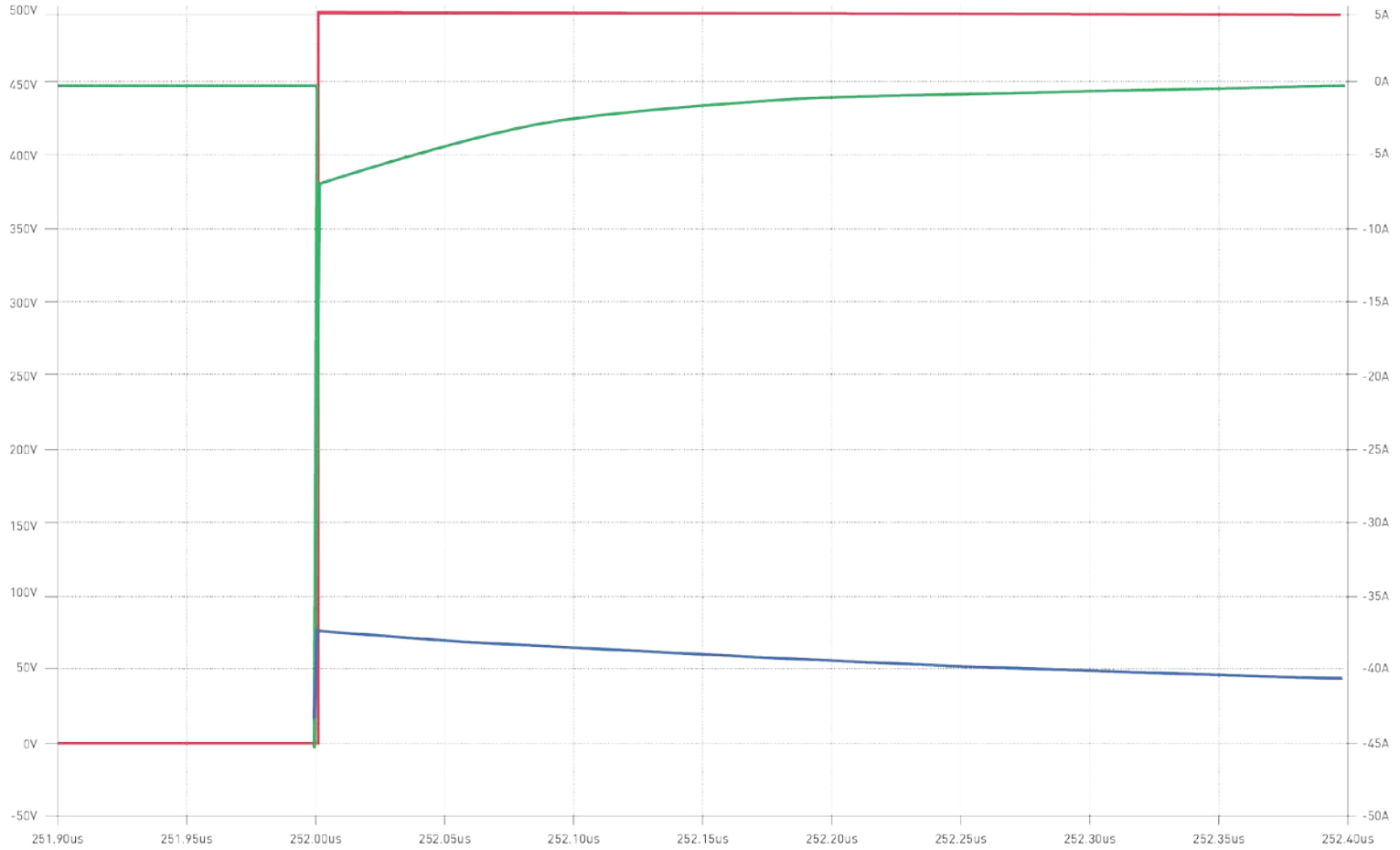
Blue: Gate Current

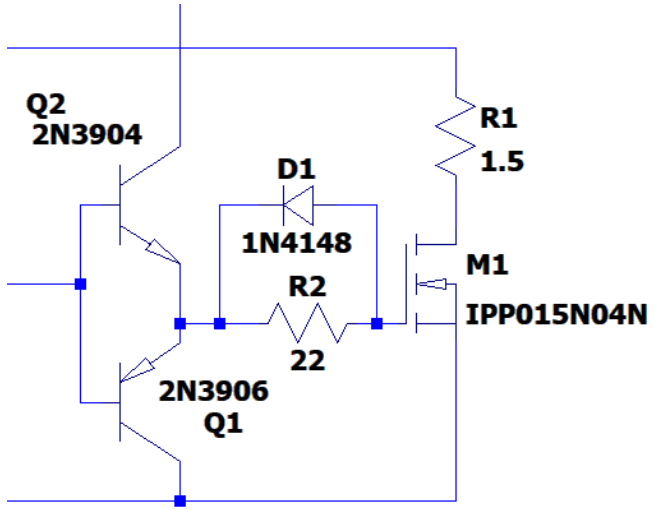
False Turn-On

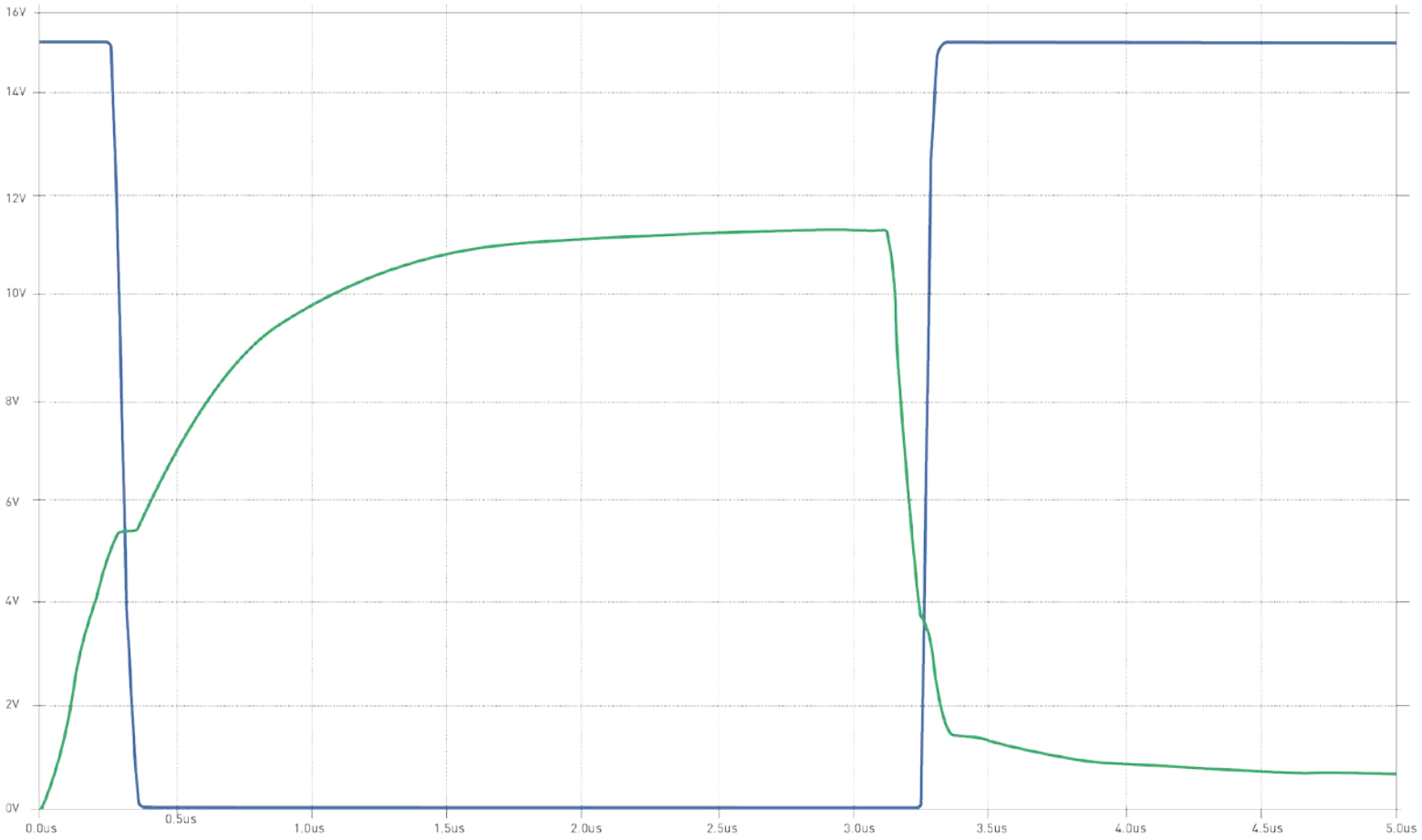




Red: Drain Voltage
Blue: Gate Voltage
Green: Drain Current

Asymmetric Gate Drive



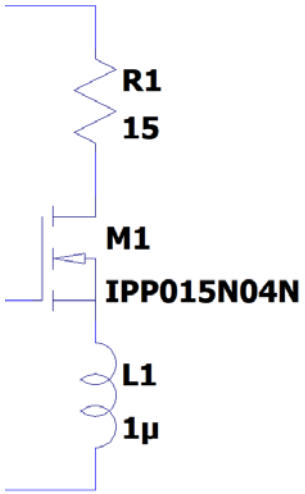


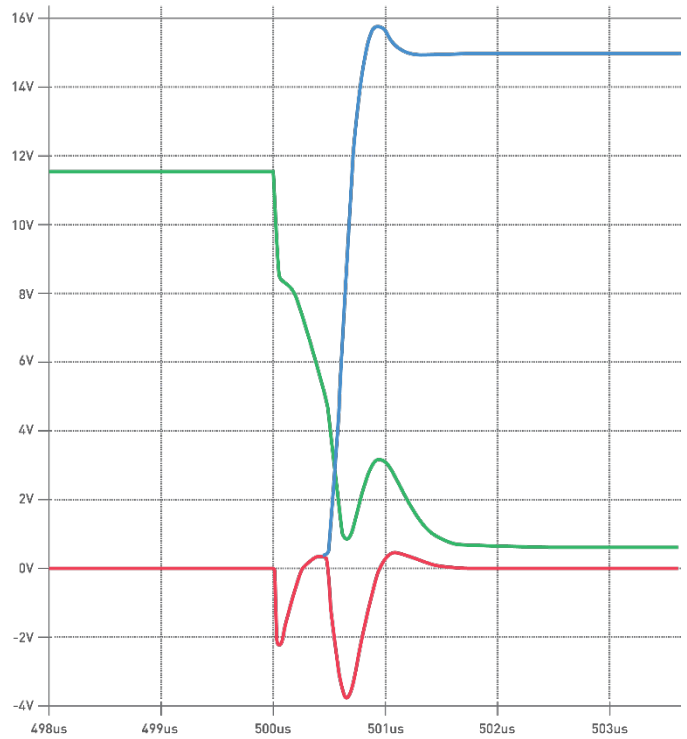
Blue: Drain Voltage

Green: Gate Voltage

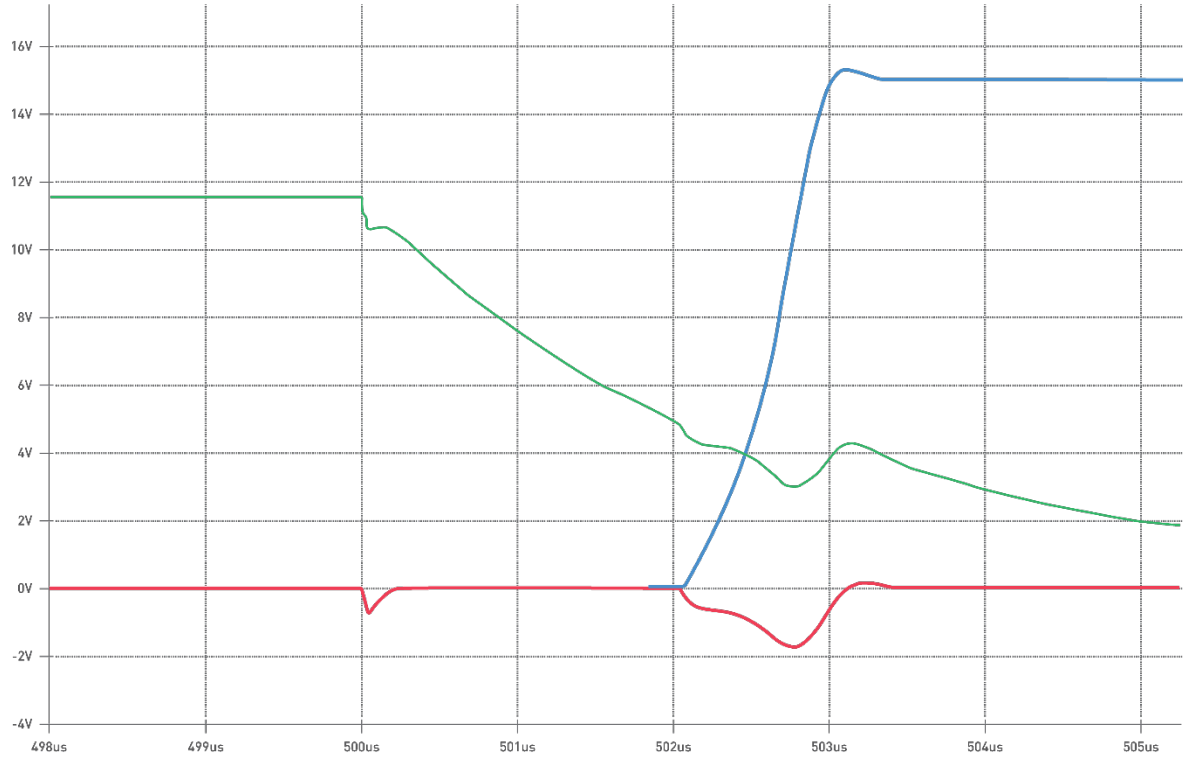
MOSFET Switching Speed

Why Slow the Gate Down?





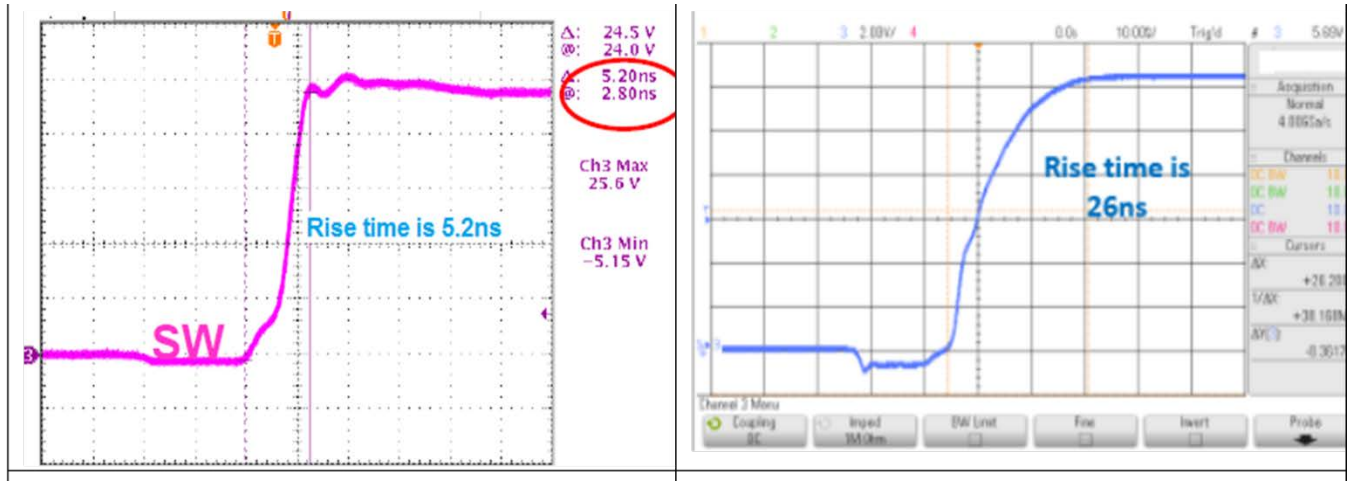
Fast

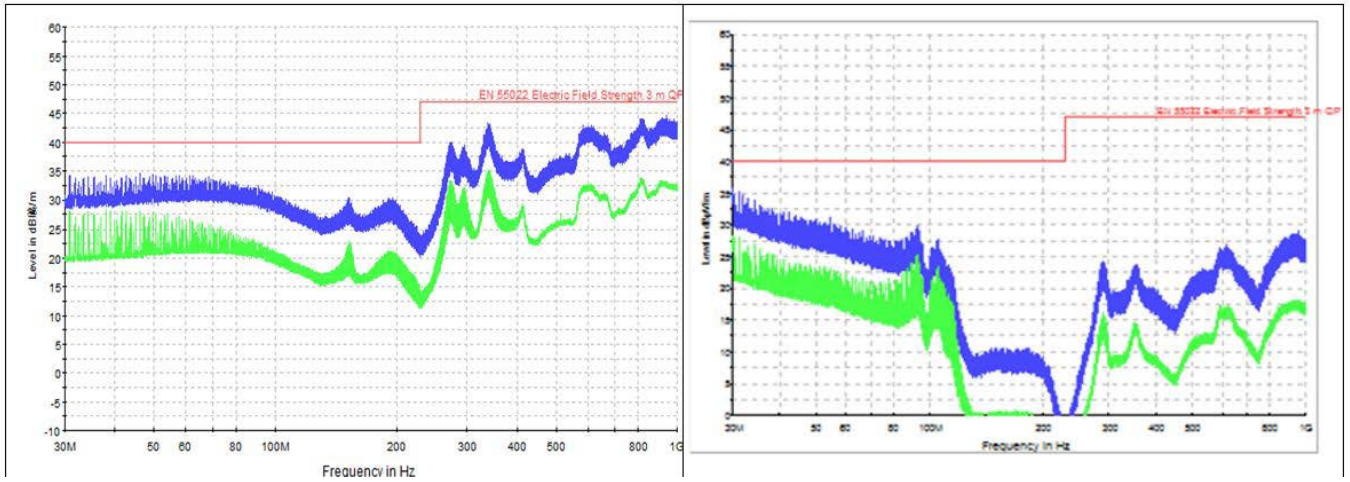


Slow

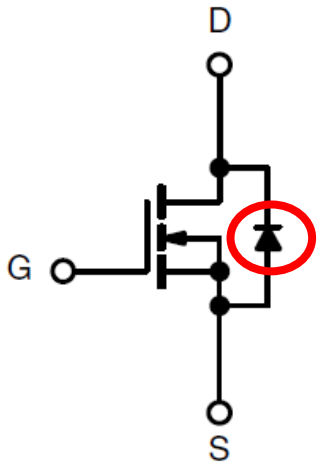
Green: Gate Voltage
Blue: Drain Voltage
Red: Source Voltage

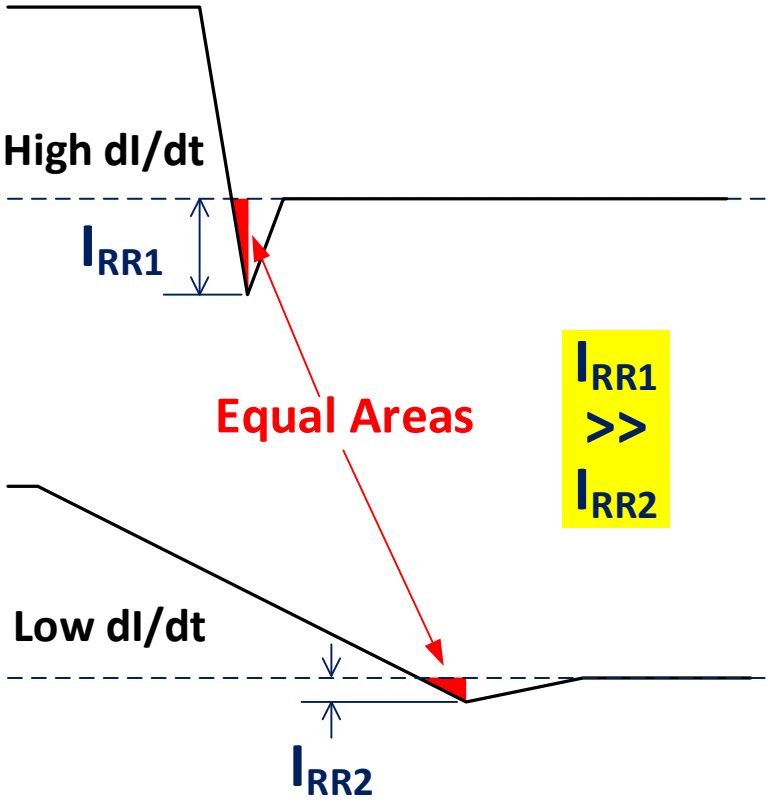
EMI Concerns

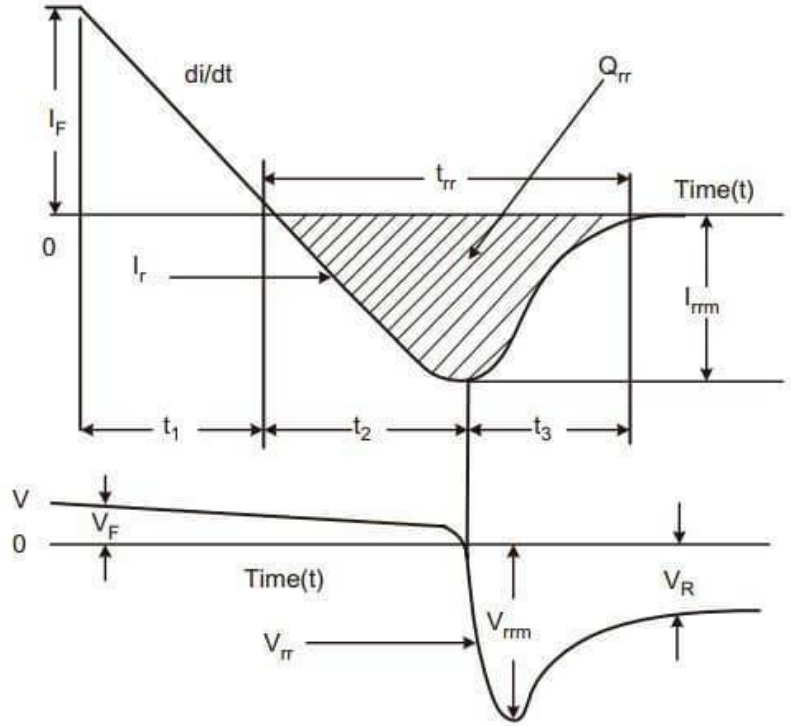




Body Diode Reverse Recovery







Summary

- Key takeaways:
  - Understand how MOSFETs work to implement a successful power circuit
  - Optimize the gate drive to control slew rate, transients, and EMI
  - Carefully design the PCB with consideration of parasitic inductances and impedances