Effect of Active Low Pass Filter Between Gate Driver and Silicon-Carbide MOSFET

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Background

Gate Driver

- Electronic device controlling voltage and current to MOSFET gate
- Ensures rapid and reliable switching of the semiconductor device
- Isolating the MOSFET to protect it from parasitics

Noise Reduction with Active Filter:

- MOSFET output noise due to signal interacting with materials like silicon
- Active low-pass filter used to minimize noise
- Improves signal/power quality controlled by MOSFET

Silicon MOSFET (NMOS)

- Transistor used for voltage control and as a switch
- NMOS chosen for its speed and common usage
- Structure: p-type substrate, thin silicon oxide insulator, metal cap on source, drain, and body
- Operation initiated by threshold voltage, defining on/off transition point

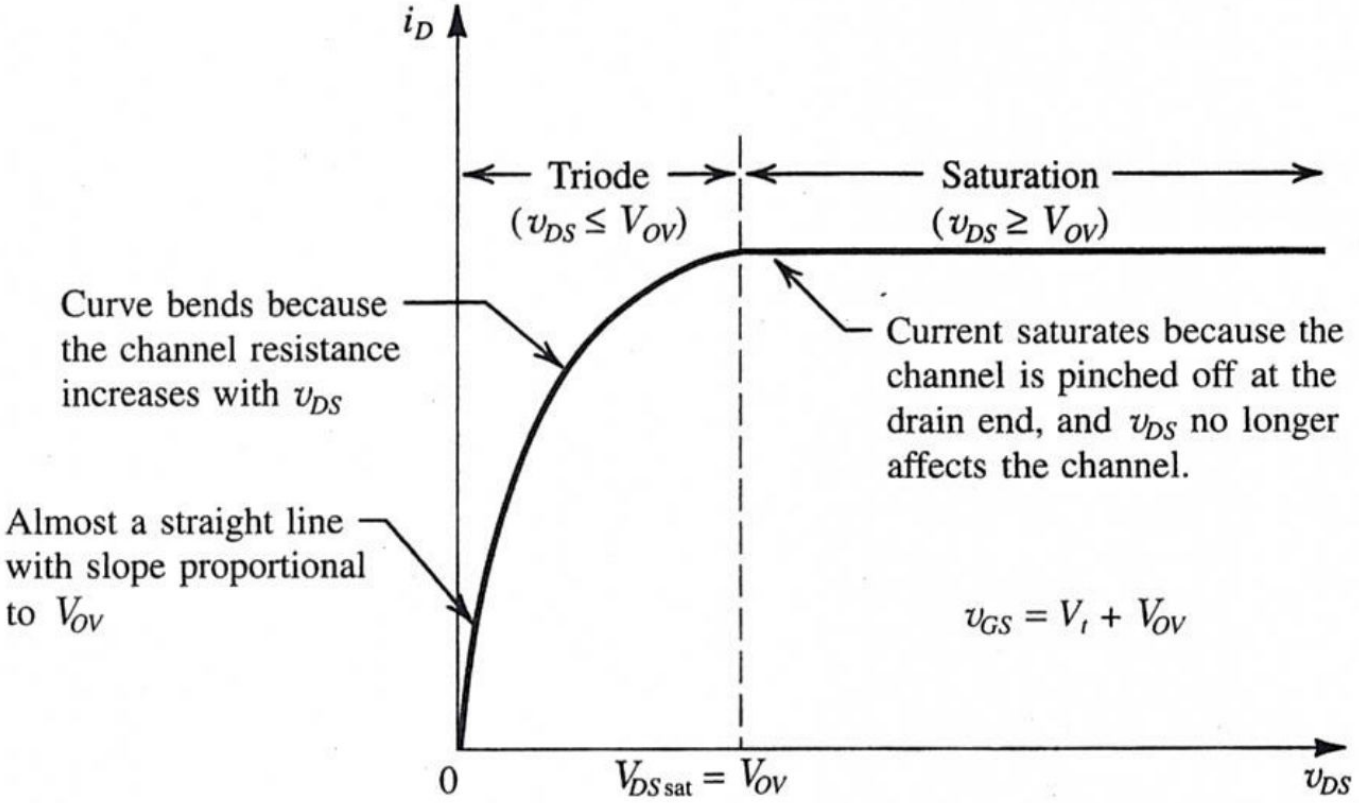


Figure 1: Voltage vs Current Graph of MOSFET

Objective

Experiment Objective:

- Observe and analyze the impact of an active filter on gate driver signal noise.

Key Points:

- Noise Source: MOSFET output noise due to current-material interaction.
- Strategy: Add a low-pass filter to minimize observed noise.
- Tradeoff: Filter reduces noise but also affects MOSFET speed.
- Analysis: Investigate the tradeoff between speed and noise reduction.
- Objective Outcome: Understand the balance between noise reduction and MOSFET operational speed.

Schematic

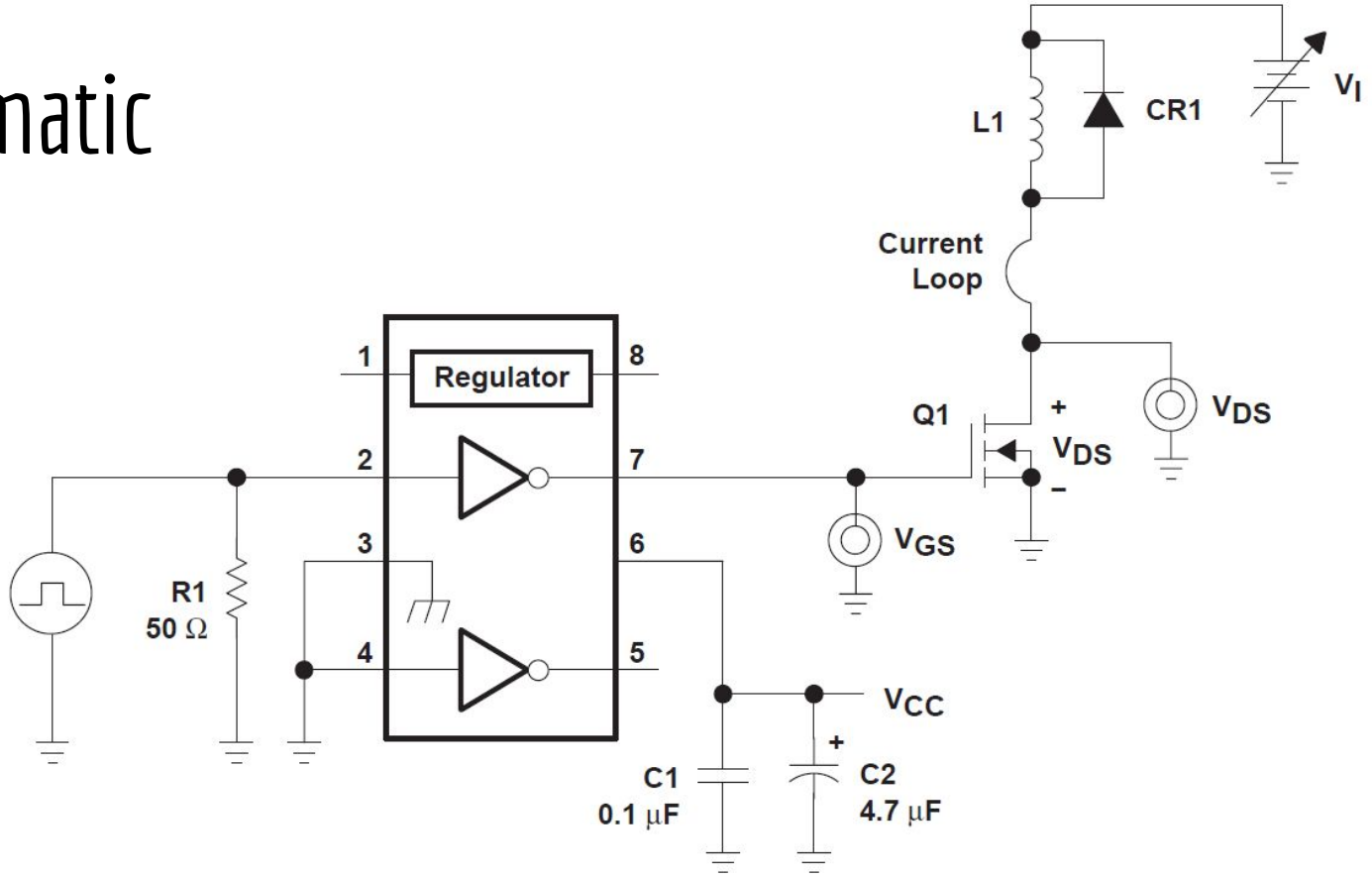


Figure 2: Basic Schematic without Active Filter

Materials/Methods

1. Design the SiC MOSFET
2. Design the gate driver (TPS2814P)
3. Combine the two circuits and make sure it runs properly
4. Add a lowpass filter to the input of the gate-driver
5. Design the active low pass filter in between the gate-driver and MOSFET

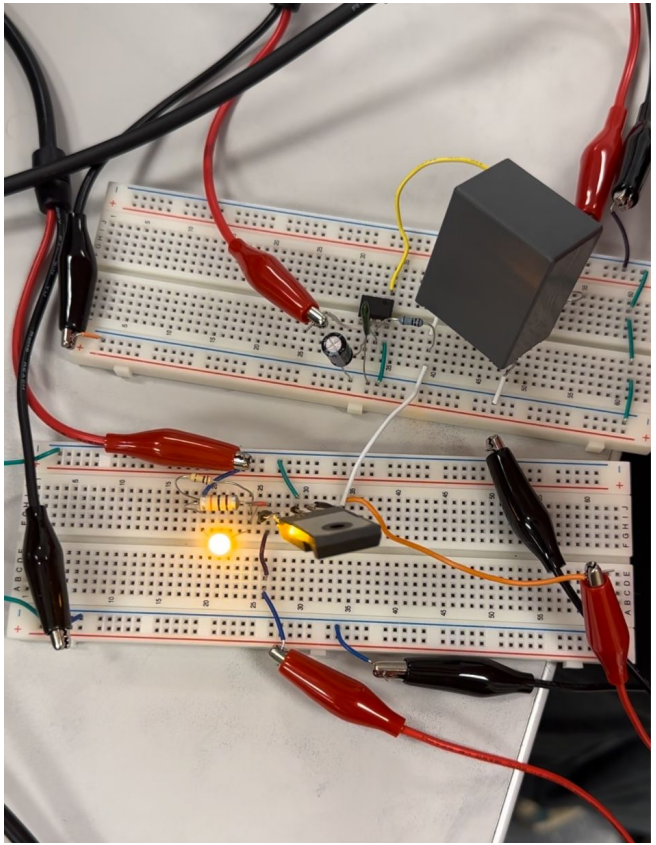


Figure 3: Circuit Board Design with Filter

Individual Gate Driver Input Filter

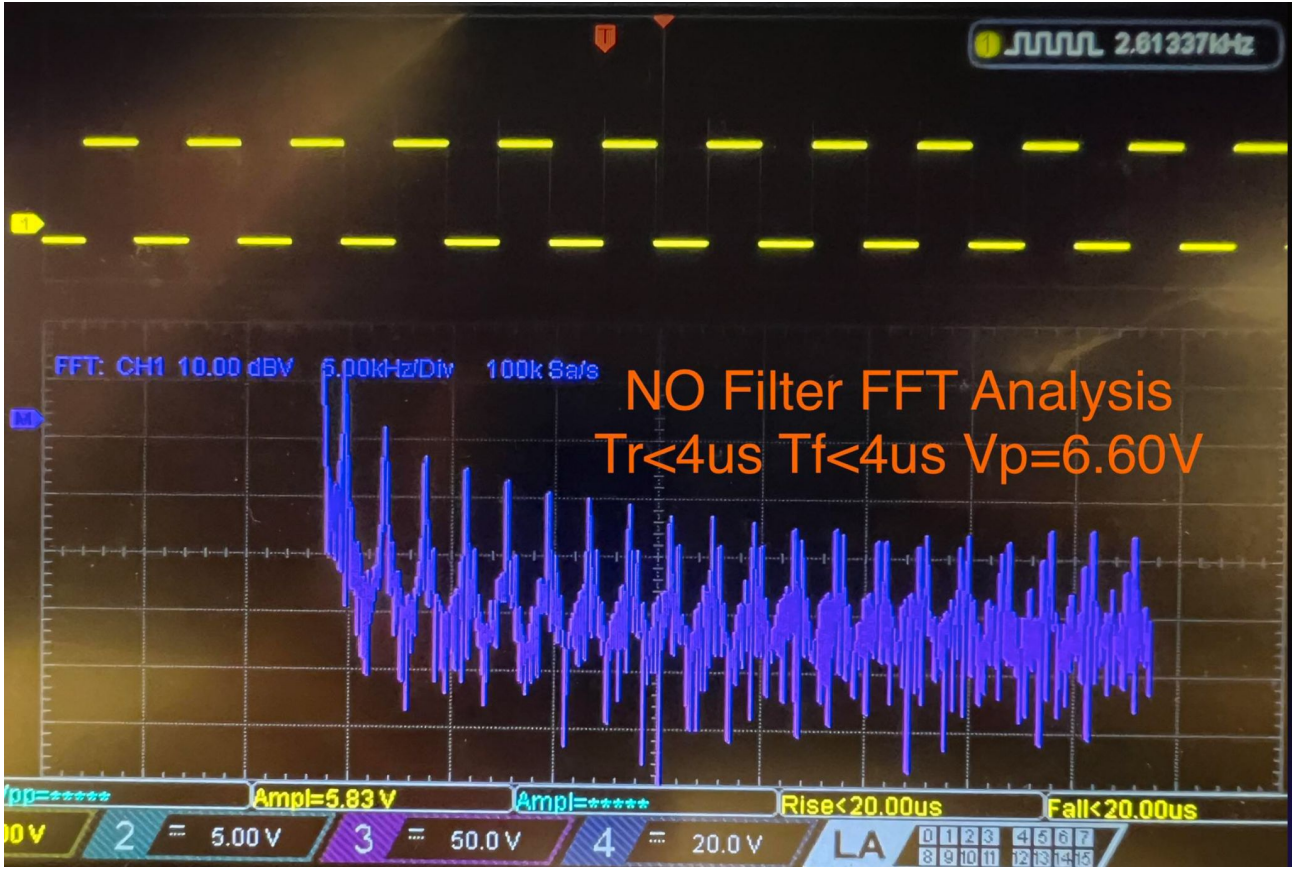
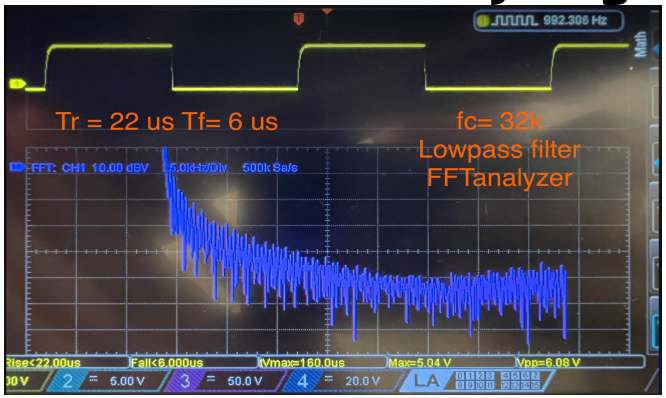
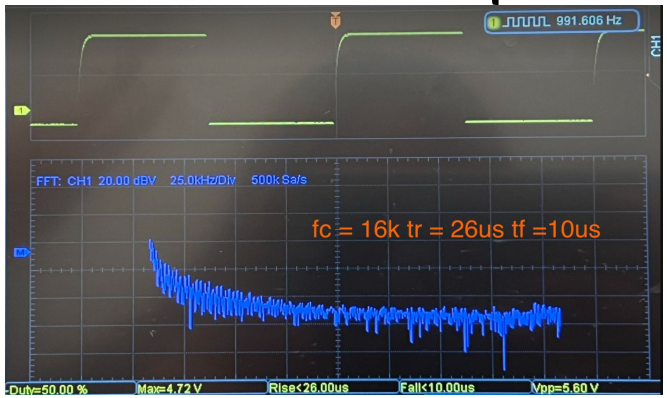
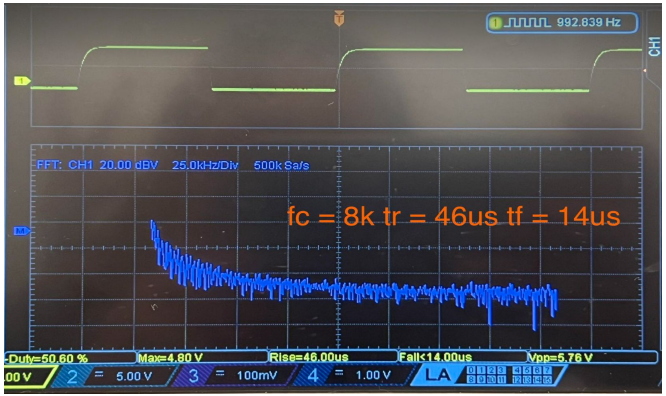


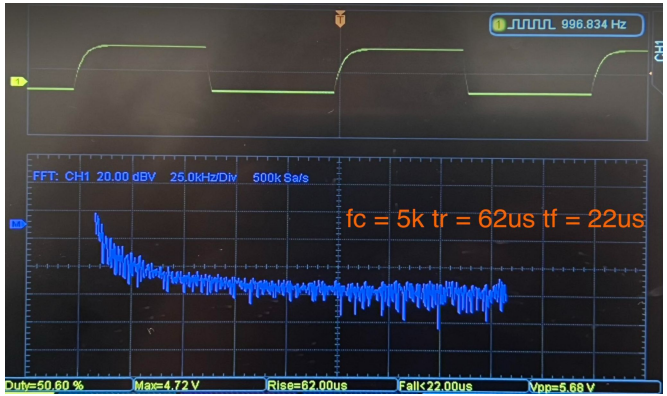
Figure 4: No Filter FFT Analysis

Input Filter with Varying Resistances (Cap: 100nF)



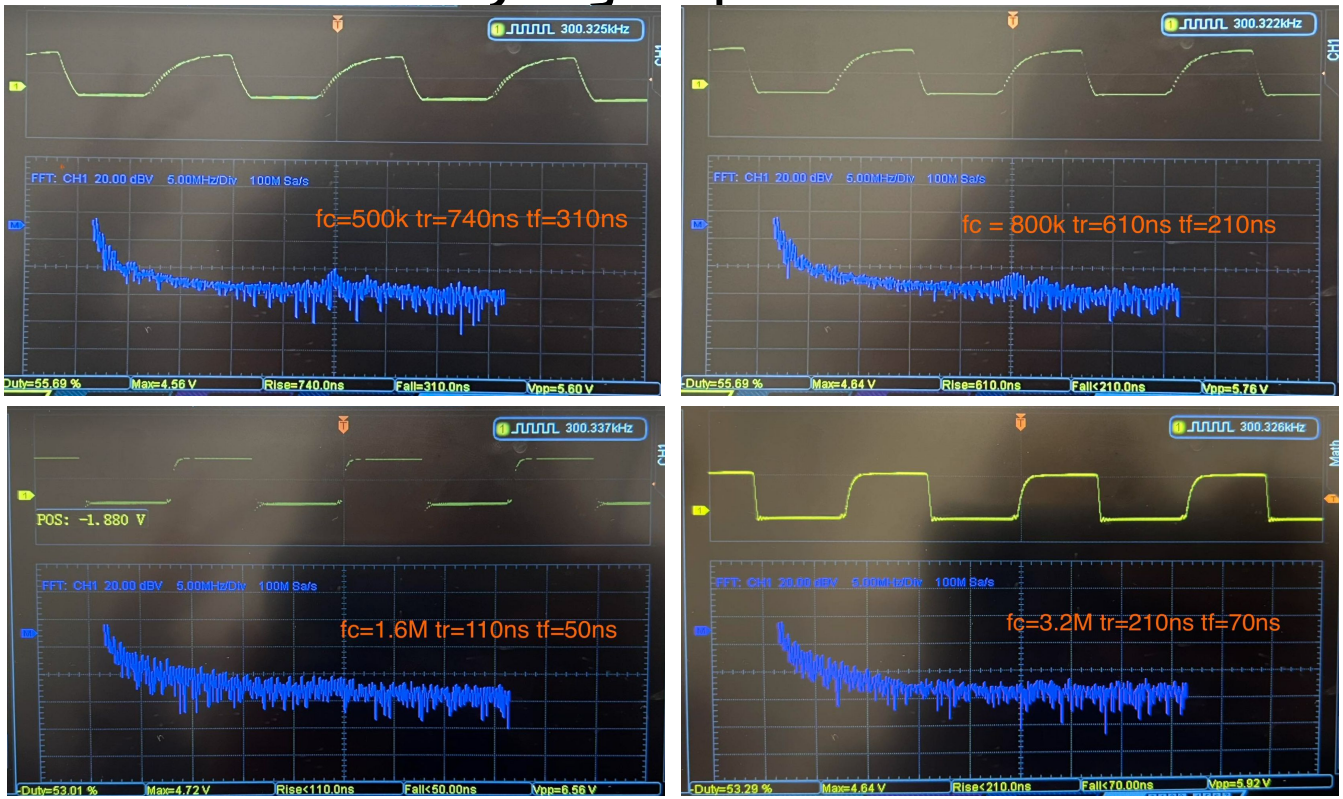






Figures 5-8 (from top left): Oscilloscope Output of Input Filter with Varying Resistance

Input Filter with Varying Capacitances (R:100 Ohms)

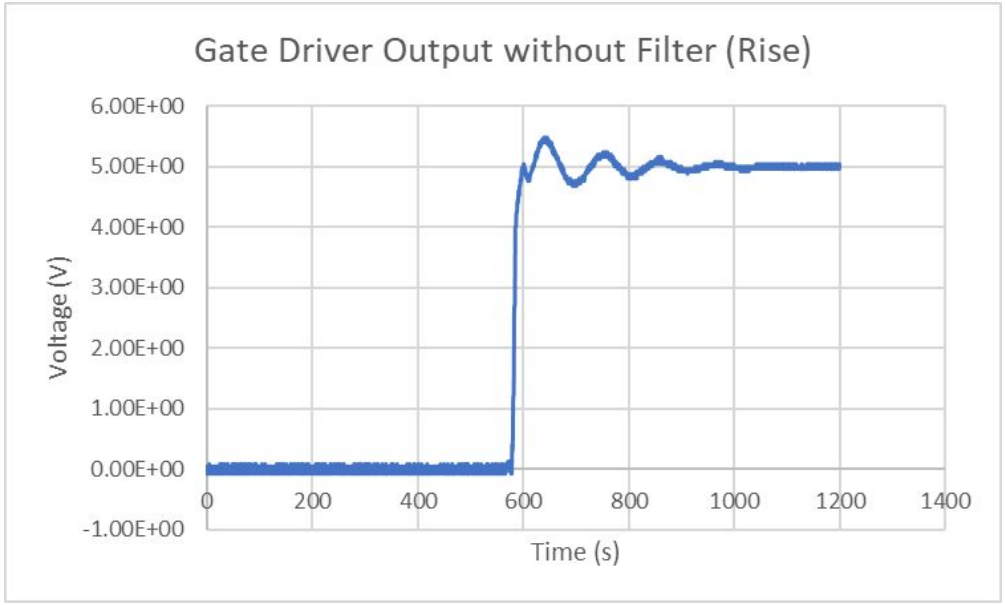


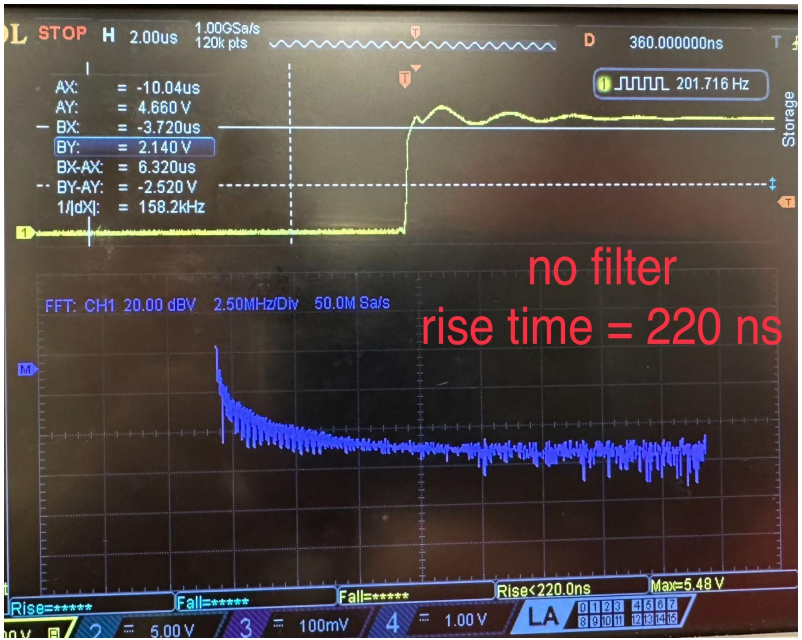
Figures 9-12 (from top left): Oscilloscope Output of Input Filter with Varying Capacitance

Gate Driver With MOSFET

- Input Filter for Gate Driver
  - Fast Fourier Transform Analysis (frequency domain)
  - Low Pass Filter Tests
    - Varying Resistance: 50, **100**, 200, 300 Ohms
    - Varying Capacitance: 3nF, 2nF, **0.1nF**, 0.05nF
  - Final Low Pass Filter Choice: 100 Ohms and 0.1nF
  - Input signal was at low frequency (1kHz - 200 Hz)
- Filter between Gate Driver and MOSFET
  - Low Pass: 1 Ohm and 6.6 microFarad

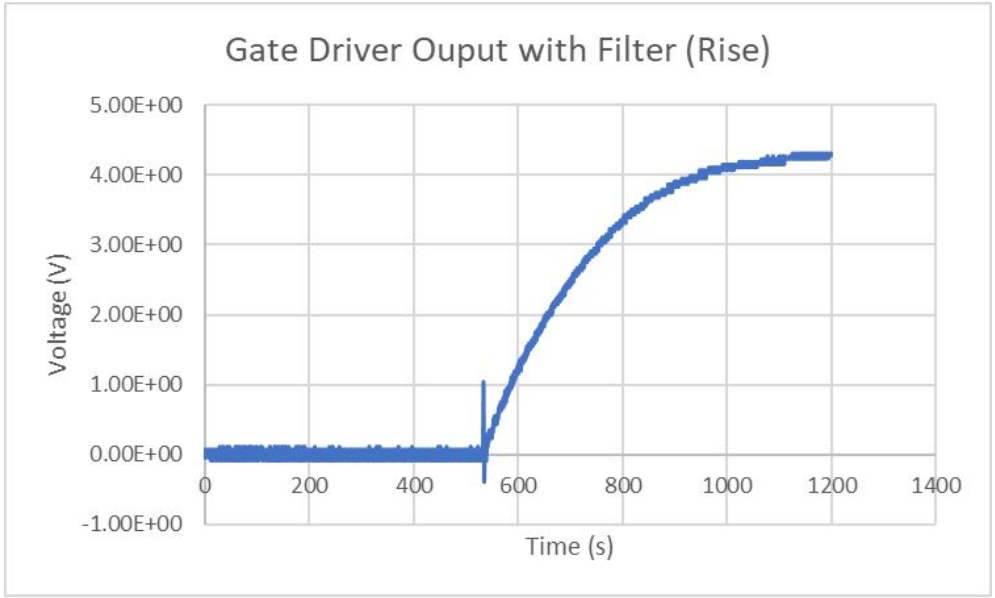
Gate Driver Output without Filter (Rise)

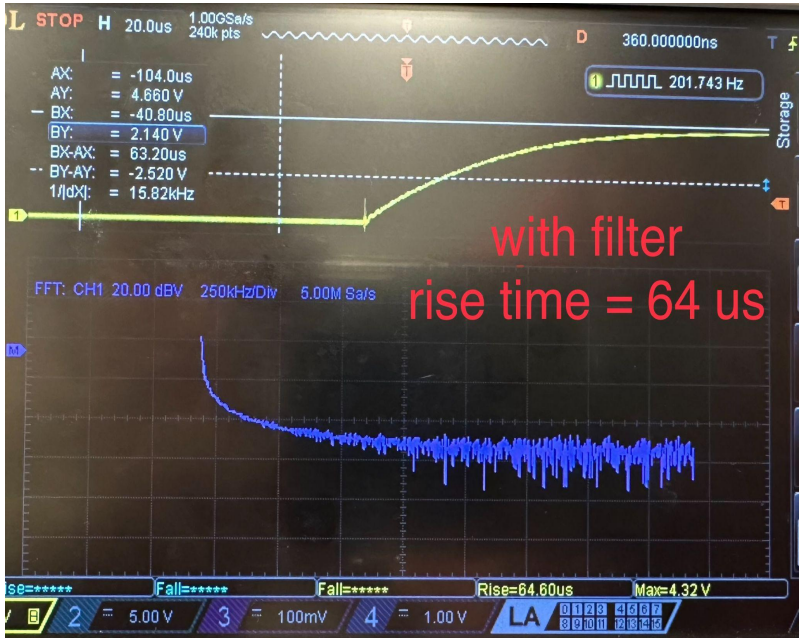




Figures 13-14 (left to right): Voltage vs. Time Graph for Gate Driver Output without Filter

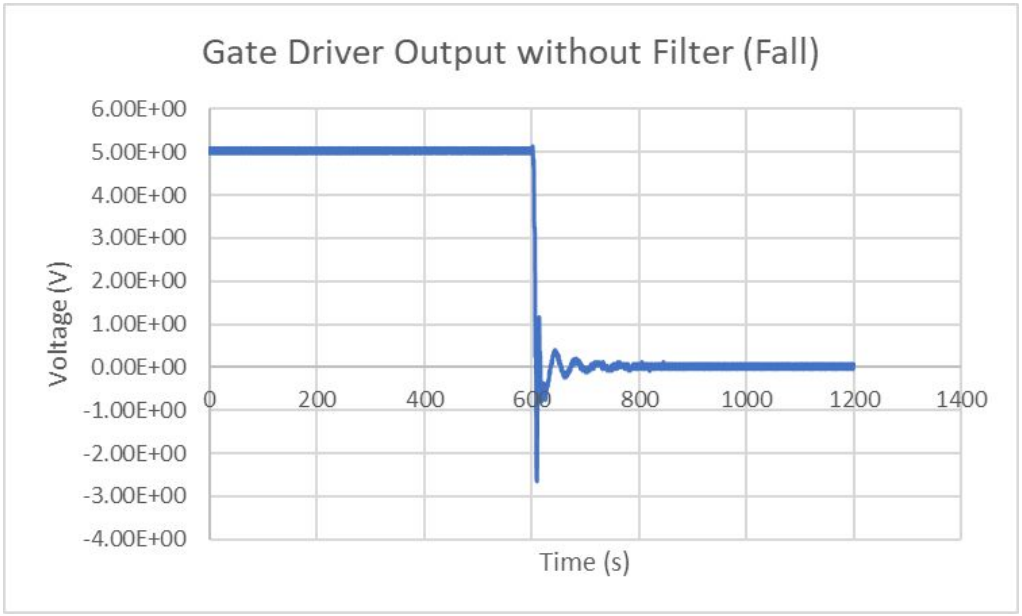
Gate Driver Output with Filter (Rise)

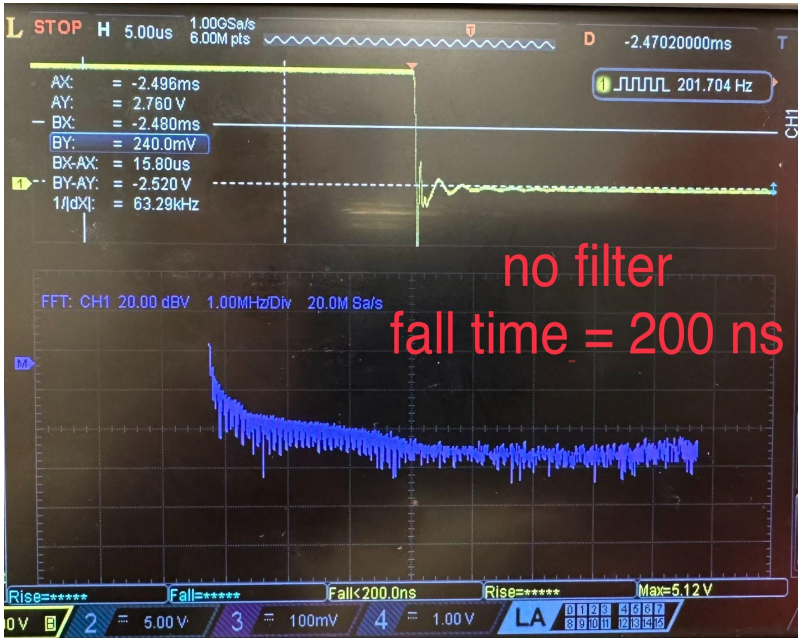




Figures 15-16 (left to right): Voltage vs Time Graph for Gate Driver Output with Filter

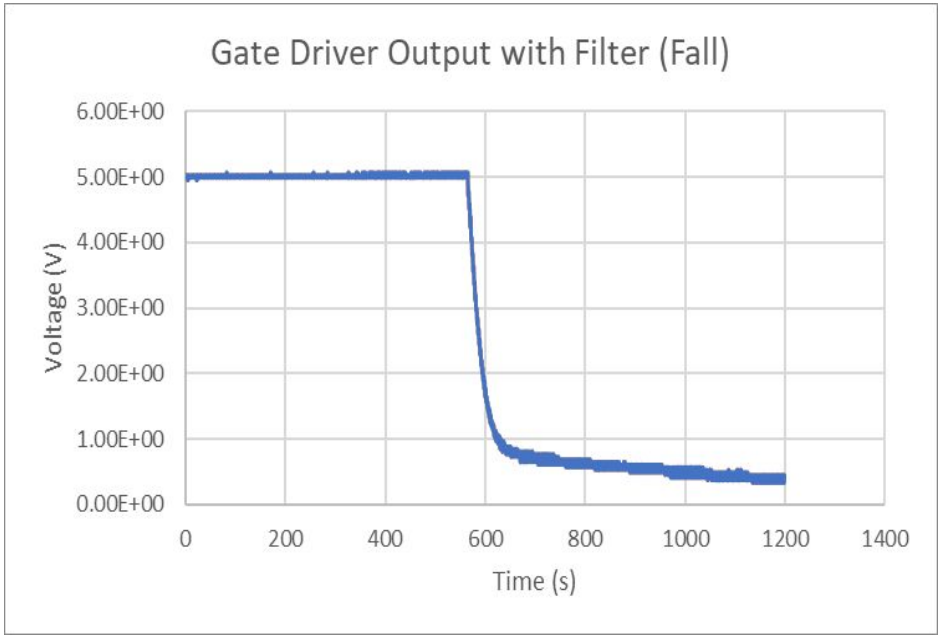
Gate Driver Output without Filter (Fall)

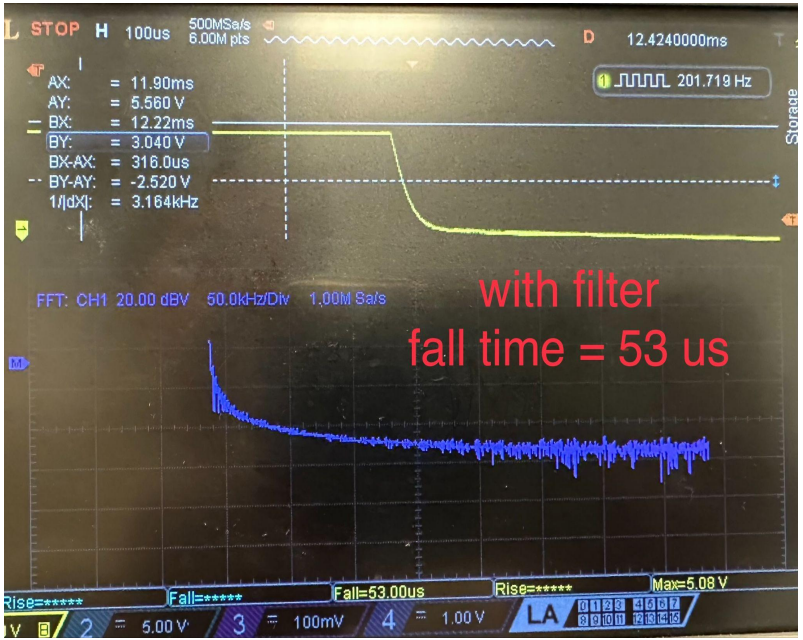




Figures 17-18 (left to right): Voltage vs Time Graph for Gate Driver Output without Filter

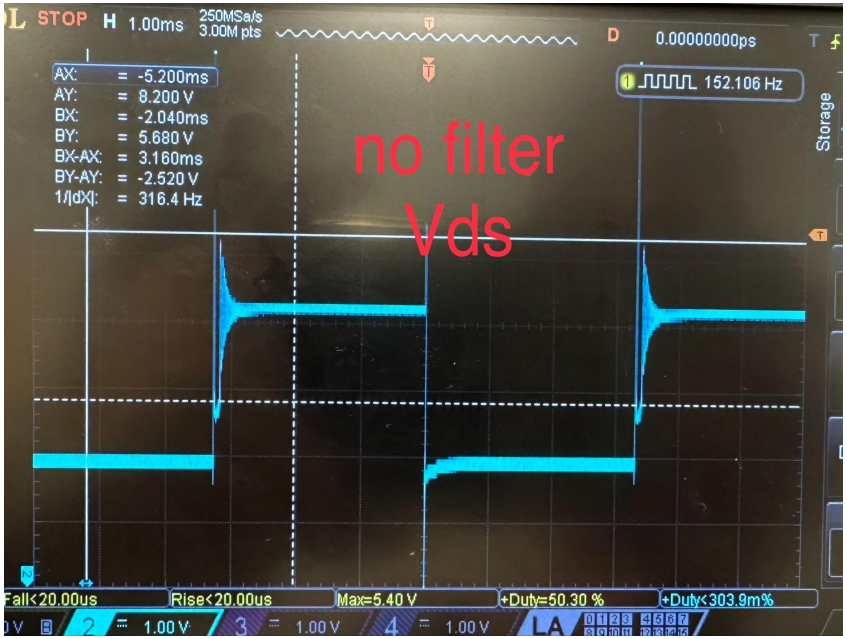
Gate Driver Output with Filter (Fall)

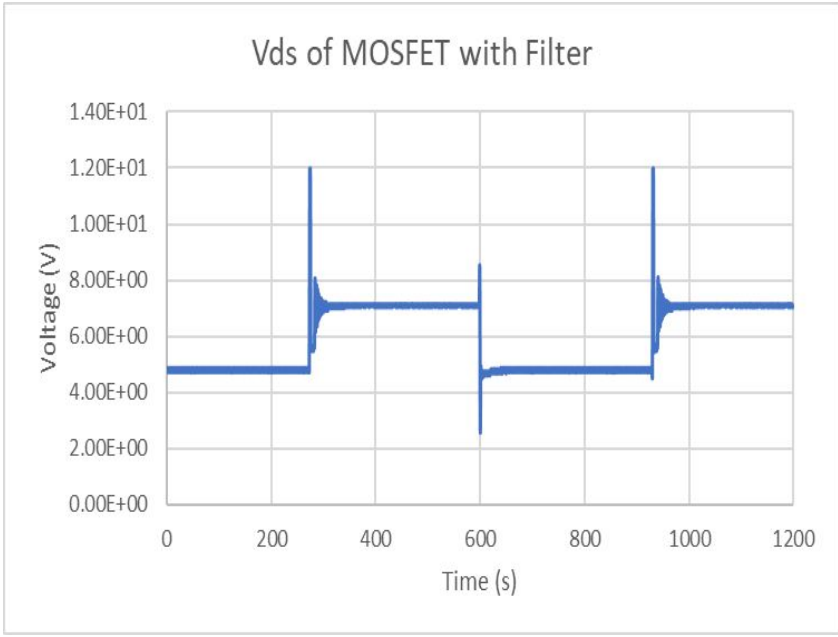




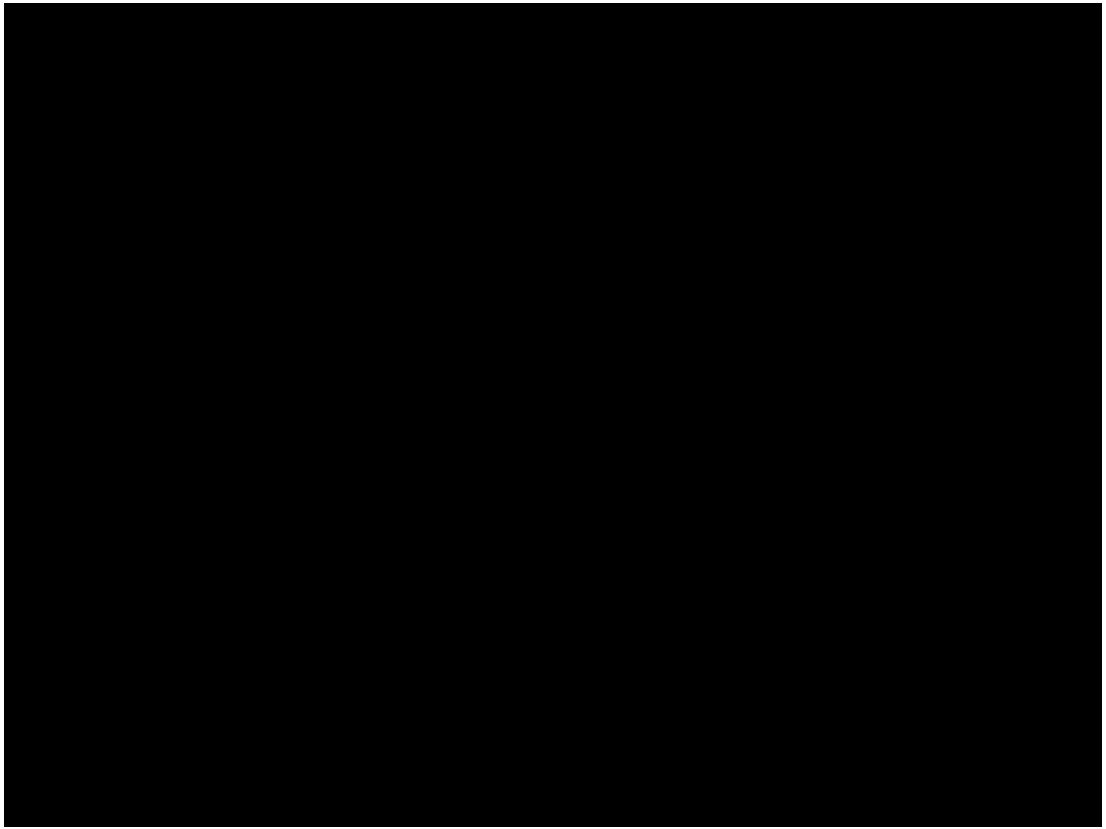
Figures 19-20 (left to right): Voltage vs Time Graph for Gate Driver Output with Filter

MOSFET (VDS)





Figures 21-22 (left to right): Vds vs Time Graph for MOSFET (without and with filter)



Video 1: Output of LED Due to Changing Frequency

Video 2: Output Signal on Oscilloscope Due to Changing Frequency and Voltage

Conclusion

Though by adding a filter between the gate driver and the MOSFET decreases the noise, the slew rate is much smaller. Based on the application of the circuit, the tradeoff between slew rate and noise has to be considered. For further testing, consider using different filters such as bandpass or high pass filters as well as testing at higher frequencies.

Reference

[1] H. Li, X. Liao, Y. Hu, Z. Huang, and K. Wang, “Analysis of Voltage Variation in Silicon Carbide MOSFETs during Turn-On and Turn-Off,” Energies, vol. 10, no. 10, p. 1456, Sep. 2017, doi: 10.3390/en10101456. https://www.mdpi.com/1996-1073/10/10/1456

[2] Texas Instruments, “AIGBT & SiC Gate Driver Fundamentals,” 2021, https://www.ti.com/lit/eb/slyy169/slyy169.pdf?ts=1700476981337&ref_url=https%253A%252F%252Fwww.google.com%252F.

[3] Adel S. Sedra, Kenneth C. Smith, Tony Chan Carusone, Vincent Gaudet, SEDRA/SMITH Microelectronics Circuits, 8th ed. NY: Oxford University Press, 2019.