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ECEN 5730 – Fall 2025

Lab 5 Report: PDN Noise and Capacitors

Objective

The objective of this lab is to build a simple slammer circuit on a solderless breadboard (SSB) to demonstrate switching noise in the power path, and to investigate how the position and value of decoupling capacitors influence the level of switching noise.

Plan of record

- Trigger a transistor by a digital signal from Arduino (Pin 13) or by an operational amplifier with rise times of 1 us and 5 ns respectively.
- Verify the rise times as well as the duty cycle of the input waveforms to the MOSFFET. Ensure that the duty cycle is less than 10%. So that the circuit doesn't smoke.
- Compare the switching noise for these different rise times with and without decoupling capacitors.
- Compare the switching noise for these different rise times with different values of capacitance.
- Explore the effect of the position of the decoupling capacitor on the power rail.

Component Listing

The specifications of the components used in this lab session are listed in the table below.

Component	Specification	Quantity	Component	Specification	Quantity
Resistor	10 Ω	1	Transistor	TIP41C	1
Capacitor	1000 uF	1	opAmp	MCP601	1
	1 uF	1	Arduino Uno	-	1

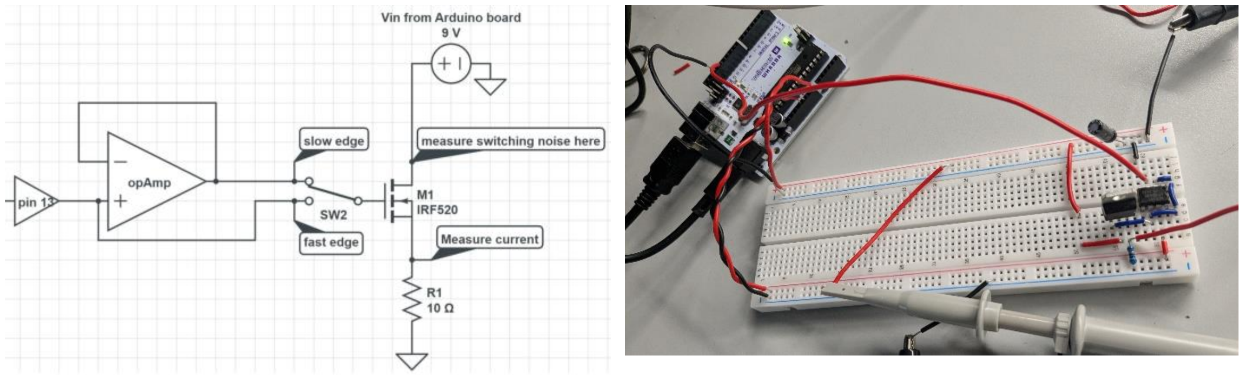
Circuit Diagram

A sketch of the major components of the circuit is shown in Fig.1.(a). The components on the SBB are illustrated in Fig.1.(b)

Measurement and Discussion

A scope capture of the duty cycles for Arduino pin 13 and the output of the opAmp is shown in Fig. 2. The duty cycles are both 4.805%. This safety precaution ensures that good amount of heat is produced in the circuit to prevent smoking. Fig. 3. shows the rise times of the two signals. We see that the rise time of pin 13 is 1.34221 us and that of the opAmp is 5.2043 ns. The short rise time has a large dI/dt and show more noise in the power rail than the long rise time. The switching noise for the slow edge without any decoupling capacitor is illustrated by the scope capture in Fig. 4. We notice in Fig. 5. that the level of switching noise decreases with decoupling capacitor from

1uF to 1000 uF. The reason is that large capacitance supply more transient charge to keep the voltage from drooping. Mathematically, $I = C\left(\frac{\Delta V}{\Delta t}\right) \rightarrow \Delta V = I\Delta t / C$, so increasing C reduces ΔV.



(a) (b)

Fig. 1. Sketch of slammer circuit (a), Photo of slammer circuit on SSB (b)

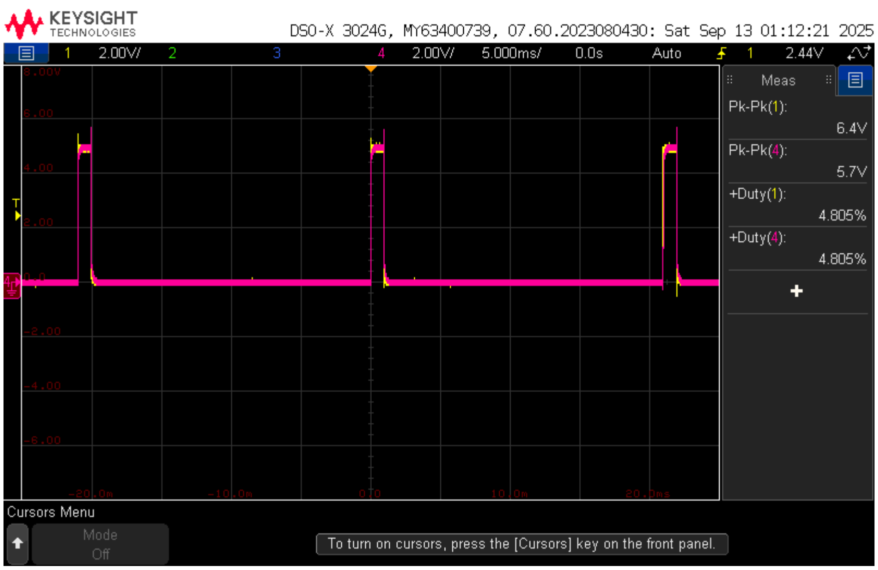
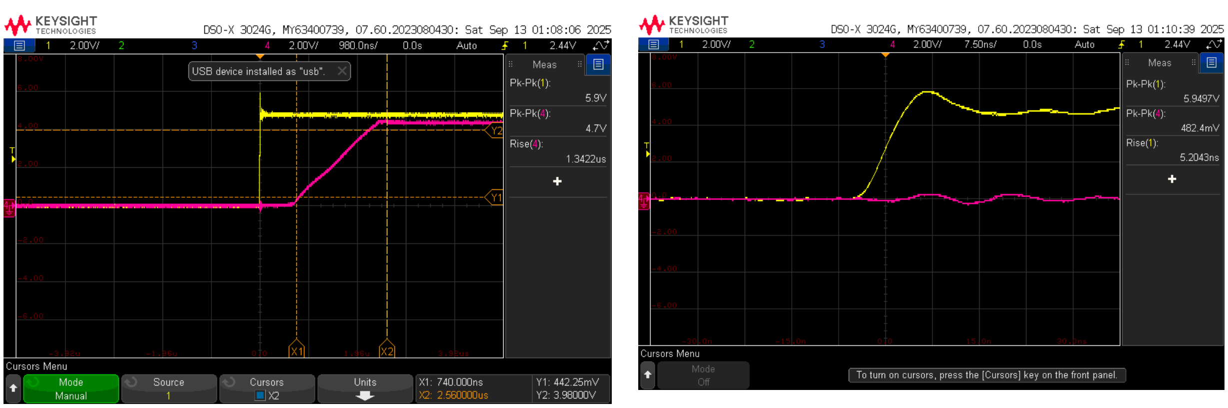


Fig. 2. Duty cycle of pin 13 signal (yellow) and opAmp output (pink)



(a) (b)

Fig. 3. Rise times of pin 13 (a) and opAmp (b)

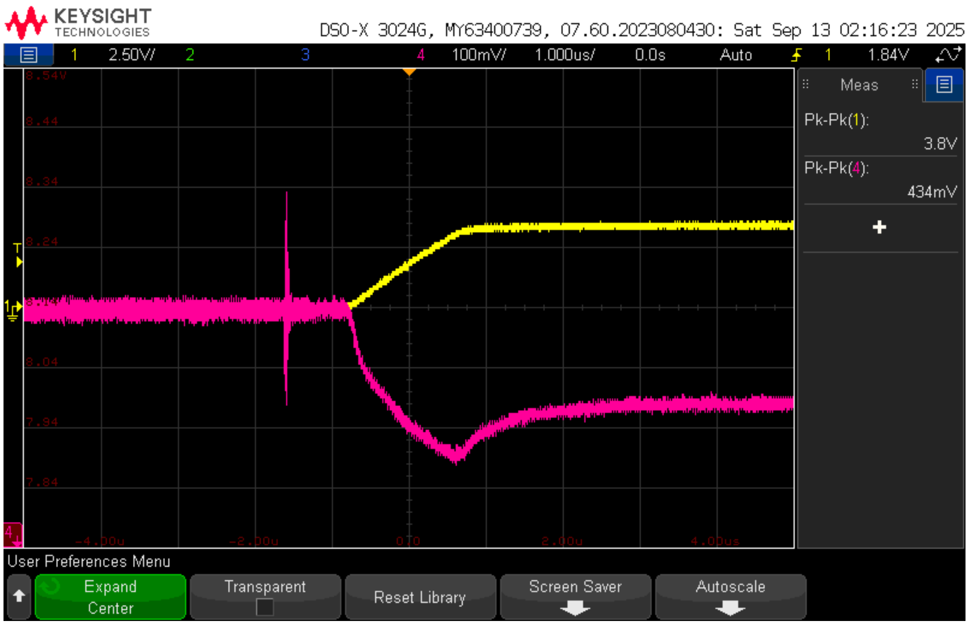
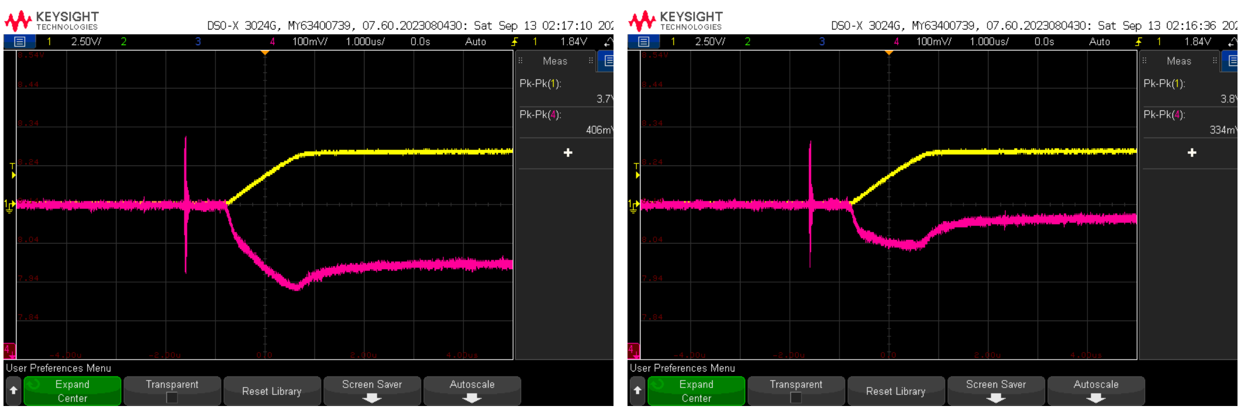
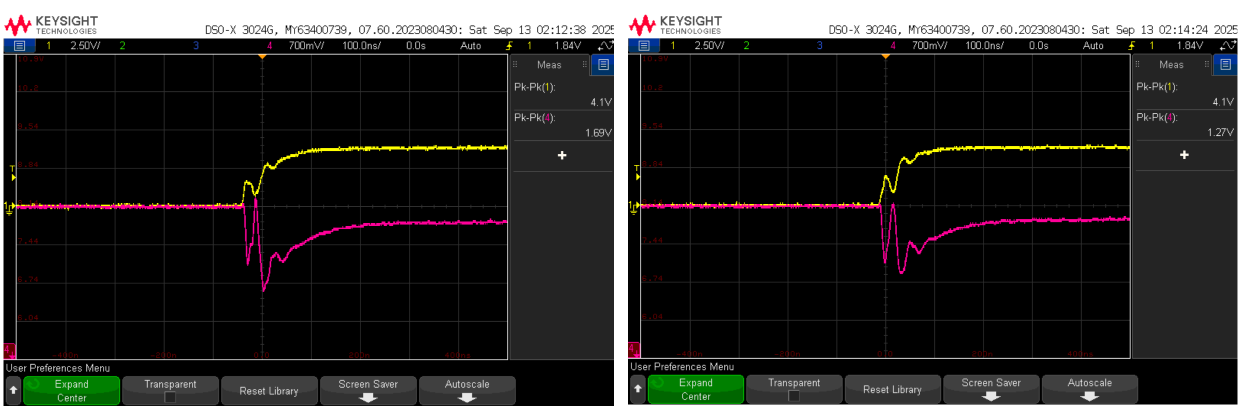


Fig. 4. Switching noise of pin 13 without a decoupling capacitor



(a) (b)

Fig. 5. Switching noise of fast edge with 1 uF (a) 1000 uF (b) capacitor



(a) (b)

Fig. 6. Switching noise of slow edge with 1 uF (a) 1000 uF (b) capacitor

A similar effect is shown in Fig. 6. for the slow edge. Furthermore, it was realized in the lab session that connecting the decoupling capacitor close to the circuit reduces the switching noise. This is because the signal does not have to travel through long distance which increases inductance.

Conclusion

In this lab, I learned that:

- Faster input rise times produce significantly larger switching noise compared to slower rise times.
- Introducing decoupling capacitors effectively reduces the switching noise with larger capacitance values providing greater suppression.
- Placing the decoupling capacitor closer to the circuit decreases the noise better.
- Both the value and placement of the decoupling capacitor are critical design factors in mitigating switching noise.