Lab 4 Report – Benefits of a Decoupling capacitor **-Rishab Shah**

Goal: The goal of this lab was to analyze that the switching noise can be reduced drastically when a decoupling capacitor is used specifically on the power rail. Switching noise is an artifact which is noticeable especially in fast rise time signals such as Arduino (typically Order of nsec)

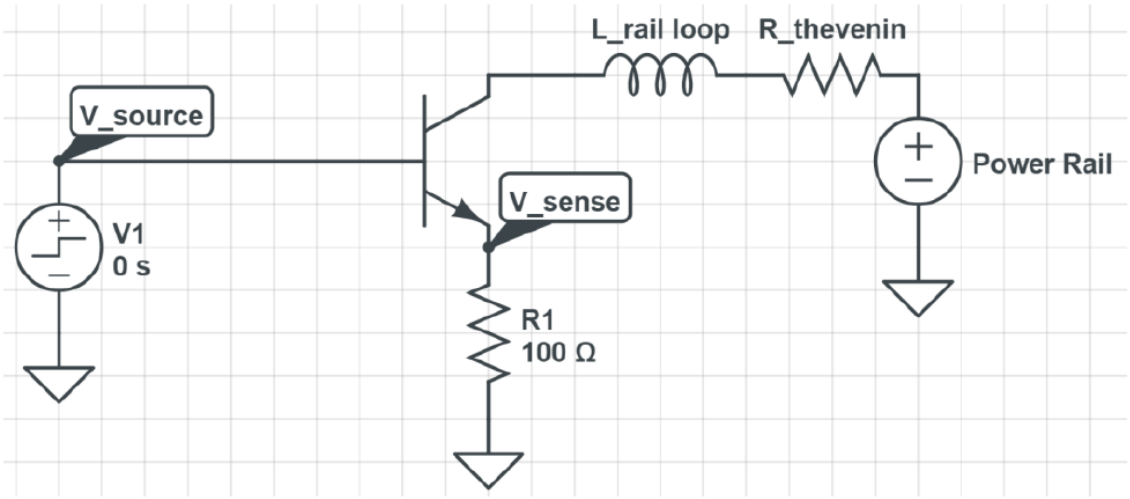


Figure 1 : Equivalent Circuit of Slammer circuit

In Figure 1, Equivalent circuit for slammer circuit represents Thevenin model of the 9 V VRM and the loop inductance of the path from the VRM to the transistor collector. When the transistor is off, the voltage observed at collector terminal is Vth and when the transistor is On, it represents Vload. The Vsource is Arduino's 5 % square wave for the fast rise time whereas arduino's 5 percent square wave + opamp (follower) for slow rise time.

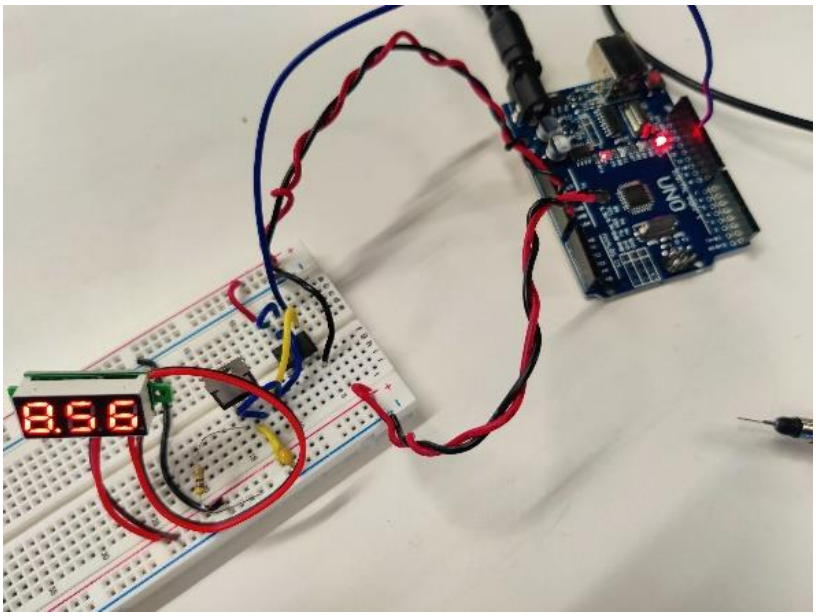


Figure 2 : Picture of the Slammer circuit using OpAmp (Follower circuit), Arduino (Power source) and Transistor (as a switch)

In Figure 2, The Arduino is used as an input source. The arduino alone as an input (Square wave with 5 % duty cycle) is used to provide a rise time of about 12 nsec whereas the arduino with the op-amp (follower circuit) provides a rise time of about 1.5 usec due to op-amp's slew rate.

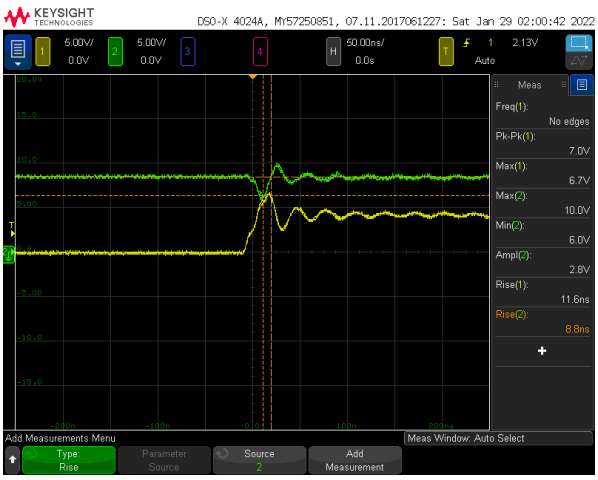


Figure 3: Switching noise with no decoupling capacitor at 9V power rail at collector of the transistor

In Figure 3, it is visible that a drop of about 2.8 V (Ampl(2)) occurs when there is no decoupling resistor. This happens due to inductance introduced due to the length of the power rail as seen in the equivalent circuit shown in figure 1.

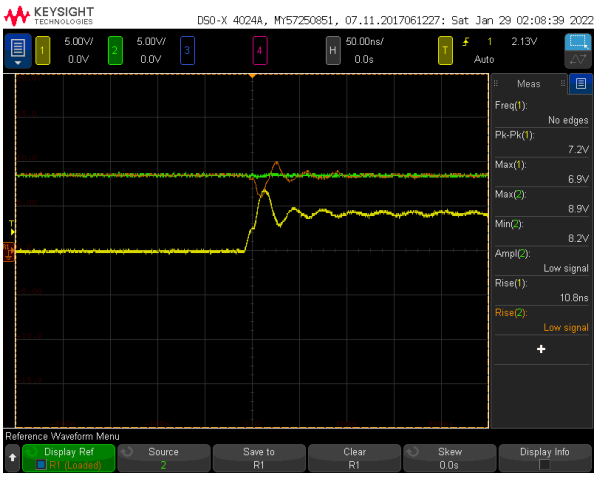


Figure 4: Switching noise with decoupling capacitor (1 uF) at 9V power rail at collector of the transistor

If Figure 4, It is seen that with the usage of 1 uF ceramic decoupling capacitor the Max(2) of noise is 8.9V whereas Min(2) is 8.2V.

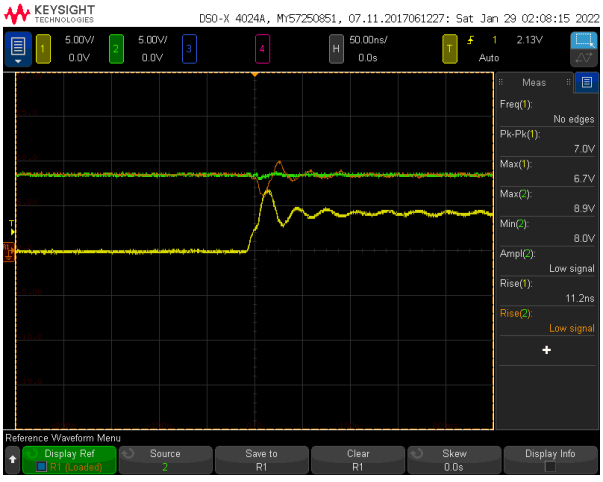


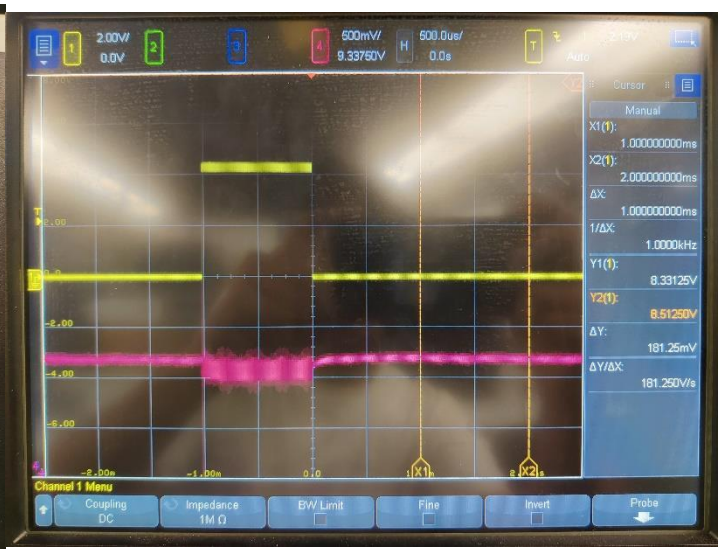
Figure 5: Switching noise with decoupling capacitor (1000 uF) at 9V power rail at collector of the transistor

If Figure 5, It is seen that with the usage of 1000 uF electrolytic decoupling capacitor the Max(2) of noise is 8.9V whereas Min(2) is 8.0V.

Inference: The electrolytic capacitor is comparatively less effective because it is comparatively bulky and would add a little inductance whereas ceramic is more effective because of its small size.

Measurement Values:

For Thevenin Resistance and Voltage,



From the above measurement,

Vth = 8.5125v (Y2 in Image)

Vl = 8.3125v (Y1 in Image)

Rth = Rl*(Vth-Vl/Vl)

= 10*(8.5125-8.3125/8.3125)

Rth = 240 mOhm

For Loop Inductance of power path,

I = V (at emitter)/R => 4.70 /10 = 470mA (from the image above)

From the above two images,

L = (delta V)*(dt/di)

= 8.6v*(21.629nSec/470mA)

L = 395.76 nH

Ans: The final calculation based on measured values sis as follows:

1. Thevenin voltage = 8.5125v and resistance of the VRM = 240 mOhm
2. loop inductance of the power path from the collector to the VRM = 395.76 nH