ECEN4730 Lab5 Solderless-breadboard and slammer circuit

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1. Lab Goal

In lab5, this lab aims to understand better how the switching noise is generated in the circuit and how the circuit topology can solve the switching noise. The switching noise is due to the power rail's inductance and dI/dt. When the voltage drops/up, there is an inrush current in the circuit; a sudden current change makes a significant voltage change in the circuit transition state. And such voltage drop produces the switching noise in the circuit. The lab will conduct many experiments and data sets to better understand this noise. In addition, this lab finds that a faster-rising edge will also introduce a considerable switching noise in the circuit. So, this lab uses some methods to reduce the switching noise by putting a decoupling capacitor close to the ICelementt and using the component with at least 1us rising edge.

2. Equivalent Circuit of the slammer circuit

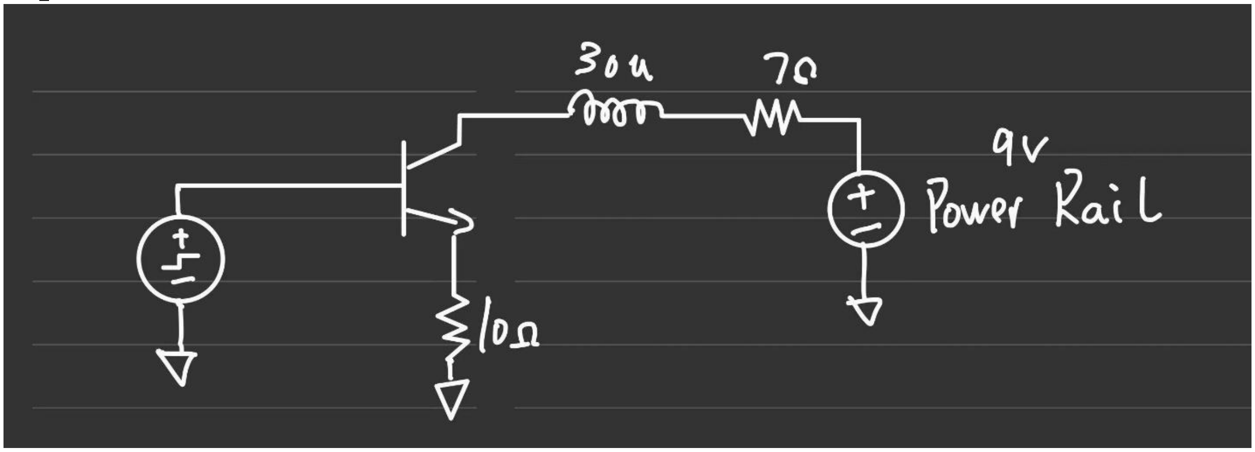

Figure 1. Equivalent Circuit of the slammer circuit

The Thevenin voltage of the Voltage regulator module(VRM) is 8V, and Thevenin resistance is calculated as 7 Ω. The analysis is shown below:

- Using Voltage divider formula: Vth = $\frac{R}{R+Rth} * Vin$
- First, shorted the power pail and measured the voltage across the power rail. I got 8.6V across it as the Vin.
- Then, put a resistor R with 1kΩ resistance, and measure the voltage across the power rail again. I got 8V as the Vth
- The only unknown in this equation is Rth. So, it is solvable by applying the voltage divider equation.

The loop inductance of the power path from the collector to the VRM is 34uH.

The analysis is shown below:

- Using the formula: $\Delta V = L\frac{dI}{dt}$
- ΔV: There is an 8V drop across the induction.
- dI: There was a 3.5V drop at the rising edge, and 10 Ω was used to measure the current. So, 0.35A.
- dt: the rise time is 1.3us.
- L can be solved, and it is 30uH.

3. Show a photo of my circuit

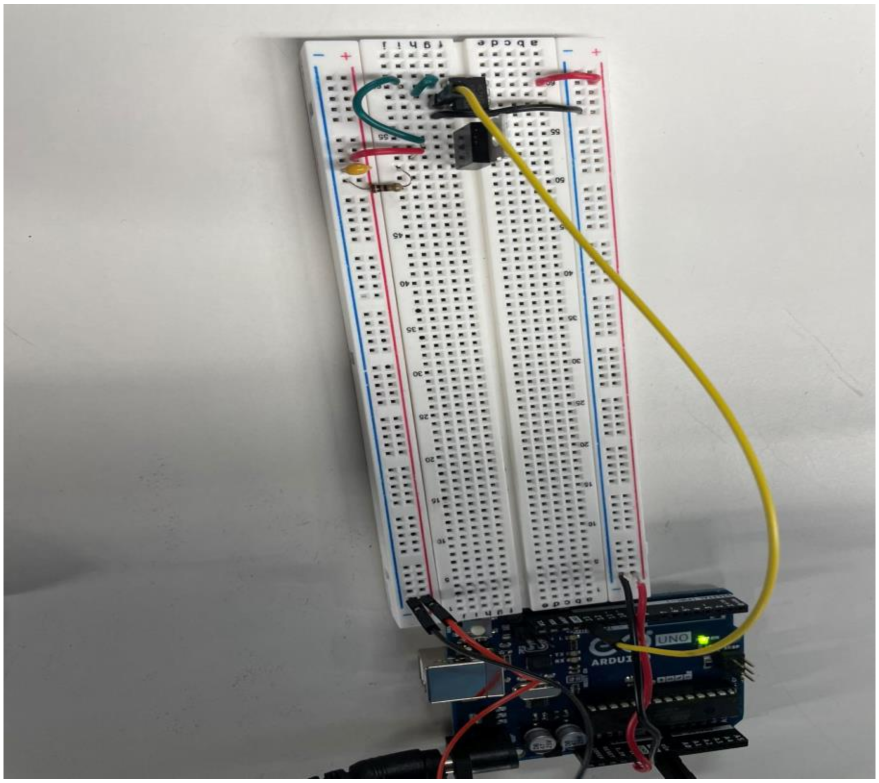

Figure 2. Slammer circuit on the breadboard

As shown in Figure 2, the circuit is built on a breadboard.

- Red: Power
- Black: Ground
- Green: Signal wire, which sends the output of the IC to the transistor.
- The yellow wire: is the signal wire, which generates the signal, has a duty cycle of less than 20%, and it goes to the pin of the IC.
- Resistor: 10Ω
- Capacitor: 1uF
- IC: MCP602
- Transistor: TIP31C

4. Illustrate the impact on the switching noise without the decoupling capacitor

Figure 3. Switching noise without the decoupling capacitor at slow fall time

Figure 4. Switching noise with 1uF decoupling capacitor at slow fall time

As seen in Figures 3 and 4, the switching noise is reduced. Without the decoupling capacitor, the signal shows more fluctuations in the transition period, and there is a more significant voltage change. However, with the decoupling capacitor, the signal shows more smooth voltage change during the transition period, and there is less voltage change. Since the switching noise is due to the inductance and the dI/dt in the power rail, the decoupling capacitor provides an instantaneous charge source so that the current wouldn't have to go the rest of the circuit. Moreover, the decoupling can keep the

IC component stable by supplying current flow when the input voltage drops and vice versa.

5. **Illustrate the impact on the switching noise of the 1uF and 2200uF capacitor.**

Figure 5. Switching noise with 2200uF decoupling capacitor at slow fall time

Figures 4 and 5 show that with the 2200uF decoupling capacitor at slow fall time, the switching noise is significantly reduced, and the signal is smoother.

However, this impact is not valid when the signal is measured at a fast fall time; the difference between using 1uF and 2200uF decoupling capacitors is insignificant. In this lab, the goal is to lower the voltage drop to 0.4V. In this lab, the capacitance no longer matters when it passes through the threshold capacitance, i.e., 1uF. And the more critical factor that can better help noise reduction is the distance between the decoupling capacitor and the IC component. The closer the capacitor to the IC component, the better the noise reduction.

6. What do I learn from these experiments

1) Colored the wires used in the breadboard circuit implementation

(a) Red:Power
(b) Black: Ground
(c) Blue: Negative power rail
(d) White: clock lines
(e) Yellow, Grey, Brown: digital lines
(f) Green: Analog signals or sometimes ground

2) The cause of switching noise

(a) the switching noise is due to the inductance and the dI/dt in the power rail

3) How to reduce the switching noise

(a) Connect decoupling capacitor
(b) Move the decoupling capacitor close to the IC
(c) Short return path
(d) Keep signal trace short
(e) Keep component leads short

4) The closer the decoupling capacitor to the IC, the better noise reduction achieved

(a) Find threshold decoupling capacitance first, then put the capacitor close to the IC as much as possible.