ECEN 3730-
PCB Design,
Connor Sorrell

Lab 18 Report: Measure the in rush current and operation current of a board

Introduction:

In this lab, we measured the steady state current of a circuit's operation as well as the inrush current. To measure power rail current, we place a small sense resistor in series with the power rail, creating a proportional voltage drop. By measuring this voltage difference, the current can be calculated, allowing for analysis of both steady-state and transient currents in the circuit

Setup:

To estimate the value of the sense resistor, I referenced the expected steady-state current of the circuit, aiming for a value that ensures that circuit operation won't be significantly affected, but still produce a measurable voltage drop. To do this, I used my best judgement based off of the circuit. The circuit has a 555 timer driving an LED through a 100Ω resistor. Estimating a high output voltage of ~3.5 V from the 555 timer, as well as a forward voltage of ~2.7 V from the LED, I calculated

$$I = V/R = (3.5\,V - 2.7\,V)\,/\,100\Omega = 8mA \;\; (expectation\ for\ steady\ state\ current)$$

Then, I aimed for a small, but measurable voltage drop of ~20mV during steady state operation.

$$R = V/I = 0.02/0.01 = 2\,\Omega.$$

Since I did not have a 2Ω resistor in my kit, I used 1.5Ω for my sense resistor, placing it on the power rail to ensure all current flowing into the IC passes through it.

Step 1: Find the steady state current

First, with the 1.5Ω sense resistor placed in series with the power rail, I used two scope probes to measure both the high and low sides of the resistor.

-The oscilloscope showcased a 10mV drop over the sense resistor during the circuits steady operation

- $I = V/R = 0.01\,V\,/\,1.5\Omega = {\sim}6.7mA$

This means that at steady state, 6.7mA is flowing through the sense resistor. This matches our expected value of the current draw of the LED, in which we estimated 8mA.

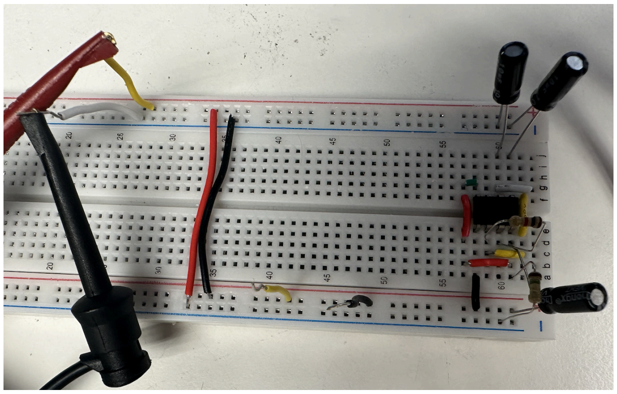

Figure 1: Shows the circuit setup with 555 timer and sense resistor

<u>Step 2: Inrush current using three different capacitance values</u>

- Across the sense resistor is a decoupling capacitor which causes an initial inrush current when the circuit is powered on.
- On the oscilloscope, I triggered the rising edge voltage of the sense resistor, and then used the math function to find the voltage difference.
- I then performed this measurement using three different values for the decoupling capacitor;
    - 10µF, 100µF, 1µF

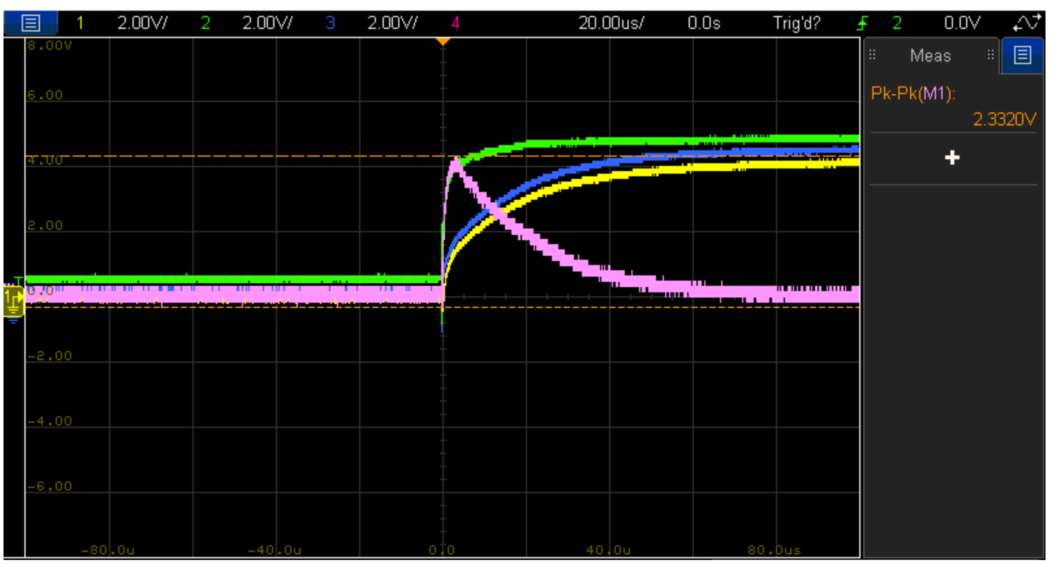

Figure 2: Shows the voltage difference across the sense resistor (pink waveform) at the moment the power is turned on (With 10µF decoupling capacitor)

- From this screenshot, we see that the circuit exhibits a significant inrush current. With ~2.2V across the resistor, I estimate $I = V/R = 2.2 / 1.5 = \sim 1.47\ A$ of inrush current while using a 10µF decoupling capacitor

- This makes sense, because when power is initially supplied, the capacitor starts charging
    - Because an uncharged capacitor acts as a short circuit, a large current rushes into the IC (~1.47 A).
    - This current (inrush) eventually levels off as the capacitor is charged, and returns back to the steady state current (6.7mA)

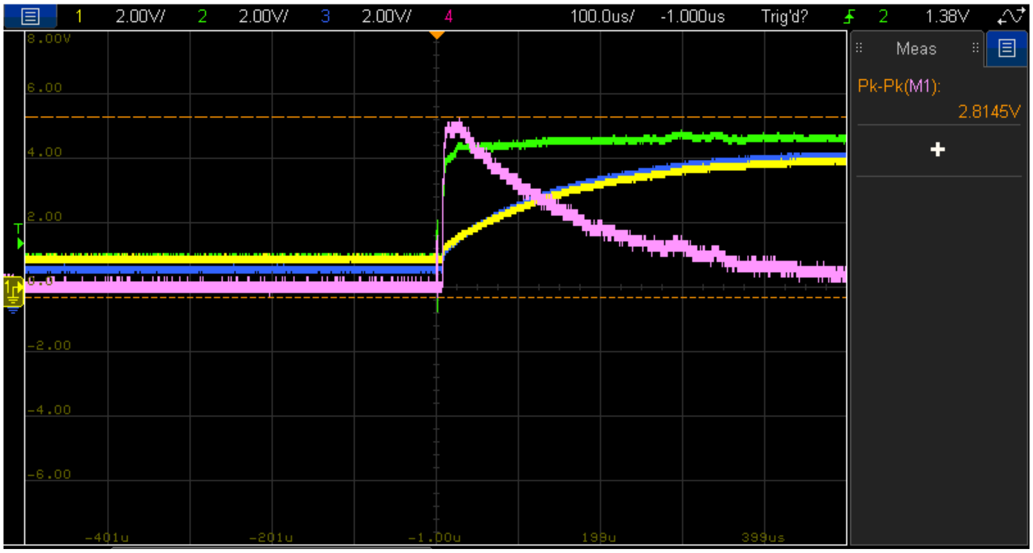

Figure 3: Shows the voltage difference across the sense resistor (pink waveform) at the moment the power is turned on (With 100µF decoupling capacitor)

- From this screenshot, we see that with a much higher capacitance, our inrush current is even larger.
- This time, we see $I = V/R = 2.7\,V / 1.5 = \sim 1.8\,A$ of inrush current
- Additionally, a higher capacitance exhibits a longer dropoff– the 100µF decoupling capacitor causes it to take over 400µs to level off back to steady state current, compared to the 10µF capacitor which levels off to steady state current in only 80µs. **(5x less time)**

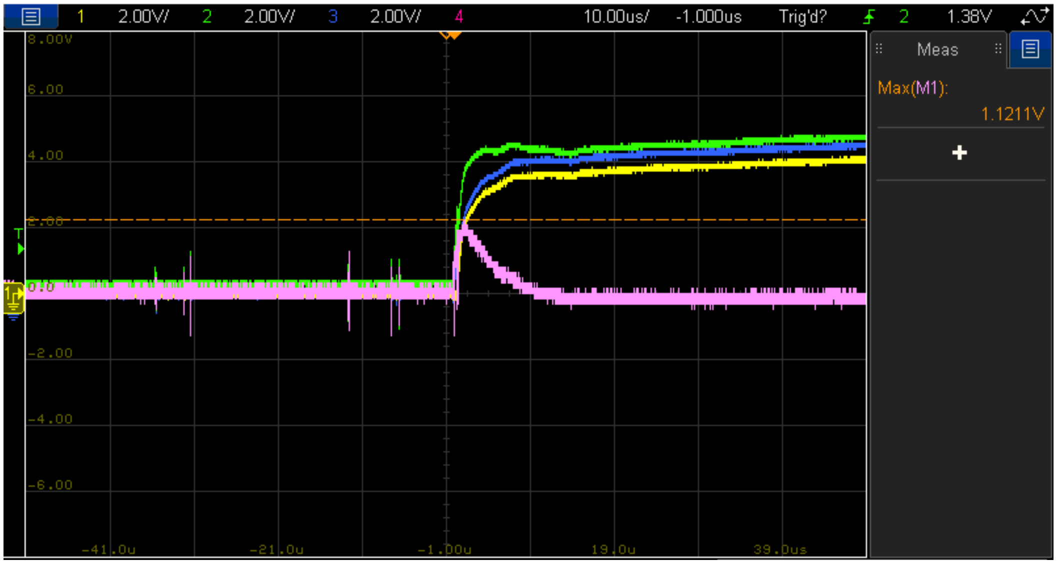

Figure 4: Shows the voltage difference across the sense resistor (pink waveform) at the moment the power is turned on (With 1µF decoupling capacitor)

- As seen from this screenshot, a 1µF decoupling capacitor causes even less inrush current. In this case, we see $I = V/R = 1\,V\,/\,1.5 = \sim 0.67\,A$ of inrush current
- In this case, it takes less than 20µs to return to steady state current

<u>Conclusion/Takeaways:</u>

- Inrush current = initial voltage spike on sense resistor upon power-on.
- A larger capacitance value results in a larger inrush current
- The duration of the inrush current also increases with capacitance
    - This confirms the expected–that the inrush current is directly proportional to the decoupling capacitor following the formula $I = C\frac{dV}{dt}$
- A high inrush current can be a potentially dangerous surge for a circuit
    - Can cause voltage drops, trip fuses, or ruin a power supply
    - A large decoupling capacitor should be used CAUTIOUSLY

Overall, I learned the importance of measuring transient currents in real world circuit design. I now better understand how capacitance value selection affects power rail stability, how to find a value for a sense resistor, and how to measure the current in the power rail to find both the steady state current and inrush current of a circuit. Moving forward, I am excited to potentially learn some techniques for mitigating this inrush current.