University of Colorado - Boulder

ECEN 5730
Practical PCB Design Manufacture — Fall 2024

Lab 18 Report - Power Rail Current Measurement

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Introduction

This lab focused on measuring the power rail current in a circuit by using a series resistor and observing inrush current effects with different decoupling capacitor values. Using an NE555 timer circuit, we evaluated the effectiveness of measuring methods and observed how current draw and inrush currents vary with decoupling capacitor values. Key objectives included understanding setup configurations and analyzing data from oscilloscope readings to calculate current measurements.

Principle of Power Rail Current Measurement

Power rail current measurement relies on inserting a known resistor in series with the power supply and measuring the voltage across it to calculate the current based on Ohm's Law. This method allows us to monitor both steady-state current draw and transient events such as inrush current. In this lab, a 1-ohm resistor was chosen as the series resistor to facilitate precise voltage readings, translating directly to current values in amperes (e.g., 10mV across 1 ohm corresponds to a 10mA current).

Setup

The circuit setup included an NE555 timer as the primary active component, with a 10uF decoupling capacitor on the power rail. Channel 1 of the oscilloscope was connected to the high side of the 1-ohm sense resistor, Channel 2 to the low side, and Channel 3 monitored the NE555 output. This configuration allowed us to capture both steady-state and inrush current effects.

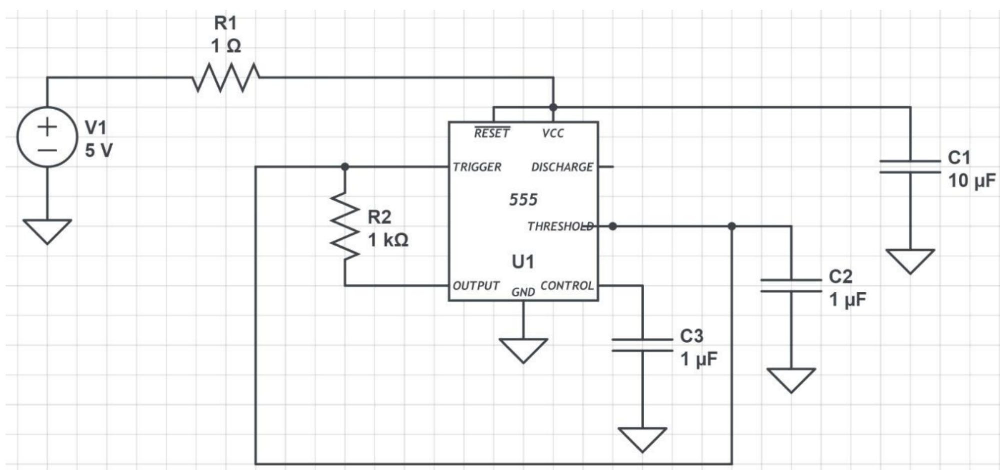

Figure 1: Circuit Schematic

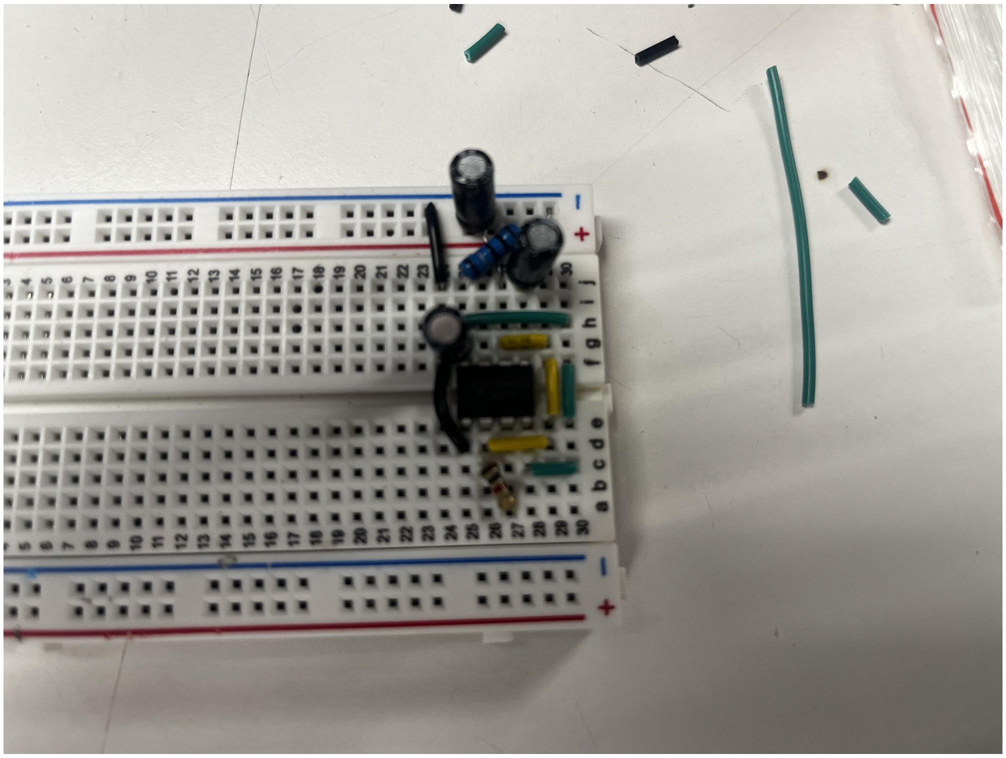

Figure 2: Physical Circuit Setup

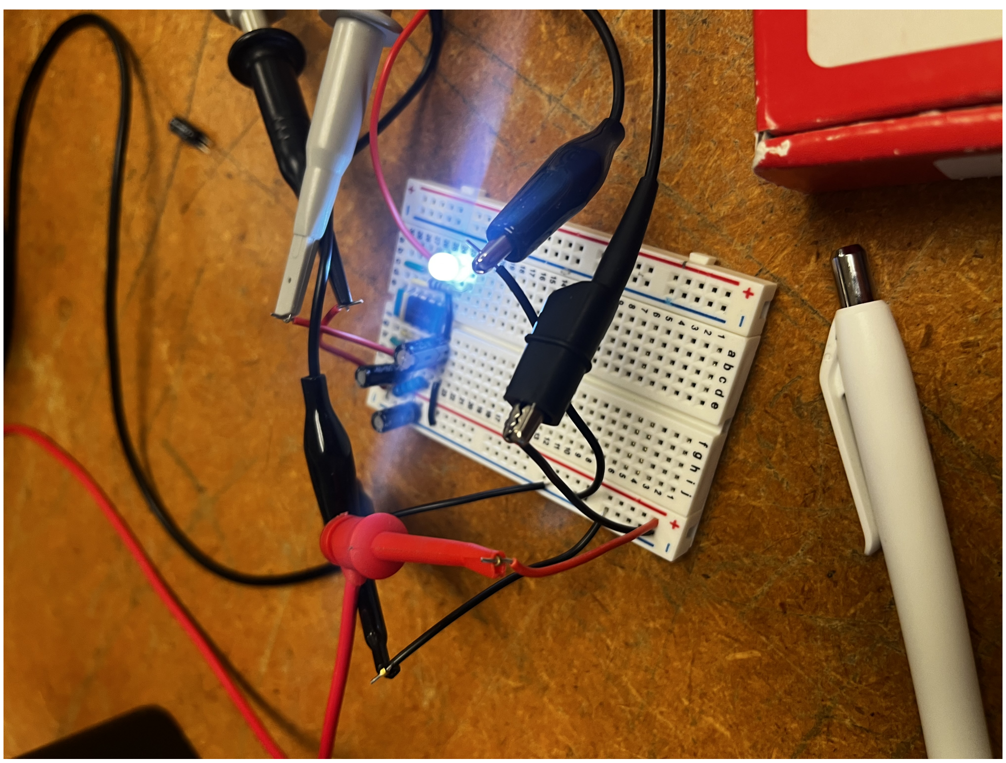

Figure 3: Oscilloscope Setup

Results

Steady-State Current Measurement

Using the NE555 timer output waveform as a reference, we measured the steady-state current across the 1-ohm resistor by observing the voltage difference between the high and low sides of the resistor. The oscilloscope capture below shows the blue trace as the trigger signal, the yellow and green traces as the voltage on the high and low sides of the resistor, and the pink trace as the differential voltage across the resistor. The 10mV voltage across the resistor corresponds to a steady-state current of approximately 10mA.

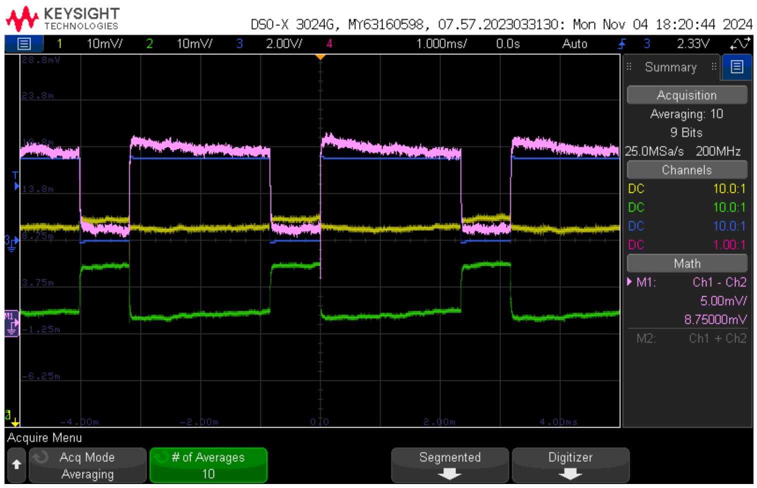

Figure 4: Steady-State Current Measurement

Inrush Current Measurement with 10uF Capacitor

To measure inrush current, we triggered the oscilloscope on the rising voltage across the sense resistor, capturing the transient current spike that occurs when the power is applied. With a 10uF decoupling capacitor, the inrush current measured was approximately 2.3V across the 1-ohm resistor, indicating an inrush current of 2.3A. This rapid current spike dissipated within 40µs.

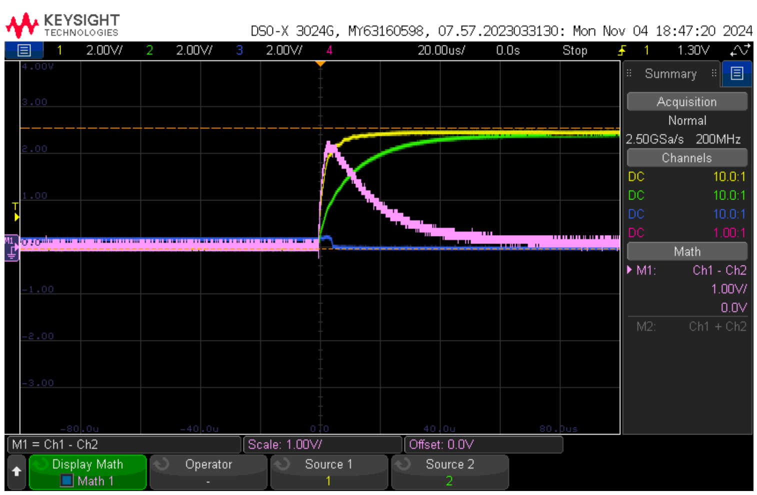

Figure 5: Inrush Current Measurement with 10uF Capacitor

Inrush Current Measurement with 100uF Capacitor

Substituting the 10uF capacitor with a 100uF capacitor resulted in a higher inrush current of approximately 3V (3A across the 1-ohm resistor) and a longer dissipation time of 400µs. This prolonged dissipation aligns with expectations, as the larger capacitance requires more time to charge and discharge due to its greater ability to store electrical energy.

Discussion

The experimental results demonstrated the impact of decoupling capacitance on inrush current behavior. With a larger capacitor, we observed both a greater inrush current and a longer discharge time, which can be attributed to the increased energy storage capacity of the 100uF capacitor compared to the 10uF capacitor. This prolonged dissipation indicates a higher power requirement for systems with larger decoupling capacitance, a critical consideration in power-sensitive designs.

Additionally, the NE555 timer circuit allowed for consistent measurements by providing a steady output waveform, which we utilized as a timing reference for all measurements. The differential measurement (yellow - green traces) showed minor noise at 5V, confirming the need to average samples for clearer readings in noisy environments.

Question Responses

1. **Explain the principle of measuring the power rail current.** By placing a known resistor in series with the power rail, we can measure the voltage drop across it and calculate the current using Ohm's Law. This technique provides real-time monitoring of both steady-state and transient currents.

2. **Illustration of series resistance circuit setup.** Refer to Figures 1-3, showing the schematic, physical setup, and oscilloscope probe arrangement for measuring voltage across the sense resistor.

3. **Circuit and resistor value estimation.** A 1-ohm resistor was selected to allow for millivolt-level readings directly corresponding to milliamp-level currents, balancing precision and minimal circuit interference.

4. **Steady-state current measurement.** The steady-state current across the resistor was 10mA, derived from the 10mV reading shown in Figure 4.

5. **Inrush current measurement with decoupling capacitor changes.** With a 10uF capacitor, we measured a 2.3A inrush current. Increasing capacitance to 100uF raised the inrush current to 3A and prolonged dissipation.

6. **Summary of observations.** The lab highlighted the significance of capacitor size in managing inrush currents and current stability. Larger capacitors increase the inrush current and extend dissipation times, which can influence power rail stability, especially in sensitive circuits. This understanding is essential for designing power-efficient circuits, where capacitor choice directly affects transient behavior.

Conclusion

This lab underscored the importance of understanding inrush current characteristics and the role of decoupling capacitors in power rail stability. Our findings suggest that while larger capacitors provide greater noise filtering, they introduce higher inrush currents and longer dissipation times, which can strain power supplies and affect other circuit components. Optimizing capacitor values is essential for achieving a balance between noise rejection and transient current management.