University of Colorado Boulder

Electrical and Computer Engineering

University of Colorado Boulder

ECEN3730 Practical PCB Design Manufacture

LABORATORY REPORT

Lab 25: Ferrite Filters

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1 Introduction

In this lab, we explore the characteristics and applications of ferrites, which are essentially inductors with inherent loss and resistance. We will focus on their role as noise filters for sensitive analog devices, not as universal power rail filters.

2 Objectives

1. Explore the application of ferrite filters in reducing noise on the power pins of sensitive analog devices.
2. Evaluate the filtering effectiveness of three different ferrite filter circuits.
3. Understand why high resistance makes ferrites unsuitable for SMPS filters.

3 Fitler Board

The board used for this lab is a premade board with three circuits on it.

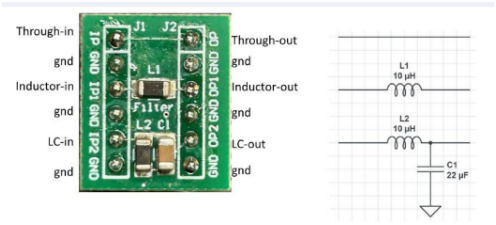

Figure 1: Ferrite Filter Board

The board has a straight-through trace, a trace with a 10uH ferrite in series, and lastly a LC filter. We will connect one end of the filters to the power rail.

We will use a slammer circuit to draw a large transient on the power rail, using a transistor to switch a large current through a resistor very rapidly. This will create lots of noise on the power rail and we can test the effectiveness of the filters. We will use an Arduino to switch on and off the transistor. We want the fastest rise time to create the most noise on the power rail.

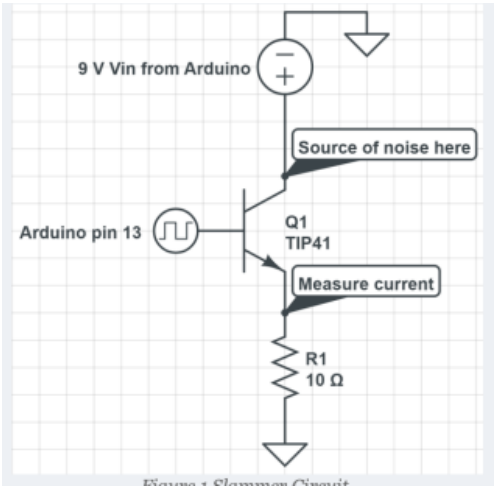

Figure 2: Schematic of Filter Board

4 Experiment

4.1 Initial predictions

We should predict what we will see when we do the measurement. We expect to see three distinct different outcomes from the three filters on the board. For the straight wire, we expect

to see the full extent of the noise, a massive rail collapse. For the ferrite filter, we expect to see less of a rail collapse, and some ripple. The ferrite alone is not enough. With the LC filter we should see almost no noise on the filter. The capacitor and the inductor will work to smooth out the noise. There is nearly a 96% noise reduction.

The LC filter is a two pole low pass filter. The expected pole frequency is: $f = \frac{1}{2\pi\sqrt{LC}}$ The frequency of this filter is 10.7khz.

4.2 Measuring Circuit

We use the slammer circuit and can view the difference between filters on an oscilloscope.

Pink - Voltage across sense resistor Blue - Straight through wire Green - Single ferrite filter Yellow - LC Filter

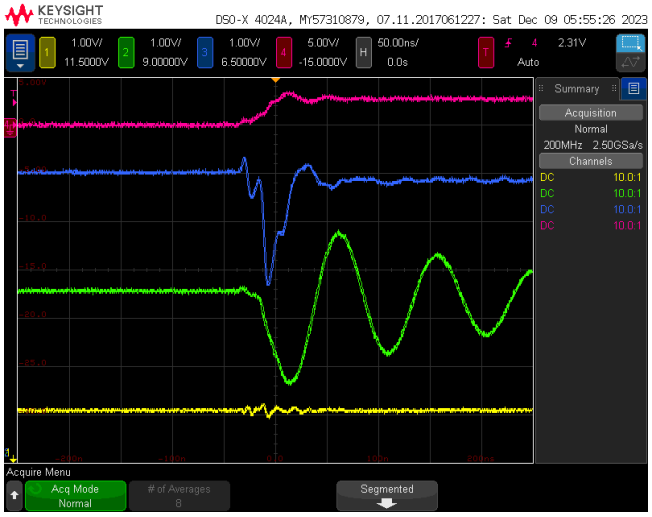

Figure 3: Gate Voltage of Board 4

We can see the three filters and their effect. The straight-through wire we can see the massive power rail collapse as we expected. The collapse is nearly 2.5Vpp. Thats a huge rail collapse. The ferrite filter is slightly better, however, it introduces a new problem. The power rail collapse does not go nearly as far down as before, but the rebound ripple is huge. The peak to peak of the voltage is around 3.5v, worse than before. To solve this, we can introduce the capacitor and make the Lc filter. We see the LC filter has only 20mVpp of noise.

4.3 Bad things about ferrite filters

While it may seem like using a filter on every power pin is a good idea, in reality, it is not. It is useful on the sensitive pins of analog devices, but not applicable in many other applications. This is due to the series resistance the ferrite comes with. This is typically around 0.1 ohm to 1 ohm. Having a 1 ohm resistor on a power pin to a large microcontroller that consumes lots of current is not a good idea. The ferrite will heat up and potentially damage the circuit. The voltage drop caused by the filter is also a potential and harmful problem.

4.4 Learnings

- Recognition of ferrites as inductors with inherent loss and resistance.
- Awareness of the unsuitability of ferrites for general-purpose SMPS filter applications due to their high resistance.
- Practical exposure to a test board featuring three independent circuits designed for noise reduction using ferrite filters.
- Understanding the significance of the correct orientation of ferrite filters for optimal performance.
- Recognition of potential challenges with increased noise when significant current flows through the ferrite.

4.5 Conclusion

Understanding the filtering capabilities of ferrite filters is crucial for applications where noise reduction is essential. The experiments conducted shed light on the effectiveness and limitations, showcasing the selective nature of the filters.