**Jamesy’s PFF (Interview) Circuit Design Log**

Problem:

Using [KiCAD](http://kicad-pcb.org/), design a circuit schematic for an analog amplifier with the following features:

1. Uses a 5VDC power supply. Assumes the signal to be amplified shares the same ground as the power supply.
2. Amplifies an input analog signal that can range from 0 to 2.0V so that the output ranges from 0 to 5V.
3. Contains a bill of materials (BOM) specifying the chosen components and how to source them.
4. Has an adjustable gain. And a low-pass filter with adjustable cut-off to filter-out noise from the input analog signal.
5. OPTIONAL: Is implemented as a routed PCB.

The design can be submitted as a GitHub repository file containing the KiCAD project and a printable (Letter) PDF with the schematic and if available another PDF in 1:1 scale of the routed PCB.

A solution:

I will start with what I do know and potential solutions, then mention some of the stuff I don’t know (which may have helped refine the design decisions) and the elaborate on my solution.

For requirement 1 and 2. Assuming we want the output to truly hit 5.0V then we will need to step up the input 5VDC to something higher before using it with op-amp. Rail-to-rail op-amps don’t really reach 100% of the full rail voltage and we shouldn’t let it saturate for a 2V input anyways. So stepping up the input voltage would allow the design to get around that limitation. For simplicity (and reducing the amount of time it takes me to get this done) I will assume that the 5VDC will not need to be stepped up for this application.

For requirement 4, I will assume that the cutoff frequency and gain need to be independently adjustable. Before learning of the needed adjustability, I was thinking of a simple RC lowpass with some non-inverting gain. I can still keep the same topology, with the addition of trimpots for manual adjustments. For simplicity (and reducing the amount of time it takes me to get this done) I will assume that digital cutoff and gain control aren’t required.

There are three key unknown design aspects for this problem. First, the input and output impedance requirements. Second, the “order” requirements of the filter. Third, the range of desired cutoff frequencies. I will use the unknowns to my advantage and design a relatively simple circuit.

Since I will be using a trimpot to adjust the cutoff anyways (along with an op-amp), I decided to change from a 1st order RC filter topology to 2nd order Sallen-Key topology. The non-inverter gain stage will remain the same.

For simplicity in calculations and minimizing BOM complexity, I will keep the capacitor values the same. Now I have to pick the resistive values for the filter. Since I wasn’t given a requirement I decided to arbitrarily make the lowest cutoff frequency ~1kHz. I decided to use 100k trimpots because that is a very common and readily available value. I decided to select trimpots with as many turns as possible to give finer manual tuning of the cutoff frequency. In my case I selected a 100k-ohm 25 turns trimpot. The selected capacitive value of 3.3nF allows me to adjust the cutoff frequency from ~1k to infinity.

I searched for rail to rail in the KiCAD standard library and the MCP general purpose OPAMP came up. So I will use it. Since I don’t have super specific requirements, it should do. Hopefully the 4.5mV input offset voltage won’t be a problem.

One of the few timed quiz questions I took issue with:

You are measuring the current in a circuit that powered by an 18V battery. The ammeter reads 40 mA. Later you notice the current has dropped to 20 mA.

How much has the voltage changed?

UM... It may not be as simple as a voltage change.

V = IR

R, or impedance of the circuit (in my experience), is more likely to change as opposed to staying the same while the battery voltage drops to half yet is still able to provide half the power.

I would need to know more about the circuit. The problem statement is too oversimplified for me to give a meaningful real world answer.

The possible answers forces me to assume that R stays the same; resulting in the battery voltage “being” 9V.