

Bandstop filter with post amplification

Given a noisy analog signal with amplitude 0–3 V containing information only in the 1 kHz–2 kHz band, design a circuit that conditions the signal for both downstream digital/analog systems and human operators, while filtering out unwanted frequencies, amplifying it to 1–5 V, providing indicator lights as needed, including reverse-polarity protection, and minimizing power consumption.

The noisy 0–3 V analog signal was conditioned using a combination of filtering, amplification, and protection circuits described below. Each circuit will be described more clearly throughout the project report.

A second-order Sallen–Key topology with high-pass (1 kHz) and low-pass (2 kHz) stages was used to create an effective stop-band filter with steep roll-off.

The filtered signal was amplified using a non-inverting op-amp and a DC offset was added to scale it to 1–5 V for downstream systems and human operators. A red LED was included to indicate signal strength visually.

Reverse-polarity protection was implemented using a P-channel MOSFET, which also minimized power loss compared to a diode. Component values were selected to achieve the desired frequency response and voltage scaling while maintaining low power consumption.

Filter circuit:

A second-order Sallen–Key topology was used to implement the stop-band filter, providing a steep 40 dB/decade roll-off near the cutoff frequencies. By combining separate high-pass and low-pass stages with an inverting amplifier, the circuit effectively rejects signals within the stop-band despite practical limitations of a standard RLC design.

Filter Schematic:

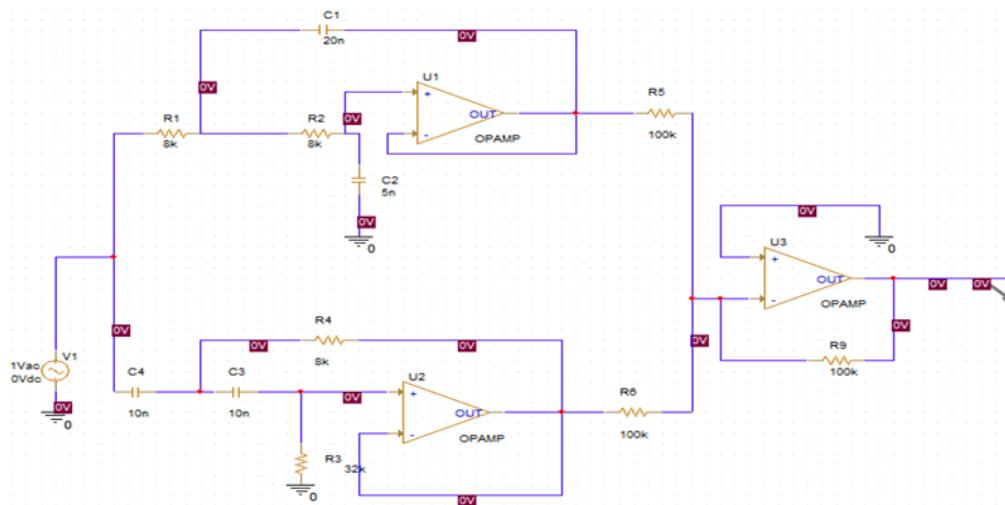


Figure 1: Image of Band stop filter circuit in Pspice

Calculations:

$f_1 = 1\text{kHz}$ -> cutoff frequency for high pass filter

$f_2 = 2\text{kHz}$ -> cutoff frequency for low pass filter

$$f_0 = \sqrt{f_1 f_2} = 1.44\text{kHz} \rightarrow \text{center of stop band}$$

Consider $Q=1$ -> for smooth edges and steeper slope in the bode diagram

R and C values will be calculated to achieve the desired quality factor (Q)

High pass filter:

$$C_1 = C_2 = 10\text{nF}$$

$$f_1 = \frac{1}{2\pi RC} = 1\text{kHz}$$

$$R = \frac{1}{2\pi f C} = \frac{1}{2\pi 1000 * 10 * 10^{-9}} = 15.9\text{k}\Omega$$

$$R_1 = 15.9/2 = 8\text{k}\Omega \text{ and } R_2 = 15.9 * 2 = 32\text{k}\Omega$$

Low pass filter:

$$f_2 = \frac{1}{2\pi RC} = 2\text{kHz}$$

$$C = 10\text{nF}$$

$$R = \frac{1}{2\pi f C} = \frac{1}{2\pi 2000 * 10 * 10^{-9}} = 7.95\text{k}\Omega = R_3 = R_4$$

$$C_3 = 10\text{nf} * 2 = 20\text{nf}$$

$$C_4 = 10\text{nf}/2 = 5\text{nf}$$

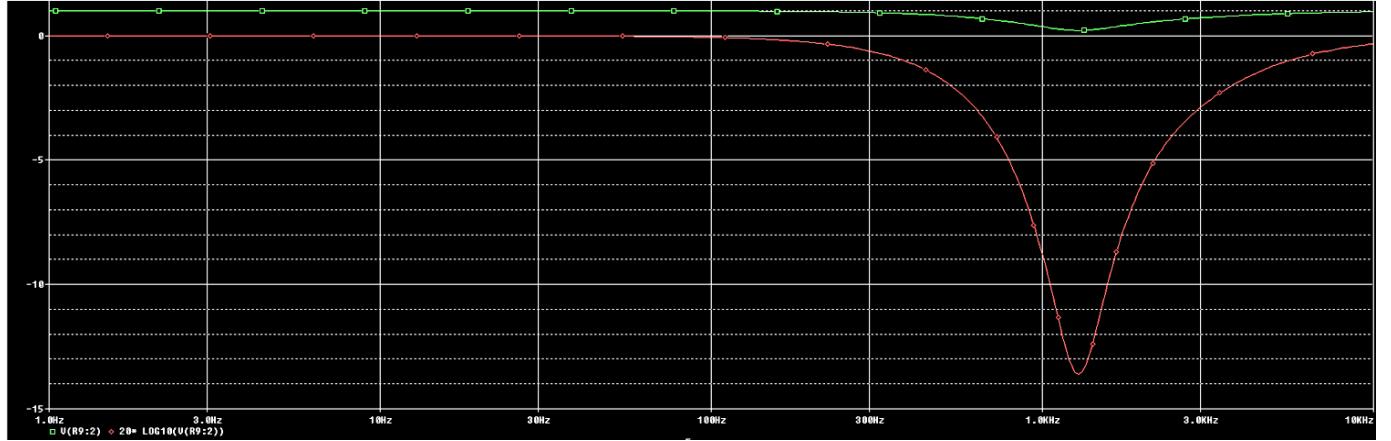
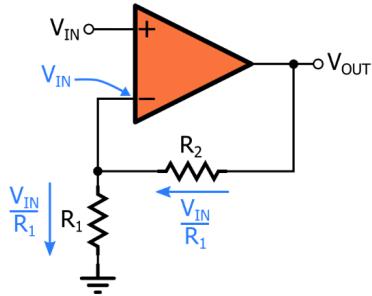


Figure 2: Filtered signals from band stop filter (x axis f, y axis dB)

Amplification and offset circuit:

Amplification Circuit: Non Inverting Op amp Voltage Amplifier



Assuming a DC offset of 1 then output voltage from the filter will be multiplied by 4/3.
Using the Gain formula for the circuit above:

$$\frac{V_{out}}{V_s} = 1 + \frac{R_f}{R_1}$$

$$\frac{V_{out}}{V_s} = \frac{4}{3}$$

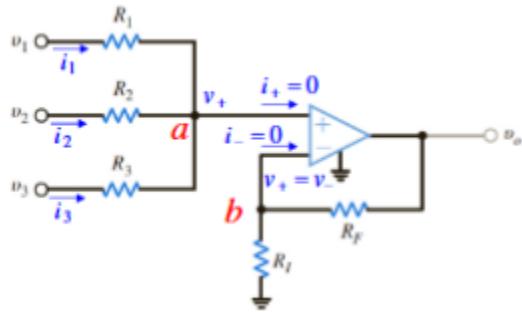
$$\frac{R_f}{R_1} = \frac{4}{3} - 1 = \frac{1}{3}$$

Use standard value resistor values:

$$R_f = 10k\Omega \text{ and } R_1 = 30k\Omega$$

Circuit implementing DC offset:

Circuit: Non inverting Summing Amplifier



Instead of 3 input voltages we will use only 2: one with which is 1V DC and the other which is the output from the amplifier circuit in Part 1

Adjust Vout formula for 2 voltage inputs:

$$R_1 = R_2$$

$$V_{out} = 1 + \frac{R_f}{R_1} * \frac{1}{2} (v_1 + v_2)$$

$$R_f = R_i$$

$$V_{out} = v_1 + v_2$$

$$R_f = R_i = R_1 = R_2 = 10\Omega$$

Amplifier and level shifting circuit schematic:

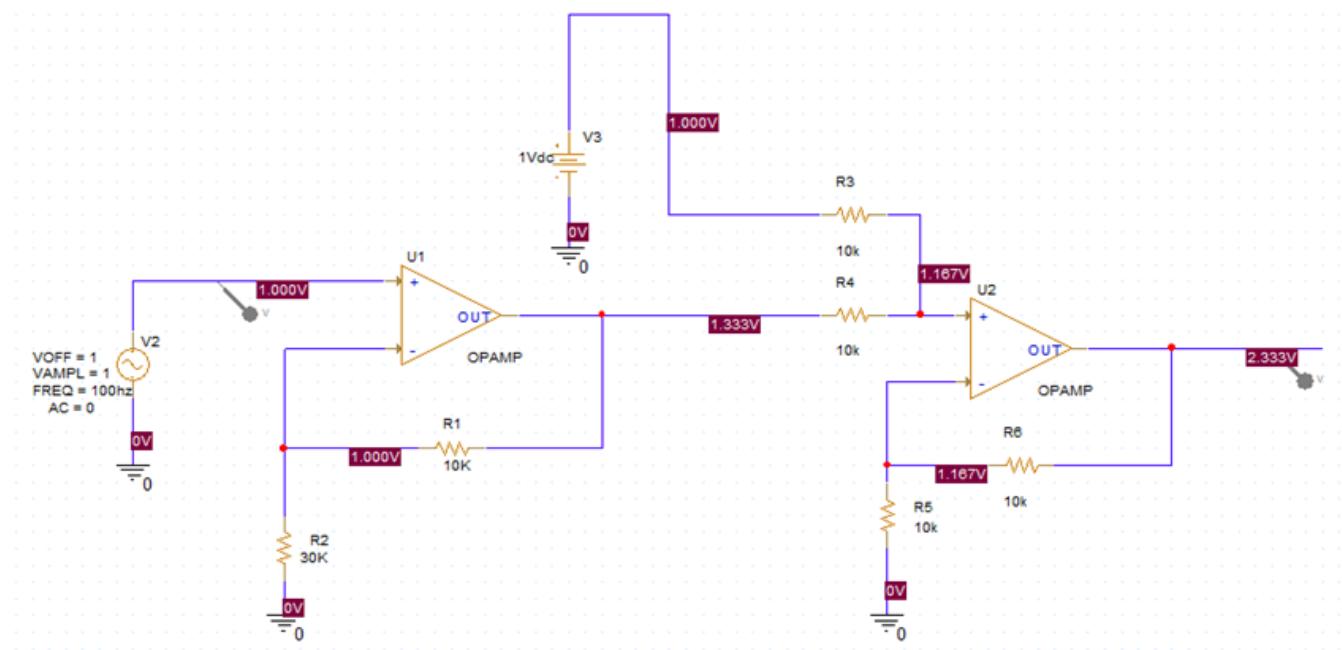


Figure 3: Amplifier and level shifting circuits connected in series

Simulation:

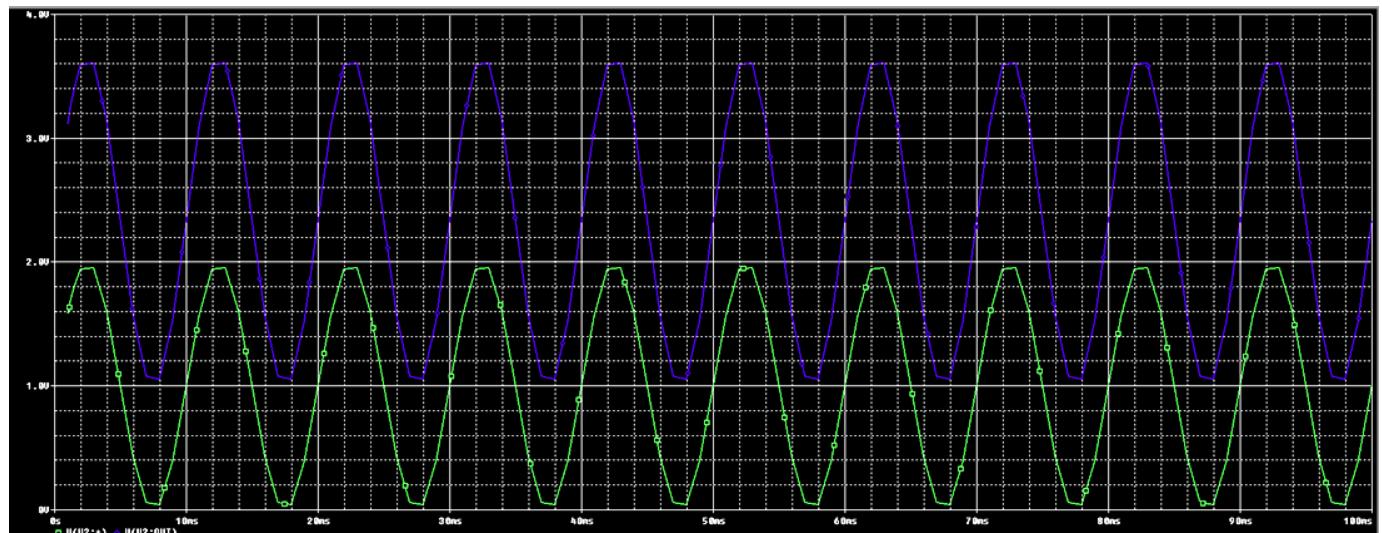


Figure 3: Image of measured values - Green (input signal), Blue (shifted and amplified output)

LED indicator

A red LED is added at the output of the amplifier part of the circuit to indicate the strength of the signal that passes through. This brightness will indicate the voltage of the signal passing through. Low brightness would indicate a low voltage signal or a signal that's been filtered out and a bright LED would indicate a strong voltage signal. It is added at the output of the amplifier part of the circuit so that it doesn't disrupt other parts of the circuit.

4) Reverse Polarity Protection

A P-channel MOSFET can be used for reverse polarity . When the power supply is connected correctly, the MOSFET turns on, allowing current to flow normally to the circuit with minimal voltage drop due to its low on-resistance. If the supply is accidentally reversed, the MOSFET remains off, effectively blocking current and protecting the circuit from damage. This approach provides efficient protection without the significant voltage drop and power loss associated with a standard series diode. This MOSFET will be used for 1V DC supply in the adder circuit. \

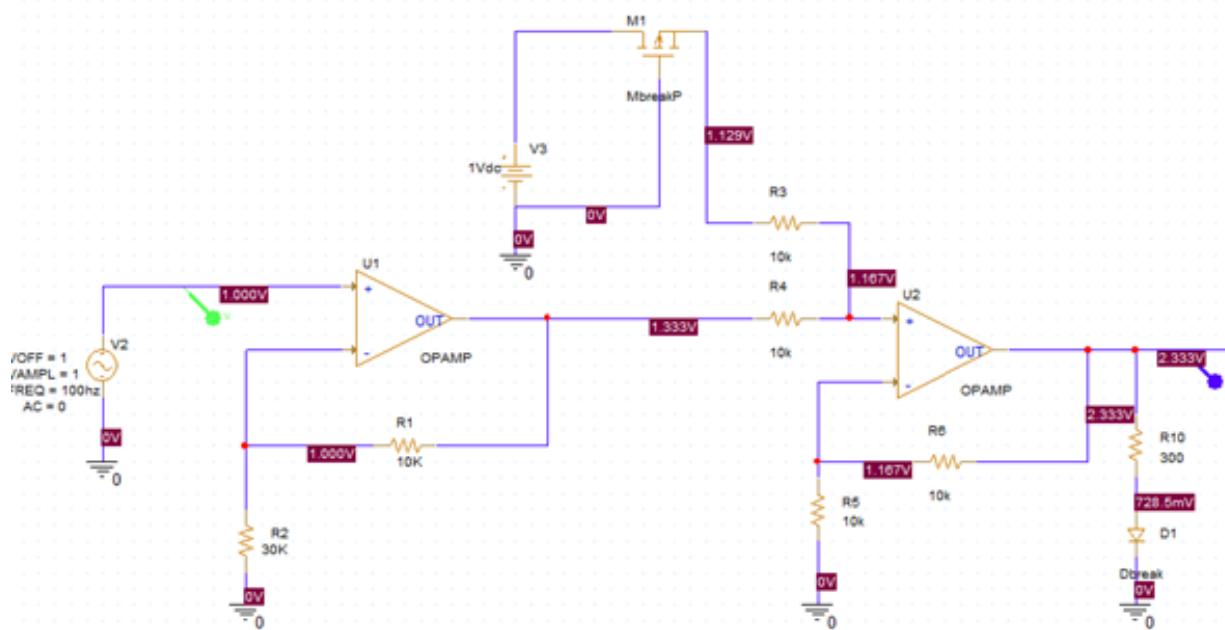


Figure 4: Reverse Polarity and LED included in the amplifier and shifter circuit

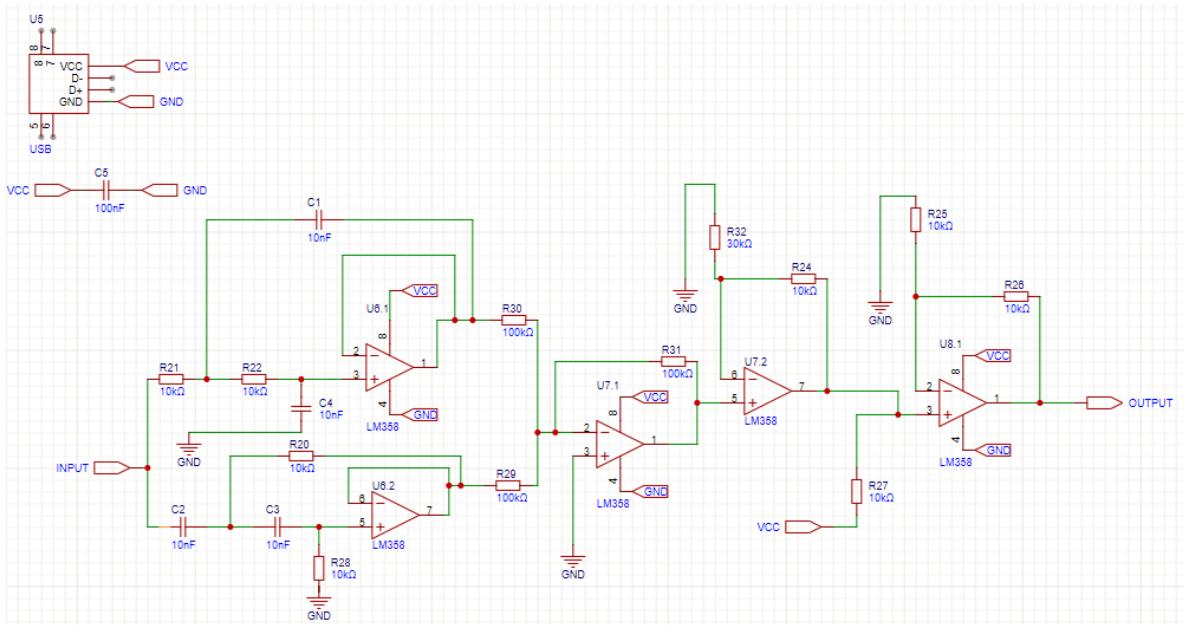


Figure 6: Image of Bandpass and level shifter circuit schematic in EasyEDA

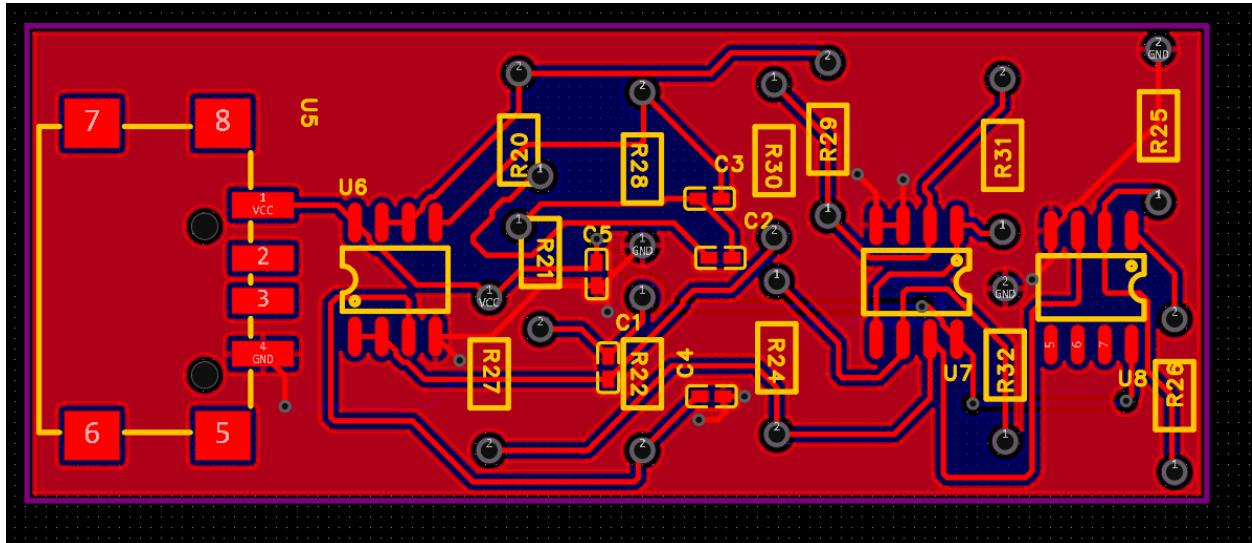


Figure 7: Screenshot of PCB design in EasyEDA

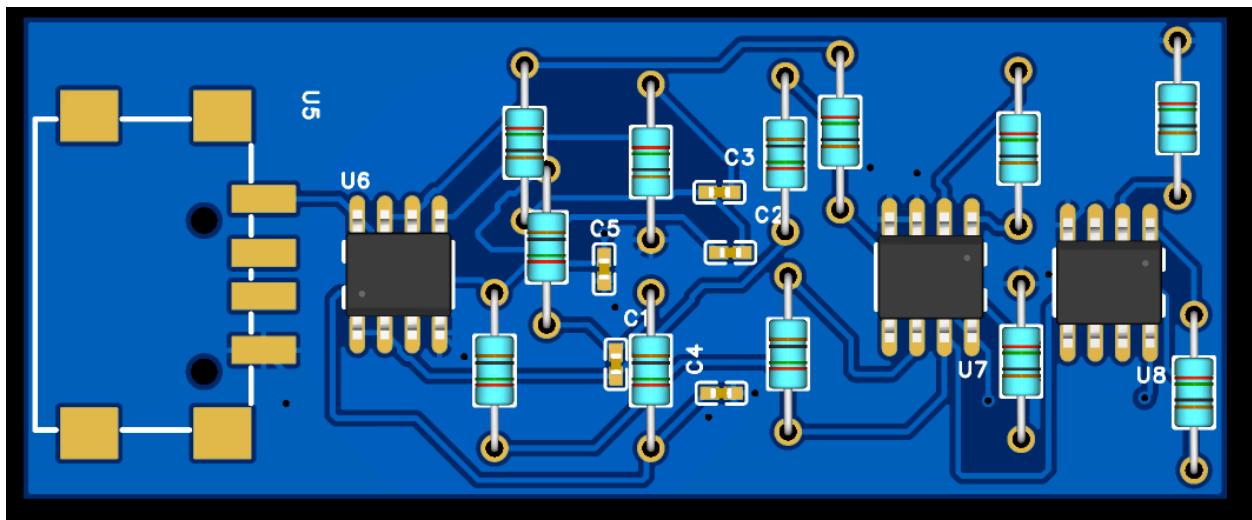


Figure 8: 3D board preview