

signal conditioning assignment

TH 2219188

by Tom Hall

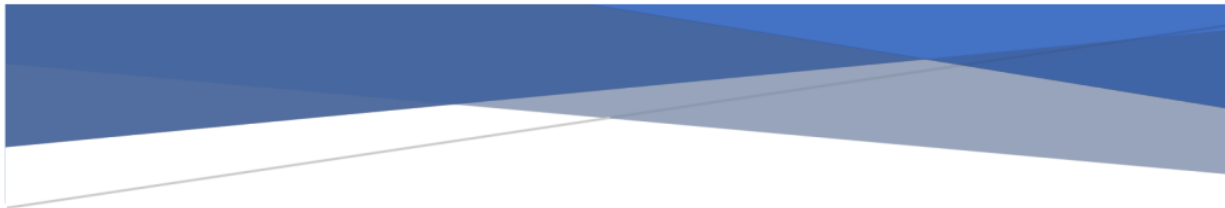
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SIGNAL CONDITIONING

Transducers and signal conditioning - ACDA5006

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Abstract

A temperature sensor output was contaminated by an AC interference. The sensor output required filtering, amplifying and level shifting to produce a readable output measuring 5V for 100°C and 0V for -50°C. The designed circuit also required overvoltage protection.

A circuit was designed to meet all the requirements, using a Zener diode-based overvoltage protection circuit, a 4 pole VCVS Bessel filter, a non-inverting amplifier and a 'level shifting' difference amplifier. Carrying out calculations, the filter was tuned to attenuate the noise leaving a measurable sensor output.

A gain of 53.7dB was achieved along with a filter attenuation of -97.08dB and a +/- 0.005V ripple.



Introduction

In this project, multiple circuits are utilised to achieve required results. These circuits feature operational amplifiers in different configurations, allowing them to carry out different functions. The main circuit used is a low pass filter. There are two main categories of low pass filters, passive and active [1]. Passive filters consist of simple RC circuits (figure 1), they can be used to remove noise from a signal. As these circuits are simply resistors and capacitors, they load the circuit drawing current from the signal. When carrying out signal conditioning this may corrupt the input signal beyond usability. Active filters solve this problem by utilising operational amplifiers which, powered by their own supply, only draw minimal current from the signal [2]. A combination of the RC circuits and the Op-amp forms a filter. Different RC configurations allow the filter to operate in different ways. The filter used in this project uses a Sallen-key architecture (figure 2), also known as a voltage-controlled voltage-source (VCVS) filter [1] [3] [4].

These filtering circuits are often used in industry where signals are corrupted due to mains supply cables being run adjacent to measuring instruments. Mains supply's frequency of 50Hz causes signal 'noise' which requires filtering. Noise can also occur due to mechanical disruption such as vibration [2, p. 51] .

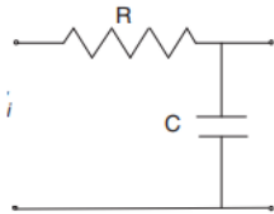


Figure 1 - Passive low pass filter [2]

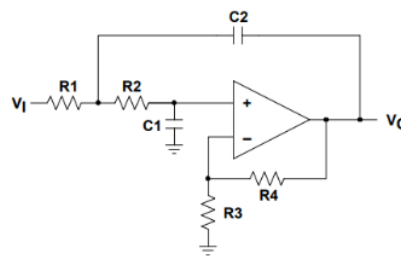


Figure 2 - Sallen-Key Low pass filter [4]

When designing a filter there are many options to consider, like whether a low or high pass filter is required. Low pass filters attenuate high frequencies, allowing low frequencies to 'pass'. High pass filters conduct the opposite function [5]. Considering the specification, the next choice would be what filter to use. Standard filter types are Butterworth, Bessel, and Chebyshev (figure 3). Each type offers different benefits.

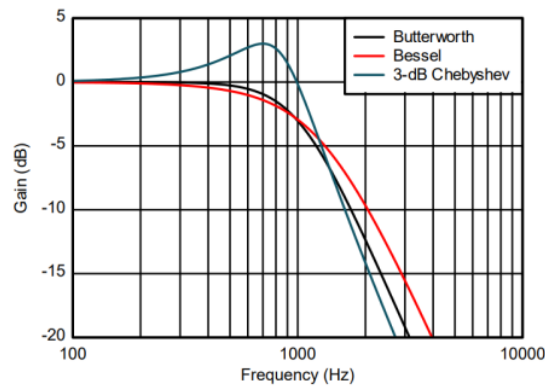


Figure 3 - Frequency response graph for standard filter types. [6]

As in figure 3, each filter type has a unique frequency response curve; each individually advantageous. A Butterworth filter is considered the best overall as it offers a very flat passband with a reasonable roll off to the stopband. This means that the passed frequency is at a steady gain before the cut-off frequency (f_c). Bessel is like Butterworth only the passband isn't as flat, creating a steady curve through the f_c . A Chebyshev response provides the sharpest roll off into the stopband allowing for better attenuation however the pass band suffers increased distortion towards the f_c [1] [6]. The area considered the passband, skirt and stopband is displayed in figure 4.

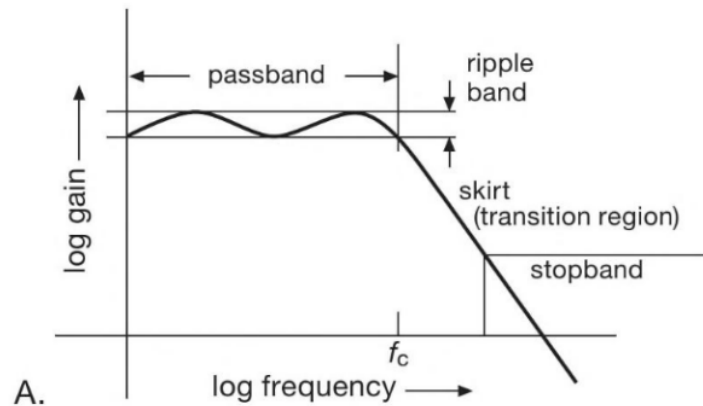


Figure 4 - Frequency response curve explanation [1, p. 400]

In addition to frequency response, these filters are analysed using a time domain graph. This plots the output voltage against time producing a waveform. Each filter exhibits imperfections, displayed in the waveform, such as overshoot, ringing and ripple. These characteristics can be observed in figure 5. A Bessel filter would have little to no overshoot or ringing, producing a near square waveform. A Butterworth would exhibit some overshoot with its ringing settling out quickly, whereas a Chebyshev would exhibit large overshoot with a longer settling period [1].

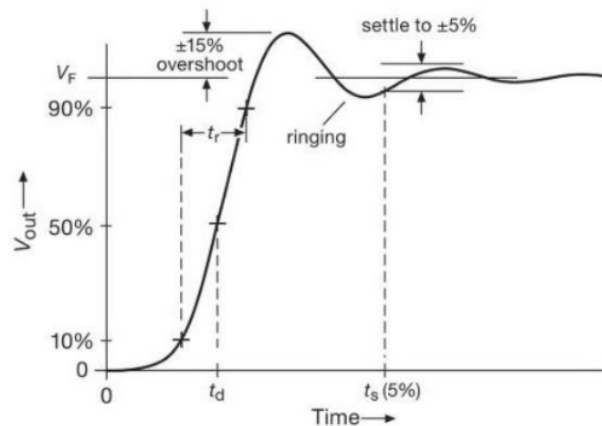


Figure 5 - Explanation of waveform errors [1, p. 401]

In this report a circuit will be designed capable of filtering out a 120mVpk-pk 50Hz interference. The circuit design will include over voltage protection, filtering, gain and level shifting. Each section of the circuit will detail the calculations used. Simulations of the circuit will be conducted using Proteus and graphs produced. The results of the circuits will be discussed, concluding on the findings.

Circuit Design

The input signal and noise voltages must be calculated. The task brief specified the use of a $68\mu\text{V}/^\circ\text{C}$ temperature sensor with $0\text{V}=0^\circ\text{C}$, where -50°C produced 0V and 100°C produced 5V . The range of voltages for the temperature sensor are calculated:

@ 100°C

$$V = 68\mu\text{V} \times 100 = 6.8\text{mV}$$

@ -50°C

$$V = 68\mu\text{V} \times \text{Caption required}$$

As this is a range of 150°C the difference in voltage calculated:

$$6.8\text{mV} - -3.4\text{mV} = 10.2\text{mV}$$

Using this input voltage range the gain was calculated:

$$\begin{aligned}\text{Gain} &= V_{\text{out}}/V_{\text{in}} \\ &= (5-0) \text{ V} / 10.2\text{mV} \\ &= 490.196\end{aligned}$$

Required gain for the circuit was converted to decibels:

$$\begin{aligned}\text{Gain (dB)} &= 20 \times \log_{10}(490.196) \\ &= 53.8074 \text{ dB}\end{aligned}$$

Circuit sensitivity = range of output voltage / range of temperature:

$$\begin{aligned}\text{Sensitivity} &= (5-0) / (100 - -50) \\ &= 5 / 150 \\ &= 0.03333\end{aligned}$$

These results were plotted in a graph showing the range of output voltages from the sensor. The Equation for range was calculated following the straight-line equation $y=mx+c$:

M =sensitivity

C = output voltage @ 0°C .

Using the calculated gain and sensor parameters:

@ -50°C , $V_{\text{in}} = -3.4\text{mV}$

Multiplied by gain of circuit

$$\begin{aligned}&= 490.196 \times -3.4\text{mV} \\ &= -1.66667\end{aligned}$$

As $-50^\circ\text{C}=0\text{V}$ output, we can use this to calculate the output voltage at 0°C , As $0\text{V}=0^\circ\text{C}$

$$V_{\text{out}} @ 0^\circ\text{C} = 1.66667$$

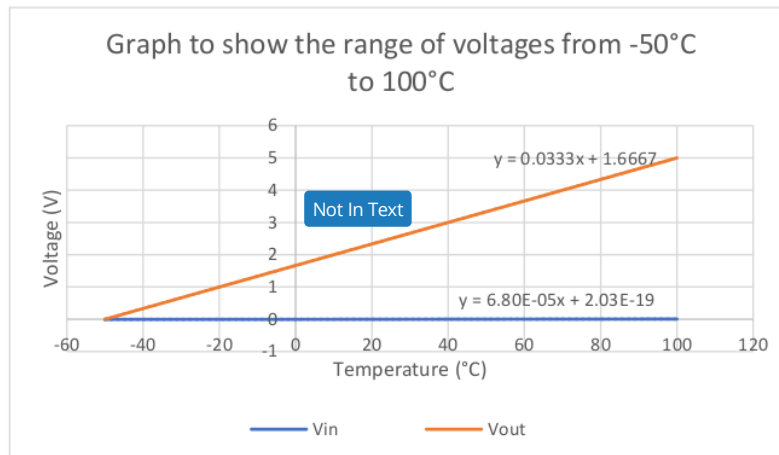


Figure 6 - Graph depicting the range of voltages for the temperature sensor

Over voltage protection

Electrical components require specified voltages, if exceeded the component fails. Zener diodes are commonly used for overvoltage protection, preventing other components from damage. Zener diodes work by only allowing current to flow forward. Each diode has a voltage rating to which it will block the flow of current in its reverse direction [7]. The diode is connected from ground to the supply, this means that it will not affect the circuit until its rating is reached. When the rating is exceeded, it will no longer block the current, creating a short to ground. This protects the circuit as current flows directly to ground. A resistor is required to protect the Zener [8]. The circuit is low voltage so 5.1V Zener (1N4733A) will protect the circuit with a small resistor of 10Ω [8]. Two opposing Zener diodes will be used for AC (figure 7).

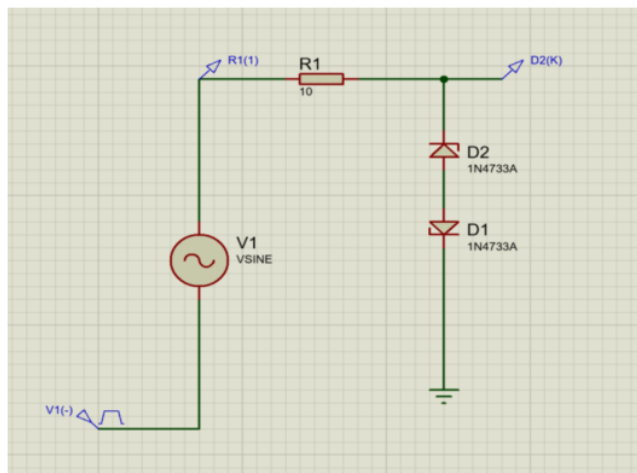


Figure 7 - Over voltage protection

Filter Calculations

Allowing for 0.25°C of noise, the required attenuation be calculated.

As 0V=0°C

Accepted noise = 0.25 x 68μV
= 17μV

Converted to decibels for noise signal:

20 x log₁₀(Vout/Vin)
20 x log₁₀(17μV/120mV)
=-76.97dB attenuation

The signal resembles a square waveform, so 4 pole Bessel is most suited [6]. Using values from figure 8, calculations were completed [1](For labelling, figure 9).

2

Table 6.2 VCVS Lowpass Filters								
Poles	worth	Bessel		Chebyshev (0.5dB)		Chebyshev (2dB)		
		c_n	K	c_n	K	c_n	K	
2	1.586	1.272	1.268	1.231	1.842	0.907	2.114	
4	1.152	1.432	1.084	0.597	1.582	0.471	1.924	
	2.235	1.606	1.759	1.031	2.660	0.964	2.782	
6	1.068	1.607	1.040	0.396	1.537	0.316	1.891	
	1.586	1.692	1.364	0.768	2.448	0.730	2.648	
	2.483	1.908	2.023	1.011	2.846	0.983	2.904	
8	1.038	1.781	1.024	0.297	1.522	0.238	1.879	
	1.337	1.835	1.213	0.599	2.379	0.572	2.605	
	1.889	1.956	1.593	0.861	2.711	0.842	2.821	
	2.610	2.192	2.184	1.006	2.913	0.990	2.946	

Figure 8 - Lowpass filter calculation table [1, p. 408]

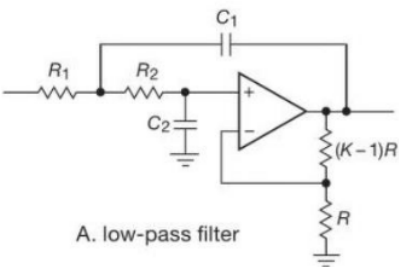


Figure 9 - Labelling guide for calculations [1, p. 407]

For Bessel filter

$R_1=R_2=R$ and $C_1=C_2=C$ [1, p. 408]

$$RC = 1 / (2\pi \times C_n \times f_c)$$

Let Frequency cut-off (f_c) = 2Hz

Let $C = 8\mu F$  4

Stage 1

Value for C_n (figure 8) = 1.432 [1]

$$RC = 1 / (2\pi \times C_n \times f_c)$$

$$R = 1 / (2\pi \times C_n \times f_c \times C)$$

$$R = 1 / (2\pi \times 1.432 \times 2 \times 8\mu)$$

$$R = 6946.3575$$

$R = 6.8k\Omega$ Nearest standard resistor [9]

For resistor (K-1) R

$$K = 1 + (R_2/R_1)$$

$$K = 1.084$$
 [1]

$$(K-1) R =$$

$$(1.084-1)6.8k\Omega = 571.2\Omega$$

560Ω Nearest standard resistor value [9]

The first stage of the filter circuit is built using a standard LM 741 op-amp as recommended in [2, p. 143]. The LM 741 is a reliable, well performing op-amp which will be more than capable of completing this operation [10]. Figure 10 is first filter stage, added to the over voltage circuit.

For stage 1

Q = sharpness of transition [1]

As $R_1=R_2=R$ and $C_1=C_2=C$

$$Q = 1/3-K$$
 [1, p. 410] [4]

$$Q = 1/3 - 1.084$$

$$= 0.5219$$

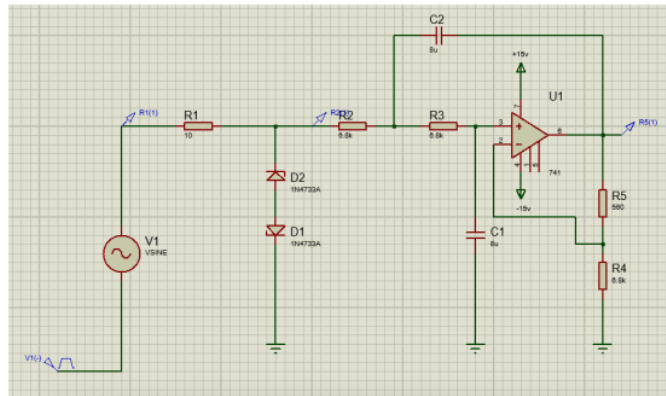


Figure 10 - First filter stage (second order VCVS)

Cascading another second order filter creates a fourth order, RC values must be recalculated using the corresponding values for Cn and K [1].

Stage 2

As before,

$$RC = 1 / (2\pi \times C_n \times f_c)$$



Let Frequency cut-off (f_c) = 2Hz

Let $C = 8\mu F$

Value for C_n from figure 8 = 1.606 [1]

$$RC = 1 / (2\pi \times C_n \times f_c)$$

$$R = 1 / (2\pi \times C_n \times f_c \times C)$$

$$R = 1 / (2\pi \times 1.606 \times 2 \times 8\mu)$$

$$R = 6193.7634\Omega$$

Nearest standard resistor value= 6.2k Ω [9]

For resistor (K-1) R

$$K = 1 + (R_2/R_1)$$

$$K = 1.759 [1]$$

$$(K-1) R =$$

$$(1.759-1)6.2k\Omega = 4705.8\Omega$$

4.7k Ω Nearest standard resistor value [9]

As before:

$$Q = 1/3-K [1, p. 410] [4]$$

$$Q = 1/3-1.759$$

$$= 0.8058$$

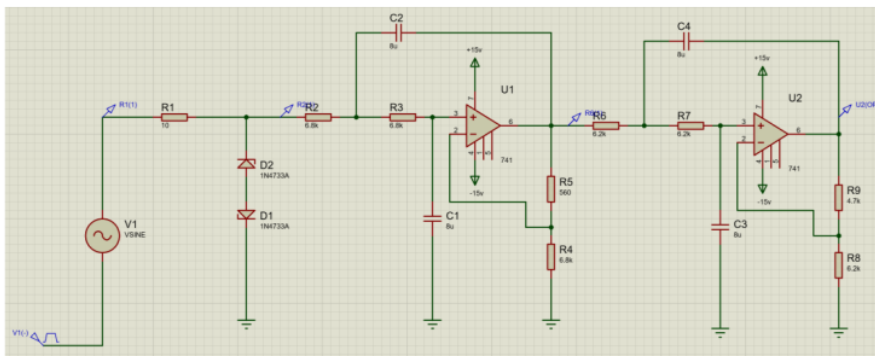


Figure 11 - Updated circuit with completed 4 pole low pass active filter (Bessel design)

Although each filter stage amplifies the signal, it requires further amplification to produce the 5V. To calculate the required gain, a gain measurement was taken from the frequency response (figure 12) with the value in figure 13.

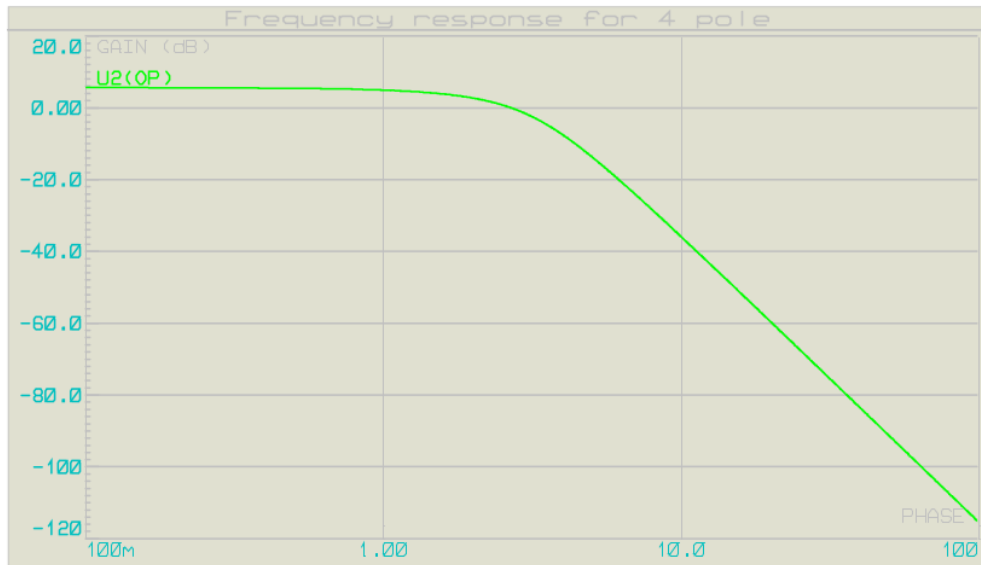


Figure 12 - Frequency response for 4 pole Bessel filter

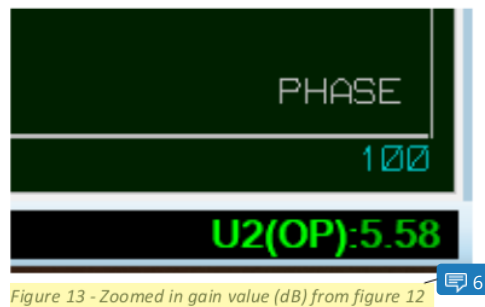


Figure 13 - Zoomed in gain value (dB) from figure 12

The required amplification was calculated by subtracting 5.58 from the calculated required gain.

$$53.8074 - 5.58 = 48.2274\text{dB}$$

converted from decibels:

$$\text{Gain Db} = 20\log_{10}(V_{\text{out}}/V_{\text{in}})$$

Caption required

$$10^{(48.2274/20)} = 257.8517 \text{ gain}$$

To achieve this amplification a non-inverting op-amp circuit was used (figure 14 from [1, p. 226]).

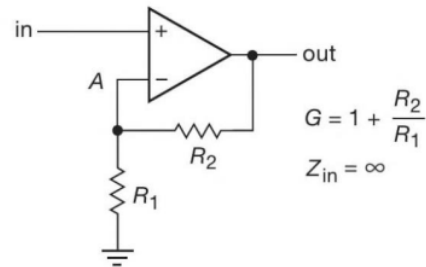


Figure 14 - non-inverting amplifier [1, p. 226]

As given in figure 14:

$$\text{Gain} = 1 + (R_2/R_1)$$

Let $R_1 = 20\Omega$ as a low R_1 will require a lower R_2 .

$$257.8517 = 1 + (R_2/R_1)$$

$$256.8517 \times 20\Omega = R_2$$

$$R_2 = 5137.034\Omega$$

Nearest standard resistor = 5.1k Ω

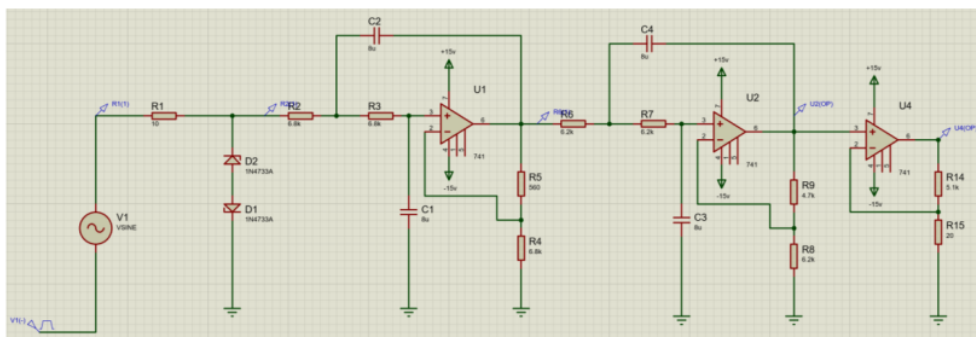


Figure 15 - Addition of non-inverting amplifier

The final stage of the signal conditioning is level shifting. As the input signal ranges from -3.4mV to 6.8mV, the conditioned signal still starts below 0v. The sensor must produce 5V for 100°C and 0V for -50°C so the signal must be shifted to 0v. This was achieved with a difference amplifier (figure 16) using a voltage input equal to the unshifted signal's starting voltage.

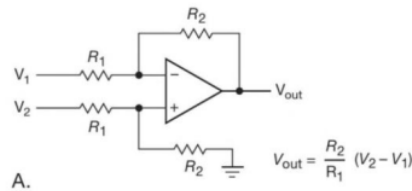


Figure 16 - Difference amplifier [1, p. 227]

Difference amps gain= R2/R1

Using the same value for each resistor eliminates the gain. The output becomes $V_2 - V_1$ [1, p. 227]. The output can be measured graphically (figures 17 and 18). An R value of 10kΩ was chosen.

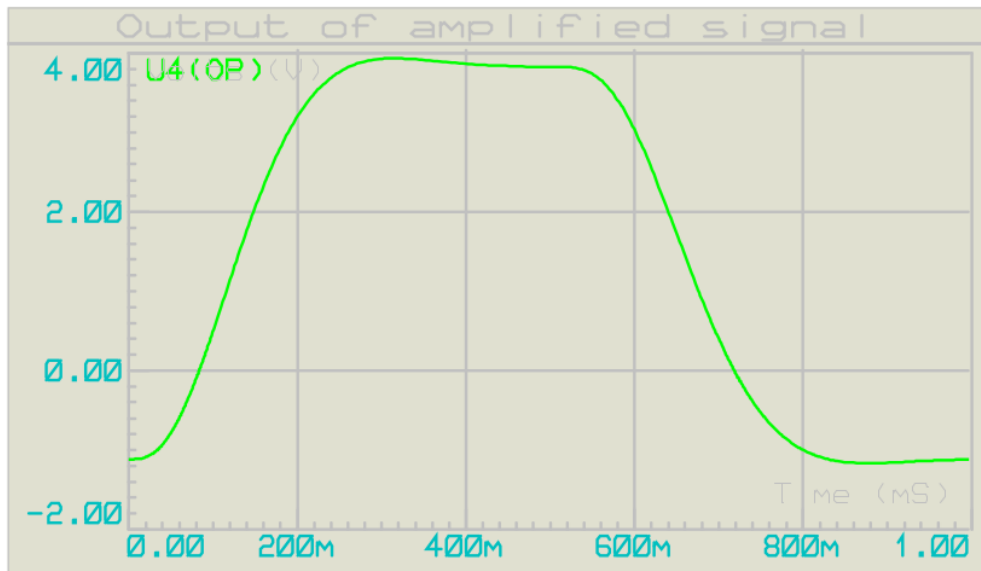


Figure 17 - Conditioned circuit before level shifting



Figure 18 - Signal starting voltage from graph

Using the equation $V_{out} = V_2 - V_1$:

$$0\text{volts} = V_2 - -1.12$$

$$0V = V_2 + 1.12$$

$$V_2 = -1.12$$

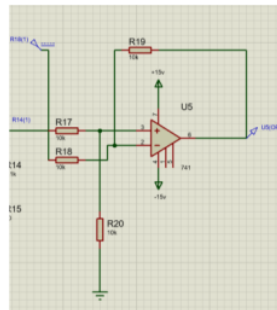


Figure 19 - Level shifting circuit

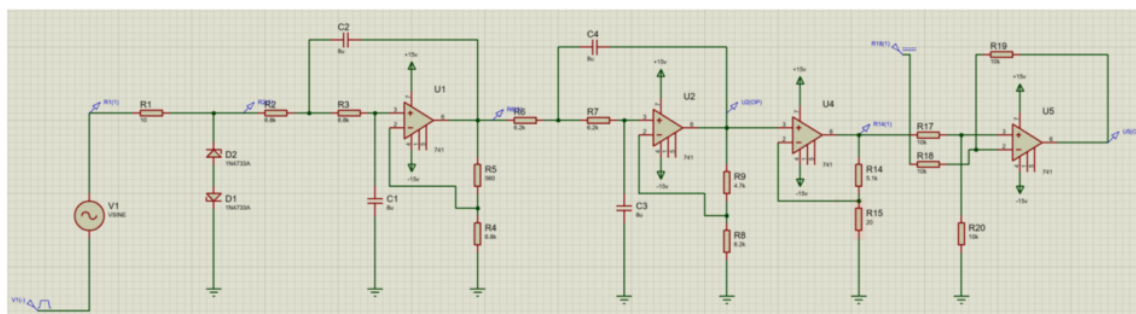


Figure 20 - Completed circuit

Simulation setups

signal and noise input

Signal voltage range: -3.2mV to 6.8mV

Using a pulse generator (figure 21)

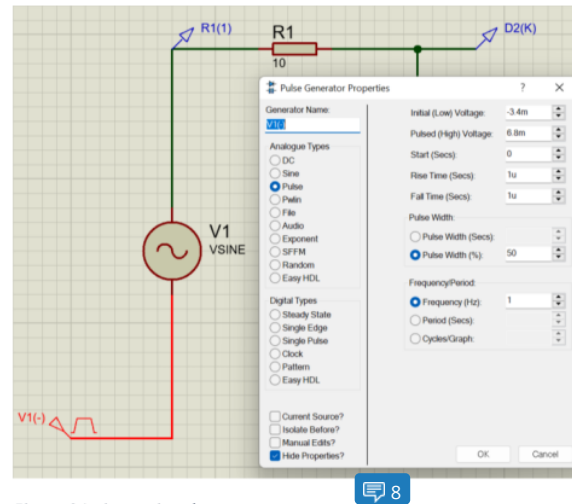


Figure 21 - input signal

Noise input: 120mV pk-pk 50Hz

Using a sine generator (figure 22).

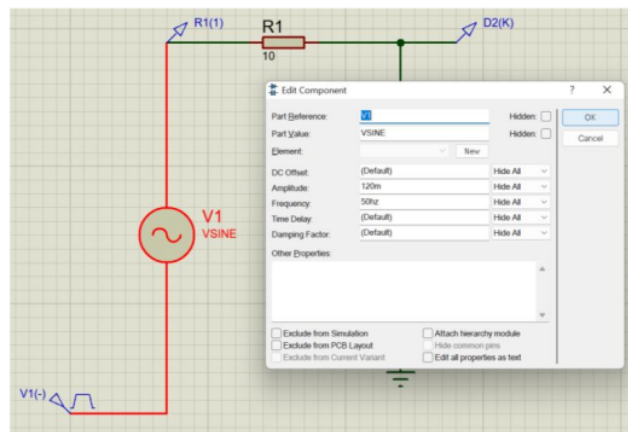


Figure 22 - Input noise

D2(K) (figure 22) is a voltage probe used to measure the signal after the voltage protection (figure 7).

The combination of the two inputs (signal and noise)

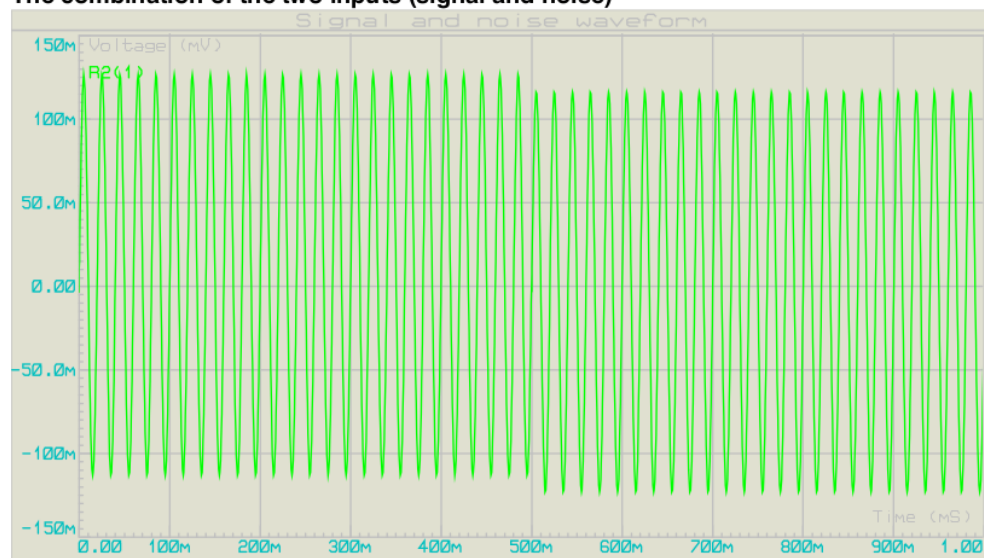


Figure 24 - Signal and noise waveform

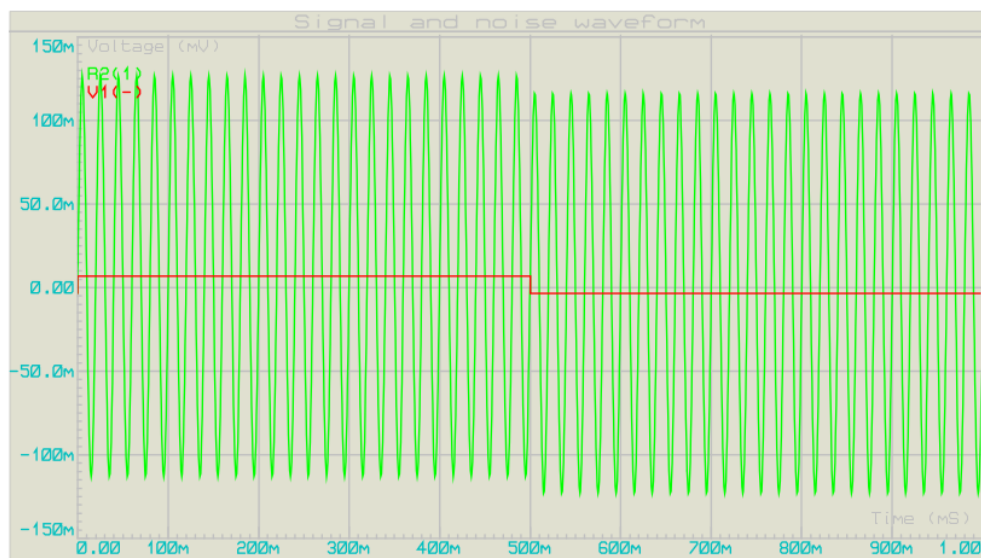


Figure 23 - Combined waveform compared to original signal.

The sinusoidal wave (figure 23) shows the ac noise contamination and the step down at around 500ms shows the presence of the signal voltage as compared in figure 24.

Voltage probes were used to measure various parts of the circuit. As seen in figure 20, after every stage of design voltage probes were added to evaluate the changes to the signal.

9 Voltages were used to create analogue analysis graphs (figure 17), or frequency response graphs, (figure 13). When creating a frequency response, graph parameters must be set as in figure 25.

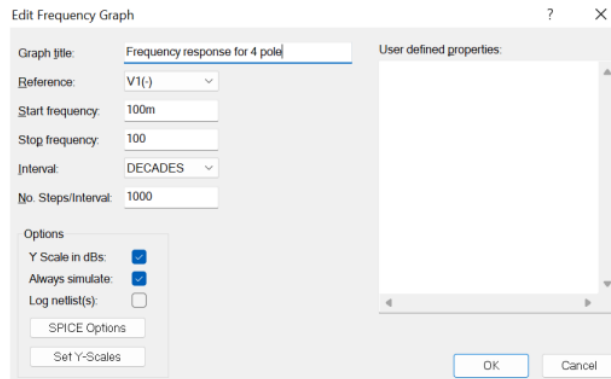


Figure 25 - Frequency response parameters

The voltage reference is set to V1(-), the signal input. The start frequency is set to 100m and the stop to 100Hz, the frequency range of the x axis for the curve.

Results

Voltage probes were positioned throughout the circuit to record graphical responses. Graphs were created after the first filtering stage. Figure 26 is the analogue analysis comparing the original input signal to the filtered combination.

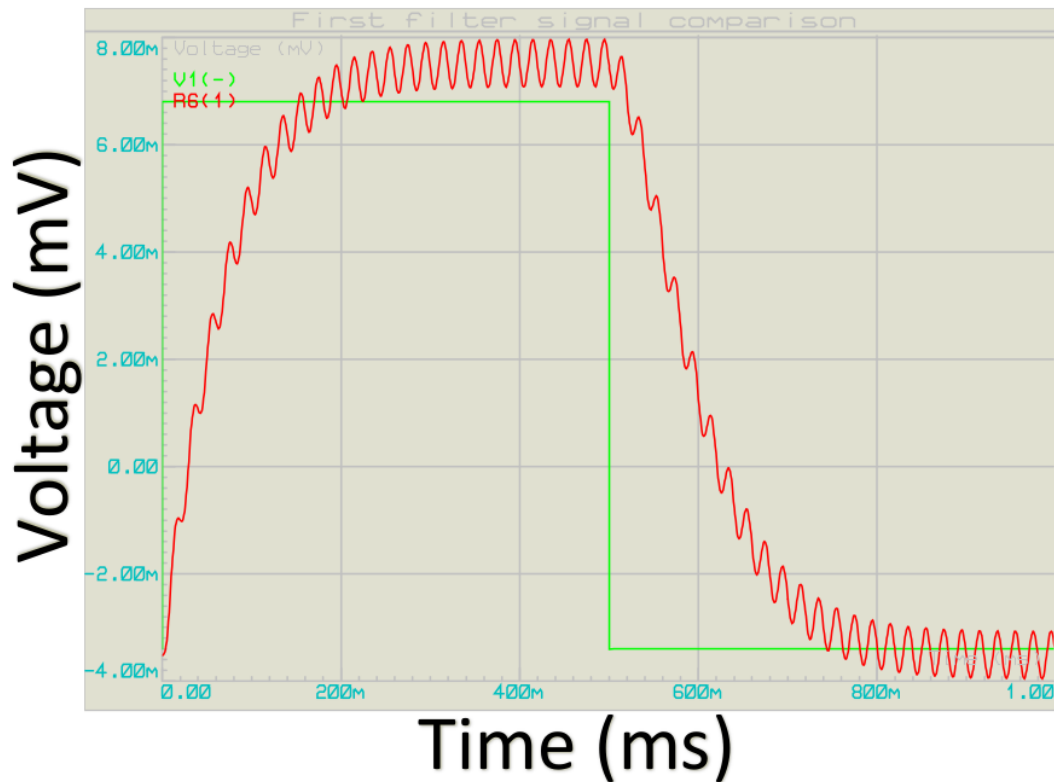


Figure 26 - Comparison between signal input (green) and filtered signal and noise waveform (red).

The attenuation can be measured from the frequency response (figure 27) to compare with the calculated required value of -76.97dB.

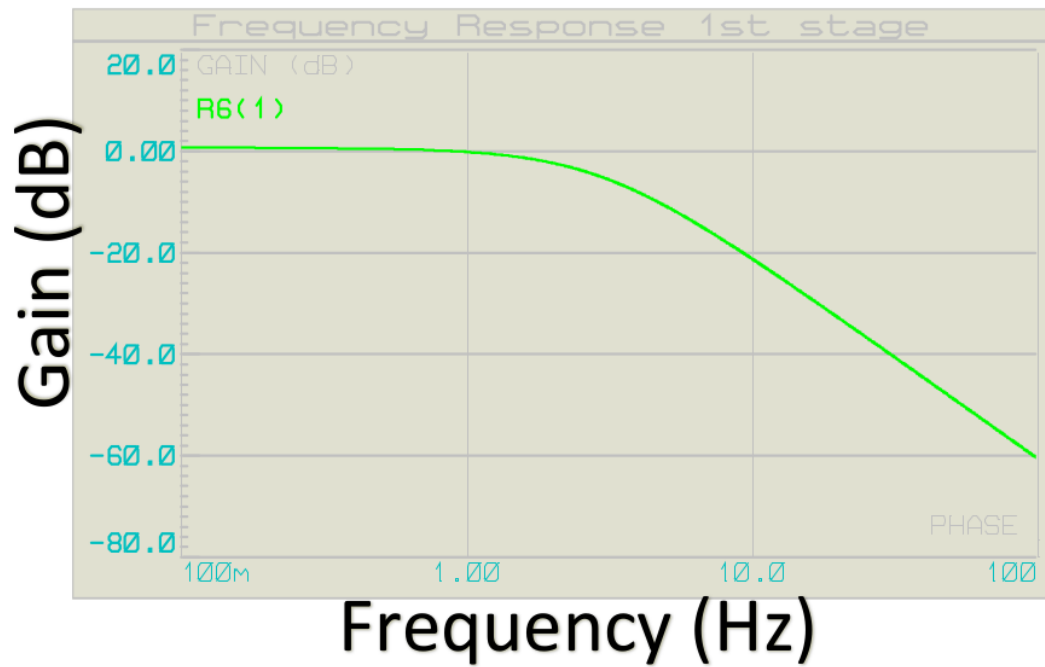


Figure 27 - frequency response for 1st stage filter

The gain before the fc point measures 675 mdB. At the stopband (50Hz) the gain measures -48.7.

$$-48.7 - 675\text{m} = -49.375\text{dB}$$

This is not enough attenuation.

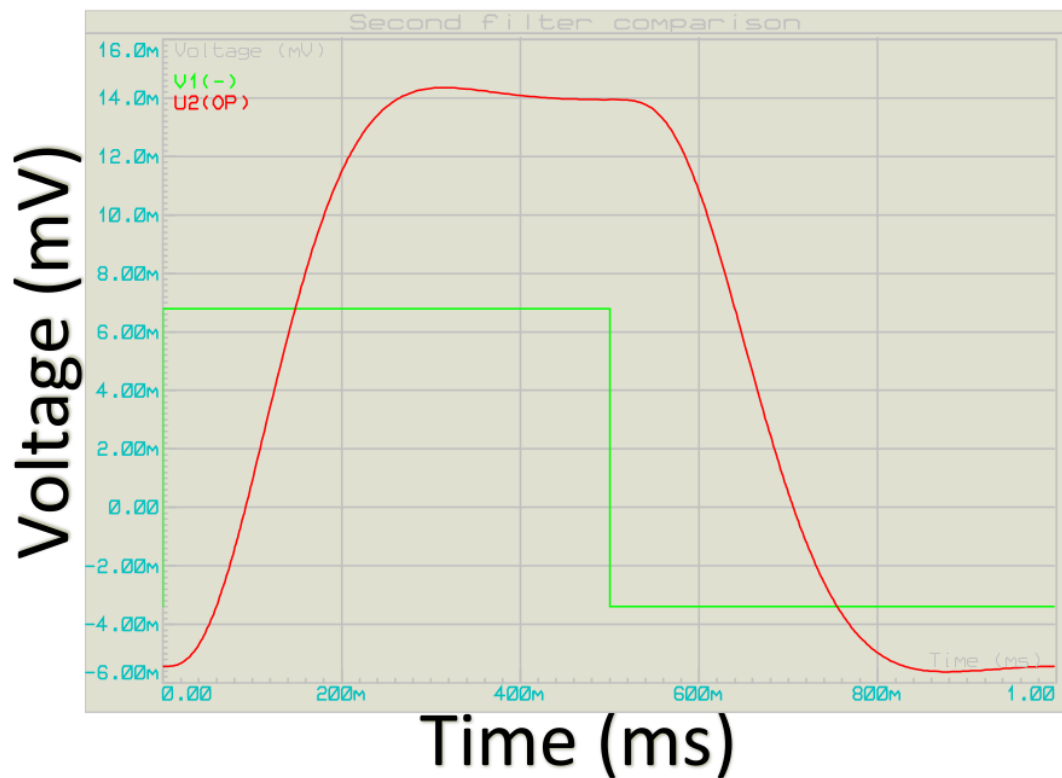


Figure 28 - Comparison between input signal (green) and 4 pole filtered output (red)

Figure 26 shows noise present. This was removed in figure 28 and there was a gain from the second filter. The waveform has clearly begun to shift to the right. The frequency response at this stage (figure 29) exhibits the required attenuation.

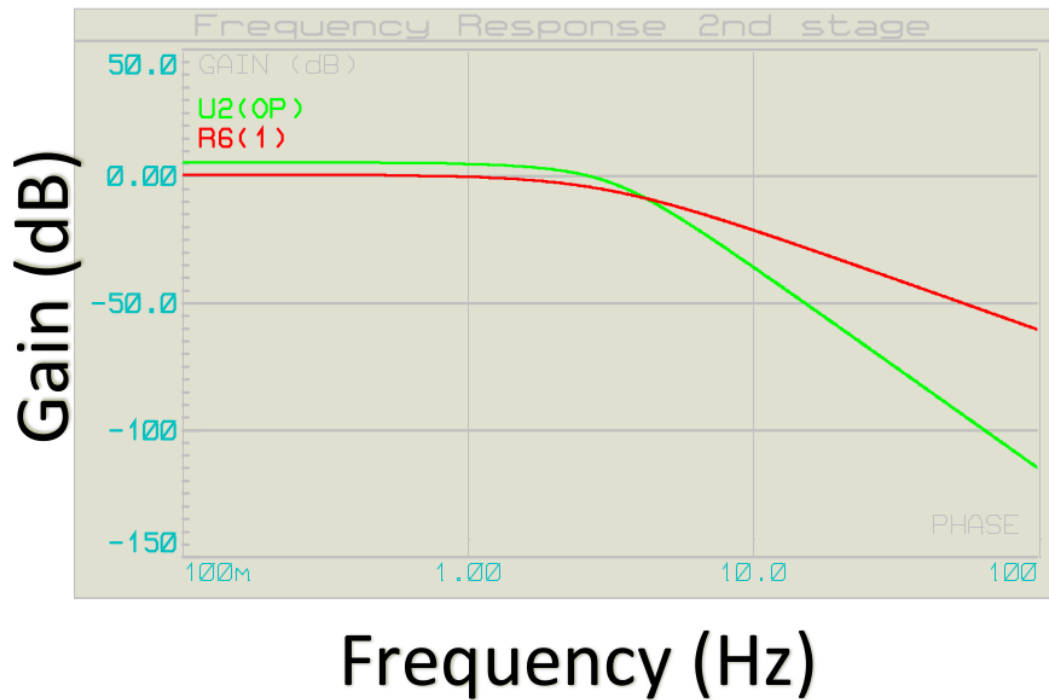


Figure 29 - Frequency response for second stage (green) compared to first stage (red)

The slope after f_c has become steeper causing increased attenuation.

@ passband = 5.58dB @ 50Hz = -91.5

$$-91.5 - 5.58 = -97.08\text{dB}$$

This is greater than our calculated value of -76.97dB meaning the filter performs well.

Figure 30 has the same waveform as previous, only amplified to the required voltage range.

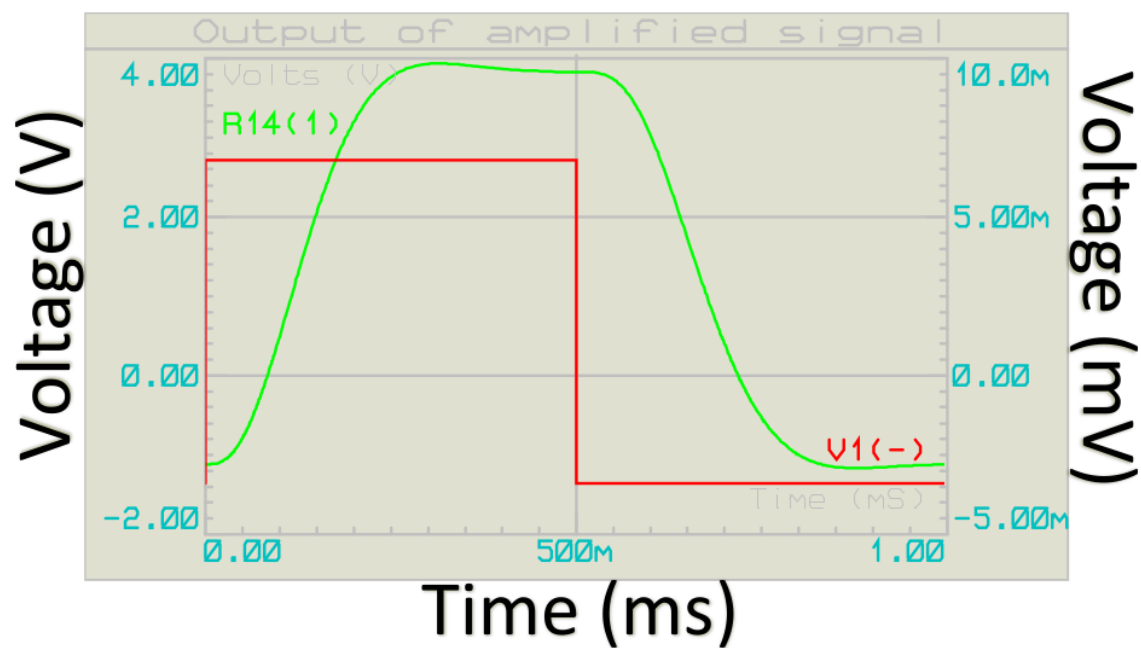


Figure 30 - Amplified waveform (green) compared to input signal (red, separate axis)

The frequency response at this stage allows the measurement of gain. From figure 31 the gain after amplification is 53.7dB, this matches the calculated requirement of 53.8074 dB.

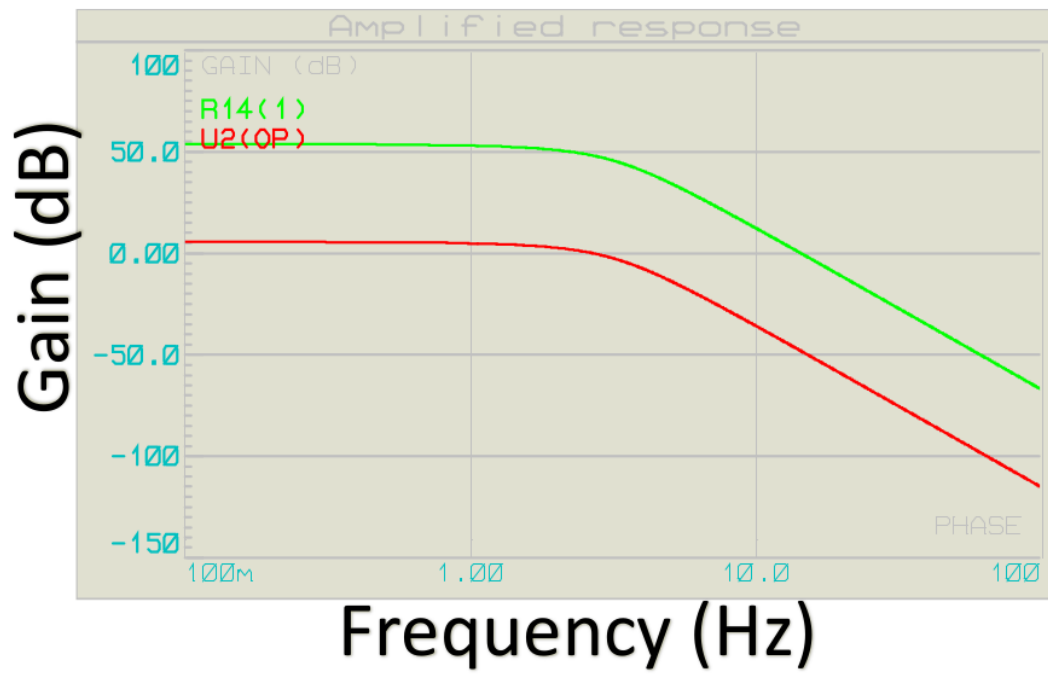


Figure 31 - Amplified frequency response (green) compared to filtered response (red)

The level shifted final waveform in figure 32 compared to the input (separate axis) highlights the shift of the waveform. The output signal exhibits the correct voltage range. From this graph the response time can be calculated.

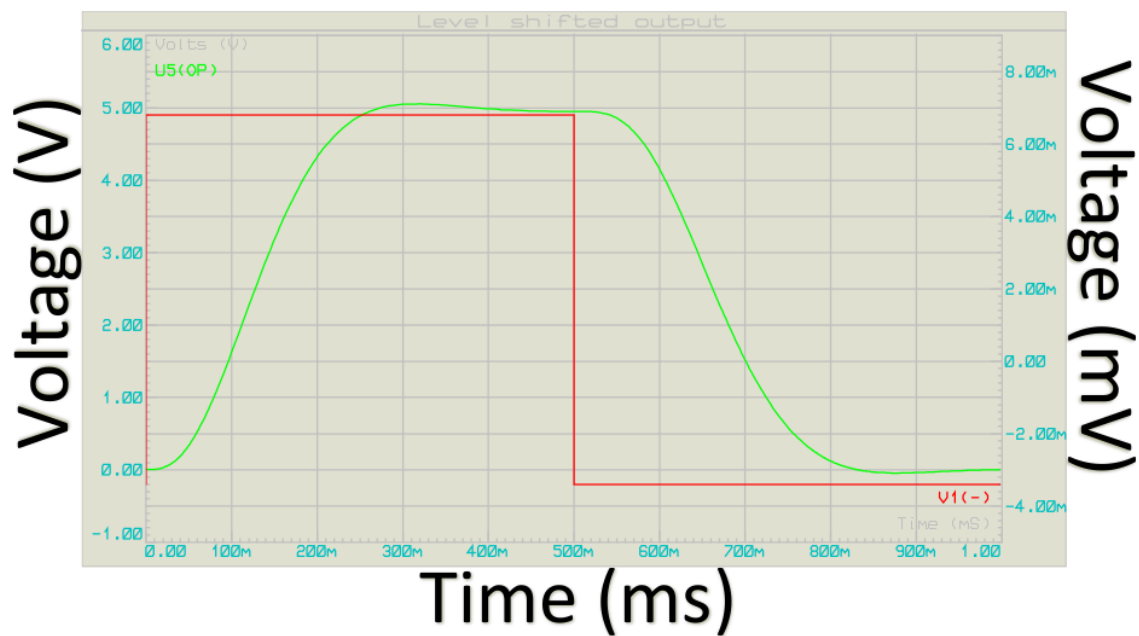


Figure 32 - Level shifted signal (green) compared to input signal (red separate axis)

Discussion

Each stage of the circuit produced results requiring analysis. Figure 26 shows the output of the first filter stage with the presence of noise still visible. As calculated from figure 27, the required level of attenuation had not yet been achieved meaning some of the noise was still allowed to pass. The addition of the second stage removed that noise. The graph in figure 28 shows the time domain characteristics of the new waveform. A slight overshoot is observed at the peak of the waveform however there is minimal ringing or ripple. According to [1, p. 406], for a 4 pole Bessel filter a 0.8% overshoot is expected using $f_c=1\text{Hz}$. The overshoot exhibited in figure 28 may be larger due as the designed circuit uses $f_c=2\text{Hz}$. Another contribution may be component rounding when calculating the filter requirements. As temperature is slow moving variable, this overshoot is more than acceptable for the circuit's purpose.

Figure 29 shows the second stage of the filter to have improved the roll off. This shows improved attenuation from the circuit, surpassing the calculated requirements.

Reviewing figure 31, the measured gain was 53.7dB, the calculated required gain was 53.8dB, this small discrepancy would go unnoticed in the circuit's application and was likely caused by rounding errors in the resistor ratio.

Figure 32 exhibits the time delay in comparison to the input signal. The input signal is a perfect square wave with instant risetime, this can't be replicated using a filter and so an increase in rise time is expected. According to [1], for a 4 pole Bessel filter ($f_c=1\text{Hz}$) a step risetime of 0.5s is expected. This is the time between 0 and 90% of the rise. At 90% of figure 32, the rise time is 212ms. This is faster than the values given in [1], making the circuit more than acceptable. For recording temperature, a fast rise time such as the original square wave is not required as temperature is a slow-moving variable. Due to the overshoot and settle time present in the output waveform, an accurate response time can be measured at the halfway point, 2.5V. At 2.5V the response time is 127ms, the response time would be 254ms (double the halfway value). The signal overshoots to 5.06V and rings to 4.95V (measured from time domain graph) producing a mean of 5.005V. From figure 5, a settle output of $\pm 5\%$ is expected. 5% of 5V is 0.25V meaning 0.005v is well within the textbook prediction.

Components and efficiency

resistor (Ω)	quantity	price	quantitiy purchahsed	cost
10	1	0.107	20	£2.14
20	1	0.101	10	£1.01
6.8k	3	0.0488	5	£0.24
560	1	0.012	10	£0.12
6.2k	3	0.0977	1	£0.10
4.7k	1	0.651	1	£0.65
5.1k	1	0.59	1	£0.59
10k	1	0.387	1	£0.39
			total price	£5.24
capacitor	quantity	price	quantitiy purchahsed	cost
8uF	4	3.72	1	£14.88
			total price	£14.88
op-amp	quantity	price	quantitiy purchahsed	cost
741	4	0.756	1	£3.02
			total price	£3.20
zener diode	quantity	price	quantitiy purchahsed	cost
1n4733a	2	0.281	5	£1.41
			total price	£1.41

Figure 33 - Components price list [12] [15] [16]

For lower costs, a quad op-amp chip like LM324 could be used instead of four 741's [11]. The RC ratio could be adjusted using more of the same resistors and smaller capacitors [1] [12].

Sourcing a suitable temperature sensor

Sensor requirements: 68μV/°C, -50°C to 150°C.

A type E thermocouple, Chromel-constantan, produces the desired output and range [13] [2, pp. 357,358]. The SA2C-E-72 thermocouple meets the requirements [14]. See datasheet (figure 34).

Self-Adhesive Thermocouples
Molded Silicone Design for Curved and Flat Surfaces

SA2 Series

- ✓ Ultra-Slim Silicone Rubber for Maximum Flexibility
- ✓ Self-Adhesive Foil Backing for Faster Response Time
- ✓ 2 Styles Available for Flat or Curved Surfaces
- ✓ Resistant to a Variety of Chemicals and Oils
- ✓ Temperature Range -50 to 200°C (-58 to 392°F)
- ✓ Available in J, K, T and E—Color Coded for Instant Thermocouple Recognition
- ✓ 24 AWG Stranded Thermocouple-Grade Lead Wire
- ✓ Stripped Leads Standard (A Variety of Connector Options are Available)

These sensors are available in 2 different mounting styles for flat or curved surfaces. The integral thermocouple sensor is bonded onto the inner surface of the self adhesive aluminum foil strip, which is provided for faster response times.

SA2F-K shown smaller than actual size.
For flat surfaces.

SA2C-K shown smaller than actual size.
For curved surfaces.

Now Available! MB/M12 CONNECTORS

Specifications
Dimensions:
SA2C: 15 x 50 x 2.5 mm (0.59 x 1.97 x 0.098")
SA2F: 35 x 12 x 2.5 mm (1.38 x 0.47 x 0.098")
Wire: 24 AWG stranded thermocouple wire, 1 m (40") and 2 m (80") lengths; custom lengths available

Optional Connectors
SMPW-CC ultimate connector.
OSTW-CC ultimate connector.

To Order	
Model No.	Description
SA2C-(-)	15 x 50 mm (0.59 x 1.97") curved surface sensor, 1 m (40") lead wire, stripped ends
SA2C-(-)-72	15 x 50 mm (0.59 x 1.97") curved surface sensor, 2 m (80") lead wire, stripped ends
SA2C-(-)-120	15 x 50 mm (0.59 x 1.97") curved surface sensor, 3 m (120") lead wire, stripped ends
SA2C-(-)-SMPW-CC	15 x 50 mm (0.59 x 1.97") curved surface sensor, 1 m (40") lead wire, ultimate mini male connector
SA2F-(-)	35 x 12 mm (1.38 x 0.47") flat surface sensor, 1 m (40") lead wire, stripped ends
SA2F-(-)-72	35 x 12 mm (1.38 x 0.47") flat surface sensor, 2 m (80") lead wire, stripped ends
SA2F-(-)-120	35 x 12 mm (1.38 x 0.47") flat surface sensor, 3 m (120") lead wire, stripped ends
SA2F-(-)-SMPW-CC	35 x 12 mm (1.38 x 0.47") flat surface sensor, 1 m (40") lead wire, ultimate mini male connector

*Specify J, K, T or E thermocouple Type.
For standard size connector, replace "SMPW-CC" in the model number and replace with "OSTW-CC", no additional charge. For additional lead wire, add additional cost per 300 mm (12").
For a male straight M8 plug add "MB-S-M" to the model number for additional cost, for a male straight M12 plug add "M12-S-M" to the model number for additional cost.
For a male right-angled M8 plug add "MB-R-M" to the model number for additional cost, for a male right-angled M12 plug add "M12-R-M" to the model number for additional cost.
Ordering Example: SA2C-K-72-SMPW-CC, self-adhesive silicone sensor for curved surfaces, Type K, 2 m (80") lead wire with ultimate mini male cable clamp connector.

A-25

Figure 34 - Data sheet for selected temperature sensor. [14]

Conclusion

In this project it was determined that for a square wave input signal, a Bessel filter was the best choice. The transient responses for Butterworth or Chebyshev exhibit excessive overshoot and ringing before settling causing a distorted waveform. The Bessel response much more closely resembles a square wave meaning the 5V output is not heavily exceeded, limiting false readings from the temperature sensor.

The importance of the RC ratio became clear. Slightly adjusting the values of either R or C led to substantial changes and distortions to the measured waveforms. Values of R and C must be proportional to produce an operational filter.

- The attenuation for the designed filter was -97.08dB
- The gain of the designed circuit was 53.7dB

12

References

- [1] P. Horowitz and W. Hill, The art of electronics, 3rd ed., New York, New York: Cambridge University Press, 2016.
- [2] A. S. Morris and R. Langari, Measurement and instrumentation, 1st ed., Waltham, Massachusetts: Academic press (Elsevier), 2012.
- [3] J. Karki, Active Low-Pass Filter design, Dallas, Texas: Texas Instruments Incorporated, 2002.
- [4] J. Karki, "Analysis of the Sallen-Key Architecture," Texas Instruments Incorporated, Dallas, 2002.
- [5] S. Mosey, "Passive and active filters," UWTSD, Swansea, 2016.
- [6] J. Karki, "Active Low-Pass Filter Design," Texas Instruments Incorporated, Dallas, 2022.
- [7] Components101, "Designing a Simple Over-Voltage Protection Circuit using Zener Diodes," Components101, 20 05 2020. [Online]. Available: <https://components101.com/articles/designing-an-overvoltage-protection-circuit-using-zener-diodes>. [Accessed 20 11 2022].
- [8] Components101, "1N4733A - 5.1V Zener Diode," Components101, 22 02 2018. [Online]. Available: <https://components101.com/diodes/1n4733a-zener-diode-pinout-equivalents-datasheet>. [Accessed 20 11 2022].
- [9] Circuit4you, "Standard Resistor Values," 18 12 2016. [Online]. Available: <https://circuits4you.com/2016/12/18/standard-resistor-values/>. [Accessed 22 11 2022].
- [10] Electrical Academia, "741 Operational Amplifier (Op-Amp) | Basics, Characteristics & Pin Configuration," 22 11 2022. [Online]. Available: <https://electricalacademia.com/electronics/741-operational-amplifier-op-amp-basics-characteristics-pin-configuration/>. [Accessed 22 11 2022].
- [11] RS Components Ltd., "LM324N Texas Instruments, Op Amp, 1.2MHz, 5 → 28 V, 14-Pin PDIP," 11 22 2022. [Online]. Available: <https://uk.rs-online.com/web/p/op-amps/9223029>. [Accessed 22 11 2022].
- [12] RS Components Ltd., "RS," RS, 22 11 2022. [Online]. Available: <https://uk.rs-online.com/web/>. [Accessed 22 11 2022].
- [13] Peak sensors, "Type E Thermocouple," 22 11 2022. [Online]. Available: <https://peaksensors.co.uk/thermocouples/type-e-thermocouple/>. [Accessed 22 11 2022].
- [14] Farnell, "SA2C-E-72," Farnell, 22 11 2022. [Online]. Available: <https://uk.farnell.com/omega/sa2c-e-72/thermocouple-e-type-50mm-200deg/dp/3799897?st=type%20e%20thermocouple>. [Accessed 22 11 2022].
- [15] Premier Farnell Ltd., "Farnell," Avnet, 22 11 2022. [Online]. Available: <https://uk.farnell.com/>. [Accessed 22 11 2022].

[16] Mouser Electronics, Inc., "Mouser Electronics," 22 11 2022. [Online]. Available: <https://www.mouser.co.uk/>. [Accessed 22 11 2022].

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

68/100

PAGE 1

PAGE 2



Comment 1

Good abstract

PAGE 3

PAGE 4

PAGE 5

PAGE 6



Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....

PAGE 7



Not In Text

You have included a figure without mentioning it in the text. You should refer to the figure in the text, otherwise it is not worth including as the reader will not know what it relates to.

PAGE 8



Comment 2

Having the caption left at the top of this table (Table 6.2 VCVS Lowpass Filters) confuses things for the reader as this caption should be:

Table 1 - Lowpass filter calculation values



Comment 3

Table 1 - this is a table not an image.



Comment 4

8 μF is not a preferred value. The vast majority of 8 μF capacitors available are motor run capacitors, which would be unsuitable for this application.



Comment 5

Would it not have been more concise to state the equations you were using once and then show a table of calculated values for all the stages?



Comment 6

What frequency was this measurement made at?



Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....



Comment 7

Does this really warrant an image adding? Could this just have been stated in the text?



Comment 8

When you write a technical report, it is just that - a technical report, not an instruction manual.

The parameters of these two sources do not need to have screenshots, they could be explained in a couple of sentences.



Comment 9

Too much detail - you are not supposed to write an instruction manual



Comment 10

The first 2nd order VCVS stage you have simulated is not 2nd order filter, it is half a 4th order filter. The K and Cn values are different for the first 2nd order section of a 4th order filter and that of a 2nd order filter.



Comment 11

Good discussion

PAGE 29

PAGE 30

PAGE 31



Comment 12

At what frequency?

PAGE 32



Ref Qual

You should try to use more high quality reference sources, such as textbooks from reputable academic publishers and articles from peer reviewed journals.

PAGE 33

GRADING FORM: SMU GENERIC_SMOSEY

TOM HALL

67.80

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



A comprehensive range of research informed literature embedded in the work. Excellent selection of relevant and credible sources. High-level referencing skills, consistently applied

3.6

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.



Excellent knowledge and understanding of the main concepts and key theories. Clear awareness of challenges to established views and the limitations of the knowledge base.

21

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.



Sound, logical, analytical thinking; synthesis and evaluation. Ability to devise and sustain persuasive arguments, and to review the reliability, validity and significance of evidence. Ability to communicate ideas and evidence accurately and convincingly. Sound, convincing conclusions / recommendations

19.8

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A very good application of a range of methods, materials, tools and/or techniques. Very good consideration of the context of the application, with perceptive use of examples, where relevant. Evidence of some innovation and creativity.

20.4

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate well, confidently and consistently in a suitable format. Work is coherent and fluent and is well structured and organised.

3