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Transducers and Signal Conditioning – ACDA5006
Signal Conditioning Design

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Abstract

Abstract - results

The brief provided describes a temperature sensor circuit containing many required elements such as over voltage protection, a filter circuit, a gain circuit, and a level shifting circuit. The input provided in the brief was 0V at 0°C producing 68uV/°C, with an interference of 120mVpk-pk and 50Hz. The required output of this circuit was 0V at -50°C and 5V at 100°C with no interference.

Introduction

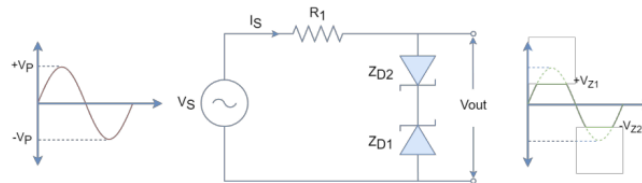


Figure 1: A full-wave clipper with two Zener diodes [1]

A full-wave clipper with two Zener diodes limits both the positive and negative voltage cycles. Z_{D1} clamps the positive cycle to V_{Z1} , and Z_{D2} clamps the negative cycle to V_{Z2} . During the positive half-cycle, Z_{D1} conducts when the voltage exceeds V_{Z1} , and during the negative half-cycle, Z_{D2} conducts when the voltage becomes more negative than V_{Z2} . This ensures that the voltage remains within the limits set by the Zener diodes, protecting the load from excessive voltage.

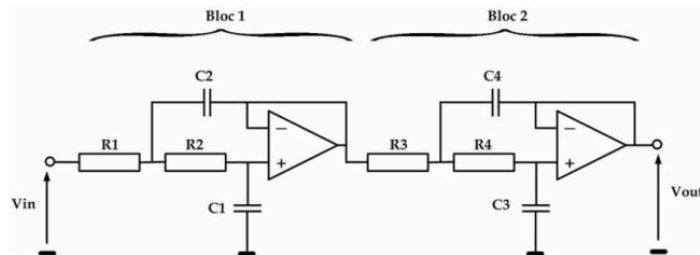


Figure 2: Fourth order Butterworth filter [2]

A fourth-order Butterworth filter is an analog filter known for a maximally flat frequency response in the passband, meaning no ripple. It has a smooth transition from the passband to the stopband, with a roll-off rate of 24 dB per decade. The filter consists of two poles and two zeros, providing a steeper attenuation compared to lower-order

filters. Its transfer function is designed to minimize ripples and ensure a smooth frequency response. This filter is commonly used in applications requiring a sharp cutoff frequency and minimal distortion, offering reliable performance in filtering unwanted frequencies.

A gain circuit using an operational amplifier (op-amp) typically involves feedback to control amplification. In a non-inverting amplifier, the input signal is applied to the non-inverting terminal, and the op-amp's output is fed back to the inverting terminal through a resistor network. The gain is determined by the ratio of two resistors, R_f (feedback resistor) and R_{in} (input resistor), with the formula $Gain = 1 + \frac{R_f}{R_{in}}$. This configuration allows for amplification with the input signal in phase with the output.

A level shifting circuit using an operational amplifier (op-amp) adjusts the voltage level of a signal to ensure compatibility between components operating at different voltages. The op-amp is typically configured with a resistor network to shift the signal's voltage either up or down while preserving its integrity. In such circuits, the op-amp can amplify or adjust the signal's voltage, allowing for proper interfacing between devices with different voltage requirements. This approach ensures that the signal is correctly translated without distortion, making it suitable for communication between systems operating at different voltage levels.

Circuit Design

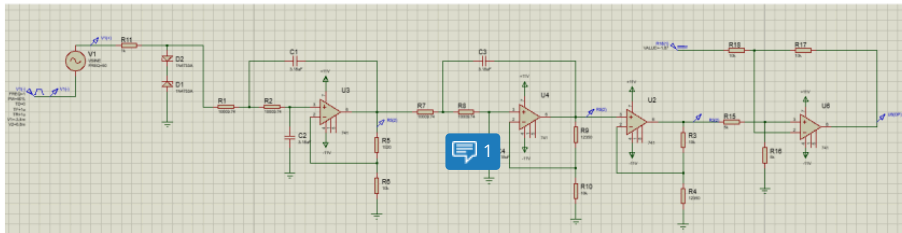


Figure 3: Final circuit design on proteus

The final circuit design comprises several key components that work together to create a functional system for signal processing. The design begins with a pulse generator, 2 produces the necessary pulses for the circuit to operate. This pulse generator is integral in triggering the subsequent stages of the system.

Next, the design includes a sine wave AC voltage generator, which is used to produce a smooth alternating current (AC) signal with a sinusoidal waveform. This is crucial for applications requiring a stable AC signal, ensuring the proper functioning of the system by supplying the desired input to subsequent components.

The circuit also incorporates an over-voltage protection circuit, which is designed to safeguard the system against voltage spikes. This protection is achieved using a 1k resistor and two Zener diodes configured as a full-wave clipper. The Zener diodes in this configuration allow for the clamping of voltage to a specific threshold, ensuring that the voltage never exceeds a safe level, thus preventing damage to the rest of the circuit.

Another important element of the design is the fourth-order Butterworth filter circuit. The Butterworth filter is known for its flat frequency response in the passband, providing a smooth signal with minimal distortion. The filter has a cutoff frequency of 5 Hz, which means it allows frequencies below 5 Hz to pass through while attenuating higher frequencies. This is achieved by using a calculated capacitor value of $3.18 \mu\text{F}$, which plays a key role in determining the filter's characteristics. The filter itself consists of eight resistors with varying values, which are calculated using the specified values from the table shown in figure 4, along with four capacitors, each set to $3.18 \mu\text{F}$. Two 741 operational amplifiers (op-amps) are also used to amplify and buffer the signal within the filter.

The gain circuit is designed to amplify the processed signal and consists of a single 741 op-amp and two resistors, which set the gain of the amplifier according to the desired amplification level. The choice of the 741 op-amp ensures reliable and stable operation in this amplification stage.

Lastly, the design includes a level shifting circuit, which is used to adjust the DC level of the signal. This is particularly useful when the signal needs to be shifted to a different voltage level for further processing or output. The level shifting circuit is composed of a 741 op-amp, four resistors, and a DC generator to provide the necessary DC offset for the signal.

Each of these components plays a critical role in achieving the desired performance of the circuit, with careful selection and calculation of component values ensuring that the system operates within specified parameters.

Poles	Butterworth K	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	1.2	0.5	2.379	0.572	2.605
	1.889	1.956	1.533	0.861	2.711	0.842	2.821
	2.610	2.192	2.184	1.006	2.913	0.990	2.946

Figure 4: K values for active filter designs [3]

The capacitor value was found using the calculation shown below:

$$C = \frac{1}{2\pi f_c 10k}$$

Caption required

The resistor values for each stage of the design are calculated using the following equations:

$$R = \frac{1}{2\pi f_c C} \quad k = 1 + \frac{R_2}{R_1}$$

Caption required

The stage one resistor value was initially calculated to be approximately $R = 10009.74\Omega$. This value was derived based on the desired parameters for the circuit's functionality, taking into account the specific resistance needed to achieve the required current or voltage characteristics at this stage. For simplicity and practicality in circuit design, R_1 was assumed to be $10k\Omega$.

With R_1 set to $10k\Omega$, the value of R_2 was then determined through the calculations, resulting in $R_2 = 1520\Omega$. This value of R_2 ensures the correct operation of the circuit in conjunction with R_1 .

In a Butterworth filter circuit, the resistor value for stage two remains identical to that of stage one. Specifically, R_1 is maintained at $10k\Omega$, while R_2 is calculated to be approximately 12350Ω .

Simulation Setups

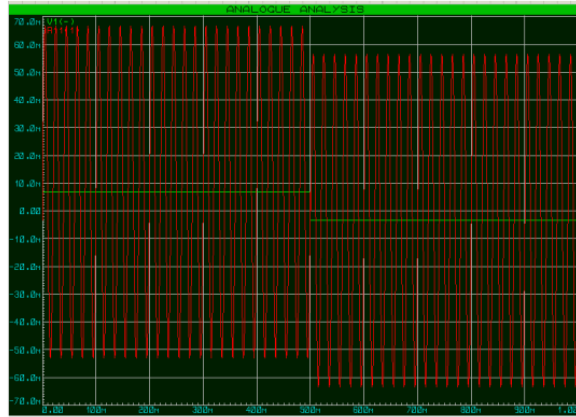


Figure 5: Graph showing AC and pulse generator inputs

Shown in Figure 5 are the AC voltage and pulse generator inputs, which play a critical role in the operation of the system. The range of the AC voltage inputs spans from 66.7mV to -63.3mV, providing a broad range of voltage variations for the system's performance. Meanwhile, the range of the pulse generator inputs is much smaller, extending from 6.8mV to -3.4mV. These voltage levels are essential for controlling and modulating the system's behavior, ensuring that both AC and pulse inputs function within their specified limits to maintain stability and accuracy in the system's output and operations.

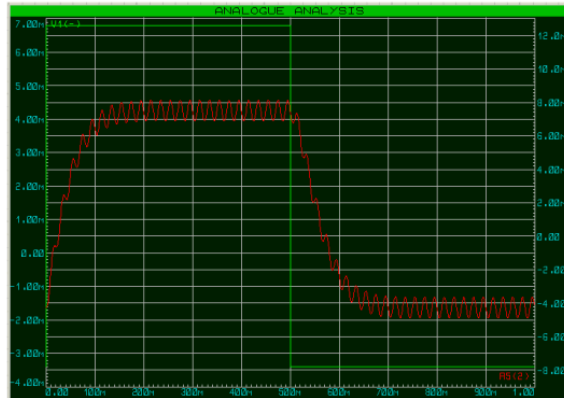


Figure 6: Graph showing inputs after stage one of filter

Shown in Figure 6 is the result of the over-voltage protection circuit and stage one of the filter circuit. The over-voltage protection circuit plays a crucial role by cutting off the voltage whenever it exceeds the specified range of the pulse generator, ensuring the system operates safely. Stage one of the filter circuit, as depicted in the graph, effectively maintains the signal within the specified voltage range. Additionally, it helps to reduce distortion, ensuring that the output remains clean and accurate. This combination of protection and filtering ensures reliable operation, preventing damage and optimizing signal quality for further processing in the system.



Figure 7: Stage two of filter circuit

Shown in Figure 7 is a graph illustrating the output of stage two of the filter circuit. Stage two demonstrates a significant improvement by further reducing interference and noise in the signal. This stage effectively smooths out any remaining irregularities from the previous stages, producing a cleaner and more stable output. The enhanced filtering process helps to eliminate high-frequency components that could affect the signal quality, ensuring that the output is both accurate and reliable. As a result, stage two plays a vital role in refining the signal, ensuring optimal performance for subsequent processing or use in the system.



Figure 8: Gain circuit output

Shown in Figure 8 is the output of the gain circuit, which plays an essential role in amplifying the signal. The gain circuit has successfully increased the amplitude of the input signal by applying the calculated gain factor of 0.5. This adjustment in amplitude ensures that the signal is at an appropriate level for further processing or use in the system. The output illustrates how the gain circuit effectively modifies the signal to meet the desired specifications, allowing it to proceed smoothly through the next stages without distortion or signal loss.

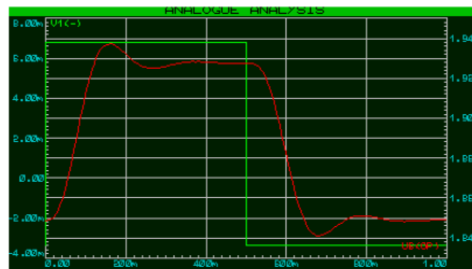


Figure 9: Final output after level shifting

Shown in Figure 9 is the final output after the level shifting circuit, which plays a crucial role in adjusting the signal to the desired voltage range. The offset of the level shifting circuit was set to -1.87V , effectively shifting the signal's voltage level to match the required specifications. This adjustment brings the output closer to the intended result, ensuring the signal is in the proper range for the subsequent stages of processing or usage. The level shifting circuit plays a vital role in optimizing the signal quality and ensuring the system operates with the correct voltage levels for accurate results.

Results

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Discussion

Conclusion

References

[1] M. Shahid, "Diode Clipping Circuits," Electronics-Lab.com. <https://www.electronics-lab.com/article/diode-clipping-circuits/> (accessed Dec. 02, 2024).

[2] L. Kritele, B. Benhala, and I. Zorkani, "(PDF) Ant Colony Optimization for Optimal Low-Pass Filter Sizing," ResearchGate, Jan. 2019. https://www.researchgate.net/publication/327108152_Ant_Colony_Optimization_for_Optimal_Low-Pass_Filter_Sizing (accessed Dec. 02, 2024).

[3] P. Horowitz, W. Hill, and Oxford University Press, The Art of Electronics, 3rd ed. New York: Cambridge University Press, 2015, p. 408.

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/100

PAGE 1

PAGE 2

PAGE 3

QM

Abstract - results

Good abstract, although you should include a statement of your results.

PAGE 4



Comment 1

This diagram is too small to see the detail.

you should:

1. reduce the distance between components - this would allow you to make the diagram larger on the page.
2. section the design with appropriate "To" / "From" connections



Comment 2

The pulse generator is to simulate the output of the thermocouple. Providing the maximum and minimum expected voltages to allow you to simulate the circuit.



Comment 3

In this application, the AC voltage source is to simulate the noise present in the input signal.

PAGE 5



Comment 4

Why was a 4th order butterworth chosen? You need to justify your choices.



Comment 5

How was this decided? You need to justify design decisions like this.



Comment 6

I don't think this is a commercially available value



Comment 7

Why are these roles critical? What are the roles? you need to be more descriptive.

PAGE 6

QM

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.

QM

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....

QM

Caption required

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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

PAGE 8

PAGE 9



Comment 8

a gain of 0.5 is a reduction though?



Comment 9

But the final output does not go from 0V to 5V

PAGE 10



Comment 10

Why is there no text in these sections?

QM

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.

JADE WILLIAMS

37.50

ENGAGEMENT WITH LITERATURE*including reading, referencing, academic conventions and academic honesty*

References to a limited range of mostly relevant sources. Some omissions and minor errors. Referencing conventions evident though not always applied consistently.

2

KNOWLEDGE & UNDERSTANDING*Knowledge of the basic underlying concepts and principles of a subject.*

Gaps in knowledge, with only superficial understanding. Some significant inaccuracies.

10.5

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.*

Some evidence of analytical intellectual skills, but for the most part descriptive. Ideas/findings sometimes illogical and contradictory. Generalised statements made with scant evidence. Conclusions lack relevance.

10.5

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



An adequate awareness and mostly appropriate application of well-established methods, materials, tools and/or techniques.
Basic appreciation of the context of the application.

12

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 effectively in a suitable format, but may have minor errors.
Mostly coherent work and is in a suitable structure.

2.5

You need to be more descriptive in your writing.