

Assignment

by Matthew Barnard

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Matthew Barnard

1702418

Transducers and signal conditioning

Signal Conditioning

Steve Mosey

Abstract

This paper is to illustrate the development of a circuit using temp sensors to determine the response time of the circuit.



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Introduction

This paper is to illustrate the design process for creating a temperature sensor circuit that runs $120\mu\text{V}/^\circ\text{C}$ with it being 0V at -80°C . It has a peak to peak output voltage of 1.2V at 50Hz.  2

This paper is to change the design so that the circuit will produce a voltage of 0V at a temperature at -20°C and 5V for 100°C . This paper will display each step taken in producing the circuit including the method, design, simulation results and discussion. The method section will describe what is happening and how the circuit was built. The design section will describe what the design looks like and how some of the more important components work and fit in to the design/

Method

The design process of this is to use Proteus to design and sum up a rough sketch of the circuit which will be used as a stepping stone before the finished product has been produced. For this circuit a few things will be needed like a temperature sensor, a Zener diode along with a few filters each of these will be described below in more detail. Once the circuit has been built the next phase will be to test the design and make sure everything is working along with taking the results and developing a graph showing the results. The requirements for this paper are to develop the circuit so that when the temperature is between -20°C and 80°C to display  3 a voltage of 0V to 5V going in increments of $120\mu\text{V}/^\circ\text{C}$. The probes that are used to measure each of the different sections will be placed in strategic places within the circuit to show variations of each of the different parts of the circuit so after each of the operational amplifiers a probe will be placed along with 1 at the start of the circuit showing the frequency response and the variation in voltage at the start of the circuit. The design of the circuit is to use level shifting to increase the voltage from a lower voltage to a higher voltage in this instance the voltage has gone from $120\mu\text{V}$ per $^\circ\text{C}$ to 41.6mV per $^\circ\text{C}$. So instead of the peak to peak voltage being 1.2V the new voltage peak to peak voltage is 5V.

Design

The design for this product will be to use Proteus to develop the circuit along with revealing the final graph giving the results required to complete this paper. For this part of the design process the temperature sensor will not be implemented into the design but instead a Sine wave will be used to generate a signal capable of showing how the rest of the circuit is functioning and therefore will change the response of the circuit but will function the same as normal.

The main components that will be used

In this section the main components will be described in more detail detailing how they work and what function they have within the circuit. The main components that will be used are the Zener diode, temperature sensor, operational amplifier and a Butterworth filter.

Temperature Sensor

There are a few different types of temperature sensors for example the RTD, thermistors, semiconductor sensor and a sensor IC. The one that will be used for this circuit design is called a Thermocouple which is made by joining two very different metals at one end. Where the two metals are joined is called the hot point and the other end is called the cold junctions if there is a difference in temperature between the 2 points a small voltage is created which is what is sent into the circuit and through the operational amplifiers giving the result. The RTD temperature sensor that varies its resistance depending on the temperature these devices are typically built using platinum, they typically have linear temperature over the temperatures that they run from. A thermistor is very similar in terms of functionality to the RTD but instead of using a very conductible material it uses a semiconductor material instead so there is a larger increase in resistance for smaller amounts of temperature change. Sensor ICs are a wide variety of sensors that can range and change depending on what preferences are required within specific projects and can be used in higher ranges of temperatures again depending on the preferences set out for the project. [1] [2]

Zener Diode

A Zener diode is the same design as a normal diode, but they are designed to have a low reverse breakdown voltage which uses any reverse voltage applied to it. Unlike a normal diode the reverse current, the Zener diode conducts once the predetermined voltage has been reached it will start to conduct in the reverse direction. In this case the voltage that was chosen was 5.1V so that the voltage of the circuit will never go above this voltage. [3] [4]

Operational Amplifier

Operational amplifiers are devices that can be used in different functions for example you can use them to boost the voltage within a circuit to drive something that requires more voltage, there are 2 types of these are an inverting operational amplifier and a non-inverting operational amplifier. A non-inverting operational amplifier will always have a Gain of 1 and will always produce the same graph as the original but with increased outputs. Whereas an inverting amplifier has a different response which is it will invert the value so if a positive voltage goes in a negative voltage will come so the graph will be inverted. Another function

that operational amplifiers are used for is acting as filters there are 4 different filters that mainly used which are high pass filter which only allows higher frequencies to come through the circuit so if the frequency is at 50Hz depending on the resistors you put in to the circuit it may let that frequency pass or it may not. A low pass filter which is what is being used in this circuit only allows low frequencies through the circuit once the cut-off frequency has been met the circuit will stop working. There is also a band- pass filter and band-stop filter, a band-pass filter only allows a select set of frequencies to go through the same as the band-stop filter. [5]

Butterworth Filter

The Butterworth filter is a type of filter that uses Capacitors instead of resistors to use to smooth the response or make the response as flat as possible depending on what order the filter is, this type of filter is used in many different fields of electronics which is an RF or audio active filter. The Butterworth filter was designed by Stephen Butterworth it has a constant gain or a maximum flat amplitude response in the attenuation level which is -3db and -20db. The design of the Butterworth filter is a lot easier than the Chebyshev and the Elliptic filters. While you increase the order of the Butterworth filter it still maintains its main shape unlike the Chebyshev and Elliptic filters which cannot maintain the shapes at higher orders. The Butterworth filter is used to shape the signals frequency spectrum most commonly used in communication systems. The filter changes its response from passband to band stop by removing its wide transition and is considered its main disadvantage of a Butterworth filter. The applications of a Butterworth filter are as follows:

- Is used in data conversion applications such as an anti-aliasing filter because of its flat passband nature.
- Radar target tracking displays used in submarines.
- High quality audio applications such as sound systems. [6] [7] [8] [9]

Chebyshev Filter

The Chebyshev filter is commonly used in distinct frequencies in 1 band from another. The windows-sink filter performance cannot be matched using this filter and are suitable for a variety of applications. The advantages of the Chebyshev filter are their faster windowed-sink and their speed, because the filters are carried out by recursion rather than convolution. Other key features of this type of filter are as follows;

- The roll-off is very steep, it reaches its roll-off quicker than other filters, 1 of the larger applications of this design is RF filters where a steeper transition between the pass-band and band stop.

- The ripple effect of the filter may provide a steeper roll-off but at the cost of the ripple, this aspect of the filter may deter people from using the Chebyshev filter. [10] [11]

Elliptic Filter

The Elliptic filter works by using a very fast transition between the stopband frequencies and the passband is required which in turn provides a larger gain ripple between the passband and stopband frequencies. A key feature of the Elliptic filter is for any situation that requires a fast transition between the stopband and the passband. The level of ripple between the 2 frequencies can be adjusted by changing features within the design. If the ripple between the 2 becomes 0 the filter becomes a Butterworth Filter instead. For this specific filter it achieves its major feature by using the minimum order that it can the more orders that are attached to this build the less likely the circuit will not work or the circuit will become a Butterworth filter which the more orders you have the better the circuit will be up to a certain amount of time. [12] [13]

The reason the Butterworth filter is chosen

The Butterworth filter is chosen because of its advantages over the other 2 filters is its naturally flat response, unlike the Chebyshev and Elliptic filters the higher the order the filter will still work to the best of its ability, along with its decreasing frequency response within the transition region.

Capacitor

The capacitor is an electronic device that can store electric charge and discharges it over time it is mostly used as a smoothing device, inside the capacitor there is a dielectric material that is used to store the electric charge there are 5 types of dielectric that can be used air, mylar, glass, ceramic and super capacitor. The most typical that is used is air the larger the capacitor the more electrical energy it can store. [14]

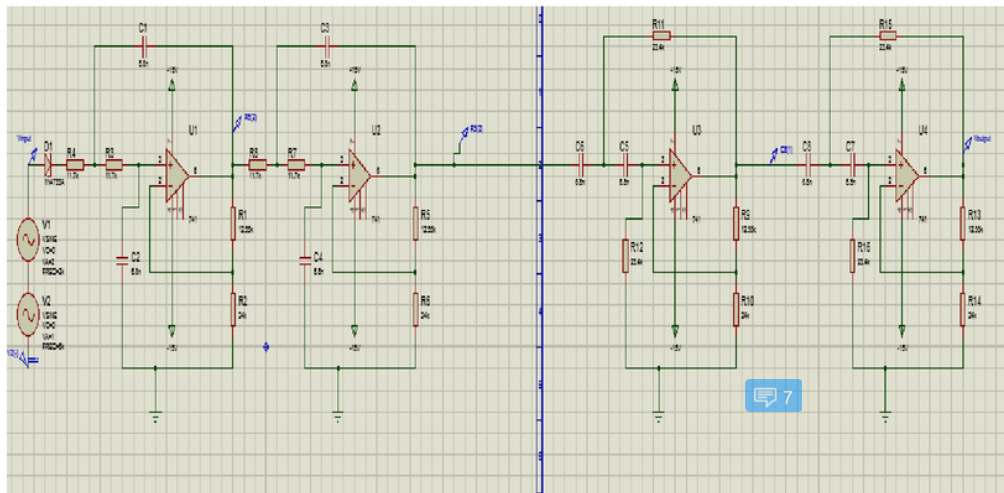
Resistor

The resistor is an electronic piece of equipment that can resist the flow of current within the circuits so if the circuit has a large current then the best way to regulate the current is by using a resistor with a larger resistance.

The final design

The final design of the circuit shown below (Fig. 1) has all the components listed above except for the temperature sensor which as stated before has been substituted by a sine wave to illustrate how the circuit works, this circuit is called a 4th order Butterworth filter meaning there is 4 different sections of the operational amplifiers being used to get to the result.

Fig. 1



Simulation results

The results for the circuit are exactly as it was needed to be providing the response required at the start of the report in the graphs below 1 shows the frequency response (Fig. 3) and the other is the voltage output (Fig. 2) of the circuit. As you can see from the voltage response graph there is a big wobble at the start of the time for 3 off the points within the circuit which are Voutput, C8 and R8 this is something that is possibly been found as a problem from Proteus as a design flaw, there is also a flaw with Voutput where for 1 cycle it has a peak to peak of 10V but then on the next clock cycle it has dropped to a peak to peak of 4.1V as an estimation therefore within the circuit there is a design flaw. The second graph is the frequency response graph which shows change of Gain within the circuit as can be shown below the Voutput and C8 have an increase before eventually dropping back down to depending on the frequency, the R8 section starts to drop instantaneously rather than showing the dip it goes straight down slowly at first but then goes down at a faster rate. The last section on the frequency response graph is the R5 graph which slowly drops through time and the rate of change doesn't change that much overtime. For the first graph which is the voltage output graph it again is set at certain points within the circuit the responses vary depending on the position it is within the circuit for example at the position of R5 the graph starts to increase as it should but as it reaches the top of the graph it flattens for a spell before

dropping back down and goes back to normal, at the C8 section starts off really wobbly and then goes back to its original graph that it should be and lastly the Voutput starts off wobbly and then goes up 5V and then drops on the next clock cycle to 4.2V at maximum.

Fig 2.

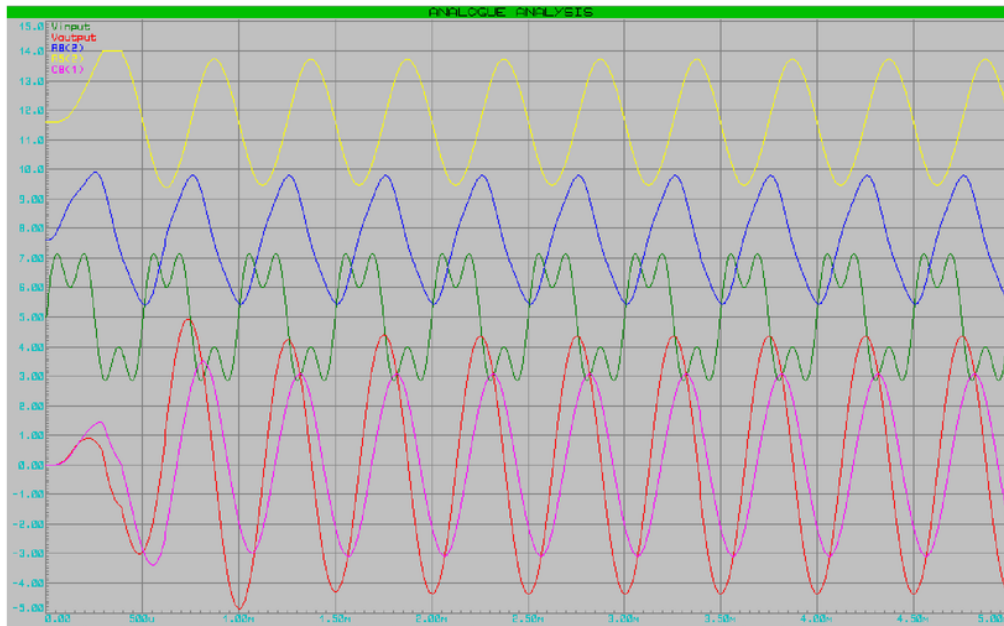


Fig. 3



Future developments

In the future this circuit could be improved by adding more filters which could drop the response of the Voutput on the graph in Fig. 3 which is the frequency response graph so that the drop will be steeper but increasing the order has a disadvantage also which is the stability within the filter become more prominent. Another feature that could be added is to figure out what caused the spike at the start of the circuit and why the output wasn't consistent and design the circuit to improve it and make the spike non-existent. Another future development could be to use the temperature sensor that was issued to be used at the start of the assignment to test to see the results would be when this feature is used mixing in with a 50Hz hum mixed with the temperature sensor using the Butterworth filter the 50Hz hum should be filtered out and won't be used. Another feature that could be used to improve the design is finding out what is giving the wobbly spikes giving at the start of the C8 and Voutput graphs and improving the design to get rid of these parts of the circuit along with finding out why the Voutput is only giving out 4.1V on the 3rd clock cycle and again redesigning the circuit to remove this feature and produce a 5V graph.

Conclusion

In conclusion this paper has illustrated the problem that was given and solved the problem, the graphs above indicate the results and the results have been recorded and described in detail. Using the equipment provided along with not using the temperature sensor but instead using a Sine wave to produce a signal and then producing a graph illustrating the details required which evidenced above shows the frequency response curve and the voltage output, where the frequency response curve is the more distinguishable graph it contains information that could be useful for example for this design the final output graph shows a slight increase and then after a certain frequency the Gain starts to drop down, at first quite slowly but then after a certain frequency more rapidly.

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Assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

54/100

PAGE 1

PAGE 2



Comment 1

Your abstract should have more information than this. It should contain not just what you have done, but why you did it and what you learnt in doing it.

PAGE 3

PAGE 4



Comment 2

This does not come from the sensor, it is electrical noise from outside the circuit.



Comment 3

Do you mean 100 deg C?

PAGE 5



Comment 4

it will have a gain of AT LEAST 1.

Gain is given by the equation

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

PAGE 6



Comment 5

Numbers nine and below should generally be written as words. This tends to make it more readable.



Comment 6

This is only applicable to filters implemented in digital signal processors as it is about the methods used to calculate individual output signal samples from the input signal samples and the filter coefficients.

PAGE 7

PAGE 8



Comment 7

Your circuit has both low pass filters and high pass filters. You were supposed to remove 50 Hz noise from a DC signal using only a low pass filter. I think you may have misunderstood what I was asking you to do.



Comment 8

...three of the points...



Comment 9

Your circuit design is analogue and should not have a clock signal. I think you may be incorrectly referring to the oscillation of your temperature sensor signal.

PAGE 9

PAGE 10



Comment 10

Probably caused by the capacitors in your filter charging up during the first half-cycle of the signal applied.

PAGE 11

PAGE 12

GRADING FORM: SMU GENERIC_SMOSEY

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



Outstanding knowledge of research-informed literature embedded in the work. Outstanding selection of relevant and credible sources. High-level referencing skills consistently and professionally applied.

4.25

KNOWLEDGE & UNDERSTANDING

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



While you have developed some functioning circuitry, I feel that you may have missed the main thrust of the assignment. You should have replaced the temperature sensor with a device which is able to provide equivalent voltages to represent the highest and lowest temperatures from the specification. These DC levels should propagate through the circuit and proportionate DC voltage levels should be output from the final stage of the circuit. As you have used high pass filters as the final stages of your circuit, the capacitors used in these filters will block these DC signals.

13.2

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.

 Evidence of some logical, analytical thinking and synthesis. You have provided a limited discussion of your simulation results and how they relate to the original design specification.

15.9

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.

 A very good application of a range of methods and techniques. Evidence of some innovation and creativity.

18

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.

2.75