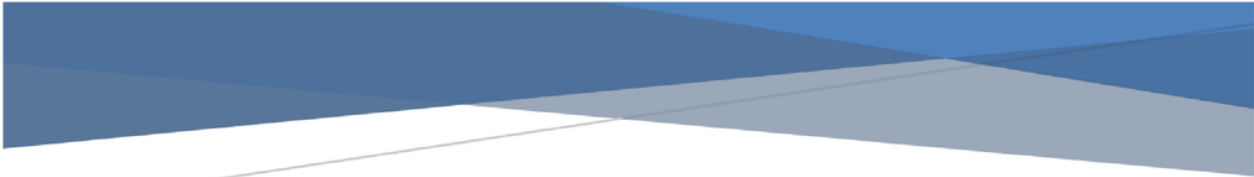


Thermocouples

by Sara Vonk

FILE	5782_SARA_VONK_THERMOCOUPLES_155401_2038833270.DOCX (1.06M)		
TIME SUBMITTED	24-JAN-2019 07:54PM (UTC+0000)	WORD COUNT	2659
SUBMISSION ID	99762211	CHARACTER COUNT	15699



TRANSDUCERS AND SIGNAL CONDITIONING

Assignment 1

[Abstract](#)

In this document it talks about the steps a student went through to complete the task that was assignment to them. They uses several software's to achieve the final amplifier they desired.

Sara Vonk

By Sara Vonk

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Task

For the module Transistors and signal conditioning it has been asked of the students to design a signal conditioning circuit that takes the input from a temperature sensor and outputs readings of 0V at -20°C and 5V at 100°C. The constraints are that the temperature sensor provides $120\mu\text{V}/^\circ\text{C}$ with 0V = -80°C and that there is contaminating noise of 1.2Vpk-pk 50Hz mains hum.

In order to do this the students are expected to design and create a working circuit on the program Proteus which they have been using in class. It is ok for the student to use other electronic equipment or programs to help them achieve their task.

Thermocouple

The temperature sensor hypothetically being used in the design is a thermocouple. A thermocouple is made up of two wires of different metals joined at one end. When two different metals are connected to each other a small voltage (mV), a potential difference occurs across the junction. If both junctions are at the same temperature the potential differences across the two junctions cancel each other out and there is no net emf. The emf generated is dependent on temperature. This is due to resistance being dependent on temperature and therefore due to Ohm's Law the temperature effects the emf generated, $V=I/R$. The total value of this emf depends on the two metals concerned and the temperatures of both junctions. Wire 'A' is attached/emerged in something of a constant known temperature such as an ice bath. Usually one junction is held at 0°C. Wire 'B' is left to become the temperate or lack of temperature in the environment. The voltage is measured where the two metals are joined.

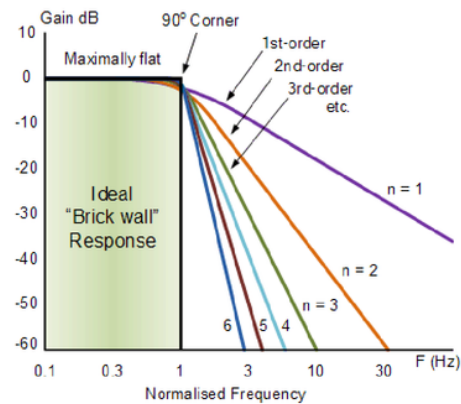
To maintain one junction of a thermocouple at 0°C it needs to be immersed in a mixture of ice and water. As this is usually inconvenient, a compensation circuit is used to provide the emf; integrated circuits are available such as AD594. [Engineering Science fourth edition W. Bolton /



Butterworth filter



The Butterworth filter is a **pacific** type of filter that is designed to have a frequency response as flat as possible in the unfiltered pass band. There are more effective filters then the butter worth, but their frequency response graphs are not as clean to read. For this reason, it is very common to see cascading Butterworth filters, as the more you have cascading the sharper and cleaner the cut of frequency value is. It is also known as a maximally flat filter.



Amplifier

To achieve the task that has been set it is important to have an amplifier as we must amplify the signal coming from the thermocouple from miller volts to regular volts. An amplifier is a circuit which multiplies a signal going in to it to produce a larger version of the signal. Not all amplifiers are the same you can get different classified circuits depending of the amplifiers configuration and how it operates.

In electronics small amplifiers are often used devices as they can amplify a small input signal for example a thermocouple into a much larger output signal.

Level shifting

Level shifting is when you take a DC current or a AC signal and add or subtract a certain amount of voltage from the original input. For example, you could have a +5v DC voltage supply but your microchip can only handle +2.5v. For this you could simply use two resistors and make a voltage divider. $V_{out} = V_{in} * R_2 / (R_1 + R_2)$. Or you could use a Zener diode to prevent any voltage over 2.5v passing through it.

Or if you wanted to level shift your voltage up/ increase it you could simply add how many volts you needed to the signal or direct current. If it is a signal it will simply ride on top of the voltage you add.

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Voltage Protection

Over voltage protection is used when delicate electronic devices that are sensitive to high voltages are run of a power source that could spick or is prone to having higher voltages than the device can handle. To fix this you could simply put a Zener Diode in to prevent excess voltage damaging the device. For more protection you could use transformers. These are used quite often then a device is being connected to the mains. It creates a totally circuit break

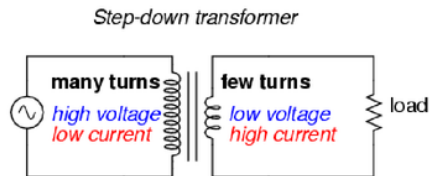


Figure 1transformers

Gain

Gain is the term used for how much an amplifier multiplies an input signal by or to put it more eloquently . “ The introduction to the amplifier gain can be said to be the relationship that exists between the signal measured at the output with the signal measured at the input. There are three different kinds of amplifier gain which can be measured and these are: *Voltage Gain* (A_v), *Current Gain* (A_i) and *Power Gain* (A_p) “

Values for thermocouple in task

In order to find the appropriate values for the thermocouple output at the required values, an excel spread sheet was used with three columns one for temperature in degrees Celsius, one for the output voltage in mV and one for the expected results after amplification and level shifting. The starting value cells had the values of -80 for the temperature and 0 for the voltage. For the next cell in the temperature column a reference to the first cell was used and added 1 to the data in that cell, for the voltage I used the same technique but added 0.12×10^{-3}

''

Ideal voltage out put	Voltage out of thermocouple	Correlating temperature
0	0.00072	-20
0.041667	0.000732	-19

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0.083333	0.000744	-18
0.125	0.000756	-17
0.166667	0.000768	-16

Using this I was able to derive a table that showed an output of 7.2mV at -20°C and 21.6mV at 100°C.

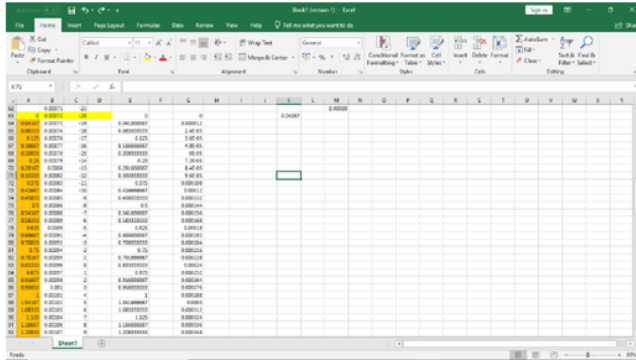


Figure 2 excel screen shot

The image above shows two other columns that have not been explained yet. Just out of curiosity and trying to work out the best was to go about the issue at hand, the different between the two voltage results was worked out. This was don't as I was trying to work out what the easiest mathematical path was to get from the first voltage values to the final voltage values ranging from 0v to 5v.

$$=5v/120steps$$

$$=0.04167v/perstep$$

$$=0.04167/ 0.000012$$

$$=3472.22$$

$$=(raw\ voltage\ *3472.22)-2.5$$

=smooth voltage increased from 0v-5v, proven as it matches the end result perfectly. See the 2 orange columns below.

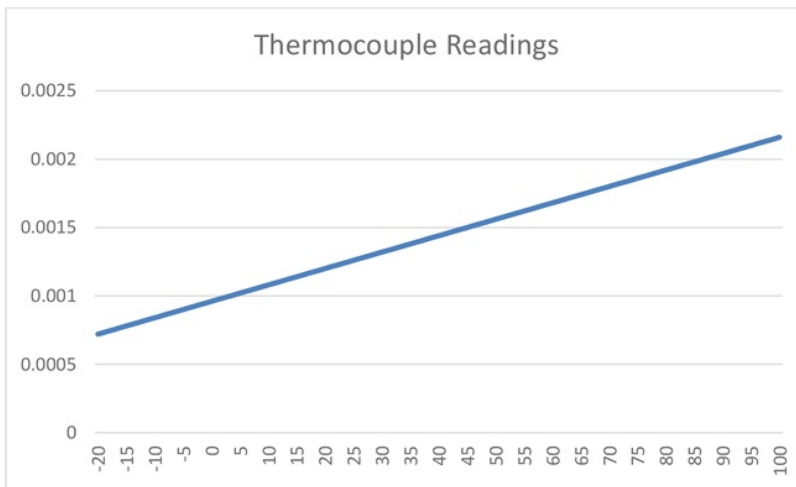
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63	0	0.00072	-20	0
64	0.04147	0.00072	-19	0.041666667
65	0.08133	0.00074	-18	0.083333333
66	0.121	0.00076	-17	0.125
67	0.16667	0.00077	-16	0.166666667
68	0.20833	0.00078	-15	0.208333333
69	0.25	0.00079	-14	0.25
70	0.29167	0.0008	-13	0.291666667
71	0.33333	0.00082	-12	0.333333333
72	0.375	0.00083	-11	0.375
73	0.41667	0.00084	-10	0.416666667
74	0.45833	0.00085	-9	0.458333333
75	0.5	0.00086	-8	0.5
76	0.54167	0.00088	-7	0.541666667
77	0.58333	0.00089	-6	0.583333333
78	0.625	0.0009	-5	0.625
79	0.66667	0.00091	-4	0.666666667
80	0.70833	0.00092	-3	0.708333333
81	0.75	0.00094	-2	0.75
82	0.79167	0.00095	-1	0.791666667
83	0.83333	0.00096	0	0.833333333
84	0.875	0.00097	1	0.875
85	0.91667	0.00098	2	0.916666667
86	0.95833	0.001	3	0.958333333
87	1	0.00101	4	1
88	1.04167	0.00102	5	1.041666667
89	1.08333	0.00103	6	1.083333333
90	1.125	0.00104	7	1.125
91	1.16667	0.00106	8	1.166666667
92	1.20833	0.00107	9	1.208333333
93	1.25	0.00108	10	1.25

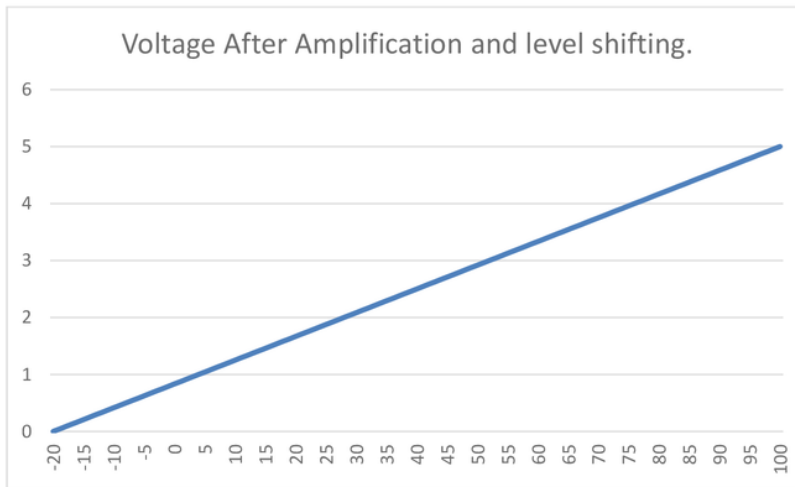
Figure 3 excel screen shot

=L61/K61

=(B64*\$M\$61)-2.5



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1st stage amplification of the signal

To get a usable signal a first order amplifier was used to take the lowest signal required 7.2mV to -0.5V using an inverting amplifier. The gain I needed to do this I calculated as

$$G = \frac{0.5}{7.2 \times 10^{-3}} = 69.44$$

Therefore using an input resistor of 1k I need a feedback resistor of

$$A = \frac{-R_f}{R_i}$$

$$A \times R_i = -R_f = 69.44 \times 1k = 69.44k$$

Inverting Amp circuit

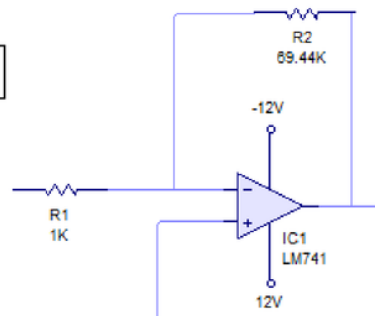


Figure 4 inverting amp circuit

Mixed signal and noise

After amplifying the signal the stage in conditioning the signal is to remove or filter out the 50Hz noise. In order to do this I use a low pass filter. As the dc signal also needs to be further amplified I have used a 'Butterworth' active filter. Active low-pass filters use an RC filter followed by an operational amplifier. The buffer has high input impedance and so has little effect on the frequency response of the RC circuit. Active filters make use of RC combinations and the reactance of the capacitor to ac signals, that is the capacitor offers less opposition to ac when.

- Its capacitance is large ie it stores more charge
- The frequency of the ac signal is high, causing the charge to flow of the plates in a shorter time

This is capacitance reactance and is denoted by X_c and is given in Ohms by the equation

$$X_c = \frac{1}{2\pi fC}$$

[Success in Electronics 2nd edition Tom Duncan]



So the capacitor used in conjunction with a resistor acts as a potential divider.

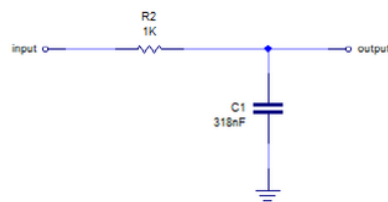


Figure 5 potential divider

An active filter uses a RC network as shown above but with an Op Amp as shown below.

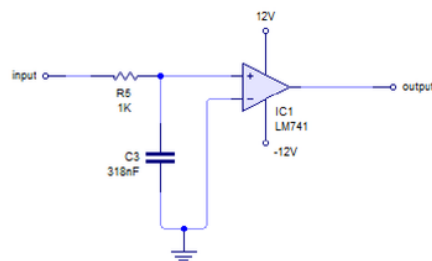


Figure 6 Op Amp

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Order of filter is defined by number of **active elements** in the filter, above is shown a first order filter, a second order low-pass filters have two reactive components, that is two capacitors and so on for third, fourth etc.

To calculate the cut off frequency for my filter I used the formula

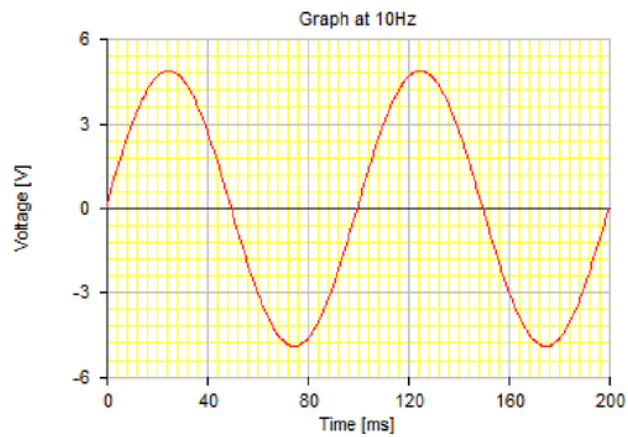
$$f_c = \frac{1}{2\pi RC}$$



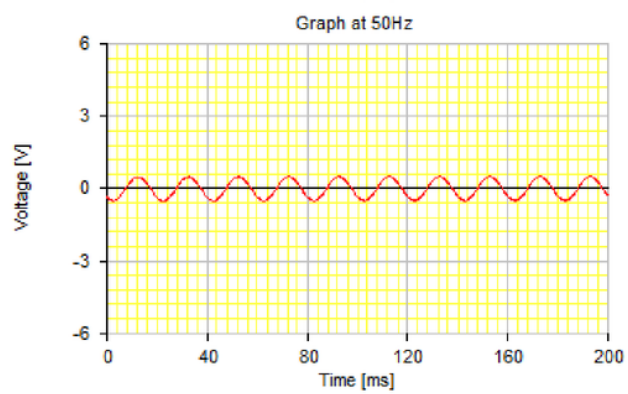
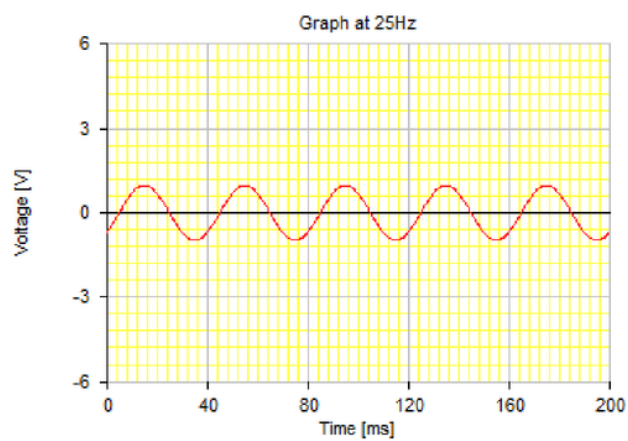
As I know the resistor value that I am using is 1kΩ and that the frequency of the AC that I need to remove is 50Hz then I rearrange the equation making C subject

$$C = \frac{1}{2\pi R f_c} = \frac{1}{2\pi \times 1k \times 50} = \frac{1}{314 \times 10^3} = 3.18 \times 10^{-6}$$

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Graphs at various frequencies using
Livewire simulation package



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For the filter we also need to amplify the input dc signal from -0.5v to -1v and as the amp I am using is a non-inverting amp I can calculate the value of the feedback resistors from output voltage is minus 1volts input voltage is minus 0.5 so I need a gain of 2.

Non-inverting amplifier equation is $A = 1 + \frac{R_f}{R_i} = 1 + \frac{10k}{10k} = 1 + 1 = 2$

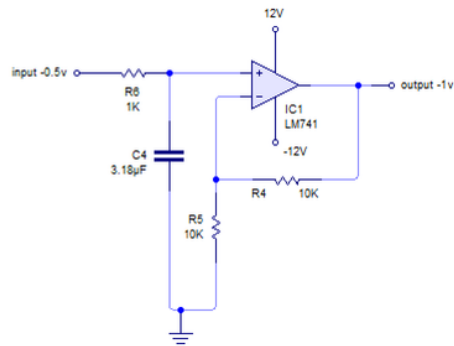


Figure 7 Live wire screen shot

so at the output of my second stage I have a dc output of -1volt.

Level shifting summing amplifier

Summing amplifier is an inverting amplifier with more than one voltage at the input terminal. For an inverting amplifier, the output voltage is given as,

$$V_{OUT} = - (R_f/R_{IN}) V_{IN}$$

So for the summing amplifier shown, the output equation would be,

$$V_{OUT} = - \{ (R_f/R_{IN1}) V_{IN1} + (R_f/R_{IN2}) V_{IN2} \}$$

At the lowest input signal we need an output of 0.0v. so with -1v on V_{IN1} and 5v on V_{IN2}

From the above equation we can derive that $V_1/R_1 + V_2/R_2 = -V_{out}/R_f$

Putting values we have $-1/1k + 5/5k = 0/R_f = 0V_{out}$

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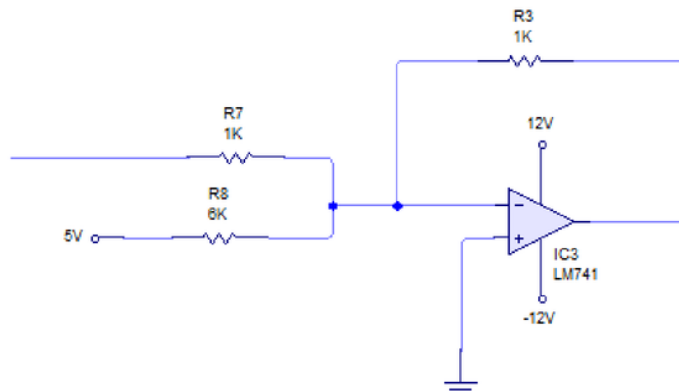


Figure 8 Livewire screen shot

For the lowest signal value R_f makes no difference, but for the higher value a 5v output is needed

Therefore using the previous equation and putting values into it we get

$$-5v/R_f = -2.75v/1k + 5v/5k = -1.75k$$

$$1/R_f = -1.75k/-5v = 0.35 \times 10^{-3} \quad \text{so} \quad R_f = 1/0.35 \times 10^{-3} = 2.9k\Omega$$

After the schematic was running smoothly on Live wire the program on the home computer, the circuit was then re-created on Proteus as that is the preferred **software** of use for the University of Wales Trinity St David's.

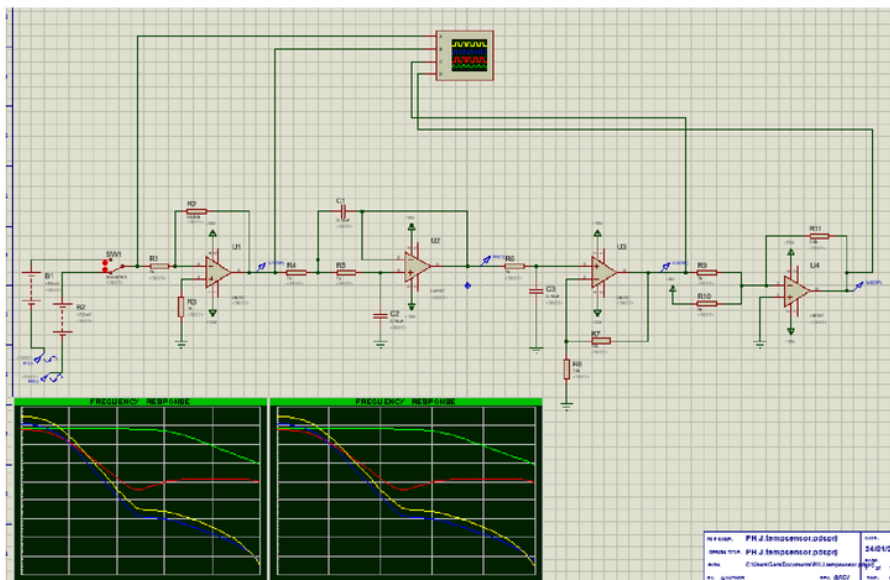


Figure 9 Proteus screen shot

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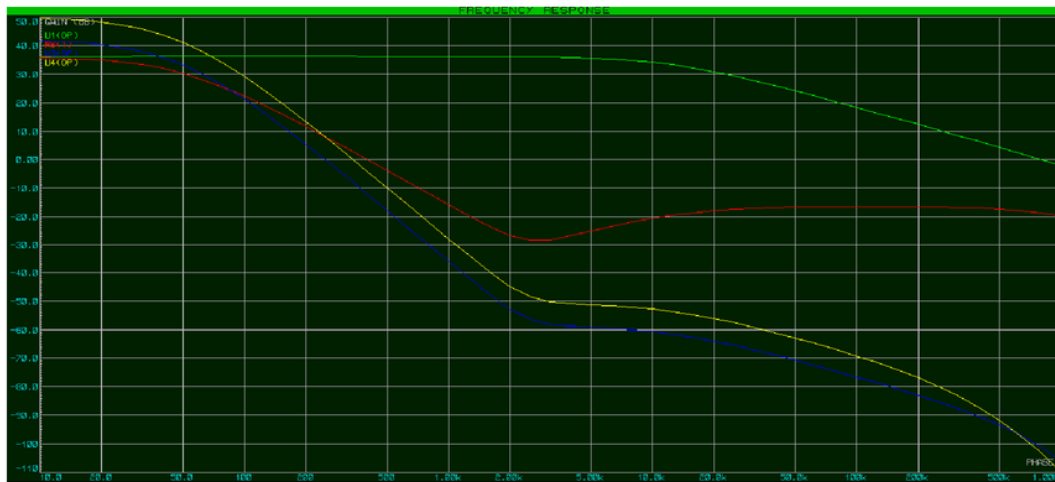


Figure 10 Frequency Response

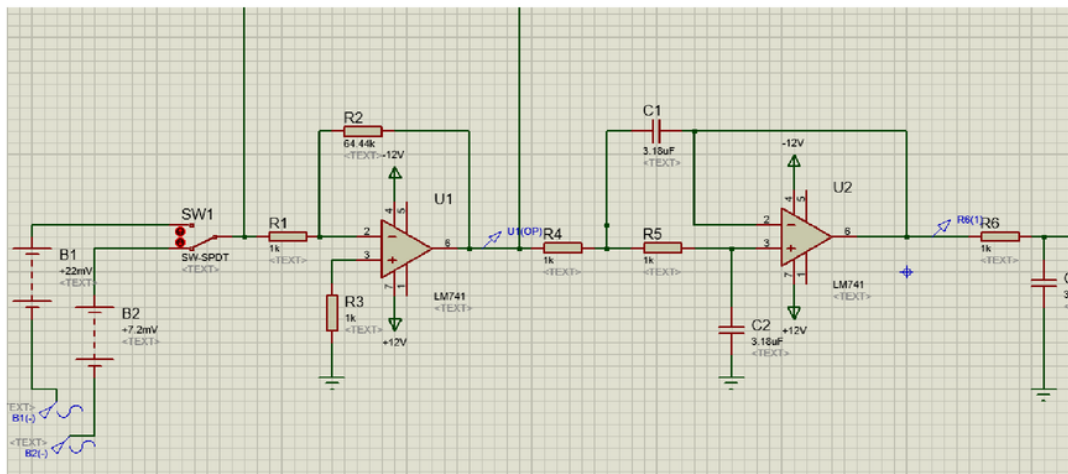


Figure 11 Screen Shot of Proteus

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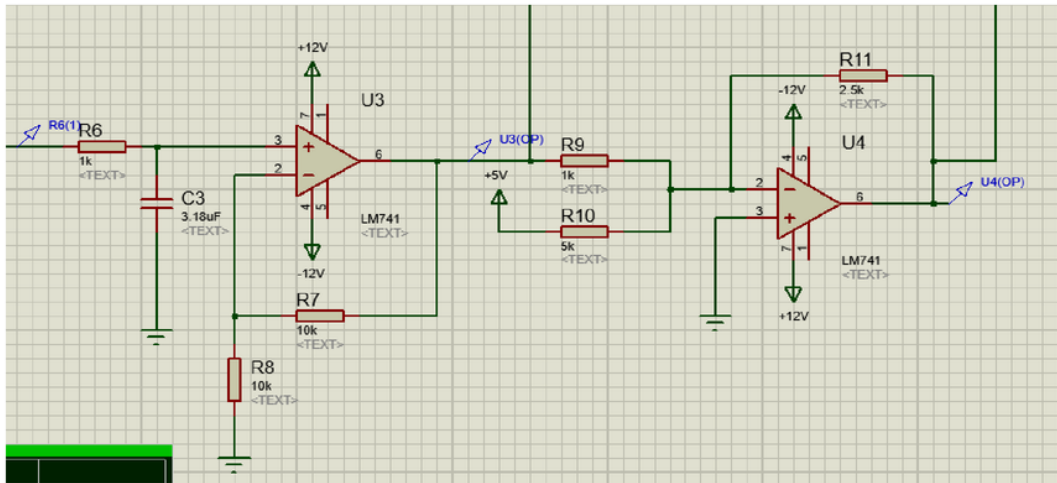


Figure 12 Screen shot of proteus

Below you can see a prototype of the Main circuit. This came from a circuit that was demonstrated to the class. Multiple changes were made from the original. The resistor values where changed to give a steeper gradient. To make the circlet more efficient.

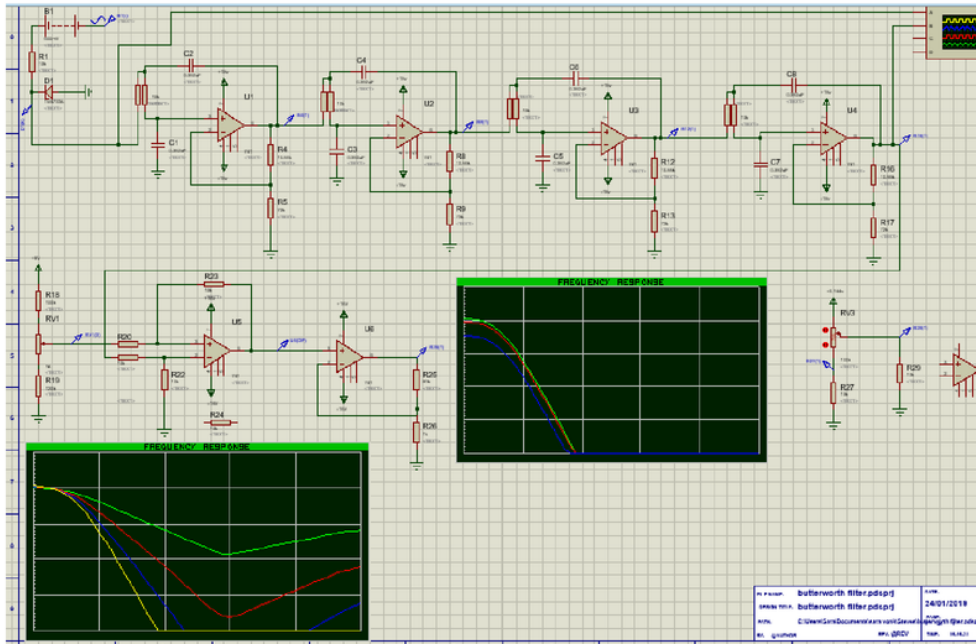


Figure 13 screen shot of class demo alterations

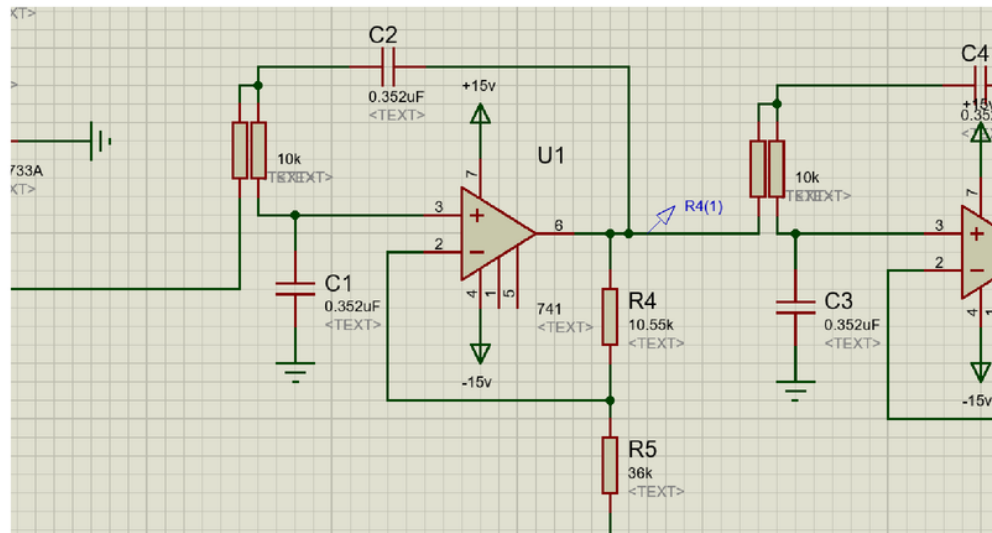


Figure 14 screen shot of Proteus

Conclusion

You will never get a perfect filter, but at the same time a filter never has to be perfect. As long as it does the job well enough for a human not to be able to detect the errors then it is classed as a working filter. You have multiple levels of this in the electronic industry. Most people could tell the difference between a device with an ok filter and a device with a good filter but not many could tell the difference between a good one and an explant one.

If this was a personal project that was going to take place for recreational purposes, then there would be more time to make a better smaller and more efficient version of the circlet. There are quite a few things that could have been improved but maybe it reflects my inexperience that the circuit isn't how I know it could have been if I felt more confident making things. I would say that personally my mathematical knowledge isn't up the standard that it should be to do a project like this well. Over all the circuit works and does the fundamental things that were expected of it. It's somewhat messy but for a basic prototype it does the job.

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Below is the a part of the excel spread sheet that was made.

0	0.00072	-20	0	0
0.041667	0.000732	-19	0.041666667	0.000012
0.083333	0.000744	-18	0.083333333	2.4E-05
0.125	0.000756	-17	0.125	3.6E-05
0.166667	0.000768	-16	0.166666667	4.8E-05
0.208333	0.00078	-15	0.208333333	6E-05
0.25	0.000792	-14	0.25	7.2E-05
0.291667	0.000804	-13	0.291666667	8.4E-05
0.333333	0.000816	-12	0.333333333	9.6E-05
0.375	0.000828	-11	0.375	0.000108
0.416667	0.00084	-10	0.416666667	0.00012
0.458333	0.000852	-9	0.458333333	0.000132
0.5	0.000864	-8	0.5	0.000144
0.541667	0.000876	-7	0.541666667	0.000156
0.583333	0.000888	-6	0.583333333	0.000168
0.625	0.0009	-5	0.625	0.00018
0.666667	0.000912	-4	0.666666667	0.000192
0.708333	0.000924	-3	0.708333333	0.000204
0.75	0.000936	-2	0.75	0.000216
0.791667	0.000948	-1	0.791666667	0.000228
0.833333	0.00096	0	0.833333333	0.00024
0.875	0.000972	1	0.875	0.000252
0.916667	0.000984	2	0.916666667	0.000264
0.958333	0.000996	3	0.958333333	0.000276
1	0.001008	4	1	0.000288
1.041667	0.00102	5	1.041666667	0.0003
1.083333	0.001032	6	1.083333333	0.000312
1.125	0.001044	7	1.125	0.000324
1.166667	0.001056	8	1.166666667	0.000336
1.208333	0.001068	9	1.208333333	0.000348
1.25	0.00108	10	1.25	0.00036
1.291667	0.001092	11	1.291666667	0.000372
1.333333	0.001104	12	1.333333333	0.000384
1.375	0.001116	13	1.375	0.000396

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1.416667	0.001128	14	1.416666667	0.000408
1.458333	0.00114	15	1.458333333	0.00042
1.5	0.001152	16	1.5	0.000432
1.541667	0.001164	17	1.541666667	0.000444
1.583333	0.001176	18	1.583333333	0.000456
1.625	0.001188	19	1.625	0.000468
1.666667	0.0012	20	1.666666667	0.00048
1.708333	0.001212	21	1.708333333	0.000492
1.75	0.001224	22	1.75	0.000504
1.791667	0.001236	23	1.791666667	0.000516
1.833333	0.001248	24	1.833333333	0.000528
1.875	0.00126	25	1.875	0.00054
1.916667	0.001272	26	1.916666667	0.000552
1.958333	0.001284	27	1.958333333	0.000564
2	0.001296	28	2	0.000576
2.041667	0.001308	29	2.041666667	0.000588
2.083333	0.00132	30	2.083333333	0.0006
2.125	0.001332	31	2.125	0.000612
2.166667	0.001344	32	2.166666667	0.000624
2.208333	0.001356	33	2.208333333	0.000636
2.25	0.001368	34	2.25	0.000648
2.291667	0.00138	35	2.291666667	0.00066
2.333333	0.001392	36	2.333333333	0.000672
2.375	0.001404	37	2.375	0.000684
2.416667	0.001416	38	2.416666667	0.000696
2.458333	0.001428	39	2.458333333	0.000708
2.5	0.00144	40	2.5	0.00072
2.541667	0.001452	41	2.541666667	0.000732
2.583333	0.001464	42	2.583333333	0.000744
2.625	0.001476	43	2.625	0.000756
2.666667	0.001488	44	2.666666667	0.000768
2.708333	0.0015	45	2.708333333	0.00078
2.75	0.001512	46	2.75	0.000792
2.791667	0.001524	47	2.791666667	0.000804
2.833333	0.001536	48	2.833333333	0.000816
2.875	0.001548	49	2.875	0.000828
2.916667	0.00156	50	2.916666667	0.00084
2.958333	0.001572	51	2.958333333	0.000852
3	0.001584	52	3	0.000864
3.041667	0.001596	53	3.041666667	0.000876
3.083333	0.001608	54	3.083333333	0.000888
3.125	0.00162	55	3.125	0.0009
3.166667	0.001632	56	3.166666667	0.000912
3.208333	0.001644	57	3.208333333	0.000924
3.25	0.001656	58	3.25	0.000936
3.291667	0.001668	59	3.291666667	0.000948

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3.333333	0.00168	60	3.333333333	0.00096
3.375	0.001692	61	3.375	0.000972
3.416667	0.001704	62	3.416666667	0.000984
3.458333	0.001716	63	3.458333333	0.000996
3.5	0.001728	64	3.5	0.001008
3.541667	0.00174	65	3.541666667	0.00102
3.583333	0.001752	66	3.583333333	0.001032
3.625	0.001764	67	3.625	0.001044
3.666667	0.001776	68	3.666666667	0.001056
3.708333	0.001788	69	3.708333333	0.001068
3.75	0.0018	70	3.75	0.00108
3.791667	0.001812	71	3.791666667	0.001092
3.833333	0.001824	72	3.833333333	0.001104
3.875	0.001836	73	3.875	0.001116
3.916667	0.001848	74	3.916666667	0.001128
3.958333	0.00186	75	3.958333333	0.00114
4	0.001872	76	4	0.001152
4.041667	0.001884	77	4.041666667	0.001164
4.083333	0.001896	78	4.083333333	0.001176
4.125	0.001908	79	4.125	0.001188
4.166667	0.00192	80	4.166666667	0.0012
4.208333	0.001932	81	4.208333333	0.001212
4.25	0.001944	82	4.25	0.001224
4.291667	0.001956	83	4.291666667	0.001236
4.333333	0.001968	84	4.333333333	0.001248
4.375	0.00198	85	4.375	0.00126
4.416667	0.001992	86	4.416666667	0.001272
4.458333	0.002004	87	4.458333333	0.001284
4.5	0.002016	88	4.5	0.001296
4.541667	0.002028	89	4.541666667	0.001308
4.583333	0.00204	90	4.583333333	0.00132
4.625	0.002052	91	4.625	0.001332
4.666667	0.002064	92	4.666666667	0.001344
4.708333	0.002076	93	4.708333333	0.001356
4.75	0.002088	94	4.75	0.001368
4.791667	0.0021	95	4.791666667	0.00138
4.833333	0.002112	96	4.833333333	0.001392
4.875	0.002124	97	4.875	0.001404
4.916667	0.002136	98	4.916666667	0.001416
4.958333	0.002148	99	4.958333333	0.001428
5	0.00216	100	5	0.00144

By Sara Vonk

Reference

https://www.electronics-tutorials.ws/amplifier/amp_1.html

<https://itp.nyu.edu/physcomp/lessons/electronics/level-shifting/>

https://www.electronics-tutorials.ws/amplifier/amp_1.html

<http://hyperphysics.phy-astr.gsu.edu/hbase/electric/tcoup.html>

<https://www.thermocoupleinfo.com/>

Thermocouples

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

51 / 100

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PAGE 3



Comment 1

Your references should be listed using the school's preferred referencing style which is the IEEE numeric style. Information on this can be found on the library's website.



Comment 2

specific

PAGE 4



Comment 3

millivolts



Comment 4

I assume you mean...

"To achieve the task that has been set it is important to have an amplifier to increase the amplitude of the signal to ensure it meets the desired specification.

PAGE 5



Comment 5

provides electrical isolation?



Comment 6

Reference style

PAGE 6

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Comment 7

Ref style

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Comment 8

active elements - operational amplifiers

reactive elements - capacitors or inductors



Comment 9

π not μ

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Comment 10

software?

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GRADING FORM: SMU GENERIC_SMOSEY

SARA VONK

50.50

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



References to a limited range of mostly relevant sources. Referencing conventions not always applied consistently.

2.35

KNOWLEDGE & UNDERSTANDING

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



Knowledge is accurate with a good understanding of the field of study.

15.9

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 some attempts to synthesise, albeit with some weaknesses. Some relevant conclusions

13.5

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



It would have been nice to see a complete circuit diagram with each section identified and labelled along with a description of its operation

16.5

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 in a suitable format but with some room for improvement. Work lacks coherence in places and could be better structured.

2.25