

Logbook Lucy

by Lucy Henson

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Workshop skills Logbook

Workshop Skills Logbook

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L4 - Workshop Skills

ACDA4022

Embedded Electronic systems
Engineering Degree Apprenticeship

Introduction

This lab report shows the process of designing, simulating and assembling an inverting operational amplifier. An Op Amp can amplify the AC signal input by a factor of 3. The op amp used throughout this lab report is the lm741. The standard formula to calculate gain of the circuit is

$$A = \frac{V_{out}}{V_{in}}$$

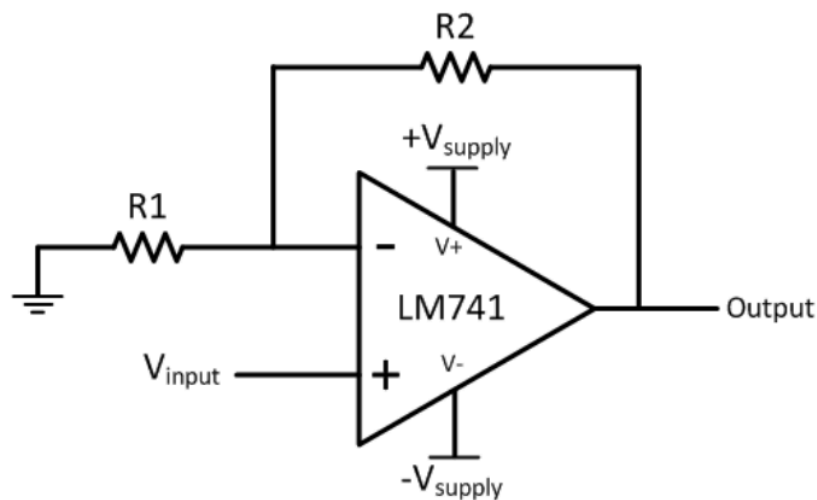


Figure 1 Inverting Amplifier lm741 schematic from manufacturer

Aim

- To create a schematic of an inverting op amp
- To design a PCB of the op amp
- To create the op amp on a breadboard
- To properly assemble the PCB

Proteus Amplifier circuit simulation

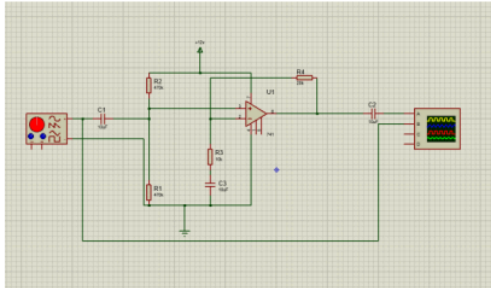


Figure 2 Proteus Op Amp schematic

The op amp I am using is an LM741. I started by focusing on building the schematic on proteus as can be seen in figure 1. I then simulated the circuit using the built-in virtual signal generator and oscilloscope and then simulated the circuit using a virtual signal generator and oscilloscope. The peak-to-peak output voltages was recorded using the oscilloscope and a signal generator was used to provide a constant sinusoidal 2V input. To calculate Gain its $A = \frac{V_{out}}{V_{in}}$. The results can be seen below in figure 3.

Simulation			
Frequency (Hz)	Input Voltage (V)	output voltage (V)	Gain(dB)
1	2	3.5	4.860760974
2	2	4.84	7.67630732
5	2	5.76	9.187849755
10	2	5.92	9.425834221
20	2	5.98	9.513423766
50	2	6	9.542425094
100	2	6	9.542425094
200	2	6	9.542425094
500	2	6	9.542425094
1000	2	6	9.542425094
2000	2	6	9.542425094
5000	2	6	9.542425094
10000	2	6	9.542425094
20000	2	6	9.542425094
50000	2	5.8	9.247959958
100000	2	3.28	4.296876961
200000	2	1.7	-1.411621486
500000	2	0.666	-9.55111533
	Lower Breakdown Frequency	Higher Breakdown Frequency	
	2.3Hz	59kHz	

Figure 3 Results from Proteus simulation showing output voltage and gain across a range of frequencies with a 2V input sine wave

In Figure 3 we can see that as long as the frequency range is between 5 and 50000Hz the Op amp behaves as expected with a gain in the circuit of 3. using the equation $\text{Gain(dB)} = 20\log\left(\frac{V_{out}}{V_{in}}\right)$ and recording the operational frequencies The simulations breakdown frequency is at 59kHz this is when the op amp gain reduces by -3dB.To work out the Gain Bandwidth Product (GBP) you multiple breakdown frequency by the gain of the op amp which is 3. The simulation has a GBP of 177kHz.

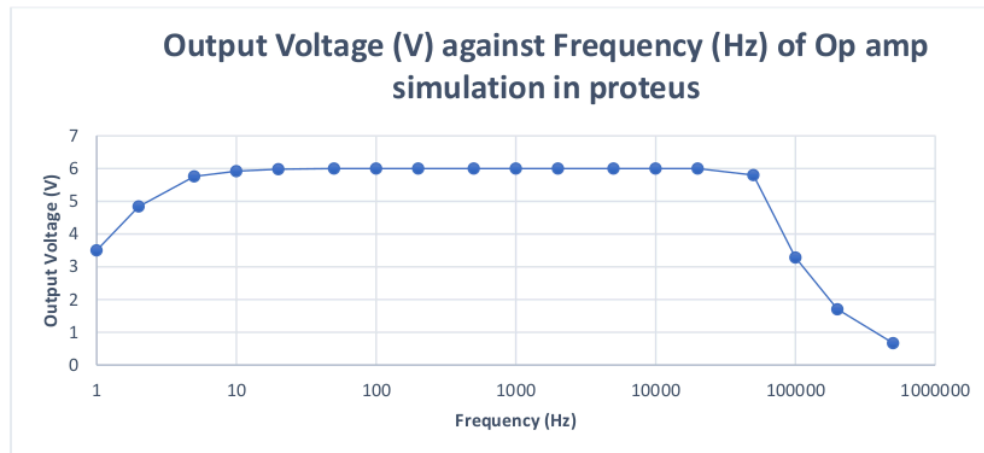


Figure 4 Graph Output voltage against Frequency results from proteus simulation

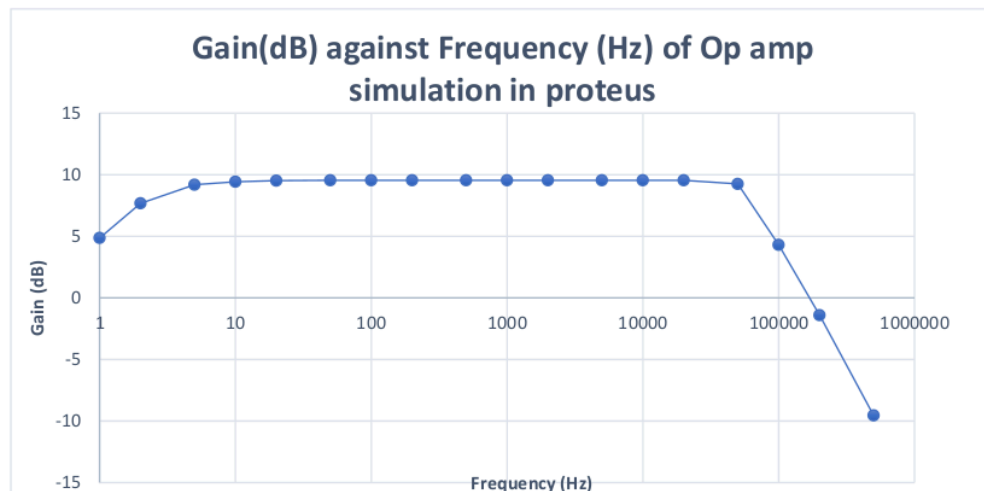


Figure 5 Graph Gain against Frequency of simulation in Proteus

Breadboarding the Op amp

Equipment used in breadboard

- Jumper wires
- Oscilloscope
- Power supply
- Signal generator

Component	Component quantity
Resistor 470K	2
Capacitor 10uF	3
LM741 op amp	1
Resistor 10K	1
Resistor 20K	1

The circuit was tested on a breadboard to test whether the circuit would behave as well in real working conditions. When assembling the circuit on the breadboard I made the mistake of not properly ground the circuit which lead to the output waveform not being amplified. The waveform generated can be seen below in figure 6. Once I sorted the ground out, I connected the green input wire to the signal generator and the purple output wire to the oscilloscope. If repeated I would make the wire length shorter so that the whole circuit is easier to see and to reduce emf interference. Below in figure 7 you can see the breadboard completed.

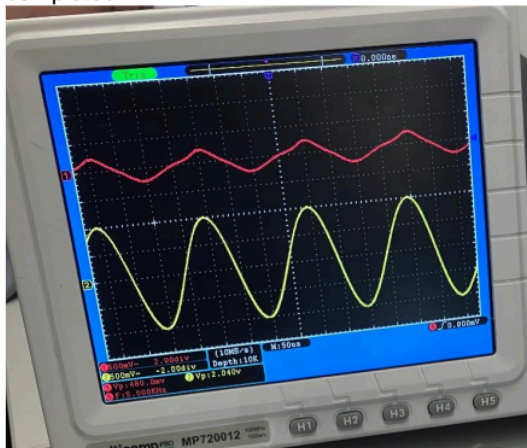


Figure 6 improper grounding of PCB waveform on oscilloscope

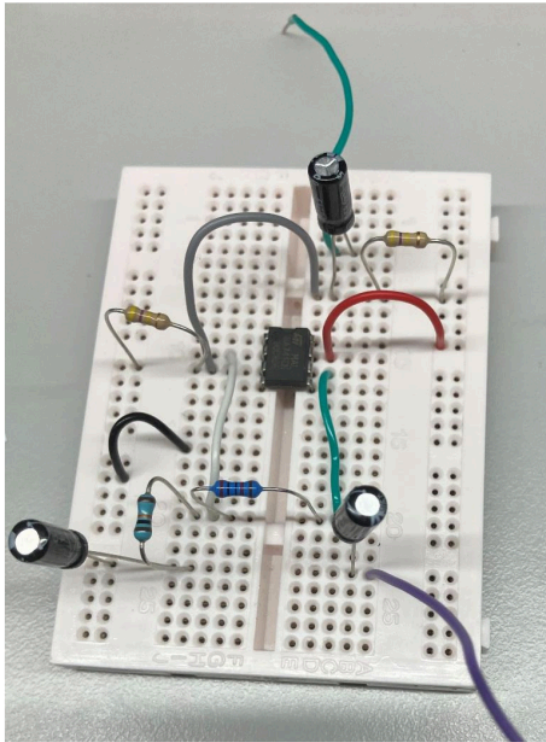


Figure 7 breadboard ready for testing

The breadboard was set up exactly as the schematic with the correct values for the resistors and capacitors. The breadboard was using an input peak to peak voltage of 2V sine wave with a frequency range from 1Hz to 500000Hz and the output was observed on an oscilloscope. The input waveform is connected to the green wire and the output waveform is connected to the purple wire can be seen above in figure 6. Shown below in figure 8 is the results for the breadboard.

breadboard ampliflyer			
Frequency (Hz)	Input Voltage (V)	output voltage (V)	Gain (db)
1	2	1.53	-2.32677
2	2	2.76	2.797582
5	2	3.84	5.666025
10	2	4.98	7.923987
20	2	6.24	9.883092
50	2	6.24	9.883092
100	2	6.16	9.771014
200	2	6.16	9.771014
500	2	6.02	9.57133
1000	2	6.02	9.57133
2000	2	6.02	9.57133
5000	2	6.01	9.55689
10000	2	5.78	9.217957
20000	2	4.68	7.384317
50000	2	3.68	5.296356
100000	2	2.04	0.172003
200000	2	1.04	-5.67993
500000	2	0.555	-11.1347
Lower Breakdown Frequency		Higher Breakdown Frequency	
1.8Hz		54kHz	

Figure 8 Breadboard results table

The breadboard and simulation both had a gain of 3db. The Breadboard amplifier had breakdown frequencies as 1.8Hz and 54kHz and a GBP of 162kHz comparing the frequencies to the simulation they are very similar to the simulation's frequencies of 59kHz and 2.3Hz. The difference in GBP can be explained by the breadboard not having a proper ground plane and the components not behaving ideally. Figures 9 and 10 show the graphs of voltage and gain against frequency for the breadboard.

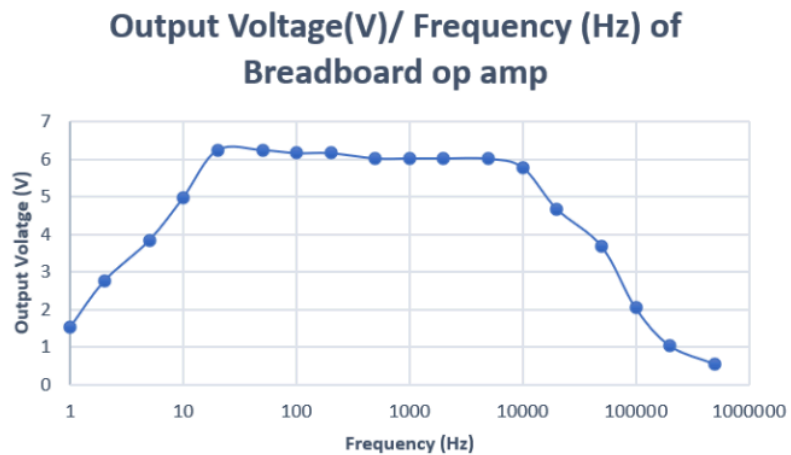


Figure 9 Output voltage (V) against Frequency (Hz) for the op amp breadboard circuit graph

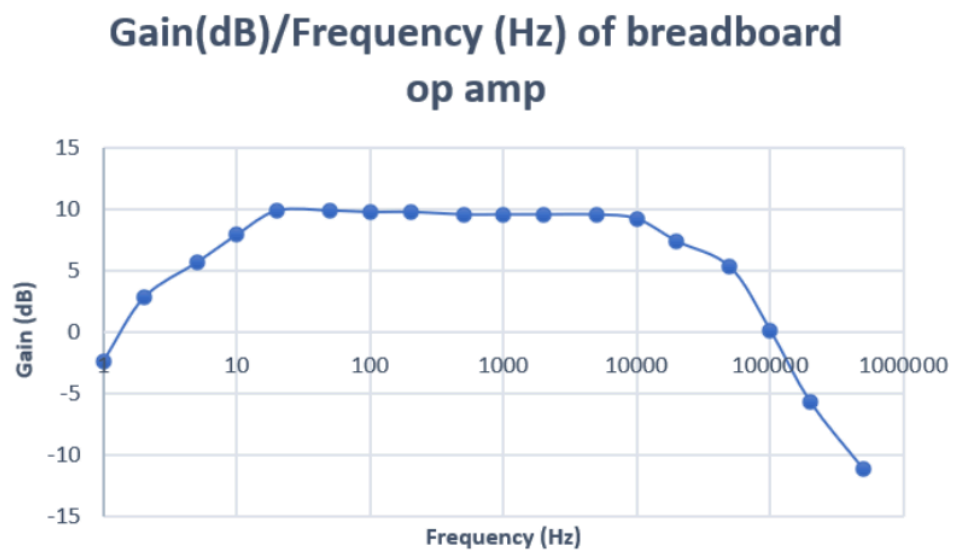


Figure 10 Gain (dB) against Frequency (Hz) for the op amp breadboard graph

PCB design and build

After proving the circuit would work on a breadboard, I then began converting the schematic into a PCB format using Easy-Pc. When replicating the schematic, I took extra care in making sure the values were correct and that the orientation of the polarized capacitors were correct. This can be seen in Figure 11

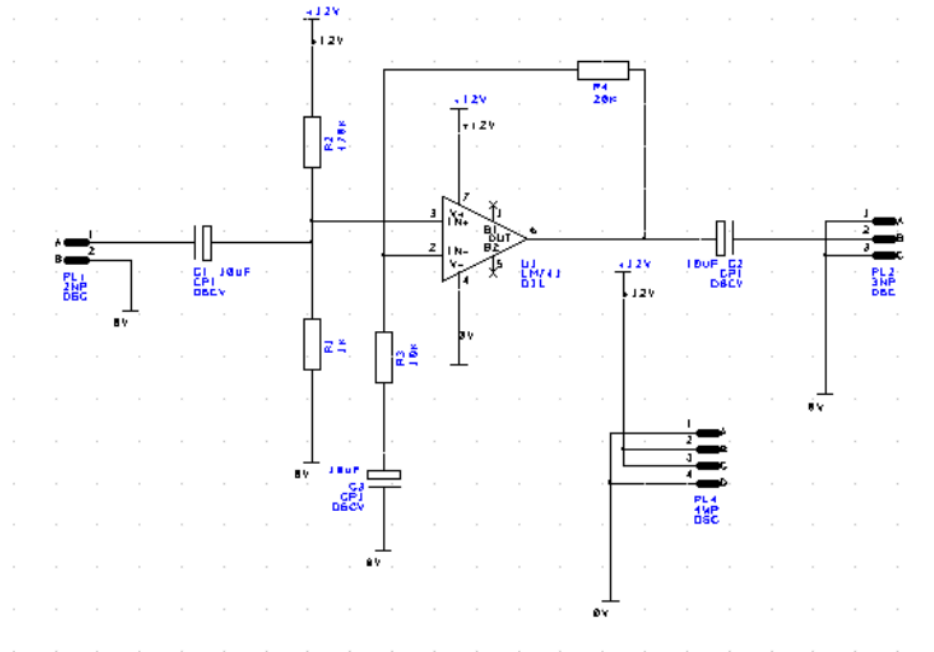


Figure 11 Schematic of Op Amp in Easy-pc

The next part of the assignment was to convert the schematic into a PCB file. When converting my schematic, originally, I had difficulties placing components too close together which could have potentially caused electromagnetic interference issues another problem presented was having the components being too close to the connectors which would have made it hard to test the board. Once I had sorted out component placements, I decided to create a ground plane adding a bottom copper layer to reduce interference. After this I

added my name on the silk screen to complete the design process. Below in figure 12 is the end results of my design.

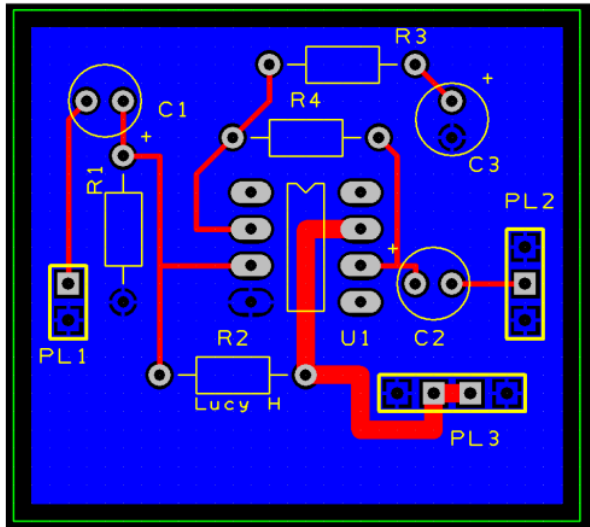


Figure 12 PCB design in Easy pc

PCB Assembly

Equipment used in assembling

- Soldering iron and sponge
- Lead free solder
- Helping hand
- Wire strippers
- Extractor fan

Component	Component quantity
Resistor 470K	2
Capacitor 10uF	3
LM741 op amp	1
Resistor 10K	1
Resistor 20K	1

Before assembling my PCB, I made sure that my workstation was clear of any hazards and that I had all the tools needed to begin the assembling. The soldering iron was properly tinned to ensure the tip would not corrode and the extractor fan was turned on. When soldering I began by soldering the resistors first as their low profile would make them easier to solder. When soldering the op amp, I made sure that the notch which indicated where pin 1 was, was correctly orientated in place before I began. In the design process I added a label to correctly indicate the correct polarity for the capacitor this meant I was able to solder them without any issues. If I were to repeat the project, I would have soldered the capacitors last as I soldered the pin connectors last which meant I needed an extra pair of hands to hold the pin connectors in place as the connectors could not stay in the helping hands and the connector had no wires which could be bent to allow the component to stay into place. This meant I found it very hard to keep the connectors straight when soldering.

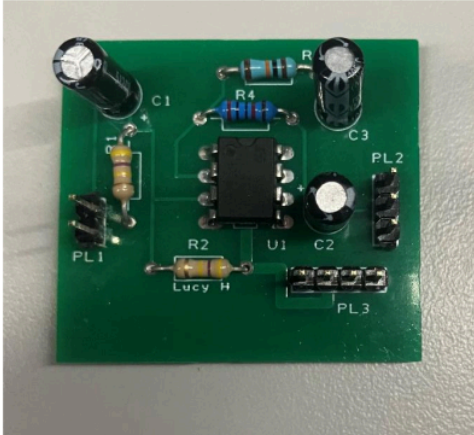


Figure 13 finished PCB top view

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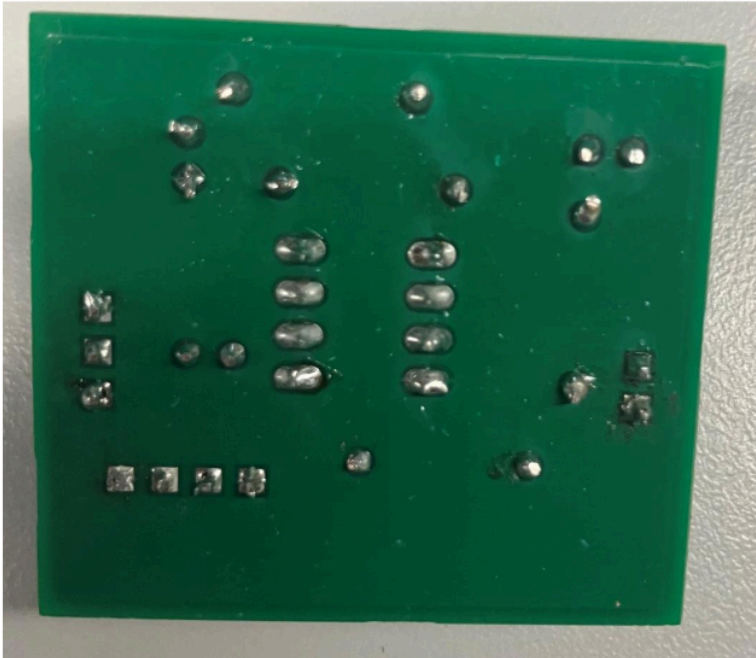


Figure 14 PCB bottom finished soldering

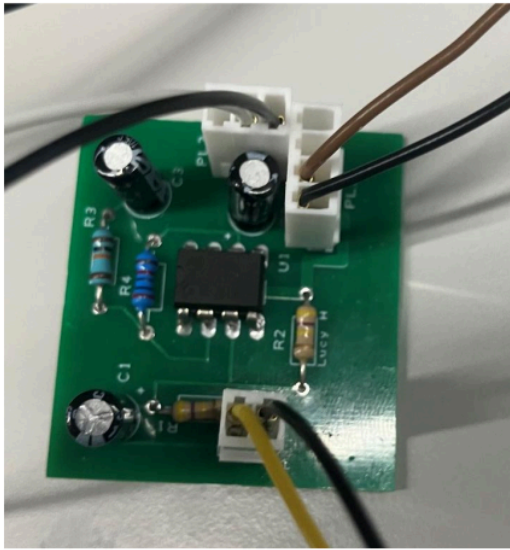


Figure 15 PCB being tested

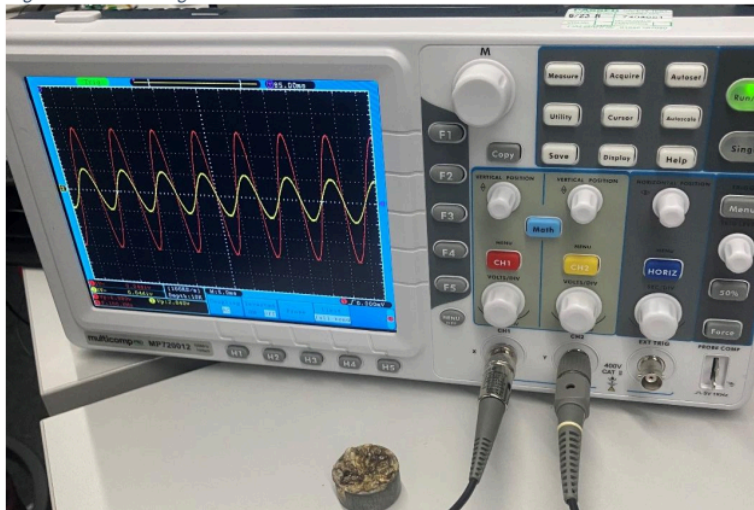


Figure 16 PCB output on oscilloscope

PCB Testing

The PCB was tested using the 2V input sine wave which can be seen in figure 16 above and the results of the output wave at different frequencies are recorded below in figure 17. The data compared to both the simulation and breadboard are very similar with the PCB performing much more like the simulated circuit. The components I soldered on to the PCB

were the exact same I used in the breadboard this eliminates any potential differences from tolerances in manufacturing process.

PCB			
Frequency (Hz)	Input Voltage (V)	output voltage (V)	Gain(dB)
1	2	2.36	1.43764
2	2	4.24	6.52672
5	2	5.72	9.12732
10	2	6.04	9.60014
20	2	6.08	9.65747
50	2	6.12	9.71443
100	2	6.12	9.71443
200	2	6.08	9.65747
500	2	6.08	9.65747
1000	2	6.08	9.65747
2000	2	6.08	9.65747
5000	2	6.12	9.71443
10000	2	6.08	9.65747
20000	2	6.04	9.60014
50000	2	4.64	7.30976
100000	2	2.16	0.66848
200000	2	1.2	-4.43697
500000	2	0.52	-11.7005
Lower Breakdown Frequency		Higher Breakdown Frequency	
2.1hz		55khz	

Figure 17 PCB results table

Comparing the data between all three the PCB behaves more like the simulation as opposed to the breadboard. The PCB had a GBP of 165kHz whereas the simulation had a GBP of 177kHz, and the breadboard had a GBP of 166kHz. The values all range in the expected range with the slight difference between the PCB and breadboard coming from the breadboard not having a proper ground plane and being more susceptible to interference due to the wires acting more like antennas compared to the PCB. The difference between the PCB and simulation can be expected as the simulation used ideal components which would not be possible in a real working environment. Below in figures 18 and 19 are the graphs for the PCB.

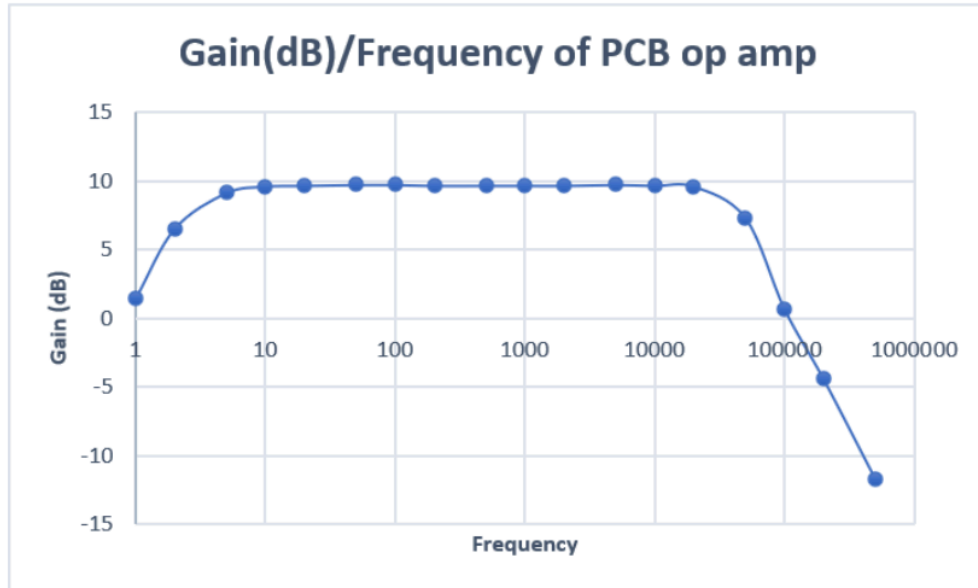


Figure 18 Graph of gain against frequency for PCB

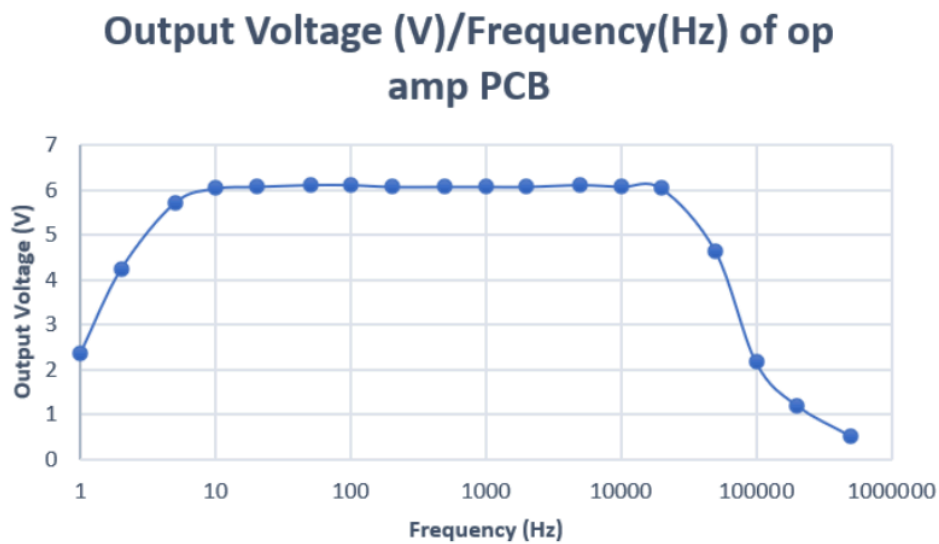


Figure 19 graph of output voltage against frequency for PCB

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FINAL GRADE

GENERAL COMMENTS

76/100

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Comment 1

There is no ground connection on your op-amp. This should connect to pin 4

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Comment 2

not if they're all part of the same circuit. The only time this becomes an issue is when there are sensitive or high frequency electronics close to something switching high power. This will cause noise from the switching to interfere with the sensitive electronics. For this circuit, this is not a problem.

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Comment 3

Generally a good layout, but the components could be placed closer together and some of the tracks could be routed better - this would have resulted in a smaller board.

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GRADING FORM: SMU GENERIC_SMOSEY

LUCY HENSON

76

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



There are no marks available for this section

0

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

28

of challenges to established views and the limitations of the knowledge base.

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.



There are no marks available for this section

0

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



Soldering 70% - Very good but some joints have too much solder on them.

Layout 70% - Not too bad although could be a little smaller.

Populating 100% - All components fitted flush to PCB with no gaps beneath.

Functioning 100% - PCB functions correctly.

$(70+70+100+100)/10=34\%$

34

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 professionally and, confidently in a suitable format.

Work is coherent, very fluent and is presented professionally.

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