

Workshop Skills ACDA 4022 - Assignment logbook - David Reynard

by David Reynard

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Workshop Skills Logbook

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L4 - Workshop Skills
ACDA4022

Embedded Electronics Systems
Engineering Degree Apprenticeship

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1. Introduction

The task assigned is to take an existing operation amplifier circuit design through the prototyping and manufacturing processes. This will include: simulated testing, bread board prototype building, and PCB design/population. Testing, diagnostics and characterisation will be required at each stage of this process.

1.1. Technical Context

The non-inverting amplifier we have been specified to manufacture, is that of standard design, using an LM741 op-amp integrated circuit (IC) chip.

This circuit has been specified to produce a voltage gain of 3, meaning that it will output a voltage level 3 times that of the input level under optimal functioning conditions.

The gain of 3 is determined in this format (Non-inverting) using the equation $\text{Gain} = 1 + (R2/R1)$ [1]. There are a number of values that could meet the criteria of 3 gain for R1 and R2, but 2 simple numbers that fit nicely are 20kΩ & 10KΩ respectively.

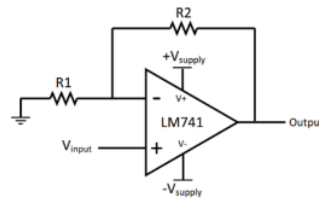


Fig. 1 - Operational Amplifier recommended application method. Adapted from [1].

2. Circuit Digitisation

To begin circuit planning, familiarisation with the circuit design and simulator: Proteus, was required. My practise covered the basics of setting up our own schematics, component selection, and component placement/connection.

2.1 – Circuit design and Simulation

Initial attempts were made to put together the op-amp circuit in the format shown in Fig. 2.

The circuit was built without major error due to the relative simplicity of the task. Upon final inspection before simulation, it was found that a few wire connections were not accurate to the diagram provided and were swiftly rectified.

The circuit was then simulated and produced an output as shown in Fig. 3. As is evident, the general structure and amplification level is almost correct but a major give away that something was wrong is indicated by the flattening of the negative peak of the signal.

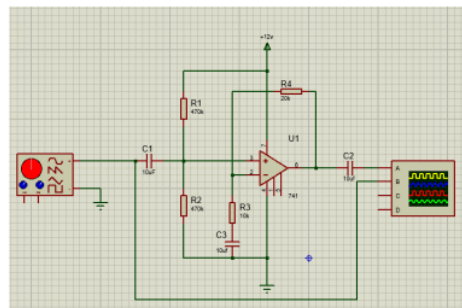


Fig. 2 – Proteus application containing op-amp circuit.

It initially suspected that this was a fault could be attributed to a capacitance issue, but this was found to be incorrect after ensuring capacitance values and component placement were not at fault. The next train of thought was to attribute these symptoms to 'clipping', a phenomena that occurs in signal amplification when the amplifier is overdriven and its power supply is unable to produce the required output. In an attempt to rectify this, input signal voltage was reduced from 3.1v peak to peak (P2P), to 2v. This resulted in the now correct output on the right side of Fig. 3.

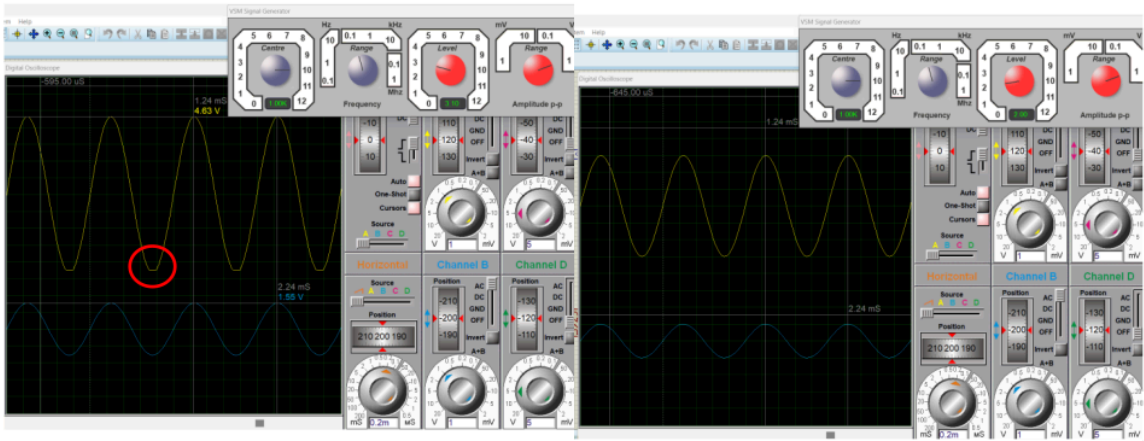


Fig. 3 - Proteus simulated oscilloscopes of active amplifier. Left containing overdriven circuit, right containing correctly driven circuit.

2.2 – Simulation Characterisation

The operational frequency of the circuit was to be evaluated at this point. This was done by calculating the gain at a logarithmic interval of frequencies using the equation:
Voltage Gain (dB) = $20 \log(\frac{V_{out}}{V_{in}})$, recording the peak to peak voltage provided by the oscilloscope output as seen in the Fig. 3. A table of values was then generated in excel, Tab. 1.

This data provides accurate insight into the bandwidth limit of the circuit, allowing for precise acquisition of the exact frequency point whereby the output drops by 3dB or 4.242v p2p in this case. The output data shows 4.242v will lay between 1-2 Hz at the lower level, and 50-100 KHz for the upper.

Investigating these frequencies, it was found that the lower level drops by 3dB at 1.4Hz, outputting 4.2v, and the upper level at 76 KHz, also outputting 4.2v. Using this, the circuit gain bandwidth product (GBP) can be calculated by subtracting the lower frequency limit from the upper frequency limit and multiply by 3. This leaves us with:

$$GBP = ((76 \times 1000) - 1.4) \times 3 = 227,995.8$$

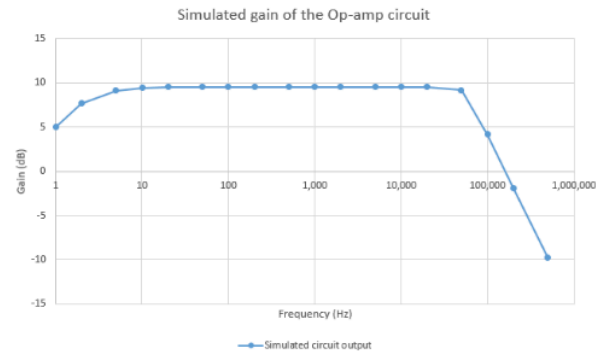


Fig. 4 - Sheet containing data and graph depicting op-amp gain vs frequency

Simulated circuit output			
F	Vpp In	Vpp Out	Gain (dB)
1	2	3.54	4.959465
2	2	4.84	7.676307
5	2	5.72	9.127321
10	2	5.92	9.425834
20	2	5.98	9.513424
50	2	6	9.542425
100	2	6	9.542425
200	2	6	9.542425
500	2	5.98	9.513424
1000	2	5.98	9.513424
2000	2	6	9.542425
5000	2	6	9.542425
10000	2	6	9.542425
20000	2	5.98	9.513424
50000	2	5.74	9.157638
100000	2	3.22	4.136518
200000	2	1.612	-1.8733
500000	2	0.65	-9.76233

Tab. 1 - Simulated circuit input and output data set, as graphed in fig. 4

3. Bread board Testing

Having validated the circuit design by simulation, prototyping can begin so as to further validate the physical feasibility of the design. Bread board prototyping is an appropriate technique for this design. This technique is used to construct an electronic representation of the circuit, without the need for permanent fixtures. This method is effective due to its speed, flexibility, and simplicity, appropriate to this design due to the low number of total components.

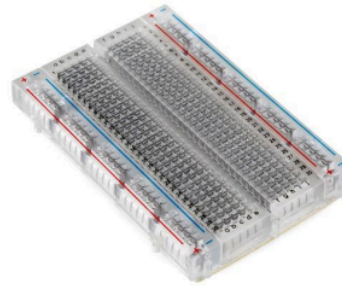


Fig. 5 - Image of standard bread board [3]

3.1 – Prototype planning

Although bread boarding is a very flexible method, part of the drawback to this flexibility is that it requires unique planning due to the connection method of the conductive tracks. To combat this a spreadsheet was employed (Fig. 6 - Spreadsheet bread board plan Fig. 6) to digitise the bread board format. The benefit of this being it allows for easy modification and manipulation without permanent commitment.

Component	Value	Size		
R1	470K	4		+12v
R2	470K	4		0v
R3	10K	4		Signal
R4	20K	4		Signal Out
C1	10uF	2		Clear
C2	10uF	2		Div Barrier
C3	10uF	2		
U1 LM741		4*3		

12V+										W1											
A					R3				R3												
B															W3						
C	W6				W5		R4										Signal +				
D																					
E	4				3		2		1						C3+		C1-				
										U1 LM741											
F	5				6		7		8						C3-		C1+				
G					R4		W1										R1				
H							W2								R2		R2				
I	C2-						C2+										W2				
J	Signal Out						W3								W3		W5				
0V										W6		W3									

Fig. 6 - Spreadsheet bread board plan

3.2 – Bread board assembly

Bread board assembly in this case consists of sticking to the plan, and ensuring components are placed correctly.

Close consideration was taken to ensure polarised components, such as capacitors, were assembled in the correct polarity. Capacitor polarity is identifiable by the strip running down the cathode side, Fig. 7.

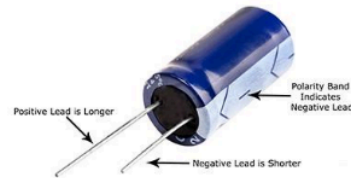


Fig. 7 - Labelled diagram of electrolytic capacitor [4]

Similarly, close attention was paid to the LM741 IC orientation, this was identified by the engraved circle marking where pin 1 would be, Fig. 8. From there, the rest of the pins are numerically ordered, counting counter-clockwise.

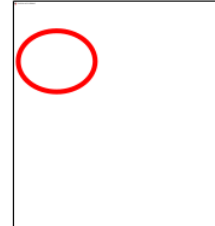


Fig. 8 - Image of LM741 IC, pin 1 identifier circled in red. [5]

Component preparation was completed to ease the assembly process. In the case of resistors, the legs were bent to a close to 90 degree angle to improve fit. Pliers were employed for precision placement in component congested areas.

In order to prepare bridging wires, correct wire stripping tools and techniques were applied to allow a clean cut, appropriately exposed conductor. Over stripping a wire can cause the conductor to peek beyond the insulated plastic surface, causing possible safety risk at higher voltages and risking circuit performance.

3.4 – Bread board function test

With the bread board prototype now being complete (Fig. 9) it must be function tested to ensure it has been correctly assembled, and can represent a successful prototype. For this we will need a number test equipment pieces:

- Oscilloscope

Used view and measure analogue signals, the tool we will use to measure the output signal voltage, and calculate the gain of the amplified signal.

- Signal generator

Used to generate a generic input sine wave, the one this circuit design will amplify.

- Digital Power supply unit

Used to generate the supply needed to power the amplifier. The design requires +12v that provides the amplifier the energy required to boost our input signal.

- Associated test leads

The listed equipment requires appropriate cables to be able to connect to the input/output of the circuit. These will be terminated on one end with a crocodile clip, to allow for interfacing with the bread board open wires.

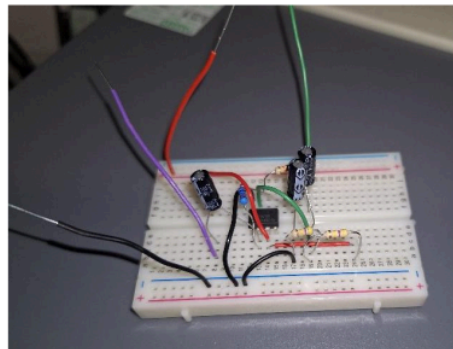


Fig. 9 - Populated bread board prototype

The configuration of this equipment, Fig. 10, is identical to that which is described in the Proteus simulation in Fig. 2. My wire colour scheme follows my bread board plan in Fig. 6.

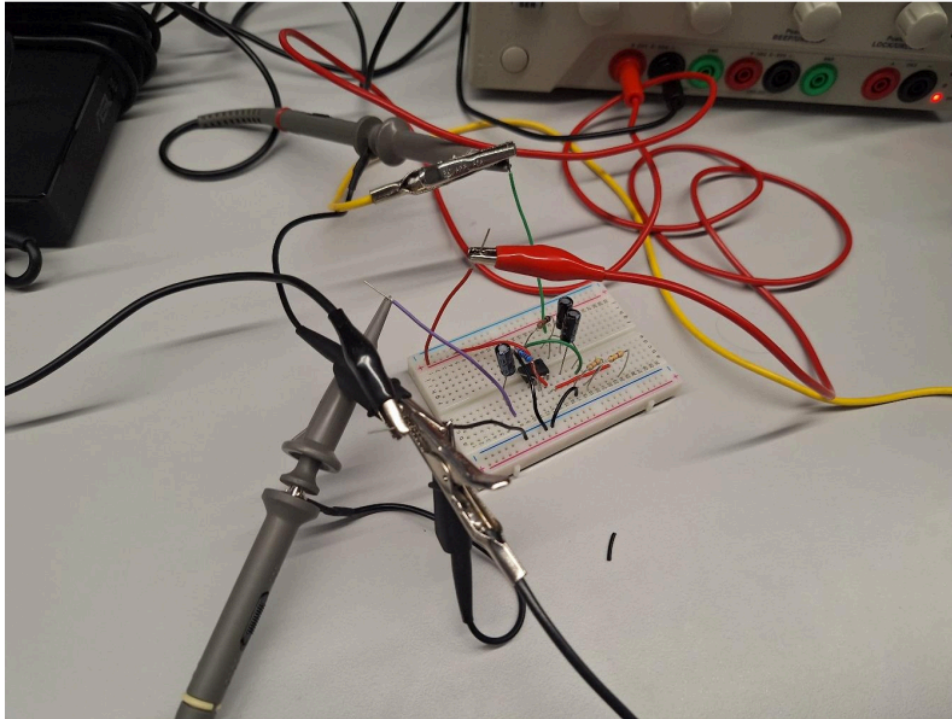


Fig. 10 - Physical test setup for bread board prototype

The circuit functioned as expected, closely following initial simulation. The output measurement, Fig. 11, shows our input P2P voltage (in yellow) to be 2.04V, and the output (in red) 6.16V P2P at a frequency within our optimal operation area [1] at 500Hz. These values result in a calculated gain of 9.60dB or 3.02, well within tolerance of the simulated 9.54dB.

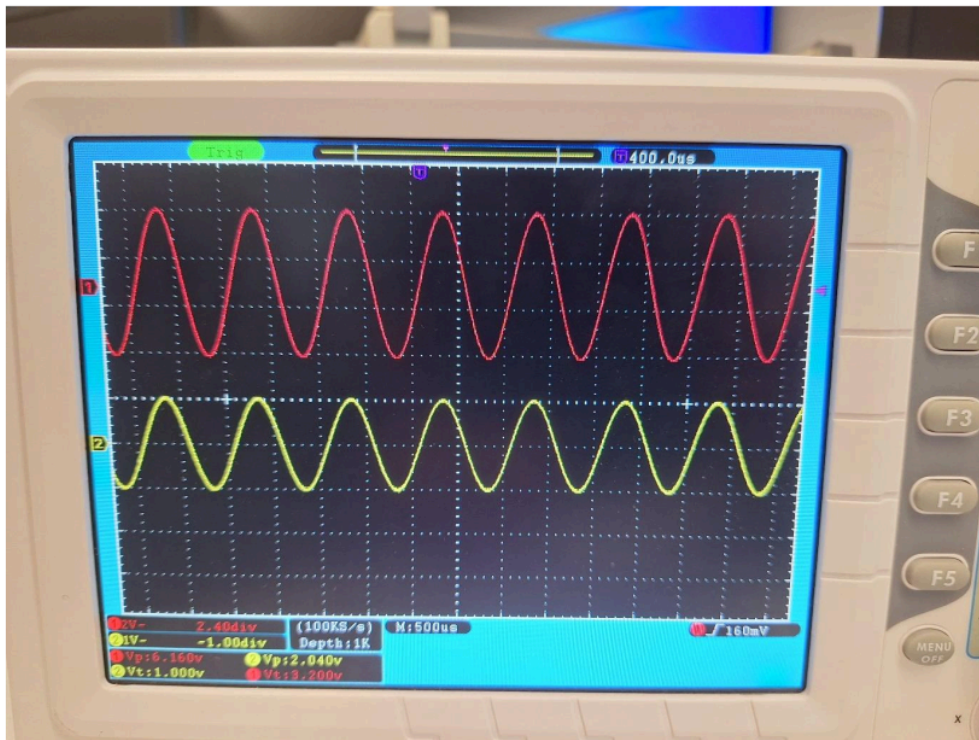


Fig. 11- Oscilloscope measurement for bread board amplifier testing

3.5 – Bread board circuit evaluation

The prototype was then characterised using the same method as before. Cycling through the input frequency and measuring the output will provide an appropriate indication of circuit operating frequency. Amending the characterised spreadsheet with this data, we generate the graph below,
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As completed with the Proteus simulation, for purposes of specification, it is appropriate to calculate the operating frequency of the circuit. The lower frequency limit was shown to be between 1-2 Hz, and the upper between 50-100 KHz. Upon tuning in closer, the lower value came to 1.3Hz, and the upper value was 52.75 KHz, both outputting 4.32v.

Using these values:

$$GBP = ((52.75 \times 1000) - 1.3) \times 3 = 158,246.1$$

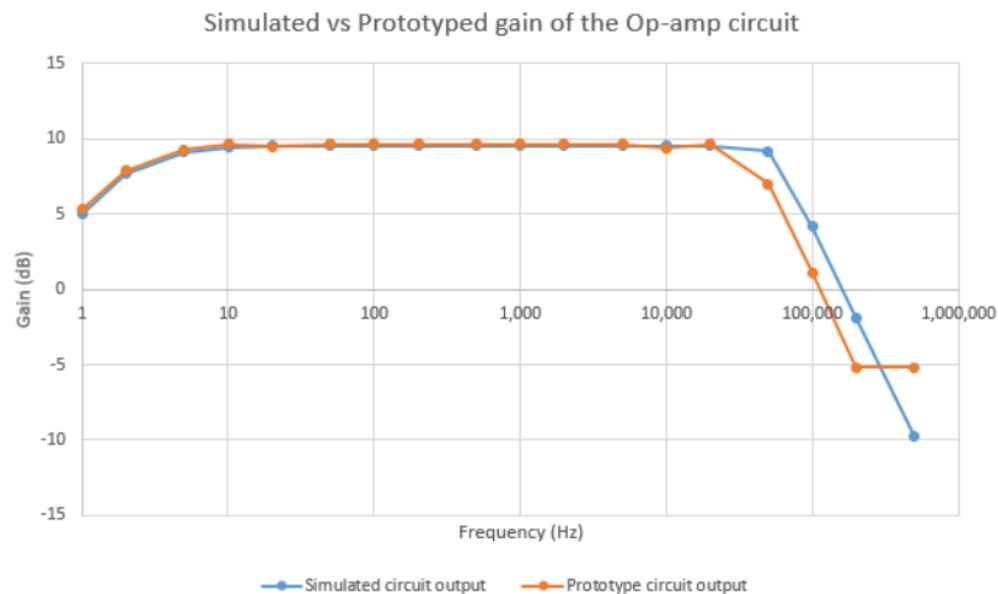


Fig. 12 - Graph representing simulated vs Prototyped gain of the Op-amp circuit

Simulated circuit output				Prototype circuit output			
F	Vpp In	Vpp Out	Gain (dB)	F	Vpp In	Vpp Out	Gain (dB)
1	2	3.54	4.959465	1	2.04	3.76	5.311154
2	2	4.84	7.676307	2	2.04	5.04	7.856007
5	2	5.72	9.127321	5	2.04	5.92	9.253831
10	2	5.92	9.425834	10	2.04	6.16	9.599011
20	2	5.98	9.513424	20	2.04	6.08	9.485468
50	2	6	9.542425	50	2.04	6.16	9.599011
100	2	6	9.542425	100	2.04	6.16	9.599011
200	2	6	9.542425	200	2.04	6.16	9.599011
500	2	5.98	9.513424	500	2.04	6.16	9.599011
1000	2	5.98	9.513424	1000	2.04	6.16	9.599011
2000	2	6	9.542425	2000	2.04	6.16	9.599011
5000	2	6	9.542425	5000	2.04	6.16	9.599011
10000	2	6	9.542425	10000	2.04	6	9.370422
20000	2	5.98	9.513424	20000	2.04	6.16	9.599011
50000	2	5.74	9.157638	50000	2.04	4.56	6.986694
100000	2	3.22	4.136518	100000	2.04	2.32	1.117156
200000	2	1.612	-1.8733	200000	2.04	1.12	-5.20824
500000	2	0.65	-9.76233	500000	2.04	1.12	-5.20824

Tab. 2 - Simulated and bread board prototype input and output data set, as graphed in Fig. 12

4. PCB Design

4.1 – Easy-PCB Circuit design

Once prototyping was complete, the design was replicated on Easy-PCB in order to begin creating the required design schematics for it to be produced externally. This process required replication of the design as produced previously on Proteus, so Easy-PCB may effectively assist in the routing and placement of components of the PCB.

The addition of pin-headers are required to allow for secure connection to the external input/output devices. Duplicate pins have been put in place in order to ensure the correct connector is plugged in during testing, this also means each way a Molex is plugged in will be correct.

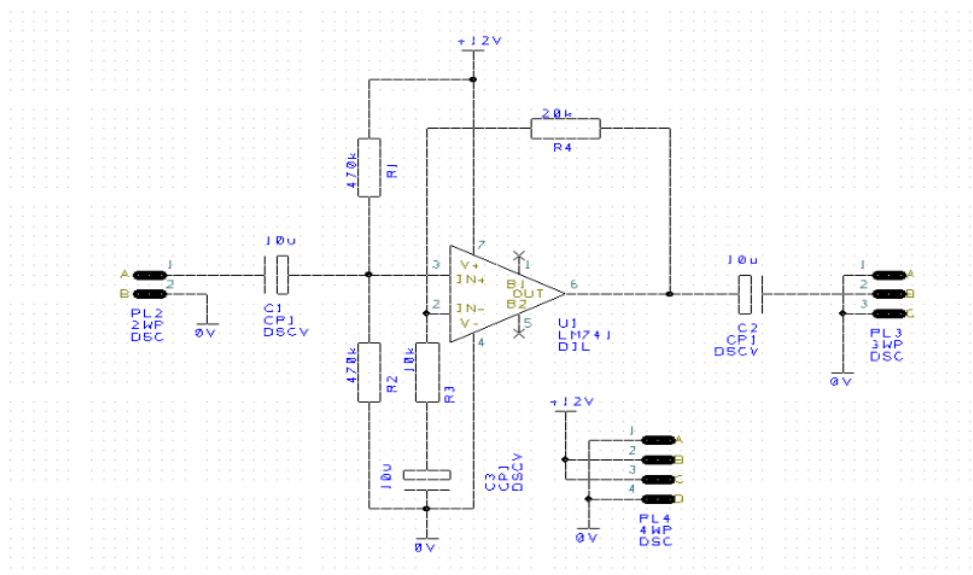


Fig. 13 - Easy-PCB Circuit design layout

4.2 – PCB Routing

The components and copper tracks needed to be routed and layers designated correctly, including a ground plane. A ground plane allowed for better grounding and simpler routing.

The initial attempt yielded inefficient component placement greatly increasing complexity. Now understanding track widths and other routing rules however, a more informed second attempt was made. On this attempt, the PCB seemed functional, and Easy-PCB's design rule check came back without error. Further optimisation was conducted to improve track lengths and component spacing.

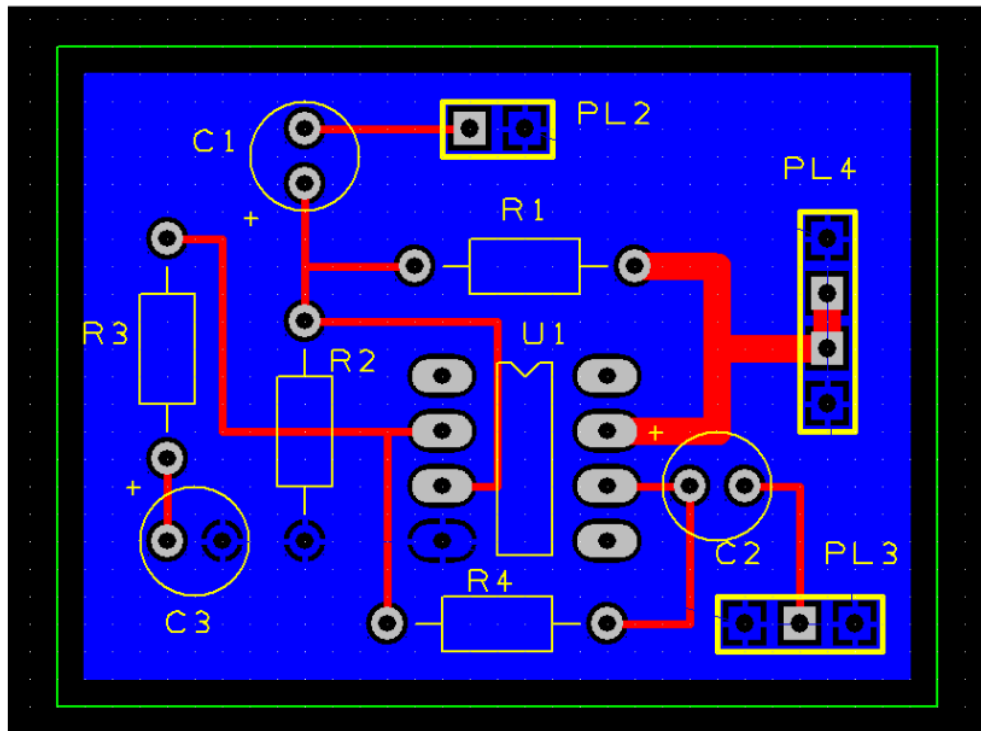


Fig. 14 - Easy-PCB PCB design layout

To finalise, the silk-screen layer (yellow text as seen in Fig. 14) was modified so as to provide insight to capacitor polarisation and component identity. Once complete, the project files from Easy-PCB were exported as Gerber files, a standardised file format for various Computer Numerical Control (CNC) machines so they could be sent off to the external manufacturer for production.

4.3 – PCB Population

The PCB manufacturer after a number of weeks shipped the design as seen in Fig. 15. A brief visual inspection provides ample confidence that this is indeed the design I sent through, and that there aren't any anomalies.

To populate this board, the same components used for the bread board prototyping will be permanently mounted into the PCB print. This nearly eliminates the consideration for a change in component value due to tolerance between measurements, should the components remain undamaged.

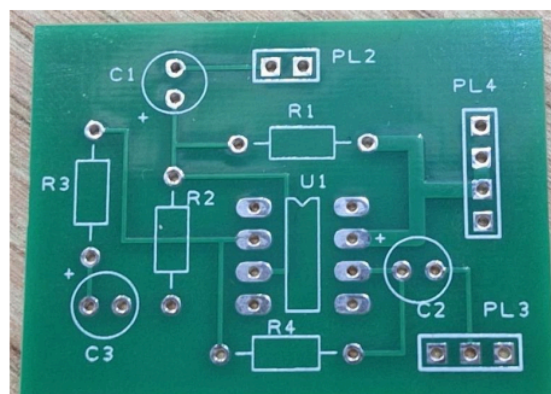


Fig. 15 - Unpopulated PCB print

Standard through-hole soldering was used to populate the circuit board with the aforementioned components. This required a hot soldering iron, solder, extractor fan and corrective tools such as a solder sucker and solder wick, just in case removal of excess or misplaced solder was required. Helping Hands were employed to secure the PCB in place, as well as providing magnification where required. I picked out a small soldering iron which provided a precise but sufficient surface area of heat to allow for controlled application of heat in the required places.

The shortest components were secured to the board first, as this allowed the board to sit nicely upside down for the majority of assembly. The actual population technique involved pushing the component through, securing the component usually by bending the legs outward slightly, ensuring the component is nicely flush to the board. Sticking to the diagram ensured all of the components went in the correct place.

A dab of solder would then be applied to the iron, which would be then pressed against the solder pad for a second or two to apply heat to the area. The solder rod would then be brought to the other side of the component leg, where it would melt, fitting to pad nicely, flowing around then entirety of the pad. I would cut the legs to about half length, to provide a larger gripping surface, should they need to be removed. These were then removed after successful testing.

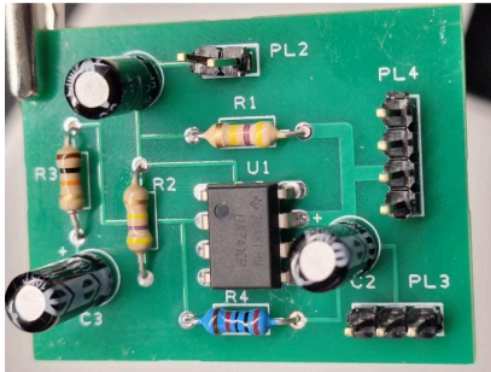


Fig. 17 – Populated PCB: Top

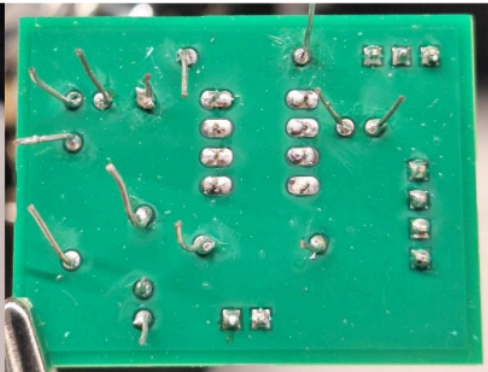


Fig. 16 - Populated PCB: Bottom

4.4 – PCB function test

The function test was nigh identical to that of the bread board testing bar the Molex connectors that were used in replacement of flying leads. See Fig. 18 & Fig. 19.

Consideration was made for the component legs as they were still half length. A quick check to ensure there were no short-circuits between legs to compromise the circuit was made before testing.

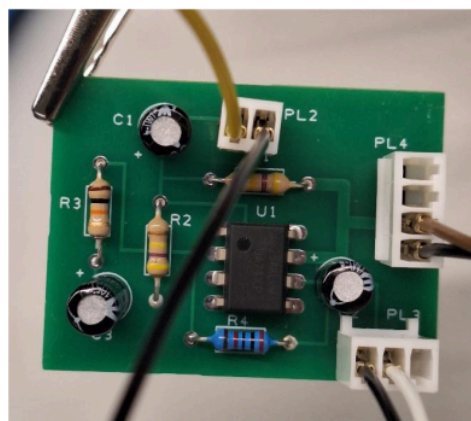


Fig. 18 - PCB with Molex connectors

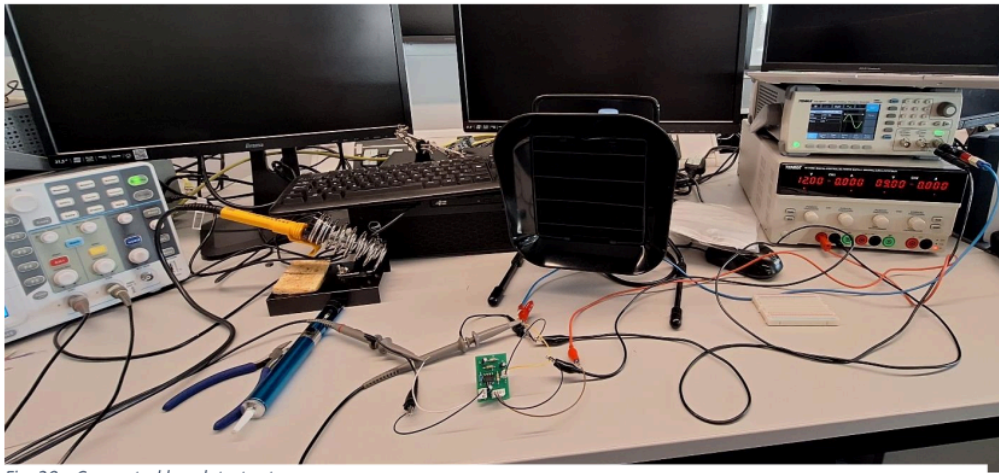


Fig. 20 – Connected bench test setup

The PCB was wired up as per the input/output requirement and a 1v, 1 KHz sine wave was passed into the input. Switching on the 12v DC power supply (see right side of Fig. 20, red LED “12.00”). Provided the red output as seen in Fig. 19. This output is correct as the wave is smooth, and the gain is: $\frac{6.24}{2.08} = 3$.

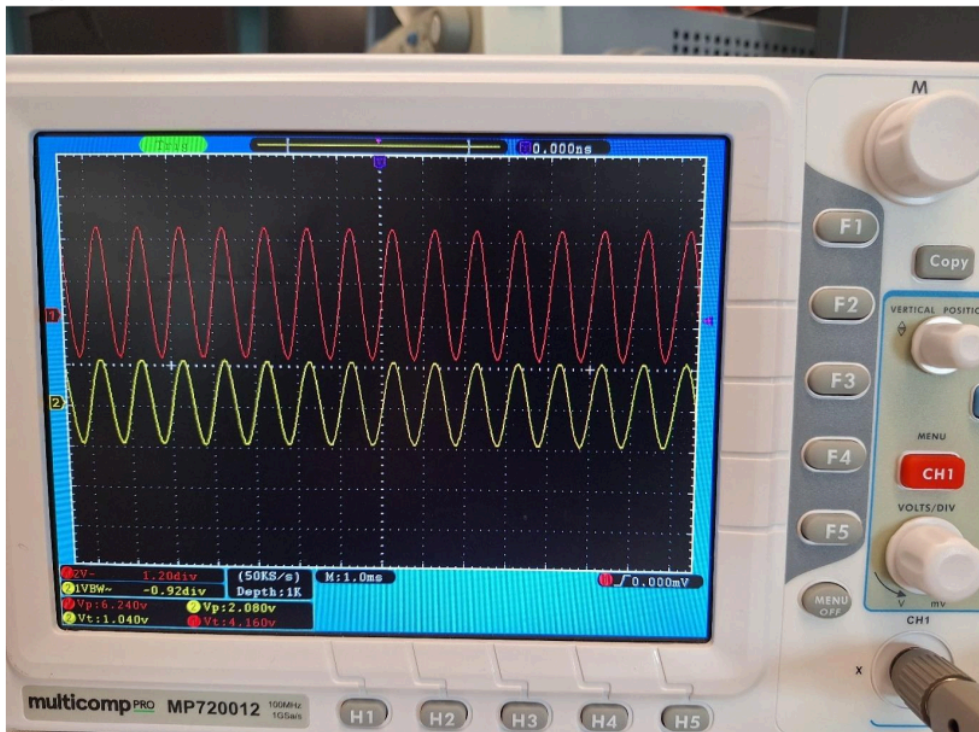


Fig. 19 – PCB oscilloscope output

4.5 – PCB Characterisation

The system then once again required characterising by running through the frequencies and measuring the output. This data (see Tab. 3) was amended to the spreadsheet data (Fig. 21) and compared with the data obtained from the simulation, and prototype.

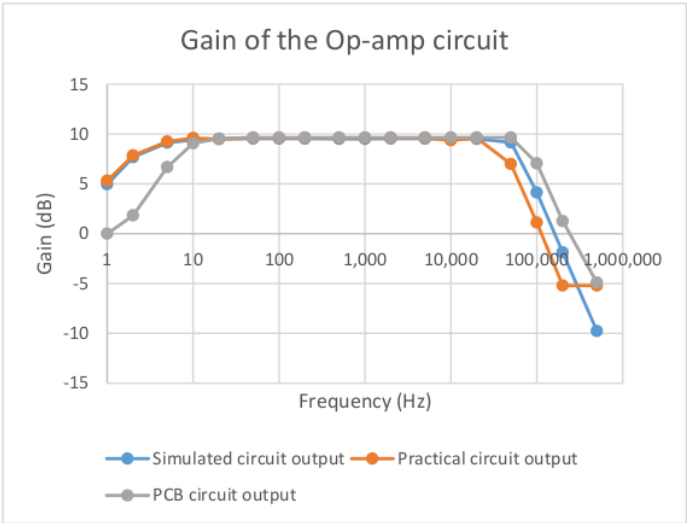


Fig. 21 - Final characterisation graph

PCB circuit output			
F	Vpp In	Vpp Out	Gain (dB)
1	2.04	2.52	1.835407
2	2.04	4.4	6.67645
5	2.04	5.8	9.075957
10	2.04	6.12	9.542425
20	2.04	6.2	9.65523
50	2.04	6.2	9.65523
100	2.04	6.2	9.65523
200	2.04	6.2	9.65523
500	2.04	6.2	9.65523
1000	2.04	6.2	9.65523
2000	2.04	6.2	9.65523
5000	2.04	6.2	9.65523
10000	2.04	6.2	9.65523
20000	2.04	6.2	9.65523
50000	2.04	4.6	7.062553
100000	2.04	2.36	1.265637
200000	2.04	1.16	-4.90344
500000	2.04	0.52	-11.8725

Tab. 3 - PCB characterisation data

There are subtle differences between all of the design instances, though none particularly anomalous or an indicator of malfunction. The data gathered from the PCB will be used in the final specification for the design if it were to be sold or handed over to a business partner. This includes the GBP, which once again requires the upper and lower optimal thresholds laying between 1 – 2 Hz, and 50 – 100 KHz. Upon closer inspection and measurement, it was found that the lower point was 1.9Hz and the upper 53KHz giving us:

$$GBP = ((53 \times 1000) - 1.9) \times 3 = 158,994.3$$

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

81 /100

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DAVID REYNARD

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

30

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

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



Soldering 70% - Very good but some joints have too much solder on them. Some component leads could have been trimmed shorter.

Layout 90% - Not too bad although the components could have been closer together.

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

Functioning 100% - PCB functions correctly.

$(70+90+100+100)/10=36\%$

36

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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