

lab-book-op-amp-1

by Nicholas Tim Jones

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Workshop skills (ACDA4001).
15/01/2018.

Single supply, Non-inverting Op-Amp Lab Report.

This report documents the process of designing, testing and the building of a single supply non-inverting amplifier. Using the schematic provided the circuit will be constructed in Proteus and tested using Proteus simulation, then constructed on a breadboard where the same tests will be conducted and finally the circuit will be constructed on a pcb using through hole components and tested. Test results are logged throughout this report.

LM741 Amplifier:

The Op-Amp used in this circuit is an LM741. It's aimed to have a closed loop gain of 3. Using a single supply means the use of Capacitors are needed to block the D.C component.

Consulting the data sheet from 'Texas Instruments (pg 3) the pins utilised for this circuit are:

- Pin 2: Inverting signal input (-).
- Pin 3: Non-inverting signal input (+).
- Pin 4: Negative supply voltage (gnd).
- Pin 6: Amplified signal output.
- Pin 7: Positive supply voltage (vcc).

Note on Gain Bandwidth Product (GBP):

The GBP represents the maximum product of gain and frequency.

$GBP = \text{Gain} \times \text{Frequency}$

LM741 has a GBP at unity of 1MHz

$\text{Frequency max} = GBP / \text{Gain}$

$\text{Frequency max} = 1\text{Mhz} / 3$

$\text{Frequency max} = 333.3\text{Khz}$

Note on Gain:

To calculate a gain of 3:

$\text{Gain} = \text{feedback resistor (R1)} / \text{Pin 2 input resistor (R2)} + 1$

$\text{Gain} = 20 / 10 + 1$

$\text{Gain} = 3$

To Convert voltage gain to dB gain:

$20\log_{10}(V_{\text{out}} / V_{\text{in}})$

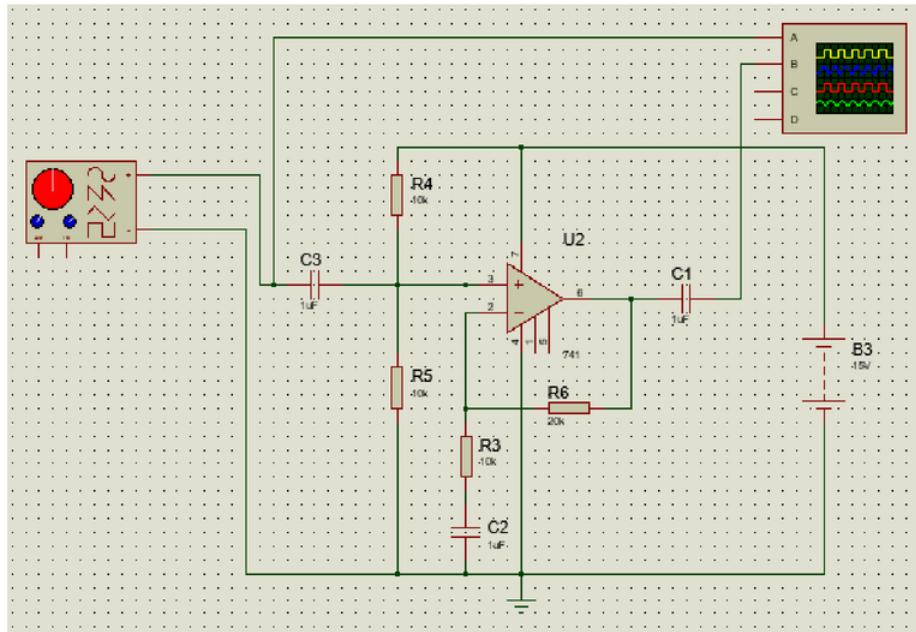
Note on test limits:

Test's will be conducted to establish at what frequency a -3dB in gain occurs, which is the minimum undistorted amplified output of the circuit.

$-3\text{dB} = V_{\text{out}} \times 0.707$

Components:

- 1 x LM741 OpAmp.
- 3 x resistors 10K Ω .
- 1 x resistor 20K Ω .
- 3 x capacitors 1 μ F.

Proteus:**Schematic in Proteus.****Test equipment setup:**

Signal generator amplitude is set to 2mV pk-pk.

Oscilloscope:

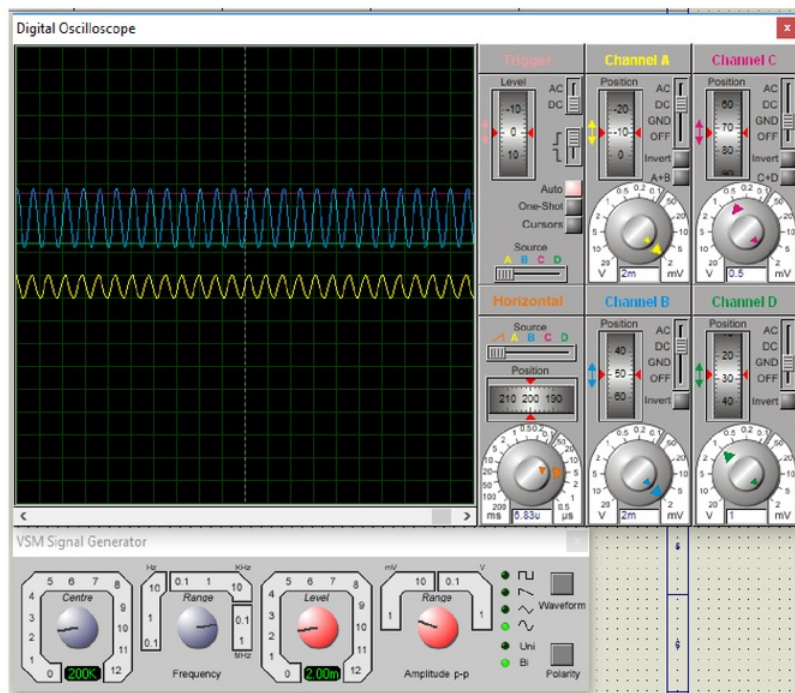
Channel A (yellow) is connected to output of signal generator.
Volts per division set to 2mV.

Channel B (blue) is connected to amplified output.
Volts per division set to 2mV.

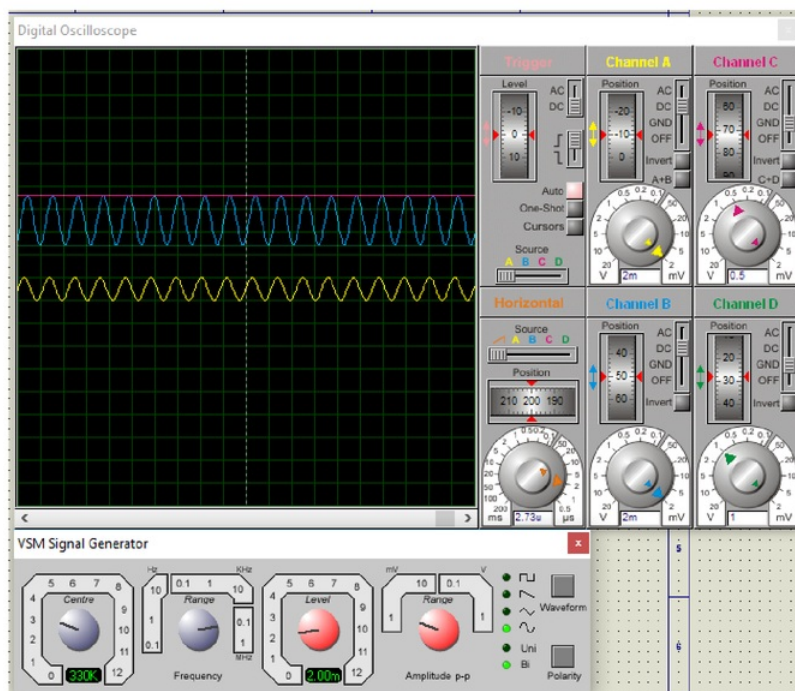
Pink and green trace highlight a -3dB drop in gain.

Time division is altered as needed to visualise the wave forms from channels A and B.

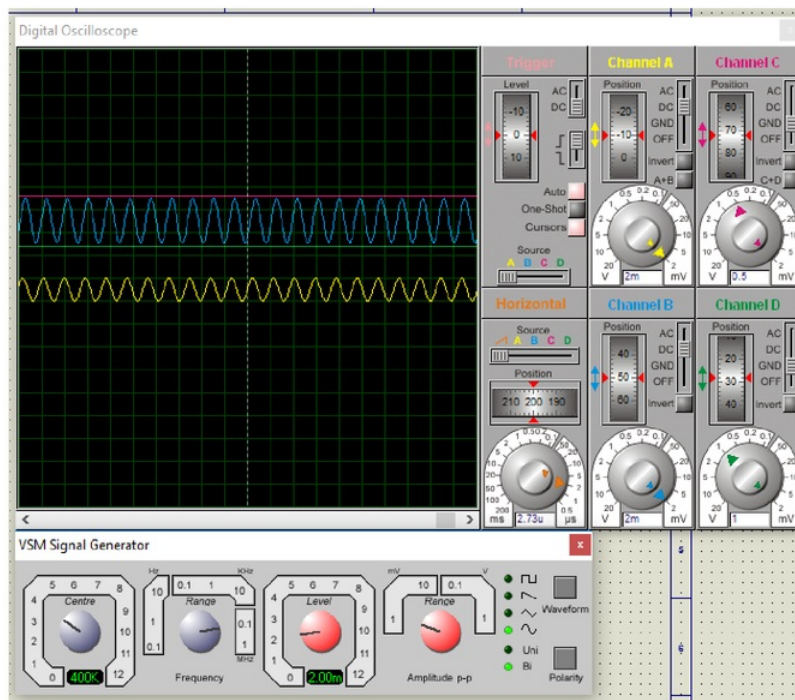
Frequency = 200Khz.



Frequency = 330Khz.



Frequency = 400Khz.

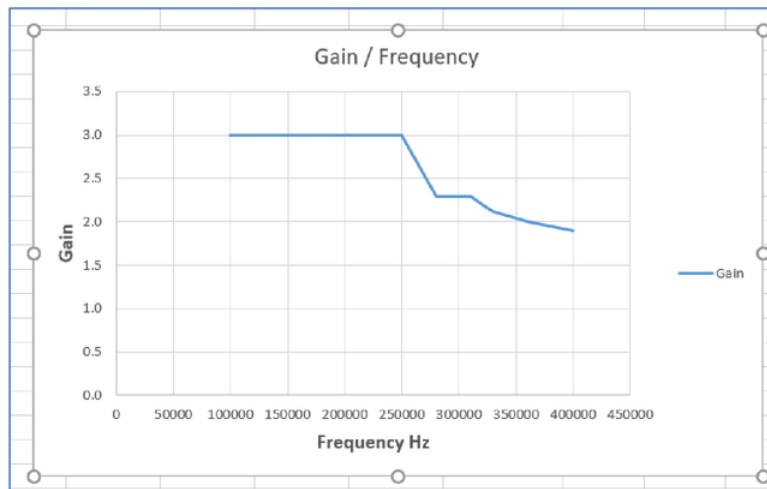


Proteus results:

Table of results from Proteus simulation.

Frequency Hz	Input mV	Output mV	Gain	Gain dB	Gain Diff, dB
100K	2	6	3.0	9.5424	0.0
200K	2	6	3.0	9.5424	0.0
250K	2	6	3.0	9.5424	0.0
280K	2	4.6	2.3	7.2346	-2.3079
290K	2	4.6	2.3	7.2346	-2.3079
300K	2	4.6	2.3	7.2346	-2.3079
310K	2	4.6	2.3	7.2346	-2.3079
320K	2	4.4	2.2	6.8485	-2.6940
330K	2	4.242	2.121	6.5308	-3.0116
360K	2	4	2.0	6.0206	-3.5218
400K	2	3.8	1.9	5.5751	-3.9674

Graph, Gain against Frequency (Proteus).



Proteus conclusion:

Maximum gbp was 330Khz.

Testing of the circuit was done by altering the input frequency and then measuring the amplified output to establish the maximum effective input frequency at a gain of 3.

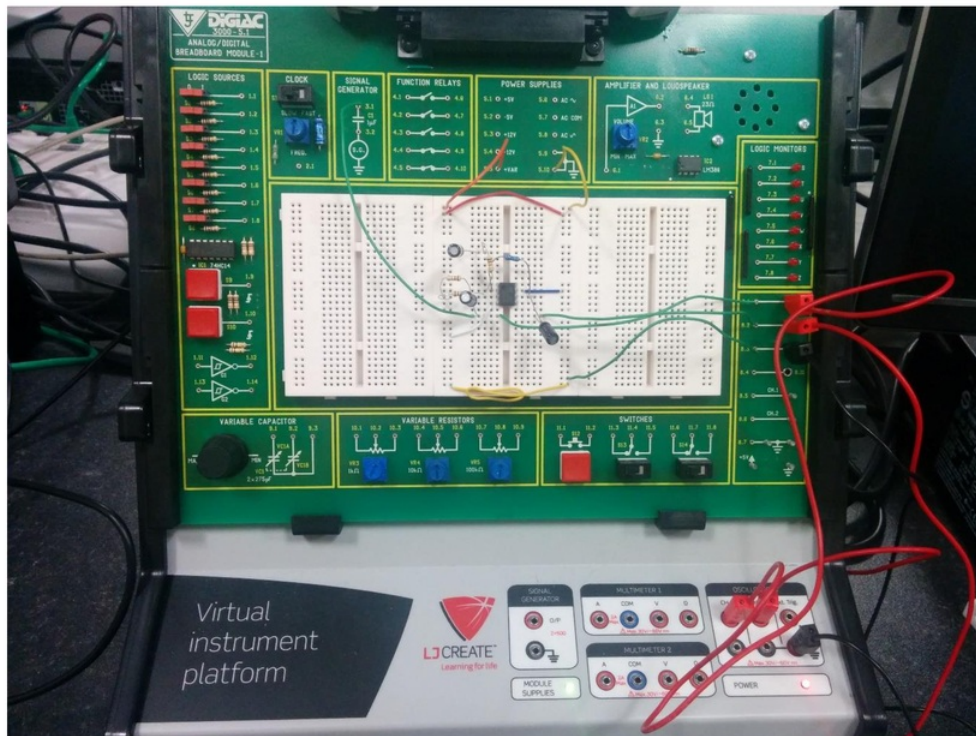
From the above results table the input frequency was adjusted 11 times, the input and output measurements are peak to peak.

The results table shows that a -3dB gain occurs at a frequency of 330Khz, as the calculated maximum frequency was 333.3Khz these results appear to be reasonably accurate.

Looking at the graph, even though it is not linear, as frequency increases the gain of the amplified output decreases. In this instance a gain of 2.1 is equal to a -3dB of the output.

Breadboard on VIP:

Circuit on breadboard.



Test equipment setup:

Signal generator amplitude is set to 100mV.

Oscilloscope:

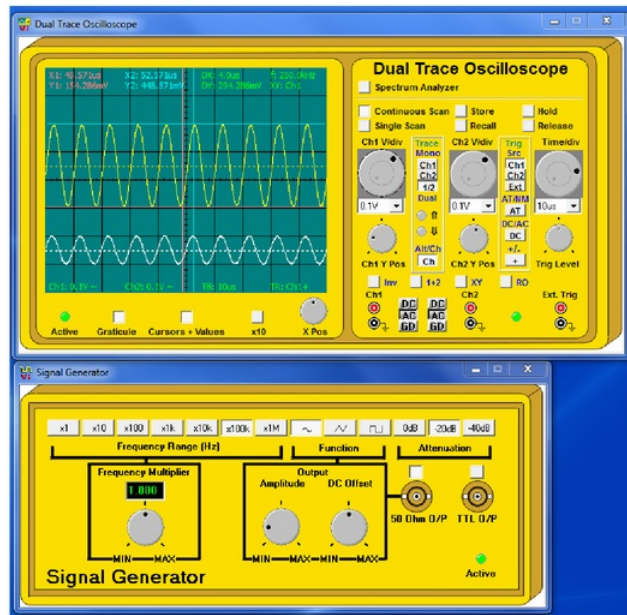
Channel 1 (White) is connected to output of signal generator.
Volts per division set to 100mV.

Channel 2 (Yellow) is connected to amplified output.
Volts per division set to 100mV.

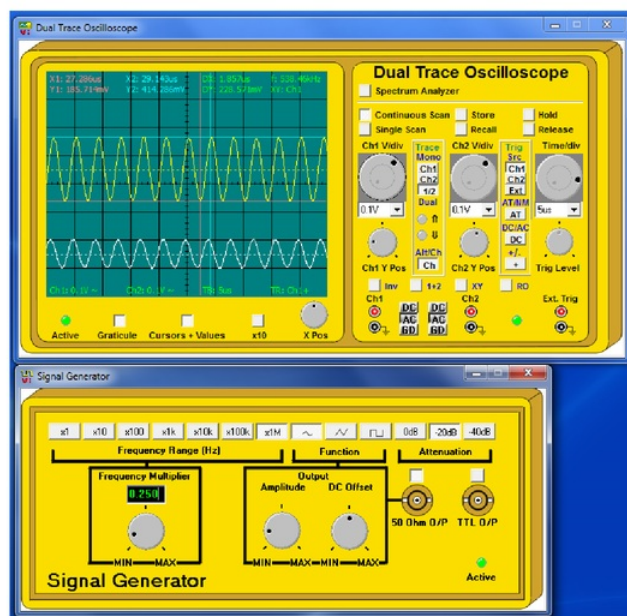
Red and Blue cursors are measuring amplified output.

Time division is altered as needed to visualise the wave forms from channels 1 and 2.

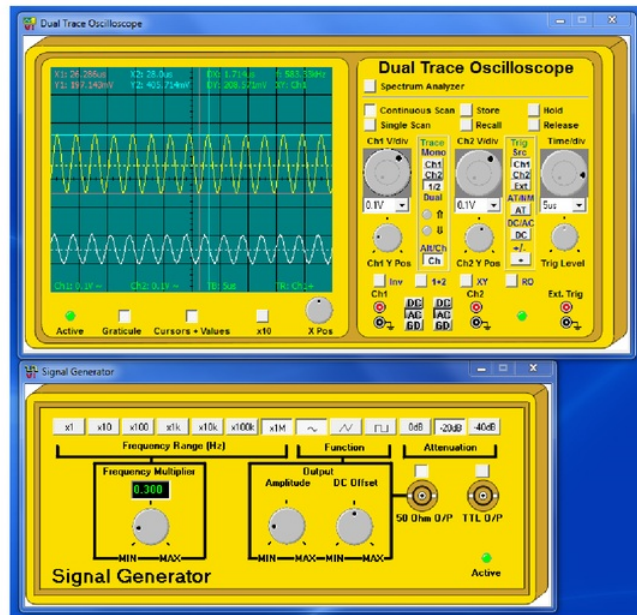
Frequency = 100Khz.



Frequency = 250Khz.



Frequency = 300Khz.



Frequency = 400Khz.

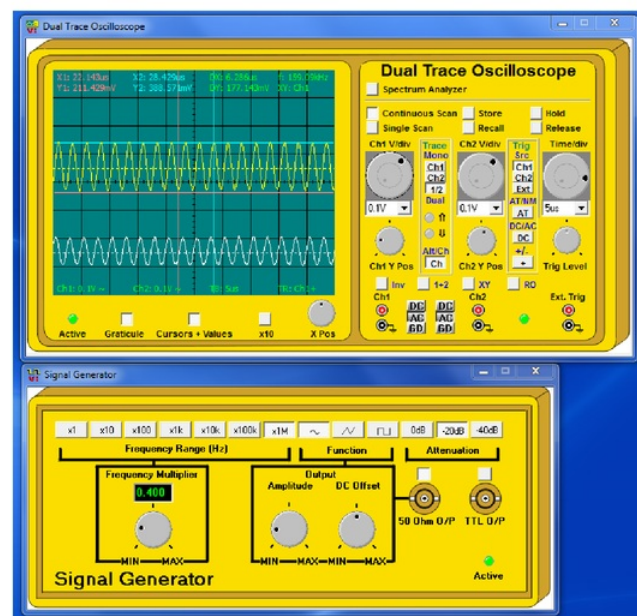
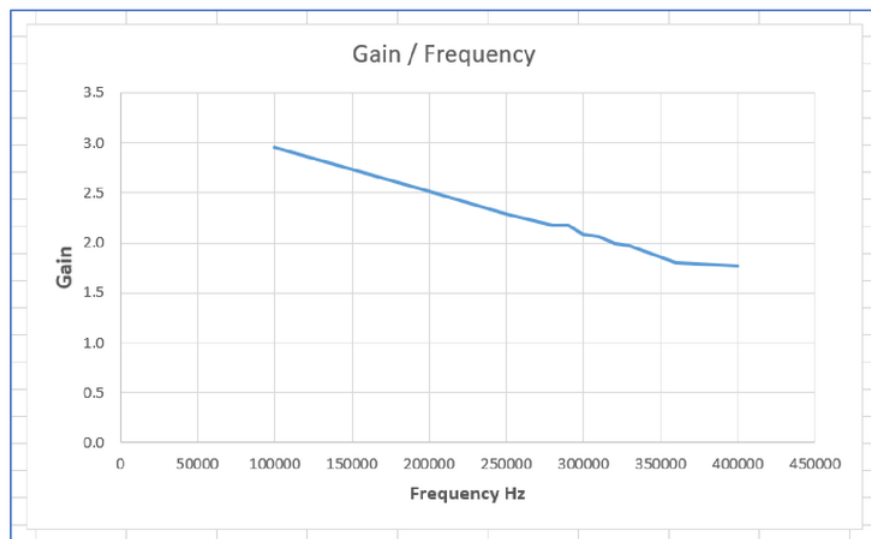


Table of results from breadboard testing.

Frequency Hz	Input mV	Output mV	Gain	Gain dB	Gain Diff, dB
100K	100	295	3.0	9.3964	0.0
200K	100	251	2.5	7.9935	-1.4
250K	100	229	2.3	7.1967	-2.2
280K	100	217	2.2	6.7292	-2.7
290K	100	217	2.2	6.7292	-2.7
300K	100	208	2.1	6.3613	-3.0
310K	100	206	2.1	6.2773	-3.1
320K	100	200	2.0	6.0206	-3.4
330K	100	197	2.0	5.8893	-3.5
360K	100	180	1.8	5.1055	-4.3
400K	100	177	1.8	4.9595	-4.4

Graph, Gain against Frequency (Breadboard).



Breadboard conclusion:

Maximum gbp was 300Khz

The same tests were conducted using real components the only difference here is the input amplitude used was 100mV.

11 test points was recorded, the table of results shows a -3dB in the output occurred at 300Khz this is a little lower than the calculated frequency max.

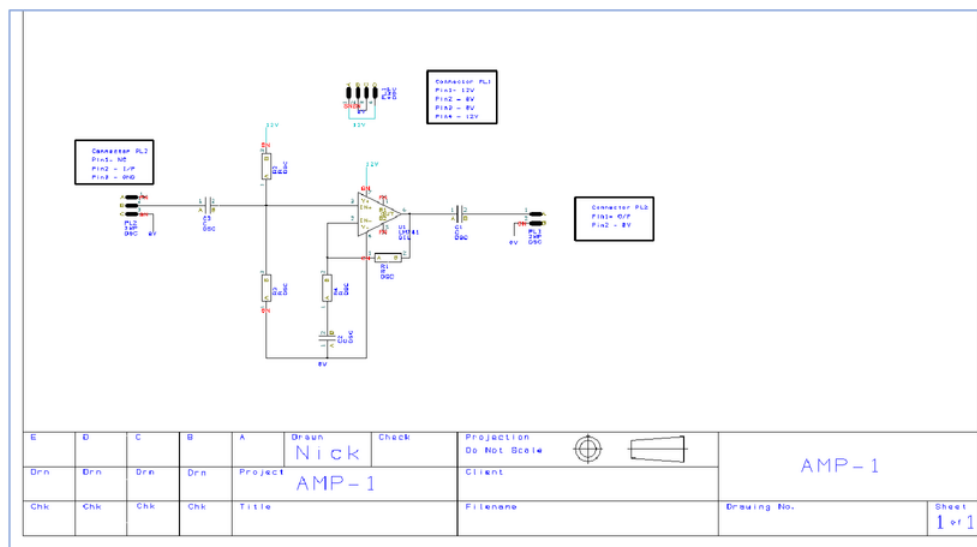
Possible reason being that real components have a certain percentage of tolerances and thus their actual values in the live circuit may not be the same as the values used when making calculations.

-3dB of the output equates to a gain of 2.1 as seen in the graph when the gain is 2.1 the frequency is at 300Khz.

Easy PC:

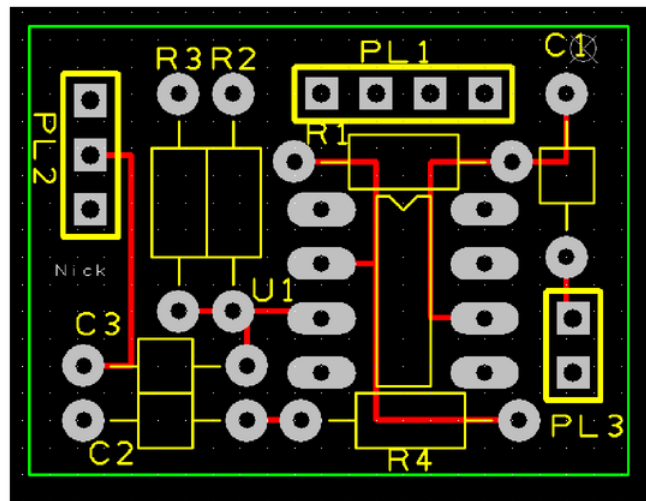
Easy PC software is used to design a through hole PCB for this circuit. All components were added to the parts bin then a schematic was created, all relevant labelling was added or altered e.g. some Net names were renamed to Net 0v and Net 12v.

Schematic drawn in Easy PC.

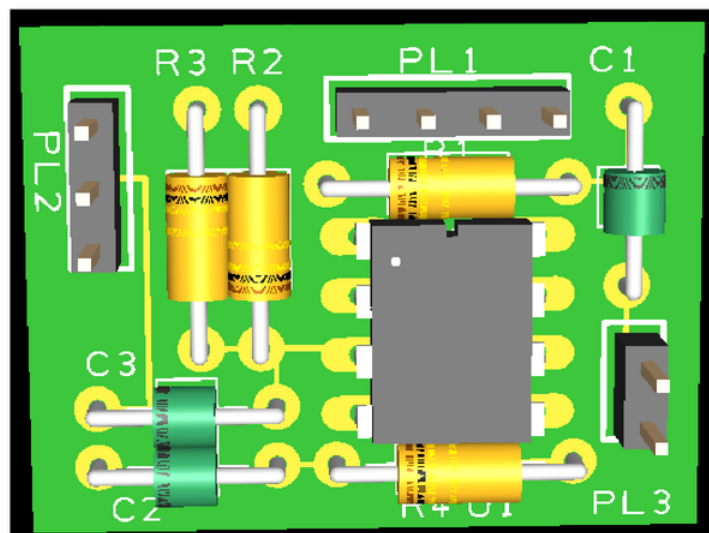


Once the schematic was finished it was time to design the PCB and populate it, all the components were placed within the board outline in such a fashion as not to waste any PCB material.

PCB populated with component outline and tracks have been routed.



3D view of completed design.



Building and testing of real circuit.

Whilst populating the pcb with the components a solder pad from capacitor C2 become dislodged rendering the pcb useless as that was one of the last component to be soldered it was decided to start again with a spare new pcb and new components.

Once the pcb was completed it was noticed that the capacitor C3 was mounted the wrong way around, after discussion with tutor it was concluded to leave it as it was and carry on.

Note: that changing to new components may return different results due to tolerance differences.

Test equipment setup:

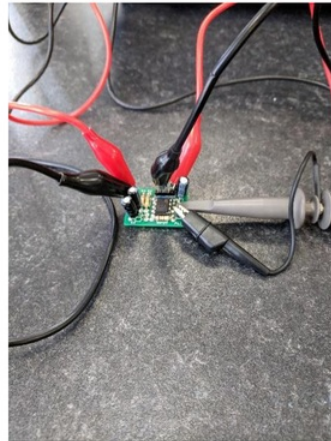
Function generator, amplitude set to 200mV pk-pk.

Power supply for the I.C 12V

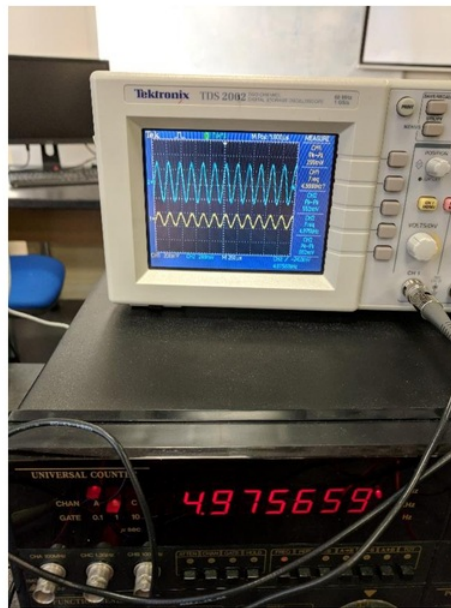
Oscilloscope:

Channel 1 connected to output of function generator.

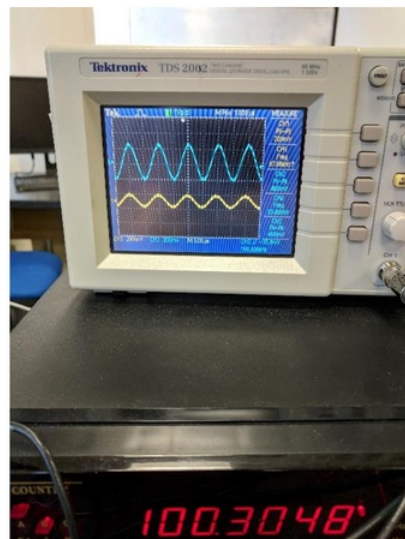
Channel 2 connected to amplified output of op-amp.

PCB connected to test equipment.

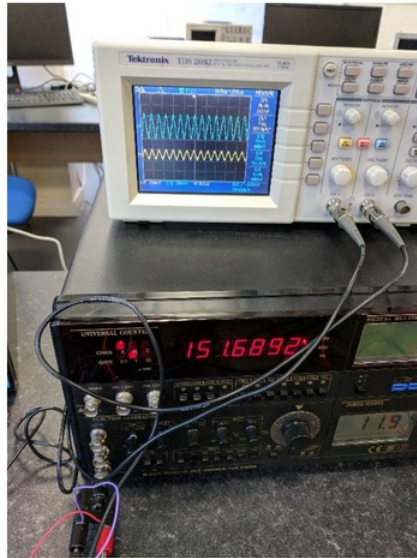
Frequency = 5Khz



Frequency = 100Khz



Frequency = 150Khz

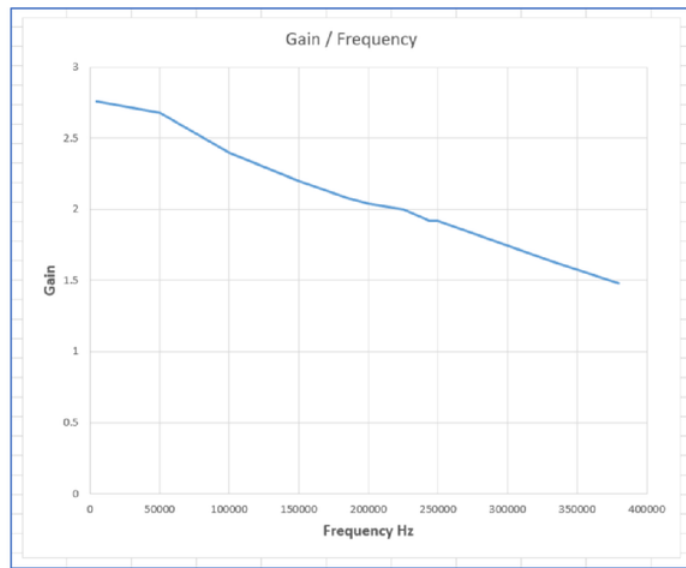


Real component results:

Table of results from real testing.

Frequency Hz	Input mV	Output mV	Gain	Gain dB	Gain Diff, dB
5000	200	552	2.76	8.8181816	0
50000	200	536	2.68	8.5626959	-0.255485761
100000	200	480	2.4	7.6042248	-1.213956807
150000	200	440	2.2	6.8484536	-1.969728025
185000	200	416	2.08	6.3612667	-2.456914942
200000	200	408	2.04	6.1926033	-2.625578293
225000	200	400	2	6.0205999	-2.797581728
243600	200	384	1.92	5.6660246	-3.152157067
250000	200	384	1.92	5.6660246	-3.152157067
330000	200	328	1.64	4.296877	-4.52130468
380000	200	296	1.48	3.4052343	-5.412947333

Graph, Gain against Frequency (Real).



Real component conclusion:

Maximum gbp was 250Khz

Testing the circuit was done in a similar fashion to the previous tests, but this time the test equipment used was a separate oscilloscope and function generator and not software controlled like Virtual Instrument Platform or Proteus, also same values but different physical components were used as noted above.

Initial testing started at a frequency of 100Khz but instantly the gain calculated to be 2.4 so the frequency was lowered to 5Khz which gave a gain of 2.76 which is a little bit closer to the calculated gain, from there tests at various frequencies were logged up as far as 380Khz

Looking at the results the gain on this build was only 2.76 and a -3db in the gain was only at 250 Khz this appears to significantly lower when compared to the breadboard tests, even if there were tolerance differences with the new components it's unsure if that would of made a difference here. Other factors to consider is the use of the equipment as measurements taken they were rounded to the nearest whole number.

The graph drawn is similar in shape to the breadboard experiment with the difference being that a maximum gain of 2.76 was achieved and at -3dB there is only a gain of 1.96

Overall this lab exercise had many learning points and good hands on experience was gained starting with theoretical calculations through simulating on to prototyping with a breadboard and finally designing a real pcb and populating it with components.

Other skills learned.**Soldering skills.**

Practiced soldering through hole components onto a scrap piece of perf board.

Practiced de-soldering the components on the perf board and de-soldering an old pcb which was populated with various components and wires.

Built a 12-sided cube using tin wire and solder dimensions was 12mm.

lab-book-op-amp-1

GRADEMARK REPORT

FINAL GRADE

80/100

GENERAL COMMENTS

Instructor

Very Good lab book with all actions and data kept in detail.

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