

GW_2410225_ACDA4022_EES_ Workshop_logbook

by George Welham

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WORKSHOP SKILLS FOR ELECTRONICS- ASSESSMENT LOGBOOK

ACDA4022

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Introduction

The following lab report records a practical electronics example of building a non-inverting amplifier circuit PCB. It contains the schematic used, simulation, breadboarding, breadboard testing, PCB schematic, and PCB testing.

Schematic of Amplifier drawing in Proteus

The following is the schematic drawn in Proteus. Once the circuit is laid out in Proteus, it can be simulated to test its functionality and measure its performance.

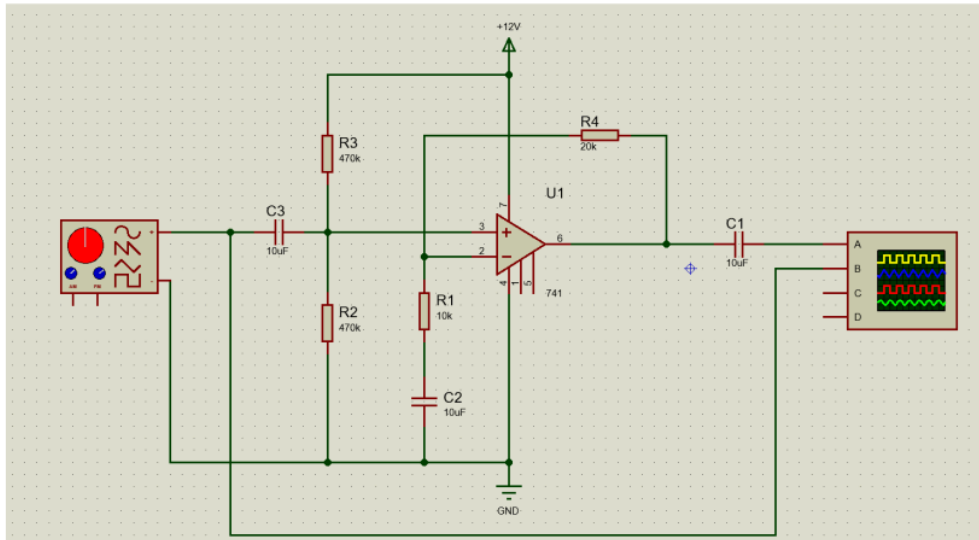


Figure 1 non-inverting amplifier in Proteus schematic capture window. The circuit design is specified in the assessment instructions. Simulation virtual instruments have been added, such as a signal generator (seen left) and an oscilloscope (seen right).

The calculated gain for this schematic is 3. This is calculated using an LM741 datasheet [1] which includes the following equation.

$$\text{"Gain"} = 1 + (R2/R1) \text{ [1]}$$

Where R2 is a feedback resistor, and R1 is connected to pin 2 of the LM741.

Due to the numbering scheme in my schematic, R4 is the feedback resistor, and R1 is connected to the inverted input.

In this circuit, C3 filters any DC current from the input AC signal. The capacitor allows for AC current to charge and discharge the capacitor, passing the AC signal through the component. R3 and R2 create a potential divider so that a +6V DC bias is applied to the input signal.

The input is then connected to pin 3 of the LM741.

Like C3, C1 removes any DC component of the output signal.

Simulation of the amplifier circuit in Proteus

The following shows the output voltage results and calculated gain from the schematic. The input signal voltage for this simulation was 1.00V and a continuous sine wave. The frequency varied during the test. Measurements are taken from the peaks of each of the waveform traces using the vertical marker.

The voltage gain in the table is calculated using the following formula:

$$\text{Gain} = 20\text{Log}_{10} (V_{in}/V_{out})$$

The following in Table 1 is the result of the simulation and is plotted against frequency in Figure 2.

Input		Output Voltage (Peak) (mV)	Voltage Gain (dB)
Frequency (Hz)	Voltage (Peak) (mV)		
1	495	888	5.08
2	500	1210	7.68
5	500	1440	9.19
10	500	1480	9.43
20	500	1490	9.48
50	500	1500	9.54
100	500	1500	9.54
200	500	1500	9.54
500	500	1500	9.54
1000	500	1500	9.54
2000	500	1500	9.54
5000	500	1500	9.54
10000	500	1500	9.54
20000	500	1500	9.54
50000	500	1490	9.48
100000	500	1350	8.63
200000	500	750	3.52
300000	500	512	0.21
500000	500	262	-5.61

Table 1 Simulated gain results for non-inverting amplifier circuit

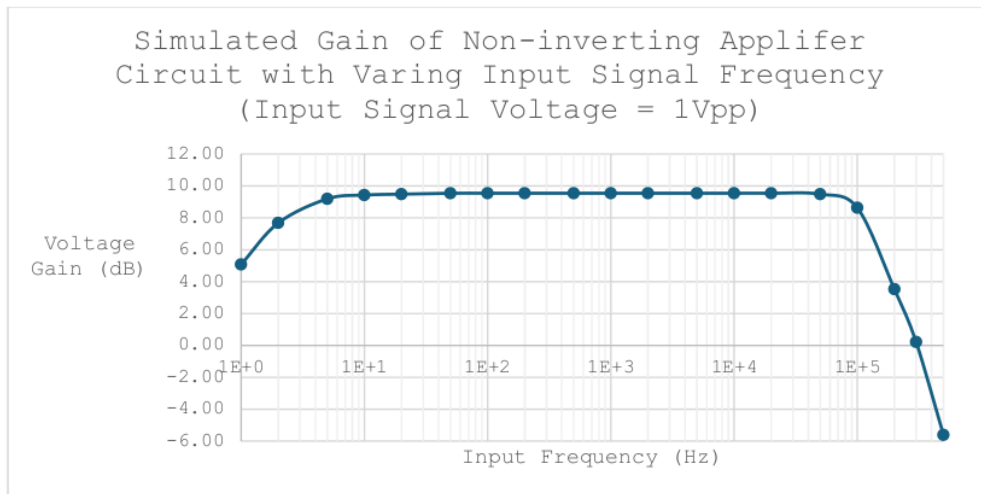


Figure 2 Graph of Simulated Gain of Non-inverting Amplifier Circuit with varying Input Signal Frequency

Simulated Bandwidth

To Calculate and measure the bandwidth of the non-inverting operational amplifier, the point at which the amplifiers drop 3dB or to 0.707 of the amplifier maximum gain.

From the results in Table 1 and Figure 2, the Bandwidth product of the non-inverting amplifier circuit can be estimated to be between 5Hz and 150KHz.

Additional measurements were taken to accurately find the low and high frequency at which the voltage gain is -3dB of maximum voltage gain.

The maximum voltage gain when simulated was 9.54 dB.

Low-Frequency Intersection (-3dB of Max Gain)			
Input		Output Voltage (Peak) (mV)	Voltage Gain (dB)
Frequency (Hz)	Voltage (Peak) (mV)		
1	495	888	5.08
1.2	495	975	5.89
1.3	495	1010	6.19
1.4	495	1050	6.53
1.5	495	1090	6.86

Table 2 Simulated Low-Frequency measurement at the point voltage gain is 3dB Less than the Maximum Gain

High Frequency Intersection (-3dB of Max Gain)			
Input		Output Voltage (Peak) (mV)	Voltage Gain (dB)
Frequency (Hz)	Voltage (Peak) (mV)		
90000	500	1410	9.00
100000	500	1350	8.63
110000	500	1270	8.10
120000	500	1210	7.68

130000	495	1090	6.86
140000	495	1050	6.53
150000	500	1020	6.19

Table 3 Simulated High-Frequency measurement at the point voltage gain is 3dB Less than the Maximum Gain

Using the following equation, the bandwidth product can be calculated as follows.

“Bandwidth Product = Bandwidth x Gain”

From the values highlighted in green in Table 2 and Table 3 and using 3 as the value of Gain.

The simulated bandwidth product for this circuit is 420KHz.

PCB Design

I created a schematic and PCB design in Easy-PC. This involved translating the schematic from Proteus into Easy-PC. I was then able to use the PCB editor to create a PCB that meets the manufacturer's design rules.

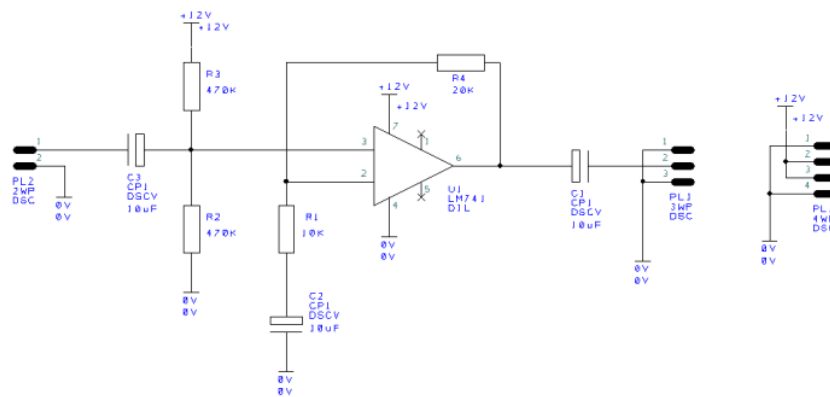


Figure 3 Cropped Screenshot of Schematic of Non-inverting Amplifier within Easy-PC

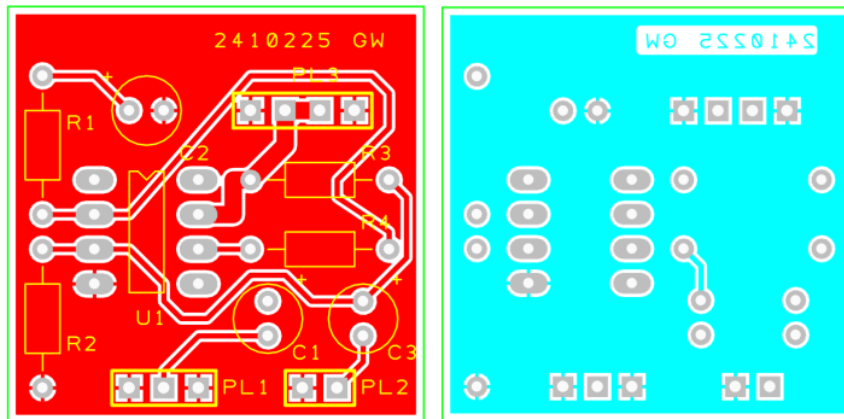


Figure 4 Images of the PCB created in Easy-PC. Left is the top copper and top silk. Right is the Bottom copper.

The board dimensions of this PCB are 1200 thou x 1200 thou. Both the top and bottom copper have a GND copper fill. My student number and initials are also placed on the top silkscreen and bottom copper.

The design was exported to a Gerber file for printing.

Breadboard Prototype

Nodal Analysis

Component Name/ Value	Nodes							
	1 (Sgin)	2	3 (+12V)	4 (GND)	5	6	7	8 (Sgout)
Capacitor - 10uF	C3							
Resistor - 470k Ohms		R3						
Resistor - 470k Ohms		R2						
741 Op-Amp		U1 (Pin3)	U1 (Pin7)	U1 (Pin4)		U1 (Pin2)	U1 (Pin6)	
Capacitor - 10uF				C2				
Resistor - 10k Ohms					R1			
Resistor - 20k Ohms						R4		
Capacitor - 10uF							C1	

Table 4 Node Analysis of Amplifier Circuit

To aid in my understanding the connections of the circuit, I made this table with the expected values at each junction/node.

Breadboard Plan

The following figure 5 is the plan for the Breadboard layout. I started by placing the most complex component in the centre, in this case, the 741 integrated circuit. I then worked outward from the middle with the other components. Ground and 12V power rails were used on the left and right of the plan.

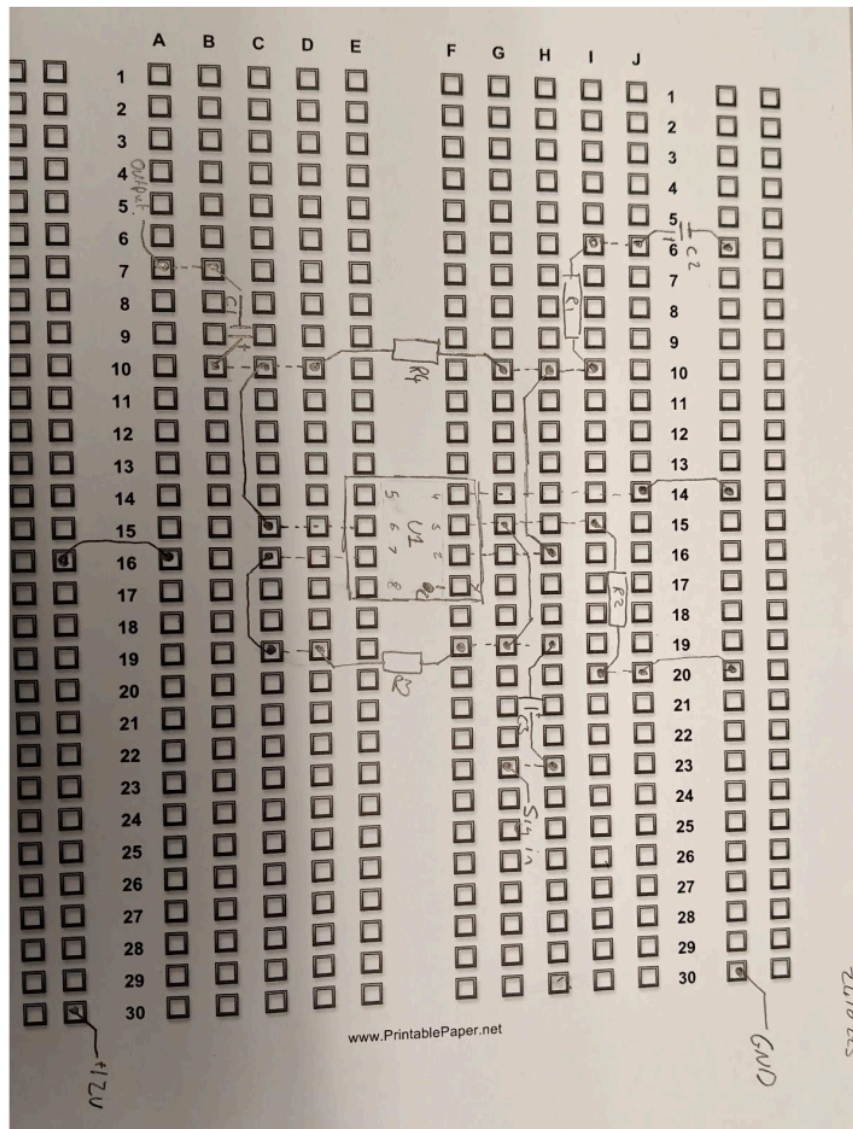


Figure 5 Breadboard planned layout of the amplifier circuit

Breadboard

Figure 6 shows my breadboard layout. The plan and the breadboard differ slightly. Where possible, wires were cut short on the board to make it easy to understand and troubleshoot.

When initially testing I discovered I had placed the input signal capacitor (C3) the wrong way round. After changing the polarity, the circuit worked.

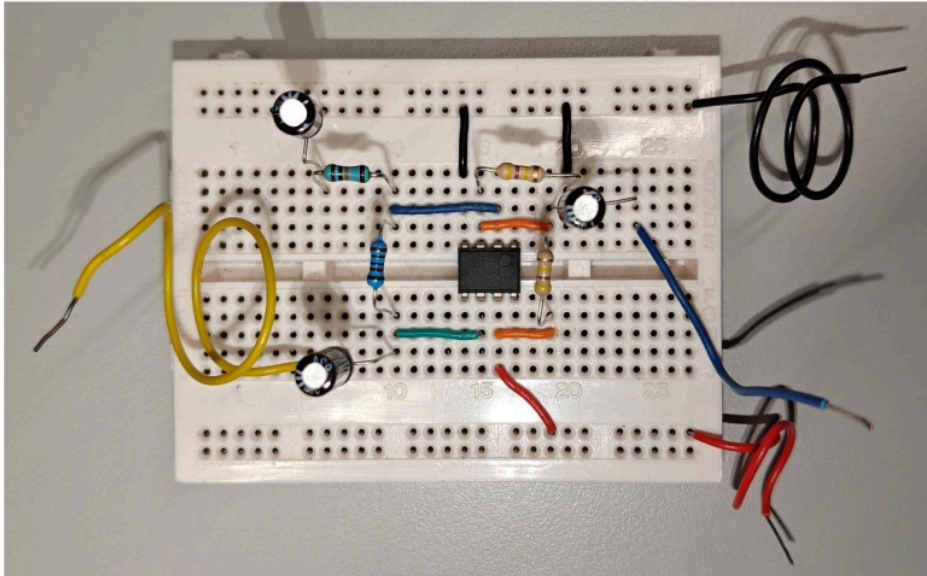


Figure 6 Picture of Breadboard amplifier circuit

Breadboard Measurements

Breadboard Test configuration

Oscilloscope connections

The oscilloscope's channel 1 lead was connected to the input signal generated by the signal generator. Channel 2 was connected to a wire from the breadboard, which was connected to the negative side of capacitor C1. Both probes' ground was connected to the ground wire.

Signal Generator connections

The output signal from the signal generator was split using a BNC T-Bar. This allowed two crocodile connectors to be used. The signal was connected to the input wire, and the signal ground was connected to the circuit ground.

Power Supply connection

A crocodile connector was used to connect input power, a second crocodile connector was used to connect the power supply to the ground of the circuit under test.

During the test, the instruments were set to the following settings, and the frequency of the frequency generator was changed.

Name	Value
Power supply input voltage	12.00V
Frequency Generator input voltage	1.000Vpp
Oscilloscope	Multicomp MP720012
Time	200.0ms – 5.0us
Channel 1 (input)	200mV /div
Channel 2 (Output)	500mV/div

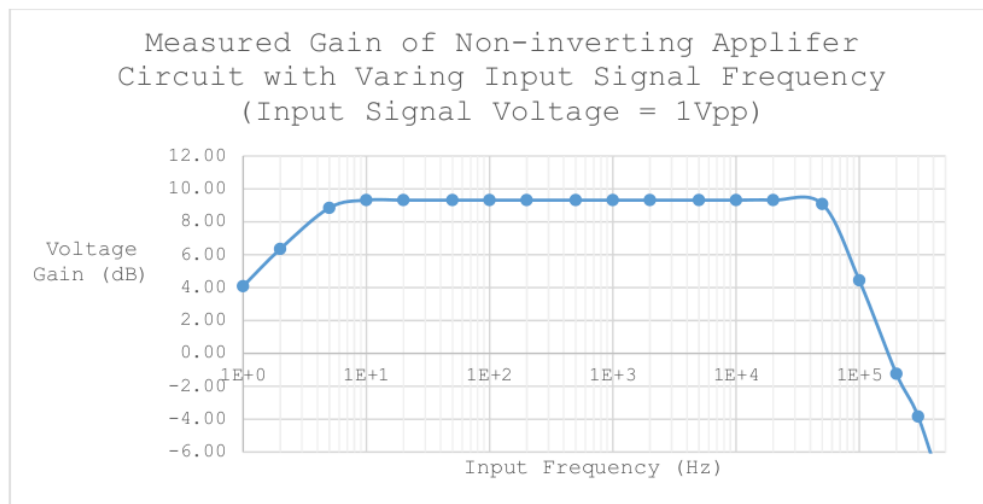
Table 2: Settings of test instrument during breadboard measurement

Breadboard Results

Table 6 and Figure 7 show the results from the breadboard testing. The input signal's voltage was set to 1.00V. During testing, the input voltage often fluctuated. The Voltage Gain in the right column was last calculated from the measured input voltage, not the displayed voltage on the signal generator.

Input		Output Voltage (Peak) (mV)	Voltage Gain (dB)
Frequency (Hz)	Voltage (Peak) (mV)		
1	400	640	4.08
2	520	1080	6.35
5	520	1440	8.85
10	520	1520	9.32
20	520	1520	9.32
50	520	1520	9.32
100	520	1520	9.32
200	520	1520	9.32
500	520	1520	9.32
1000	520	1520	9.32
2000	520	1520	9.32
5000	520	1520	9.32
10000	520	1520	9.32
20000	520	1520	9.32
50000	520	1480	9.09
100000	600	1000	4.44
200000	600	520	-1.24
300000	560	360	-3.84
500000	560	200	-8.94

Table 6 Breadboard Operational Amplifier circuit. Voltage Input, output and calculated gain



Once at a high frequency (>100kHz) the signal starts to distort to closer resemble a sawtooth waveform instead of an amplified continuous sine wave. As seen below in figure 8.

Breadboard Bandwidth

The following tables show additional measurements of the breadboard to find the low and high frequencies where the voltage gain is 3dB lower than the maximum gain.

Low-Frequency Intersection (-3dB of Max Gain)			
Input		Output Voltage (Peak) (mV)	Voltage Gain (dB)
Frequency (Hz)	Voltage (Peak) (mV)		
1	344	620	5.12
1.2	376	760	6.11
1.3	392	800	6.20
1.325	392	820	6.41
1.35	392	820	6.41
1.4	400	860	6.65
1.5	416	920	6.89
1.8	424	1020	7.62
2	448	1080	7.64
2.2	464	1140	7.81
2.5	472	1200	8.10
3	480	1268	8.44

Table 7 Breadboard Low-Frequency measurement at the point voltage gain is 3dB Less than the Maximum Gain

High-Frequency Intersection (-3dB of Max Gain)			
Input		Output Voltage (Peak) (mV)	Voltage Gain (dB)
Frequency (Hz)	Voltage (Peak) (mV)		
90000	504	1060	6.46
91000	504	1060	6.46
91500	504	1040	6.29
93000	504	1040	6.29
95000	504	1020	6.12

Table 8 Breadboard High-Frequency measurement at the point voltage gain is 3dB Less than the Maximum Gain

From the values highlighted in green in Table 7 and Table 8 and using 3 as the value of Gain.

The bandwidth product for the circuit, when measured on the breadboard, is 273KHz

PCB Component Population and Soldering

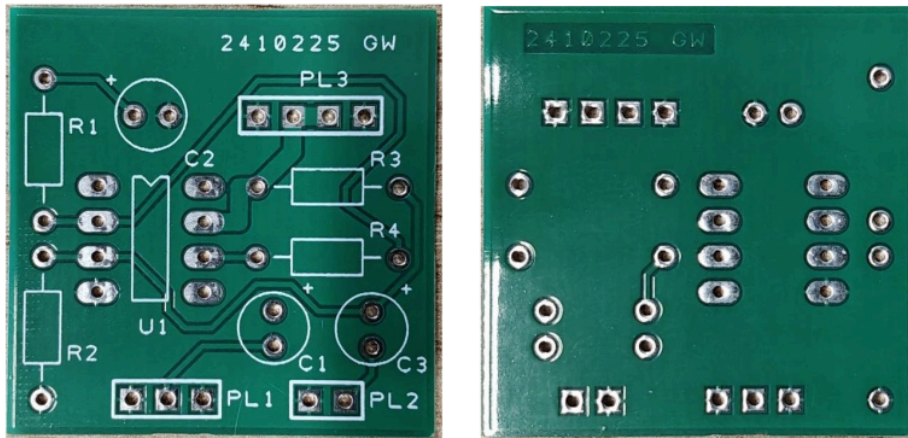


Figure 9 PCB without components

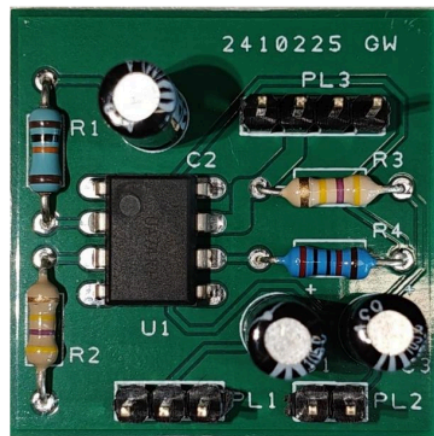


Figure 10 PCB With components soldered in place

When soldering the components in place, all components were flat to the PCB. The shortest components were populated first, so the order of soldering was resistors, 741 IC, Pin headers, and capacitors.

When soldering the pin headers, to keep the pin header straight, I placed the pins in a spare breadboard to give support whilst soldering.

When soldering the 741 IC, I was mindful not to unnecessarily heat the component. As the absolute maximum rating soldering of 300 °C for 10 seconds [1]. Beyond this limit, could cause permanent damage to the amplifier.

PCB Measurements

Table 9 and Figure 11 show the results from the PCB testing.

Input		Output Voltage (Peak) (mV)	Voltage Gain (dB)
Frequency (Hz)	Voltage (Peak) (mV)		
1	360	620	4.72
2	460	1080	7.41
5	520	1420	8.73
10	520	1500	9.20
20	520	1520	9.32
50	520	1520	9.32
100	520	1520	9.32
200	520	1520	9.32
500	520	1520	9.32
1000	520	1520	9.32
2000	520	1520	9.32
5000	520	1520	9.32
10000	520	1500	9.20
20000	520	1500	9.20
50000	520	1440	8.85
100000	500	1000	6.02
200000	520	500	-0.34
300000	500	320	-3.88
500000	500	180	-8.87

Table 9 PCB Amplifier circuit. Voltage Input, output and calculated gain

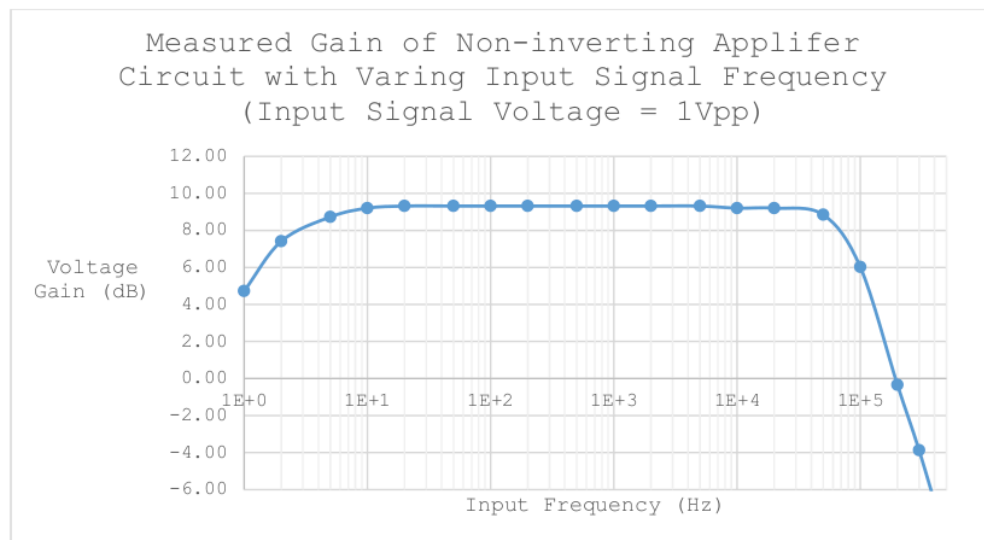


Figure 9 PCB Gain of Non-inverting Amplifier Circuit

PCB Bandwidth

The following tables show the frequency of -3dB of Max Gain.

Low-Frequency Intersection (-3dB of Max Gain)			
Input		Output Voltage (Peak) (mV)	Voltage Gain (dB)
Frequency (Hz)	Voltage (Peak) (mV)		
1	344	620	5.12
1.2	376	760	6.11
1.3	392	800	6.20
1.325	400	820	6.24
1.35	400	820	6.24
1.4	400	860	6.65
1.5	416	920	6.89
1.8	424	1020	7.62
2	448	1080	7.64
2.2	464	1140	7.81
2.5	472	1200	8.10
3	480	1268	8.44

Table 10 PCB Low-Frequency measurement at the point voltage gain is 3dB Less than the Maximum Gain

High-Frequency Intersection (-3dB of Max Gain)			
Input		Output Voltage (Peak) (mV)	Voltage Gain (dB)
Frequency (Hz)	Voltage (Peak) (mV)		
90000	504	1060	6.46
91000	504	1060	6.46
91500	512	1060	6.32
93000	504	1040	6.29
95000	504	1020	6.12

Table 11 PCB High-Frequency measurement at the point voltage gain is 3dB Less than the Maximum Gain

From the values highlighted in green in Table 10 and Table 11 and using 3 as the value of Gain.

The simulated bandwidth product for this circuit is 274KHz.

Simulated, Breadboard and PCB Gain Compared

Table 12 and figure 14 show the Simulated breadboard and PCB circuits compared on one table and graph.

Input Frequency (Hz)	Simulated Voltage Gain (dB)	Breadboard Voltage Gain (dB)	PCB Voltage Gain (dB)
1	5.08	4.08	4.72
2	7.68	6.35	7.41
5	9.19	8.85	8.73
10	9.43	9.32	9.20
20	9.48	9.32	9.32
50	9.54	9.32	9.32
100	9.54	9.32	9.32
200	9.54	9.32	9.32
500	9.54	9.32	9.32
1000	9.54	9.32	9.32
2000	9.54	9.32	9.32
5000	9.54	9.32	9.32
10000	9.54	9.32	9.20
20000	9.54	9.32	9.20
50000	9.48	9.09	8.85
100000	8.63	4.44	6.02
200000	3.52	-1.24	-0.34
300000	0.21	-3.84	-3.88
500000	-5.61	-8.94	-8.87

Table 12 Simulated, Breadboard and PCB gain at a range of frequencies

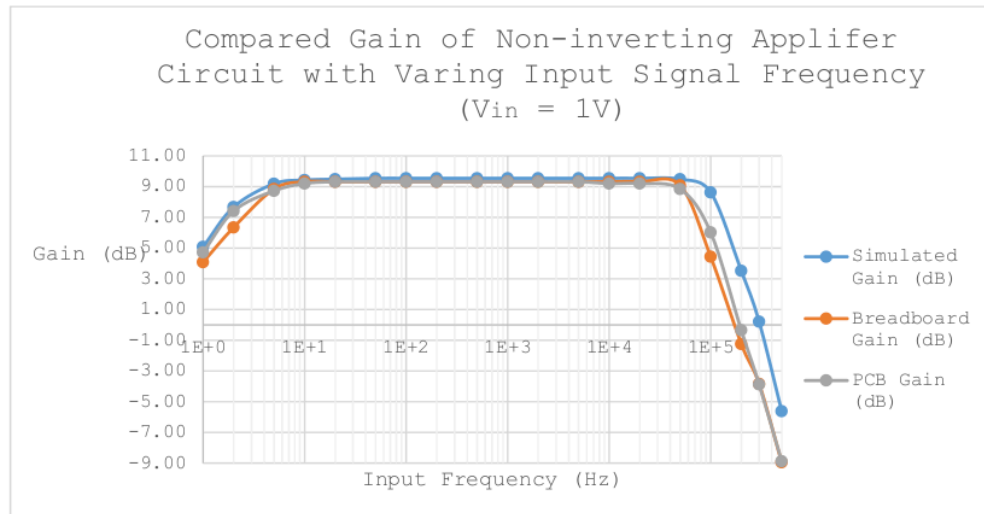


Figure 10 Graph of Compared Simulated and Measured gain of the amplifier circuit, overlayed

References

- [1] Texas Instruments, "LM741 Operational Amplifier Datasheet," October 2015. [Online]. Available: <https://www.ti.com/lit/ds/symlink/lm741.pdf>. [Accessed 13 October 2024].

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

79/100

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GRADING FORM: SMU GENERIC_SMOSEY

GEORGE WELHAM

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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.

28

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 90% - Not too bad although C1 and C3 are a bit close to the power pin header.
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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