School of Electrical and Electronic Engineering

First Year Laboratory

Semester 2

Module: **Electronic Circuit Design I**
Code: **EEEN10029**
Lecturer:

Experiment: **NI ELVIS Analogue Circuits I – room C18**

Aims

Use the designs from experiment 1 NI Multisim environment
To introduce the prototype board NI ELVIS as a circuit breadboard.
To introduce the operational amplifier (op amp) as a component
To use the op amp as a simple amplifier

Marking Scheme

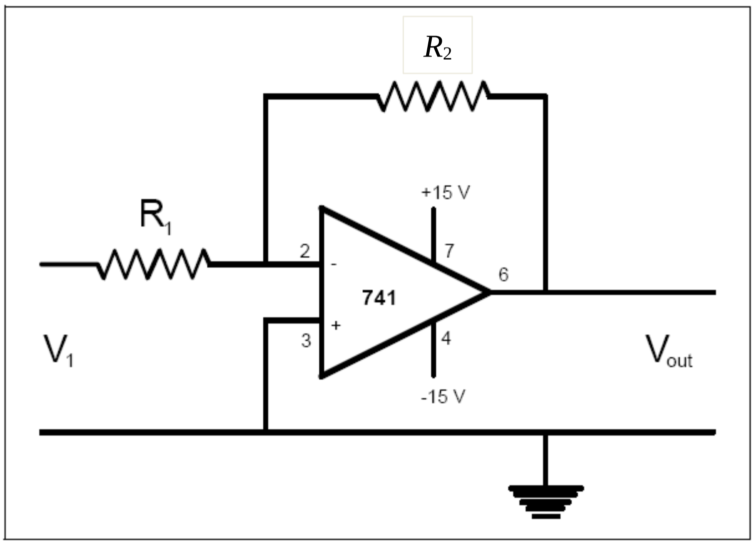
Exercise 1.1 (Measurement of Component Values): 3 marks
Exercise 1.2 (Building a Voltage Divider Circuit on the NI ELVIS): 6 marks
Exercise 1.3 (Using the DMM to Measure Current): 6 marks
Exercise 1.4 (Frequency Response of the Basic Op Amp Circuit): 13 marks
Exercise 2.1 (Measuring the Op Amp Frequency Characteristic): 12 marks
Exercise 2.2/Exercise 2.3 (Choice): 12 marks
Total: 52 marks

Introduction

The NI ELVIS environment consists of the hardware workspace for building circuits and interfacing experiments, and the NI ELVIS software. The NI ELVIS software, all created in LabVIEW has two main types: the soft front panel (SFP) instruments and LabVIEW virtual instruments for custom control and access to the features of the NI ELVIS benchtop workstation.

NOTE: IN THE EXPERIMENTS, DO NOT SWITCH ON ELVIS POWER BEFORE YOU HAVE COMPLETED THE WIRING! OTHERWISE, THE OP-AMP CAN BE DESTROYED!

The op amp input voltage is differential i.e. it exists across two input terminals but the output voltage is referred to the earth. To describe the usual mode of use of an op amp consider the following circuit – the *inverting amplifier***.**



R_1 is known as the input resistor and R_2 is known as the feedback resistor. The circuit can be analyzed as follows:

1. The non-inverting input is connected to earth (0V)
2. Therefore the inverting input is also at zero potential and is a *virtual earth*
3. There must be a voltage drop of V_1 across R_1 and so a current of V_1/R_1 must flow from left to right (Ohms Law)
4. No current flows into the inverting input so this current must flow through R_2
5. If a current V_1/R_1 flows through R_2 and the left hand side of R_2 is at 0V the voltage on the right hand side of R_2 must equal - $V_1 R_2 / R_1$ (Ohms Law)
6. But this voltage is V_{out}
7. Therefore:

$$V_{out} = \frac{-R_2}{R_1} V_1$$

It is important to realise that the gain of this amplifier V_{out}/V_1 is the ratio R_2/R_1 and is defined by the selection of only two resistors.

Op amps are discussed in more detail during lectures.
A second important circuit is the *non-inverting amplifier*. We can analyze this circuit as follows:

1. The non-inverting input is connected to V_1
2. Therefore the inverting input is also at the potential V_1
3. There is a voltage of V_1 across R_1 and therefore the current of V_1/R_1 flows the earth through R_1
4. The current through R_2 is $(V_{out}- V_1)/R_2$
5. Therefore:

$$V_{out} = \frac{R_1+R_2}{R_1}V_1$$

Goal

This lab introduces the NI ELVIS workstation to show how electronic component properties can be measured. Circuits are then built on the bread board and later analyzed with the NI ELVIS software based soft front panels (SFP) or software instruments.

Important: To complete the report you will need your answers from the Multisim experiments.

Equipments Used in this Lab

NI ELVIS II
Lab Digital Multimeter (DMM)
Lab Function Generator (TG315)
Lab Oscilloscope (54622A)

Exercise 1.1 - Measurement of Component Values

Components Used in this Lab

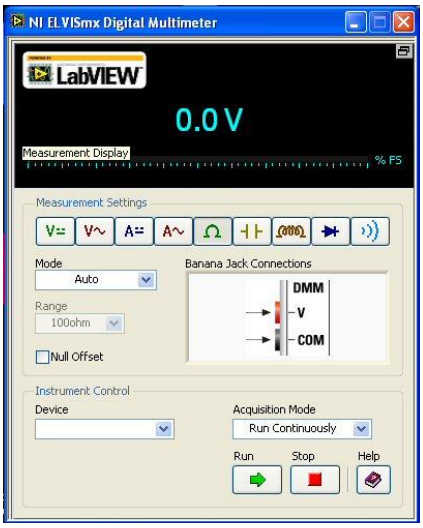
1.0 kΩ resistor R1 (Brown, Black, Red)
2.2 kΩ R2 (Red, Red, Red)
1.0 MΩ resistor R3 (Brown, Black, Green)
1 µF capacitor C

Soft Front Panels (SFP) Used in this Lab

Digital Ohmmeter DMM[Ω], Digital Capacitance meter DMM[C], and the Digital Voltmeter DMM[V]

When NI Instrument Launcher is launched, a toolbar gives access to different virtual instruments such as a digital multi-meter and oscilloscope.

Select the digital multi-meter DMM.



Mode: Auto

Range: 100ohm

Acquisition Mode: Run Continuously

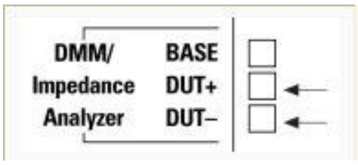
The Digital Multimeter SFP can be used for a variety of operations.

NI ELVIS II DMM[Ω] measurements

Connect two banana type leads to the DMM current inputs on the workstation left side panel. Connect one lead to DMM and the other to ground COM. Connect the other ends of the leads to one of the resistors.

Click on the **Ohm** button [Ω] to use the Digital Ohmmeter function DMM[Ω]. Measure R1, R2, and R3.

Click on the capacitor symbol [╪] on the DMM. To measure the capacitor C plug the capacitor into the prototype board using sockets 29 (DUT+) and 30 (DUT-) on the left hand side of the board and read the capacitance on the DMM screen.



Lab DMM measurements

Select the **Ω** switch and connect the input probes to the **VΩ** socket and common socket (**COM)** .Connect the other ends of the leads to one of the resistors and measure R1, R2, and R3.

SHOW YOUR RESULTS TO A DEMONSTRATOR

REPORT

Make the following table in your report and complete

Measured By	R_1 (Ω)	R_2 (Ω)	R_3 (Ω)	C_f (µF)
	1 kΩ nominal	2.2 kΩ nominal	1 MΩ nominal	1µF nominal
DMM [V]	Ω	Ω	Ω	µF
Lab DMM	Ω	Ω	Ω	

End of Exercise 1.1

Banana Jacks

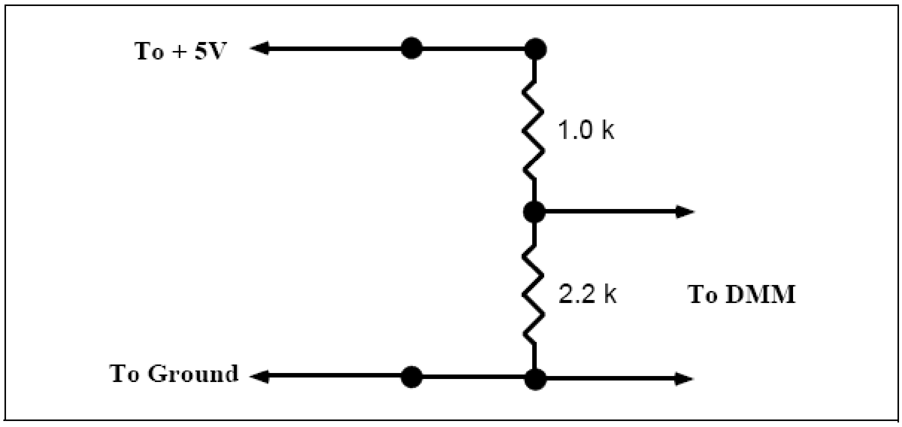
The Elvis Board provides four Banana jacks for use as auxiliary I/O. These connectors may be used for auxiliary signal input or for signal output to test equipment. The Banana jacks are color-coded, red, and black.

BNC Jacks

The Elvis Board provides two BNC jacks for use as auxiliary I/O. This connector may be used for auxiliary signal input or for signal output to test equipment.
For most circuit configurations, BNC- should be connected to GND.

Exercise 1.2 - Building a Voltage Divider Circuit on the NI ELVIS Protoboard

Using the two resistors, R_1 and R_2, assemble the following circuit on the NI ELVIS prototype board.



NI ELVIS II DMM[V] measurements

The input voltage V_o is connected to the [+5 V] pin socket 54 and the common to the NI ELVIS [Ground] pin socket 53 on the left side of the prototype board. Use the two banana type leads from Exercise 1.1, connect the end of DMM lead to jack BANANA A and the other to BANANA B. Then wire from pin 38 to the DMM current input and pin 39 to ground.

Lab DMM measurements

Select the **DC** voltage switch and connect the input probes to the **VΩ** socket and common socket (**COM) .** Connect the other ends of the leads to ELVIS BANANA A and BANANA B jacks and measure V_1.
Circuit theory tells us that the output voltage $V_1 = R_2 V_o / (R_1+R_2)$.

Using the previous measured values for R_1, R_2, and V_o, calculate V_1. Then, use the DMM[V] to measure the actual voltage V_1.

SHOW YOUR RESULTS TO A DEMONSTRATOR

REPORT

Copy the circuit theory equation above and complete the values below.

V_1 (calculated) ________________
V_1 (measured by Multisim DMM [V]) ________________
V_1 (measured by DMM [V]) ________________
V_1 (measured by Lab DMM) ________________

How well does the measured value agree with your calculated value?

End of Exercise 1.2

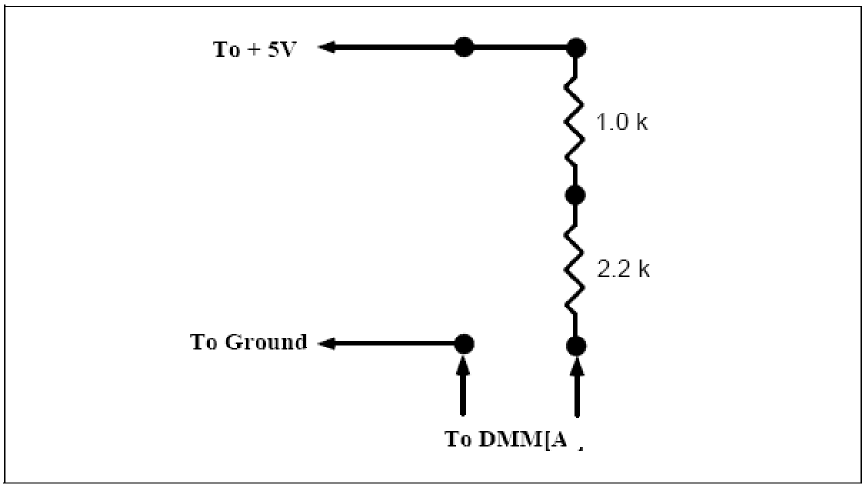
Exercise 1.3 - Using the DMM to Measure Current

From Ohms law, the current ***I*** flowing in the above circuit is equal to V_1/R_2.

NI ELVIS II DMM[A] measurements

Perform a direct measurement of the current. Do this by moving one the external leads from DMM VΩ to DMM A below on the workstation left side panel then connect the other ends of the leads to BANANA A and BANANA B jacks

Wire the other ends to the circuit as shown below to the pins 38 (BANANA A) and 39 (BANANA B)



Select the function DMM[A--] on the DMM front panel and measure the current.

Lab DMM measurements

Select the **DC** current switch and connect the input probes to the **mA** socket and common socket (**COM) .** Connect the other ends of the leads to ELVIS BANANA A and BANANA B jacks and measure the current

SHOW YOUR RESULTS TO A DEMONSTRATOR

REPORT

Using Ohms law calculate the current ***I*** using the measured values of V_1 and R_2.

I (calculated) ________________
I (measured by Multisim DMM [A]) ________________
I (measured by DMM[A]) ________________
I (measured by Lab DMM) ________________

How well do the measured values agree with your calculated values?

End of Exercise 1.3

Exercise 1.4 - Frequency Response of the Basic Op Amp Circuit

NOTE: IN THE EXPERIMENTS, DO NOT SWITCH ON ELVIS POWER BEFORE YOU HAVE COMPLETED THE WIRING! OTHERWISE, THE OP-AMP CAN BE DESTROYED!

Using Virtual Function Generator and Oscilloscope.

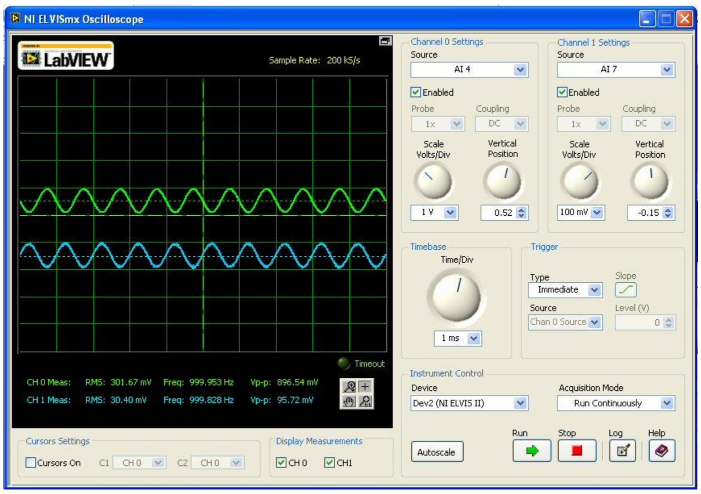
Remember you have built this circuit before during the MultiSim laboratory. On the workstation protoboard, build a simple 741 inverting Op Amp circuit with a gain of 10 as shown in the schematic diagram earlier.

Notice that the Op Amp uses both + 15 V and – 15 V supplies. These are found on the left hand side protoboard pin sockets (labeled as +15V, –15V, and Ground, pin sockets 51, 52 and 53). Connect the Op Amp input voltage V1 to [FGEN] on the left hand side of the prototype board (pin socket 33). Then wire from FGEN to the positive connection of CH0 and also from the negative pin of CH0 to ground. Connect the Op Amp output voltage Vout to the positive pin of CH1 and wire from the negative pin to ground.

On NI ELVIS II Breadboard

On the NI ELVIS Breadboard everything is the same just wire from FGEN to the positive connection of an analogue input signal channel (e.g AI 7+). The analogue channel must also be grounded. To do this connect the negative pin socket of the chosen AI channel to ground (e.g AI7- wired to AIGND at pin socket 18).
Connect the Op Amp Vout to another analogue input signal channel (e.g AI6+). The analogue channel must also be grounded. To do this connect the negative pin socket of the chosen AI channel to ground (e.g AI6 - wired to AIGND at pin socket 18).
From the NI ELVIS Instrument Launcher, select Function Generator and Oscilloscope.

Check your circuit, then power up the protoboard. Run the FGEN and OSC continuously. Observe the test voltage V1 appears on channel B and the Op Amp output voltage Vout on channel A.



Sample Rate: 200 kS/s

Channel 0 Settings: Source AI 4; ☑ Enabled; Probe 1x; Coupling DC; Scale Volts/Div 1 V; Vertical Position 0.52

Channel 1 Settings: Source AI 7; ☑ Enabled; Probe 1x; Coupling DC; Scale Volts/Div 100 mV; Vertical Position -0.15

Timebase: Time/Div 1 ms

Trigger: Type Immediate; Source Chan 0 Source; Level (V) 0

CH 0 Meas: RMS: 301.67 mV Freq: 999.953 Hz Vp-p: 896.54 mV
CH 1 Meas: RMS: 30.40 mV Freq: 999.828 Hz Vp-p: 95.72 mV

Instrument Control: Device Dev2 (NI ELVIS II); Acquisition Mode Run Continuously

Cursors Settings: ☐ Cursors On C1 CH 0 C2 CH 0

Display Measurements: ☑ CH 0 ☑ CH1

Using Lab Oscilloscope and Virtual Function Generator.

Measure the amplitude of the Op Amp input (CH B) and output (CH A) from the oscilloscope window. Notice the difference in scaling (Volts / div) between the two channels. Notice also the output signal is inverted with respect to the input. This is to be expected for an inverting Op Amp circuit.

From the NI ELVIS Instrument Launcher, select Function and set the same parameters
Waveform: **Sine wave**
Amplitude: **0.1 V**
Frequency: **1 kHz**
DC Offset: **0.0 V**

Disconnect the NI ELVIS from the Lab Function Generator and Connect Lab Oscilloscope Channel 1 to the BNC 1 jack and Channel 2 to the BANANA 1 and BANANA 2 jacks

Then wire the output voltage to the pin 38 and connect the pin socket of the BNC 1 to the ground. Run the Function Generator and measure the amplitude of the Op Amp input (CH1) and output (CH2) from the Lab Oscilloscope screen.

SHOW YOUR RESULTS TO A DEMONSTRATOR

REPORT

Calculate the voltage gain (the voltage ratio channel A /channel B). Remember the negative sign for inverting configuration.
Complete the following table for a range of resistor values. **Use your answers from the MultiSim laboratory to complete the last column.**

R_1 (Ω)	R_2 (Ω)	Ideal gain	Av=(voltage ratio channel A /channel B) using ELVIS VIs	Av=(ratio channel A /channel B) using Laboratory Oscilloscope	Av obtained in the pre-lab using MultiSim Oscilloscope
10 k	**100 k**				
100 k	**100 k**				
100 k	**1 M**				
10 k	**1 M**				
1 k	**100 K**				

For each set of new results (not the MultiSim results) comment on how your measurements agree or disagree with the theoretical gain of ($-R_2 / R_1$)

End of Exercise 1.4

Exercise 2.1 Measuring the Op Amp Frequency Characteristic

NOTE: IN THE EXPERIMENTS, DO NOT SWITCH ON ELVIS POWER BEFORE YOU HAVE COMPLETED THE WIRING! OTHERWISE, THE OP-AMP CAN BE DESTROYED!

Soft Front Panels (SFP) Used in this Lab

Digital Ohmmeter DMM[Ω], Bode Analyzer

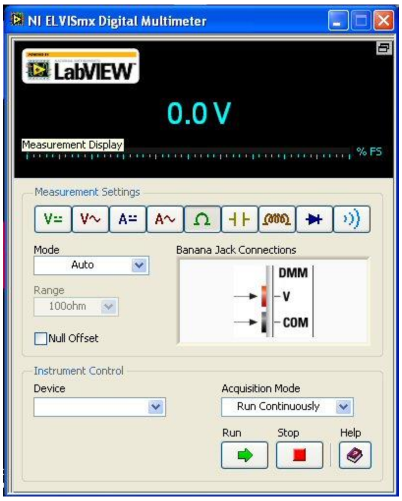
Components Used in this Lab

1.0 kΩ resistor = R_1
10 kΩ resistor = R_2
1 µF capacitor C
741 op amp

Build a simple 741 inverting Op Amp circuit with a gain of 10.

First you can check the value of the resistors using a digital multimeter (DMM) and measure the resistance in Ohms across the leads of the resistor.

Select the digital multi-meter DMM from the toolbar.



NI ELVISmx Digital Multimeter

0.0 V

Mode: Auto

Range: 100ohm

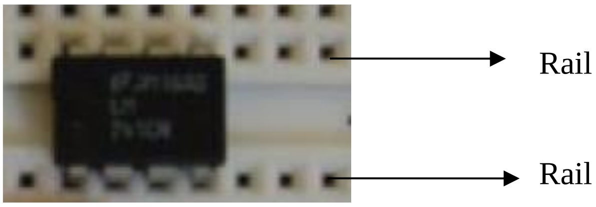
☐ Null Offset

Acquisition Mode: Run Continuously

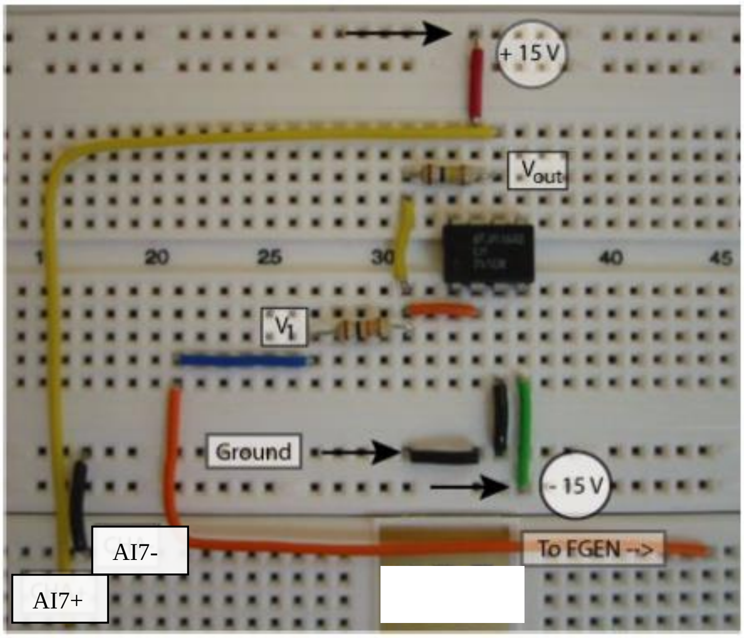
The Digital Multimeter SFP can be used for a variety of operations.
Connect two banana type leads to the DMM current inputs on the workstation left side panel. Connect one lead to DMM and the other to ground COM. Connect the other ends of the leads to one of the resistors.

Click on the **Ohm** button [Ω] to use the Digital Ohmmeter function DMM[Ω] and measure R_1 and R_2.

The op amp should be placed across the divide between terminal rails E and F on the protoboard:



Notice that the Op Amp uses both the + 15 V and – 15 V DC power supplies. After you have connected the resistors in the correct place shown in the schematic above connect pin 7 of the op amp to +15V and pin 4 to -15V terminals. These are found on the left hand side protoboard pin sockets (labeled as +15V, –15V, and Ground, pin sockets 51, 52 and 53). Connect the Op Amp input voltage V1 to [FGEN] on the left hand side of the prototype board (pin socket 33). You should use wire to connect between terminals.
See below for an example of wiring. **This is intended to help in learning how to route signals and should not be followed exactly**.



Wire from FGEN to the positive connection of an analogue input signal channel (e.g AI 1+). These are found on the left-hand side of the board. The analogue channel must also be grounded. To do this connect the negative pin socket of the chosen AI channel to ground (e.g AI1- wired to AIGND at pin socket 18).

Connect the Op Amp output voltage Vout to another analogue input signal channel (e.g AI0+). The analogue channel must also be grounded. To do this connect the negative pin socket of the chosen AI channel to ground (e.g AI0- wired to AIGND at pin socket 18).

From the NI ELVIS Instrument Launcher, select **Bode Analyzer**.

The signals, input (V_1), and output (V_{out}), must be connected to the Analog Input pins as follows:

V_1+ ACH1+ (from the FGEN Output)
V_1– ACH1– AIGND

V_{out}+ ACH0+ (from the Op Amp Output)
V_{out} – ACH0– AIGND

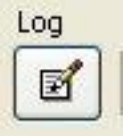
From the Bode Analyzer, set the scan parameters as follows:
Start **5 (Hz)**
Stop **50000 (Hz)**
Steps **10 (per decade)**

Press **Run** and observe the Bode plot for the Inverting Op Amp circuit.
Also check out the phase response.

REPORT

YOU MUST SHOW RESULTS TO A DEMONSTRATOR

Save the data using the LOG button on the Bode Analyzer and plot the data in Excel.



Explain the results of both the magnitude and phase response of the 741 op amp

End of Exercise 2.1

NOTE: CHOOSE BETWEEN EXERCISE 2.2 AND EXERCISE 2.3

NOTE: IN THE EXPERIMENTS, DO NOT SWITCH ON ELVIS POWER BEFORE YOU HAVE COMPLETED THE WIRING! OTHERWISE, THE OP-AMP CAN BE DESTROYED!

Exercise 2.2 High Pass Filter

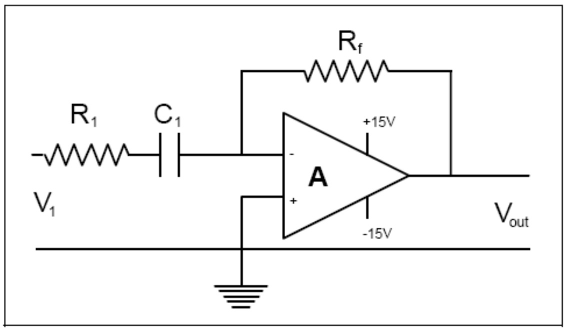
Adding a capacitor C_l in series with the input resistor R1 generates a high pass filter. The low frequency cutoff point f_L is given by the equation:

$$2\pi fL = 1/ R_1C_l$$

where f_L is measured in Hertz. This is the frequency where the Gain (dB) has fallen by –3 dB. This point (–3dB) occurs when the impedance of the capacitor equals that of the resistor. The high pass Op Amp filter equation is similar. At the –3 dB point, the impedance of the input resistor is equal to the impedance of the input capacitor:

$$R_1 = 1 / (2\pi f_L C_l) = X_C$$

Add a 1 μF capacitor C_l in series with the 1 kΩ input resistor R_1 in the Op Amp circuit. 10 kΩ resistor = R_2

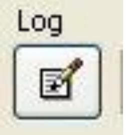


Re run the Bode plot using the same scan parameters as in Exercise 2-1. Use the cursor function to find the low frequency cutoff point; that is, the frequency at which the amplitude has fallen by –3 db or the phase change is 45 degrees.

REPORT

YOU MUST SHOW RESULTS TO A DEMONSTRATOR

Save the data using the LOG button on the Bode Analyzer and plot the data in Excel.



Explain the results of both the magnitude and phase response of the high pass filter using the 741 op amp. Record the low frequency cutoff point. How does it agree with the theoretical prediction of $2\pi f_L = 1/ R_1C_1$?

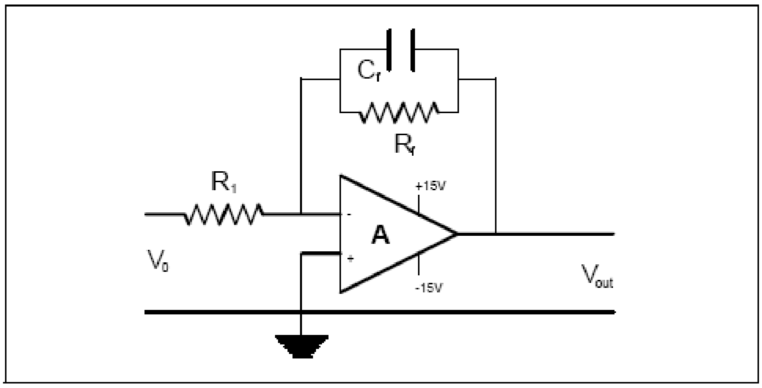
End of Exercise 2.2

Exercise 2.3 Low Pass Filter

The high frequency roll off in the Op Amp circuit is due to the internal capacitance of the 741 chip being in parallel with the feedback resistor R_f. If we add an external capacitor C_f in parallel with the feedback resistor R_f, one can reduce the upper frequency cutoff point to f_U. This new cutoff point can be predicted from the equation:

$$2\pi f_U = 1/ R_f C_f$$

Remove or short the input capacitor (you will use this in Exercise 2-3) and add the feedback capacitor C_f in parallel with the 10 kΩ feedback resistor.

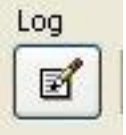


Re run the Bode plot using the same scan parameters as in Exercise 2-1 and 2-2. you should observe a change in the high frequency response.
Use the cursor function to find the low frequency cutoff point; that is, the frequency at which the amplitude has fallen by –3 db or the phase change is 45 degrees.

REPORT

YOU MUST SHOW RESULTS TO A DEMONSTRATOR

Save the data using the LOG button on the Bode Analyzer and plot the data in Excel.



Explain the results of both the magnitude and phase response of the high pass filter using the 741 op amp. Record the high frequency cutoff point. How does it agree with the theoretical prediction of $2\pi f_U = 1/ R_f C_f$?

End of Exercise 2.3

EXTRA EXERCISE

Exercise 2.4 Band Pass Filter

If you allow both an input capacitor and a feedback capacitor in the Op Amp circuit, then the response curve has both a low cutoff frequency f_L and a high cutoff frequency f_U. The frequency range ($f_U - f_L$) is called the bandwidth. For example, a good stereo amplifier would have a bandwidth of at least 20,000 Hz.

Keeping the circuit form Exercise 2-3 replace C_1 (or remove the short on C_1) and re-run a Bode plot using the same scan parameters as before.

By drawing a line at 3 dB below the maximum amplitude region, the frequency range contained by all frequencies above this line defines the pass band.

End of Exercise 2.4