

OPERATIONAL AMPLIFIERS

YOUR NAME _____

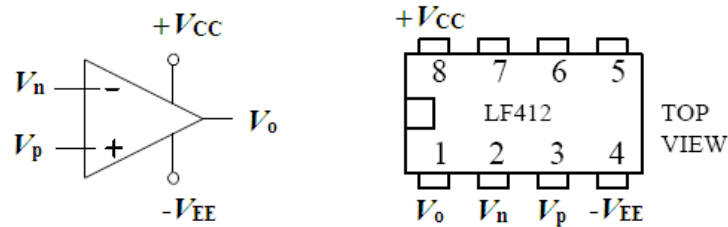
GTA'S SIGNATURE _____

LAB MEETING TIME _____

Objectives: To use the function generator, the oscilloscope and the AC mode of the multimeter; to build a comparator circuit; to build an inverting amplifier circuit; to build a circuit having a dependent source and determine its Thévenin resistance.

INTRODUCTION TO THE INTEGRATED CIRCUIT OP AMP

In these experiments you will be using an Op Amp made by Texas Instruments, model LF412. The LF412 consists of two identical Op Amps in an integrated circuit chip mounted in a dual-in-line package. You will use only one of the Op Amps.



LF412 Op Amp

<http://www.ti.com/product/lf412>

Some specs and advice:

- Open loop gain (typical) = 200,000
- Absolute **MAXIMUM** ratings:
- Supply voltage = +/- 18 V → To minimize unpredictable oscillations, attach a capacitor (~0.01 to 0.1 μ F) between V_{CC} and ground
- Input range = +/- 15 V
- Power dissipation = 670 mW
- The wrong polarity of the power supply voltages of $+V_{CC}$ and $-V_{EE}$ will *destroy* the chip. (Thus, inadvertently installing the package backwards in the socket is a big mistake).
- Neither input should be allowed to exceed $|V_{EE}|$.

INTRODUCTION TO THE FUNCTION GENERATOR, OSCILLOSCOPE, AND AC MODE OF MULTIMETER

Agilent 33522A Function / Arbitrary Waveform Generator



Upon switching on the power, the output is zero. No signal is output until you press the “1” or “2” button from Channel setup above the channels and then press **Output Off / On**. Do not do this before setting up desired signal. Channel 1 is selected by default.

Select CHANNEL 1 then under OUTPUT LOAD select SET TO HIGH Z option. This setting should be used for all future measurements.

Press WAVEFORM and select the sinusoid by pressing appropriate softkey below the screen.

Press softkey below FREQUENCY and enter 100 on the keypad and press softkey to choose Hz. It is also possible to use the knob to change the value as well as cursor keys and change digit by digit if needed.

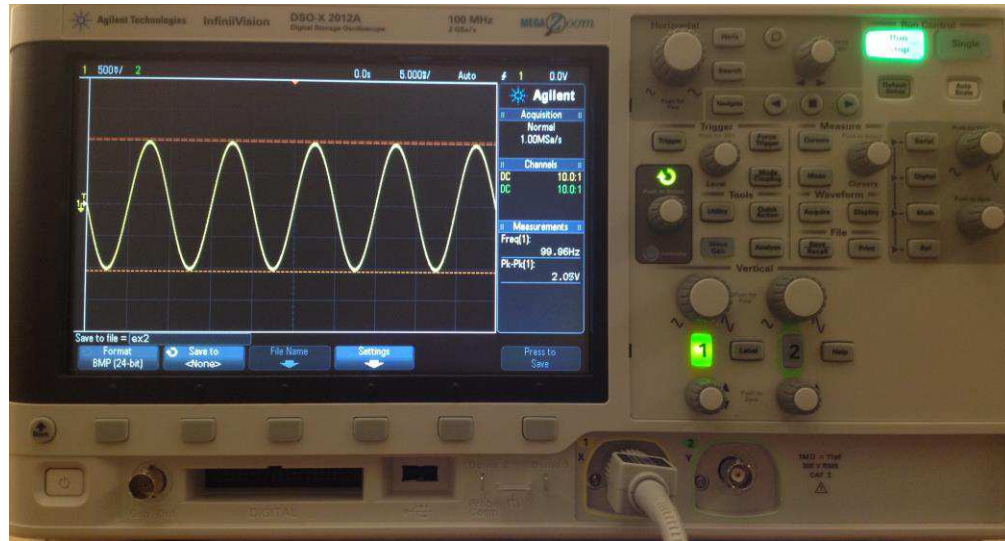
Under AMPLITUDE enter 2 and choose V_{pp} . Leave OFFSET and PHASE having zero value.

Now, you can output the signal and connect it to the multimeter. The multimeter should read 0.707 V. Why is it reading 0.707 V when $V_{pp} = 2V$? First, the amplitude of the sinusoid is 1.0 V. Second, the AC multimeter displays the RMS (root-mean-square) value of the input signal. For a sinusoid, the RMS value is $\sqrt{2}/2$ times the amplitude, or, in this case, $0.707 \times 1.0 \text{ V} = 0.707 \text{ V}$.

If you press button UNITS there is possibility to change input parameters: from Frequency to Period, from Amplitude and Offset representation of the signal to Low and High signal levels, as well as possibility to enter rms instead of peak to peak value of desired signal.

The generator itself is now displaying the values of V_{pp} and frequency: 2 V and 100 Hz. Now try different values of these parameters. Leave the generator running now with a 100 Hz sinusoid output having a peak-to-peak voltage of 2 V, and leave the multimeter connected.

Agilent DSO-X-2012A Oscilloscope



Turn on the power. Connect a GRAY probe to channel 1 input. Connect this probe to the output of your Function Generator. Push AUTO SCALE to automatically choose a useful vertical scale for the trace. Play with the HORIZONTAL and VERTICAL dials to see what their function is. Play with the RUN/STOP and SINGLE buttons to see what they do.

Under MEASURE press the MEAS button in order to find your peak-to-peak value and frequency. Insert a USB, then under FILE press SAVE/RECAL then SAVE and save the trace on your USB. Check on the computer if you were able to properly save the trace.

AC with DC Bias

On the function generator, press Offset and enter 1.0. The sinusoid should now shift upward by 1 volt.

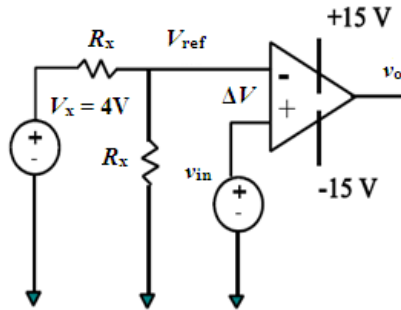
VOLTAGE COMPARATOR

8. Build the circuit shown below.

For the DC voltage V_X , use the +6V output and COM terminal of HP 3630A DC power supply.

To establish $+V_{CC}$ and $-V_{EE}$, use the HP 3630A DC power supply with the outputs wired using the 20/-20 V outputs set to 15 V and COM connected to the ground of your circuit.

Set $V_X = 4$ V and measure V_{REF} with the digital multimeter.



Use Agilent 33522A function generator to provide v_{in} and use the oscilloscope to display $v_{in}(t)$ and $v_o(t)$ simultaneously (you will need two GREY probes). Use DC coupling on the oscilloscope inputs.

a) **Comparing two DC voltages:**

Test your comparator circuit with LED readout you designed in the homework. Set $V_{REF} = 1$ V and demonstrate to your GTA that the LED is ON when $v_{in} > 1$ V, but OFF otherwise. Do this by using the function generator as a DC source (set $V_{PP} = 0$ V and offset to DC value V_{DC}).

Remember GTA's signature for comparator operation: _____

b) **Comparing DC and AC voltages:**

Now set the controls $V_{DC} = 0$ and $V_{PP} = 5.0$ V and observe $v_o(t)$ and $v_{in}(t)$ on the oscilloscope screen while you vary V_X (0-6 V). Capture and save several cycles of the resultant waveforms, being sure to indicate zero voltage lines and the peak voltages. Record the v_{in} and v_o waveforms for $V_{REF} = 0$ V and $V_{REF} = 1.0$ V.

Include printout of measurement results in your lab report. Include both v_{in} and v_o on the same graph.

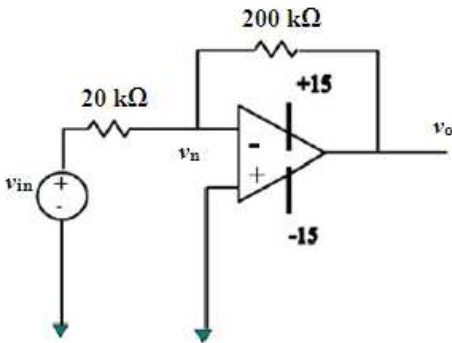
Discuss your measurement results.

c) What value of V_{REF} would set your output to be -15 V, if $v_{in} = 5 V_{pp}$?

d) What value of V_{REF} would set your output to be +15 V, if $v_{in} = 5 V_{pp}$?

INVERTING AMPLIFIER

9. a) Construct the circuit below to measure v_{in} and v_o using a DC input voltage $-2 V < v_{in} < 2 V$.
Note: This input voltage range should put the Op Amp into saturation part of the time.
 Explain why output reaches saturation.



- b) **Comparing input and output voltages of the OpAmp:**

Use the HP power supply for the DC source of v_{in} and measure at least 20 points for the graph in 9.c.

v_{in} [V]	v_o [V]	v_{in} [V]	v_o [V]	v_{in} [V]	v_o [V]	v_{in} [V]	v_o [V]

- c) Plot experimental values of v_o versus v_{in} using Matlab or excel. Label your plot and insert it immediately following this page.

- d) In the space below, compare your measured data to the predictions of the PreLab homework. Use the slope of your measured curve to obtain measured value of the closed loop gain A_{CL} .

A_{CL} (theory) = _____ A_{CL} (measured) = _____

$v_{o,Min}$ (theory) = _____ $v_{o,Min}$ (measured) = _____

$v_{o,Max}$ (theory) = _____ $v_{o,Max}$ (measured) = _____

e) **Comparing voltages of two input terminals:**

Measure at least 20 points for the graph in 9.f.

v_{in} [V]	v_n [V]	v_{in} [V]	v_n [V]	v_{in} [V]	v_n [V]	v_{in} [V]	v_n [V]

- f) Plot experimental values of v_n versus v_{in} using Matlab or excel. Label your plot and insert it after the plot from 6.c.
- g) In the analysis of the inverting amplifier circuit that you did in the PreLab homework, you assumed that $v_n = 0$. However, your measurements show that it is not always zero. Explain this departure from the ideal Op Amp model in 5-10 sentences.

h) **Changing the magnitude of the AC input signal:**

Apply a 1000 Hz sine wave to the input at v_{in} and observe the voltage waveforms $v_{in}(t)$ and $v_o(t)$ on the oscilloscope. Capture several cycles of $v_{in}(t)$ and $v_o(t)$ for two cases:

- $v_{in} = 1$ V (peak-to-peak), $f = 1$ kHz
- $v_{in} = 5$ V (peak-to-peak), $f = 1$ kHz

Include printout of measurement results in your lab report. Include both v_{in} and v_o on the same graph.

- i) Explain the shape of $v_o(t)$ for each case.

FREQUENCY DEPENDENCE OF THE CIRCUIT AND BODE PLOTS

10. a) Set magnitude of the AC input signal v_{in} to 1 V ($V_{pp} = 2$ V). Increase frequency of the sine wave input from 1 kHz to 100 kHz and observe magnitude of v_{out} . Record *at least* five points along the way.

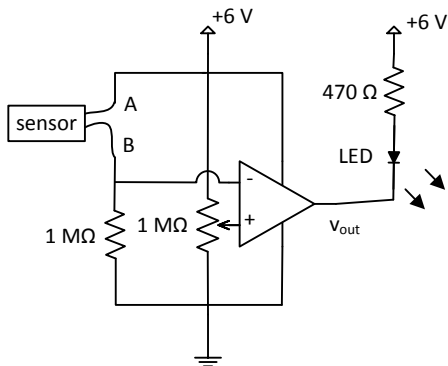
f [kHz]	v_{out} [V]	f [kHz]	v_{out} [V]

11. Graph results of your measurements. If possible, try graphing log-normal curve, where $20\log(V_{out}/V_{in})$ is on the vertical axis and $20\log(f)$ on the horizontal. Is this the general trend you expected from the frequency information in the pre-lab?

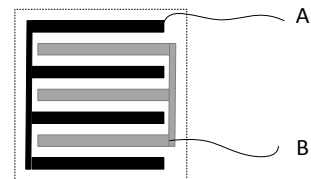
Remember GTA’s signature for amplifier circuits: _____

RAIN SENSOR

12. a) Connect circuit below using your own rain sensor. Move sensor as far away from the bread board and test equipment as leads will allow. Place sensor on the paper towel. Make sure that circuit works as intended and then proceed to part b)



Sensor:



LED: $V_{LED} = 1.5 - 1.8$ V when “on”

b) Measure the following voltages:

For “dry” conditions: $v_+ =$ _____ V

$v_- =$ _____ V

$v_{out} =$ _____ V

For “wet” conditions: $v_+ =$ _____ V

$v_- =$ _____ V

$v_{out} =$ _____ V

c) Explain measurement results. Is LED glowing for high or low output voltage v_{out} ? Why do you think it is so?

d) How would you design a new kind of rain sensor that will light LED for dry conditions, and turn LED off when it starts raining? Propose the idea in the space below.

Remember GTA’s signature for rain sensor _____

POSTLAB: DESIGN CHALLENGE

13. Door opening alarm:

Propose design of a circuit similar to the rain sensor that will turn on the LED once the door is open.

You don’t have to connect and test it; just attach a sheet of paper with proposed design and explanation how it works.

Note: do not use wording “... some kind of a sensor...” You have to come up with the idea for the circuit and “sensor” that will help detect when the door is open. You are allowed to use R, L, C, OpAmp, diode, LED and transistor. You are not allowed to use microcontroller! (For example: you can not say “connect ... sensor... to the input of the microcontroller”).