

ELECTRONICS I

Lab 3 Op Amp I

TRADITIONAL LAB

Experimental procedure

I. Inverting Amplifier

Connect the Op-Amp IC on a breadboard. Make sure the polarity of the power supplies is correct, or else the device will be destroyed.

Please note down the pin-out numbers and related terminals from the manufacture's data handbook.

Connect the inverting amplifier configuration as shown in Fig. 3.2

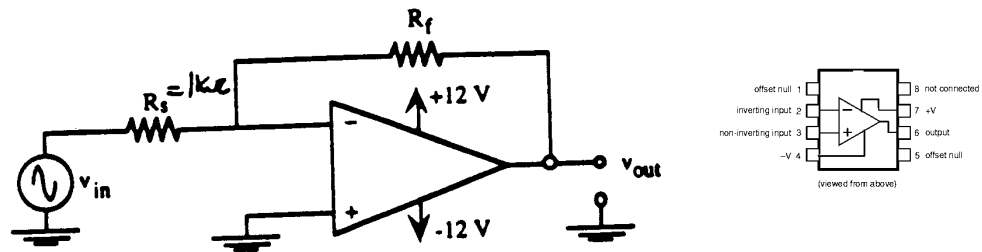


Fig. 3.2 Inverting Amplifier

Set $R_s = 1\text{ K}\Omega$. Use Table 3.2 below to obtain the indicated voltage gains of 10, 100, 500. Select from the available resistors the values closest to R_f .

Measure R_s and R_f using the digital mul-timeter (DMM) for all combinations.

This will tell you exactly what gain to expect from the circuit.

Apply input voltage of 0.2 volts peak-peak at 100 Hz sinusoidal.

Use a scope to measure V_{in} and V_{out} . Note the nature of the waveforms

Table 3.2 Inverting Amplifier Data

R_s K Ω	R_f K Ω	Nominal Gain R_f/R_s	Actual R_s K Ω	Actual R_f K Ω	Actual Gain R_f/R_s	V_{in}	V_{out}	Measured Gain V_{out}/V_{in}
1	10							
1	100							
1	1000							

Frequency Response

Now introduce a sinusoidal input at a frequency of 100 Hz. from a function generator and measure the-gain V_{out} . Use $V_{in} = 20$ mV peak and repeat the measurement for the three different gains. Collect data over the range of input signal frequencies given in the Table 3 below.

In order to measure V_{out} (frequency and amplitude) you may use the DMM on the AC scale or the scope. Use th scope, because of it has superior frequency response.

Table 3.3 Frequency Response ($R_s = 1$ K)

Frequeuncy KHz	Gain 10 $R_f = 10K$	Gain 100 $R_f = 100K$	Gain 1000 $R_f = 1$ M
0.1			
0.2			
0.5			
1.0			
2.0			
5.0			
10.0			
20.0			
50.0			
100.0			
200.0			
500.0			
1000.0			

Note that V_{in} will not change as you increase the frequency, so you only need to measure V_{out} .

Plot your results gains versus frequency on semilog paper. According to your plots, up to what frequency is the amplifier linear for each of the three gains? What is the BW for each gain? Comment on your results.

What comments can you make regarding the phase of input vs. output sinusoids? Comment qualitatively on the phase vs. frequency behavior of the op-amp. You may easily see this by displaying both V_{in} and V_{out} on the scope and look at their phase relationship as you change the signal frequency from low to high frequencies.

2. Non-inverting amplifier

I Connect the circuit shown in Fig. 3.3 selecting a ratio $R_f/R_s = 10$.

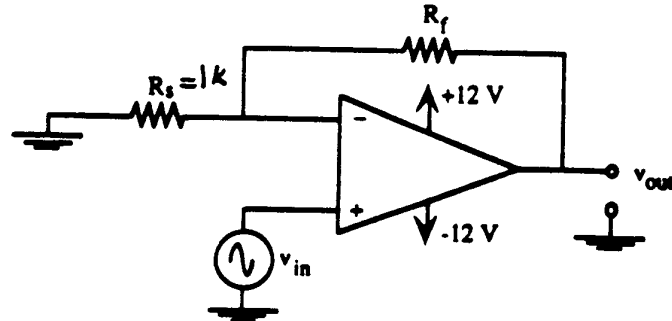


Fig. 3.3 Non-inverting Amplifier

According to the theory, the gain $V_{out}/V_{in} = 1 + R_f/R_s$ should then be equal to 11.

Verify that this is in fact the case and note any discrepancies.

Use a $V_{in} = 0.1$ volt peak at 100 Hz.

Are V_{out} and V_{in} in phase? Is this what you expect for a non-inverting amplifier?

For the non-inverting amplifier, Gain = $1 + R_f/R_s$, i.e. at $R_f = 0$ (short circuit), $V_{out} = V_{in}$. It is a useful concept for impedance isolation.

Function generators have internal (output) impedance. In other words, they can be modeled by an ideal AC generator v_g in series a resistor r_s .

Estimate the actual source impedance of the generator in two steps as follows:

- Measure the open circuit output voltage of the generator as shown in Fig. 3.4.

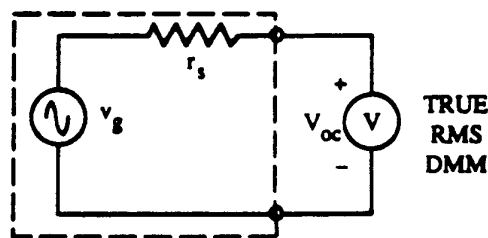


Fig. 3.4 Function Generator Open Circuit Test

Do this by setting the generator frequency at 100 Hz and adjusting the amplitude to read 1 volt rms. Record your value below.

$$V_{oc} =$$

(b) Connect a resistive load R_L (say 100 ohms) across function generator (leave setting same as in (a)) and measure load voltage Fig. 3.5

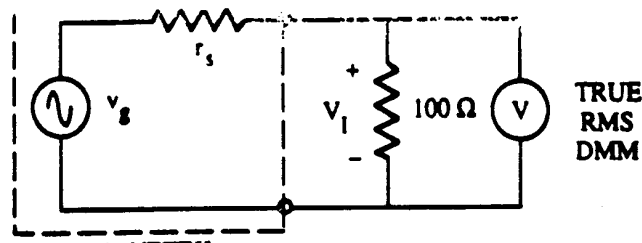


Fig. 3.5 Function Generator - Measurement of Internal Resistance R_s

$$V_L =$$

Then from voltage division $V_L = (R_L / (R_L + r_s)) V_{oc}$

Rearranging gives $r_s = ((V_{oc} / V_L) - 1) R_L$

Note down the serial number/model of the function generator you are using because you will need the value of internal resistance r_s for future work in amplifier designs in terms of overall gains.

What you have just accomplished is to demonstrate the effect of loading on a generator. This phenomenon generates the need for impedance isolation.

Connect the impedance or "buffer" circuit shown in Fig. 3.6

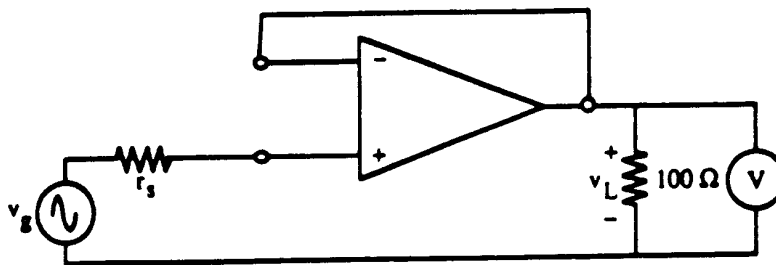


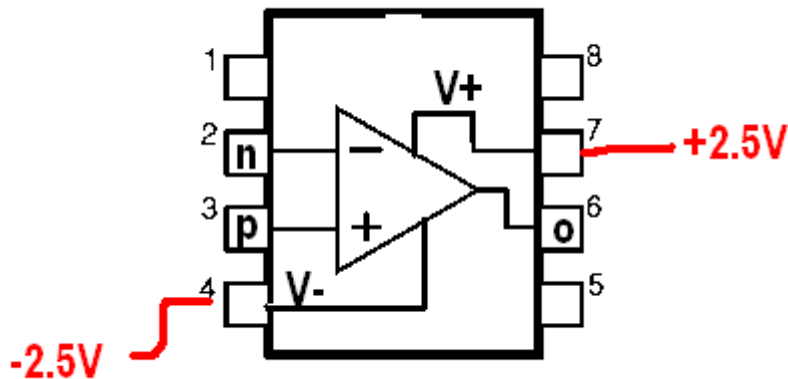
Fig. 3.6 Op-Amp Voltage Follower -Buffer Circuit

Use the same settings for the generator, and measure the load voltage, V_L . Do you see any loading effects now? Comment.

MOBILE STUDIO LAB

1. Inverting Amplifier

First thing we keep in mind, due to the limitation of the IOBoard, we cannot supply higher than +5V and lower than -2.5V to any circuit. In Fig. 3-2, +12V and -12V are connected to the Op Amp, but the maximum (or minimum) voltage we can supply for Mobile Studio Lab is +/- 2.5V. Also, the range of function generator output from the IOBoard is between 0.4 V and 1.4 V. Therefore we have live within the limitation.



So we the following changes:

1. Change input signal specification from 0.2 V to 0.4 V peak-to-peak.
2. Since the max (and min) voltage to Op Amp is [-2.5, +2.5], and that is the max(or min) output voltage at the output, the reasonable gain is upto 6. Therefore the range of the resistance of R_f must be [1K, 6k], not 10K, 100K, or 1000K.

So we use six (6) 1 K resistors: 1 for R_s , and 1 to 5 (in series) for R_f .

After all these changes, the new Table 3.2 looks like below:

R_s	R_f	R_f/R_s	V_{in} (pp)	V_{out} (pp)	Measured Gain (V_{out}/V_{in})	Wave shape
1K	1K		0.4V			
1K	2K		0.4V			
1K	3K		0.4V			
1K	4K		0.4V			
1K	5K		0.4V			

Figure below shows the overall connection for the Inverting Amp experiment.

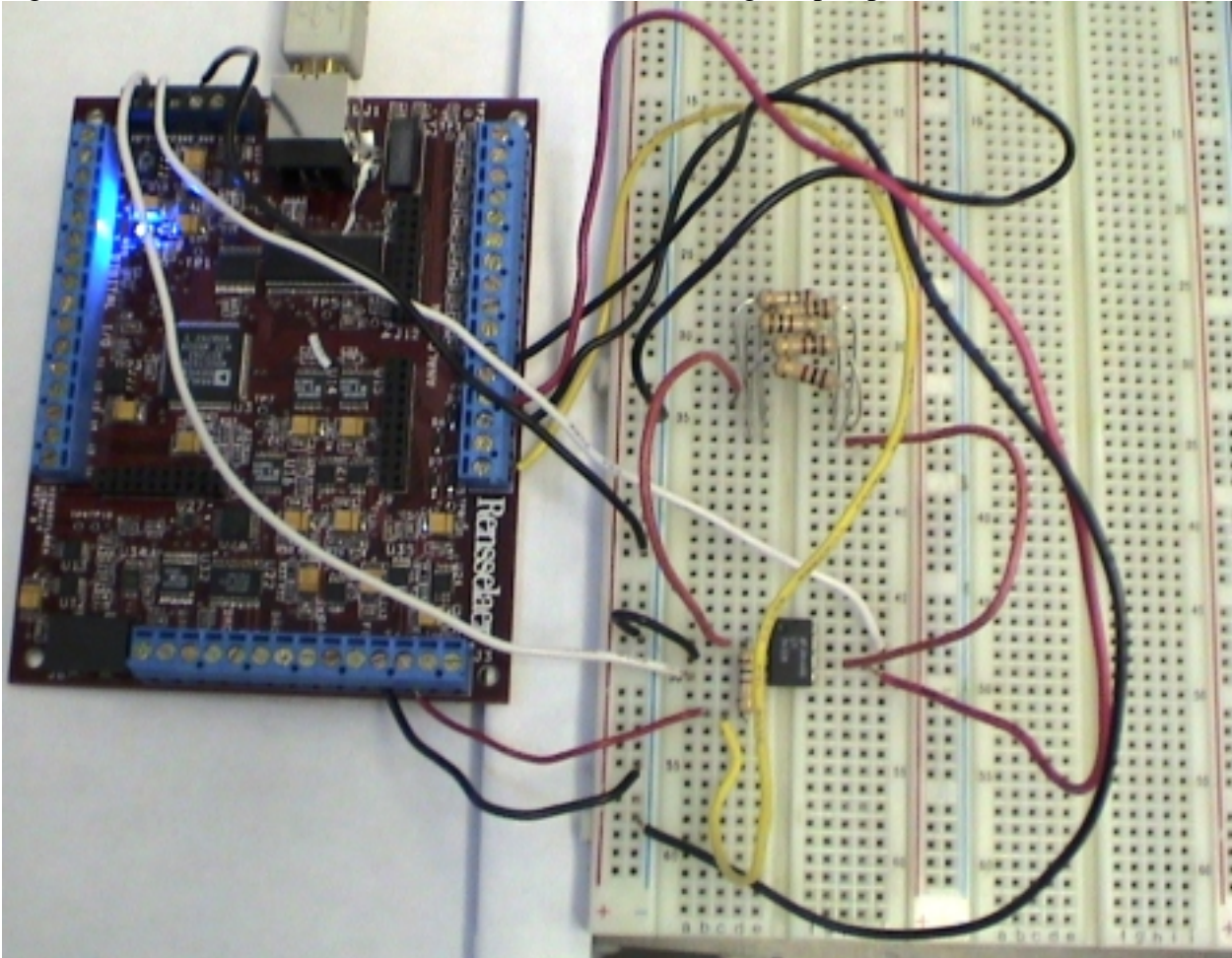
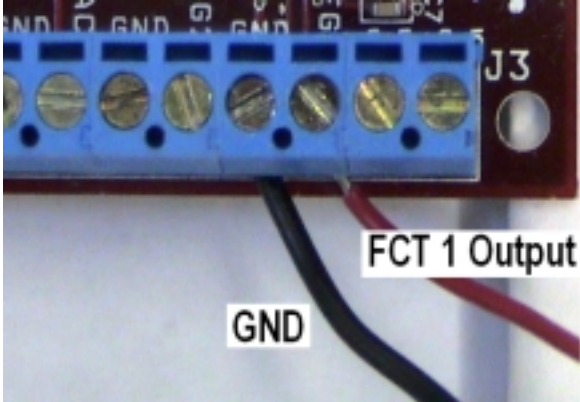
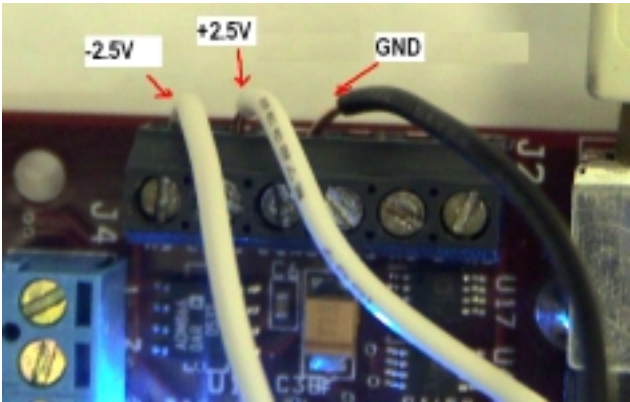
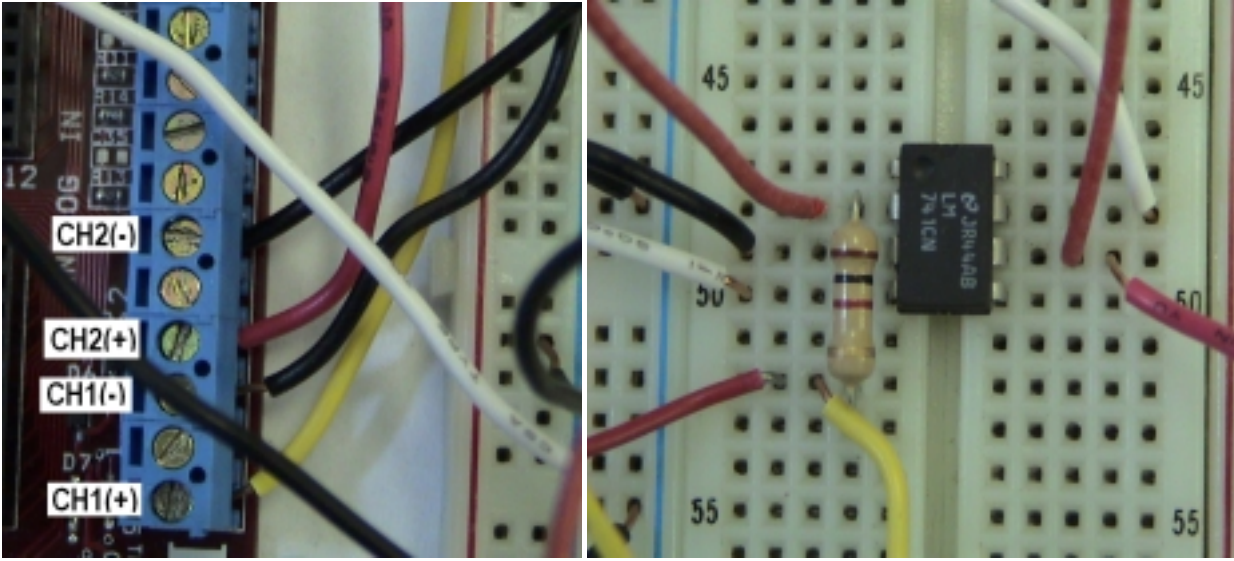


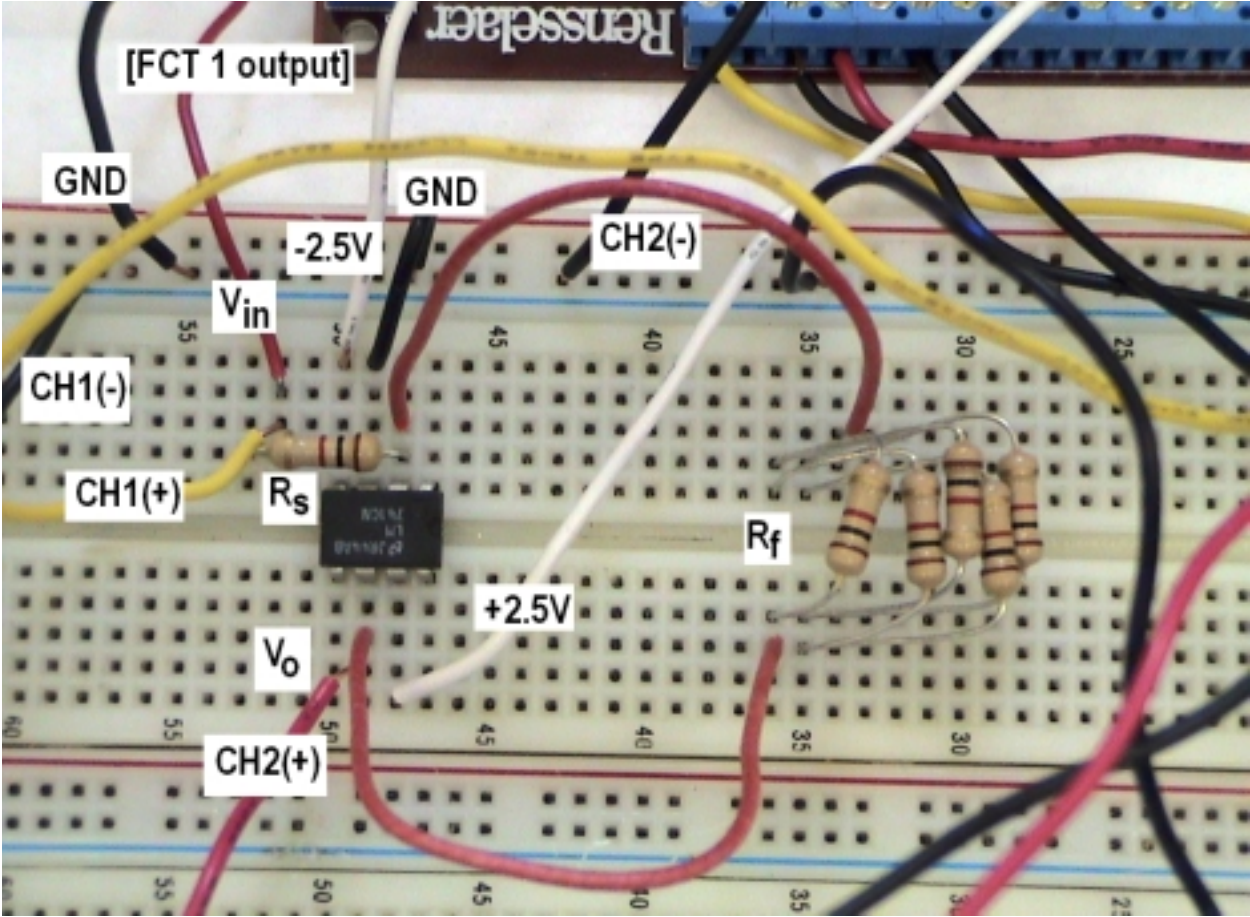
Figure below left is for the +/- 2.5V supply connection from the IOBoard. Below right shows the input source from the terminals for function generator 1 output from the IOBoard.



Next one (below left) is the scope probe connection from the IOBoard. Below right is circuit implementation on the breadboard surrounding uA741 Op Amp and the input resistor R_s .

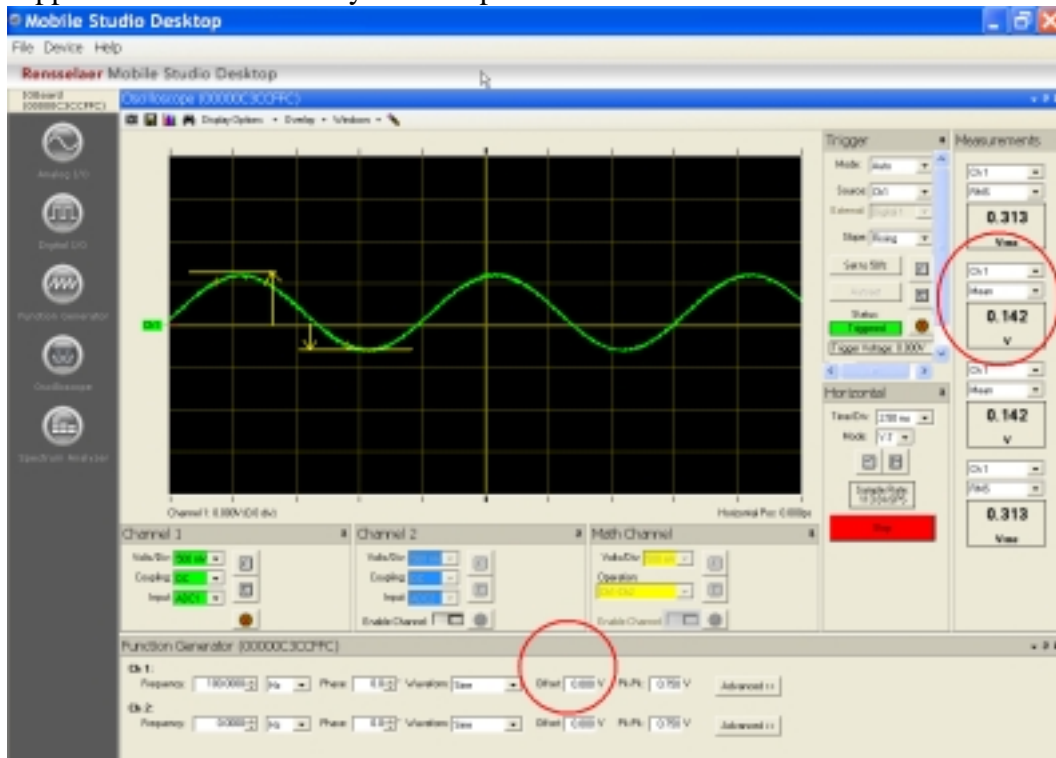


Detailed description of the connection is shown below.

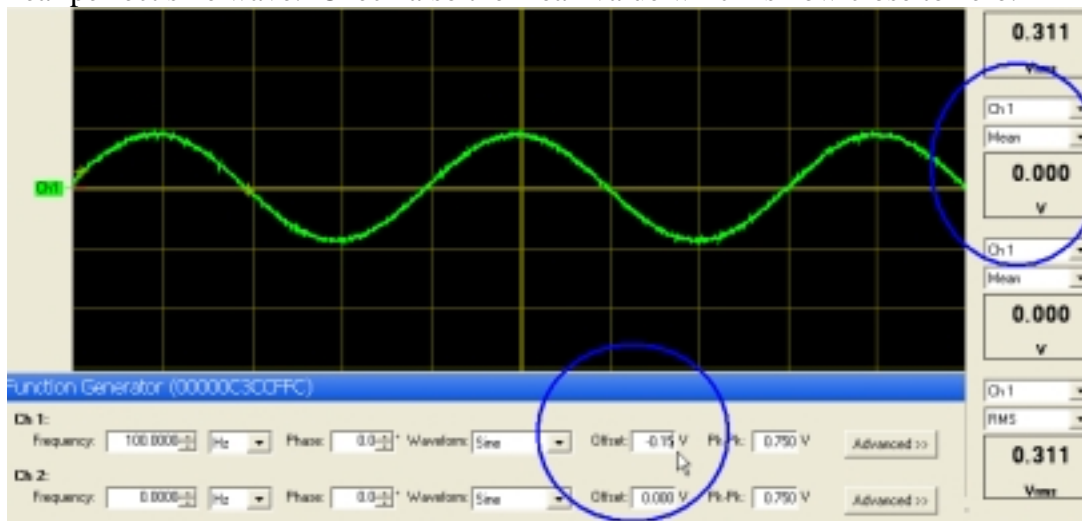


Note on Function Generator Output From IOBoard

The signal generated from the function generator output may have DC offset. In other words, your desired output, say a sine wave, may contain a little DC component in it. Then, the resultant waveform on your scope screen would be shifted up or down from the zero line. A pure sine wave waves around the zero line. As you see the screen shot below, a 100Hz sine wave has DC offset and thus it is waving around a line slightly above the zero line. As you can see at the right side, the mean value of the sine is not zero, even though the generated output is supposed to not contain any DC component.

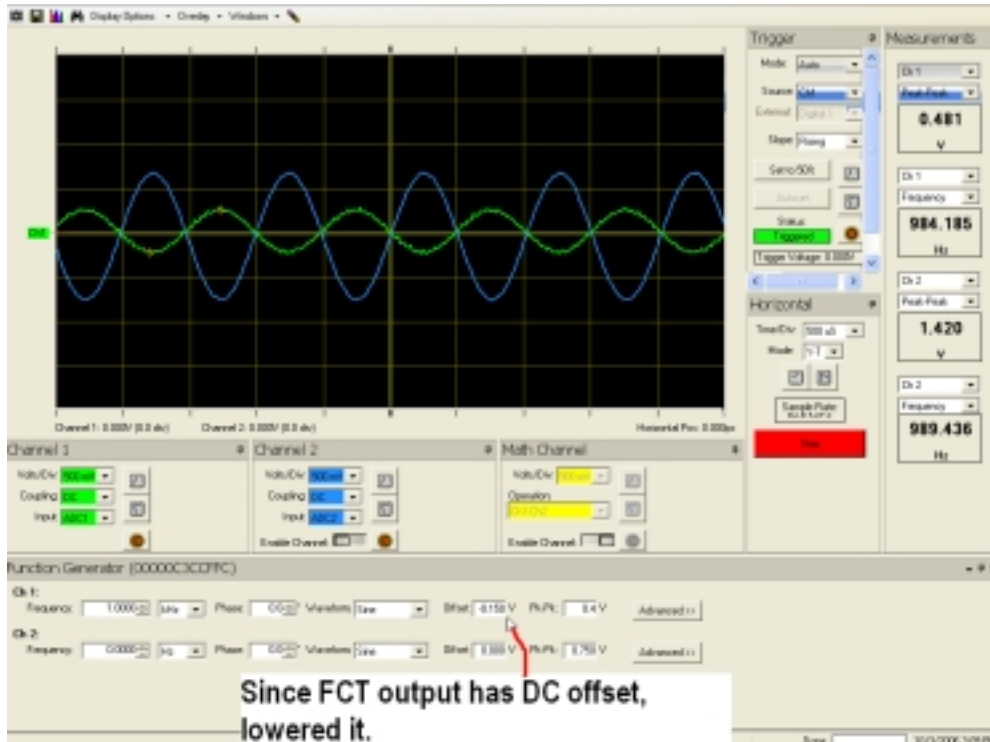


In this case, we are forced to lower that floating sine wave to the zero line, by intentionally adding negative DC offset (in this case -0.15). See in the next screen shot how we can make a near perfect sine wave. Check also the mean value which is now close to zero.

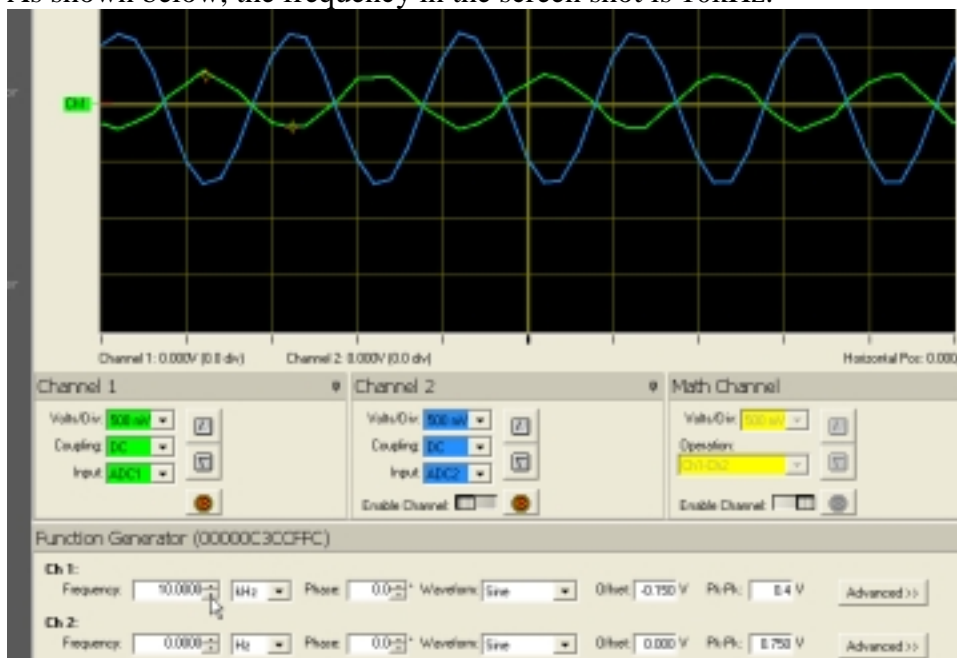


OK. Now back to the lab.

A screen shot for the experiment is shown below. Note that the function generator output may have some DC offset (that means, your input signal from function generator does not cross zero line). In such case you intentionally add DC offset amount (up or down) so that your input signal is centered on the zero line.



By clicking the up/down button, you can increase/decrease the frequency of your input signal. As shown below, the frequency in the screen shot is 10kHz.



Frequency Response

In this experiment, we keep the input voltage the same, but change the input frequency from 0.1KHz to 1000KHz. Since the function generator output from the IOBoard becomes unstable above 10kHz, we will apply input frequency up to 10kHz, and the revised Table 3.3 looks like this:

Input (Vs) with Rs=1K		Output (Vo)		
Voltage (pp)	Frequency (kHz)	When Rf=2K	When Rf=3K	When Rf=4K
0.4V	0.1			
0.4	0.2			
0.4	0.5			
0.4	1.0			
0.4	2.0			
0.4	3.0			
0.4	4.0			
0.4	5.0			
0.4	10.0			
0.4	20.0			
0.4	50.0			

*** Use the same circuit for the Inverting Amplifier for this process.**

2. Non-Inverting Amplifier

The circuit connection can be easily done for the circuit shown in the manual.

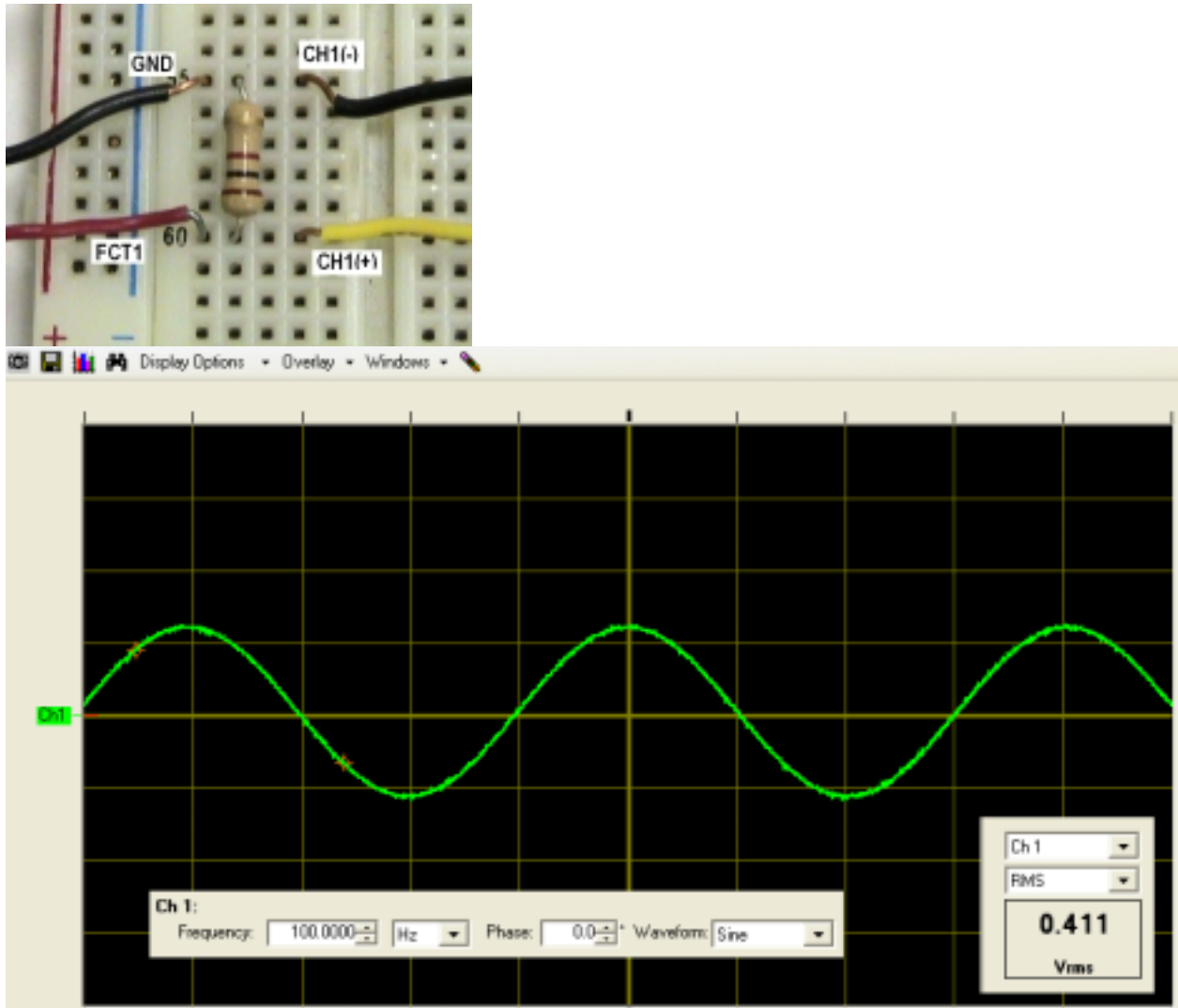
3. Voltage follower/Isolation Application: In the lab, there is a discussion on the difference in output across a resistor which is fed by the signal from function generator when there is no Op Amp involved and when there is Op Amp inserted between the function generator and the resistor. This is of the so-called loading effect. In other words, a load at the output terminals lowers the output from the source (V_s), since there is a slight voltage drop across the internal resistance (R_s) of the source. The internal resistance (R_s) and the load (R_L) form a series resistance circuit, and if you apply voltage divider, the output voltage (V_o) at the load will be:

$$V_o = \frac{R_s}{R_s + R_L} V_s.$$

Now the experiment is to highlight the benefit of using an OP Amp in between the source and the load. Since, in the ideal OP Amp in the voltage follower set up, the output voltage is the same as the input voltage: Node n is tied to node o and $V_n = V_p$ means that $V_p = V_o$.

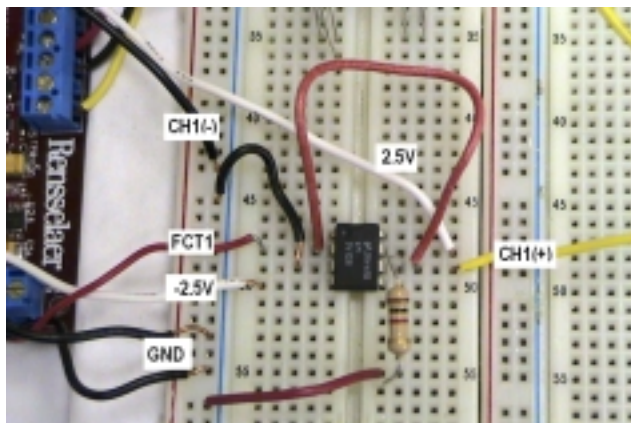
Direct connection of a resistor at the terminals of the function generator:

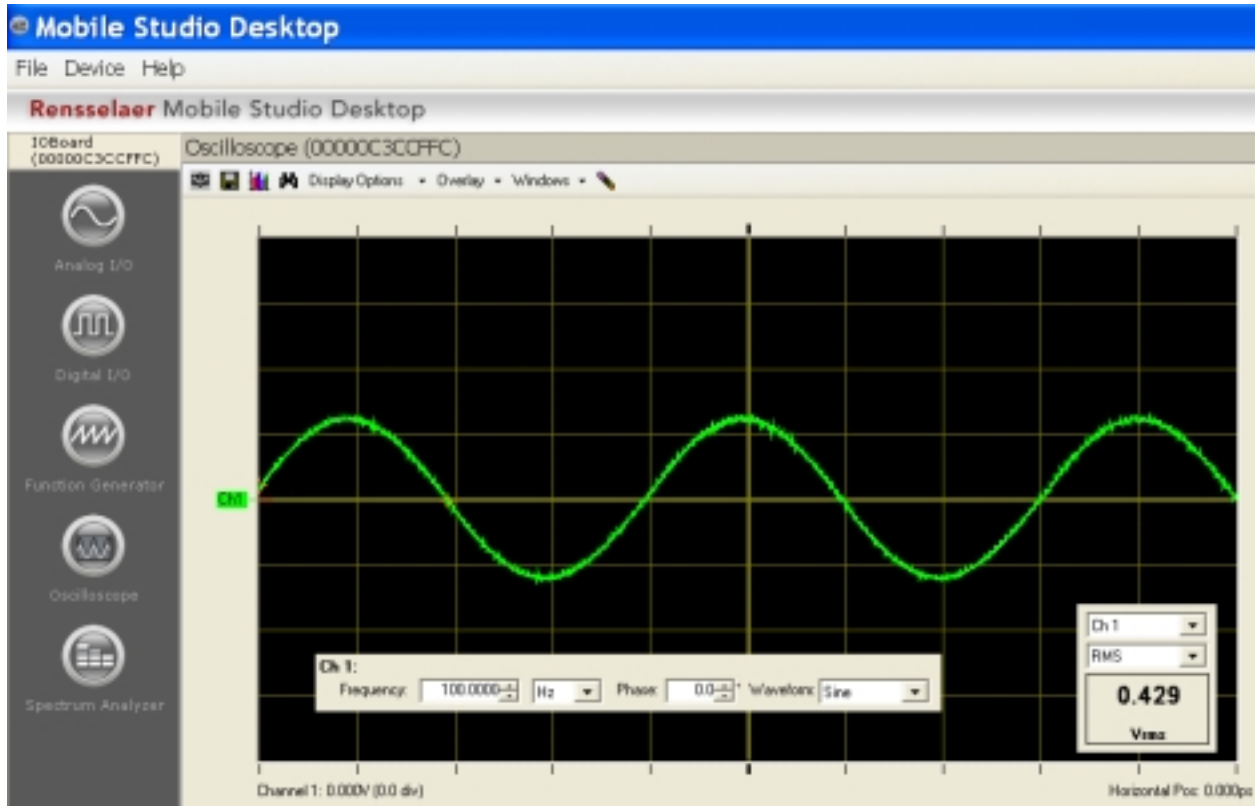
As depicted next, the voltage across a resistor which is connected at the FCT 1 terminal is first measured using the channel 1 probes of the scope.



As you can see above, the RMS value of the curve (which is the voltage across the resistor) is 0.411 Vrms.

Now let's insert a voltage follower between the FCT 1 output and the resistor. See the depiction below.





I am not sure the difference you see here is very convincing but the message is clear: voltage follower isolates source and load sides and it minimizes load effect if there is any.

Keep MSL-ing! Mobile Studio Lab!