Objective

The student should learn to implement and use various circuits that are applicable to real-time control and signal processing. Using operational amplifier circuits and continuous signals, the student should be able to demonstrate amplification, summation, gain adjustment, and integration.

Note: You will be using signals with very low-frequency spectral content (often including DC). Use a direct-coupled (DC) input to the NI 5102 oscilloscope since using the AC coupling will attenuate and shift the phase of low-frequency signals.

Prelab

Bring a printout of the National Semiconductor Corp performance specifications for the 741 Op Amp.

Procedure

AMPLIFICATION AND SUMMATION

1) Set up an inverting amplifier, as shown in Fig 1, using the 741 Op Amp on the breadboard provided.
   a) Connect the 8102 power supply to provide a "dual ended" voltage of ±15 V DC.
   b) Verify the power supply output with the NI 4060 Multimeter.
   c) Using the NI 5411 Function Generator DC Offset control, set the input DC voltage \( V_1 \), to \( 0.25 \) V (verify this with the NI 4060 Multimeter)
   d) Set the coupling of the NI 5102 Oscilloscope to “DC”
   e) Make sure that the Power Supply (8102), Oscilloscope, NI 4060 Multimeter, and NI 5411 Function Generator have a common reference (ground)
   f) View \( V_1 \) on Ch 1 of the NI5102 and \( V_2 \) with Ch 2 of the NI 5102 oscilloscope.
   g) Determine if you obtain the expected output \( V_2 \), and repeat with several gain factors by changing the resistance ratio \( R_2/R_1 \). See the attached data sheet for values of \( R_1 \) and \( R_2 \)

Note: Linear operation of the Op Amp is limited to an output voltage that is slightly less than the DC supply voltages to the Op Amp (±15 volts). The NI 5102 oscilloscope is limited to a maximum of 5 volts on its display. In order to observe this "clipping" characteristic it will be necessary to reduce both sides of the "dual ended" power supply simultaneously before reapplying the power to the Op Amp. Reduce the input voltage to ± 5 V DC. Verify the
voltage with the NI 4060 Multimeter prior to reapplying the power to the Op Amp. Observe the input and output simultaneously.

2) Replace the source V1 with a 5 Hz, 0.5 V pk sinusoid using the NI 5411 Function Generator and recheck the result.
   a) Use R1 = 1 MΩ, R2 = 2 MΩ
   b) Set the Timebase on the NI 5102 oscilloscope to 50 ms/div
   c) Set Ch1, Ch2 volts/div to 500 mV
   d) View V1 on Ch1 and V2 on Ch2
   e) Read the MAX values of Ch1, and Ch2 for gain measurements (Measure → Ch 1(Ch 2) → MAX)
   f) Remember that V1 is applied to the inverting input of the Op Amp so take that into account when calculating the gain.

3) Using the schematic for a summing amplifier shown in Fig 2, revise the circuit to sum two inputs (one DC input and one sinusoid input from the NI 5411 function generator). Verify the summing operation.
   a) Input A: 2 V DC from the adjacent NI 5411 Function Generator (Note: Make sure all systems have a common reference i.e. ground)
   b) Input B 0.5 V pk, 5 HZ sinusoid
   c) R1 = 1 MΩ, R2 = 1 MΩ, RF = 2 MΩ
   d) Adjust the NI 5102 Oscilloscope Volts/div: Ch1 = 200 mV, Ch2 = 2 V
   e) View the sinusoid input on Ch1 and the summing output Vout on Ch 2 of the NI 5102 Oscilloscope
4) DISCUSSION
   a) Define the following terms common in operational amplifier component specifications: Small Signal Frequency Response, Slew Rate. How do these characteristics influence component selection for applications such as audio amplifiers or DC amplifiers?
   b) Discuss the differences between theoretical and measured output values in Part 2.
   c) The MegaDesignomatic Corporation’s marketing department has decided that it’s time to break into the health care industry with a new portable electrocardiogram machine. Your pointy haired boss has decided that an Op Amp would be the perfect input device to amplify the signals from the EKG leads and has instructed you to select an appropriate device. Identify a specific Op Amp (manufacturer and model) that would be a good choice for use as an input amplifier for a portable electrocardiogram machine. Some characteristics you should consider are power supply requirements, bandwidth, output impedance, environmental performance (temp, vibration, etc). You may need to do some quick research on the nature of cardiac signal levels. Justify your recommendation based on cost and performance.
### Amplification and Summation

Adjust v1 to .25 V

<table>
<thead>
<tr>
<th>R1</th>
<th>R2</th>
<th>V2</th>
<th>Ideal gain (-R2/R1)</th>
<th>Measured Gain (V2/V1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1M</td>
<td>1M</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1M</td>
<td>2M</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100K</td>
<td>1M</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100K</td>
<td>2M</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) Use the 5 Hz 1 V $V_{pk}$ sinusoid as v1, R1=1MΩ, R2=2MΩ. Ideal gain=_________, measured gain=_________. Attach a hardcopy of the oscilloscope output showing v1 and v2.

c) Input A is 2V DC, input B is a 0.5V $V_{pk}$ sinusoidal wave. Feedback resistor R2=2MΩ, $R_A=1MΩ$, $R_B=1MΩ$. Attach a hard copy of the input B and the output showing peak values.