



Università di Pavia



**Dept. of Electrical, Computer and
Biomedical Engineering**



V5.0 – 2024/25

Operational Amplifier Configurations: Inverting and Non-Inverting





Purpose of This Lab Activity



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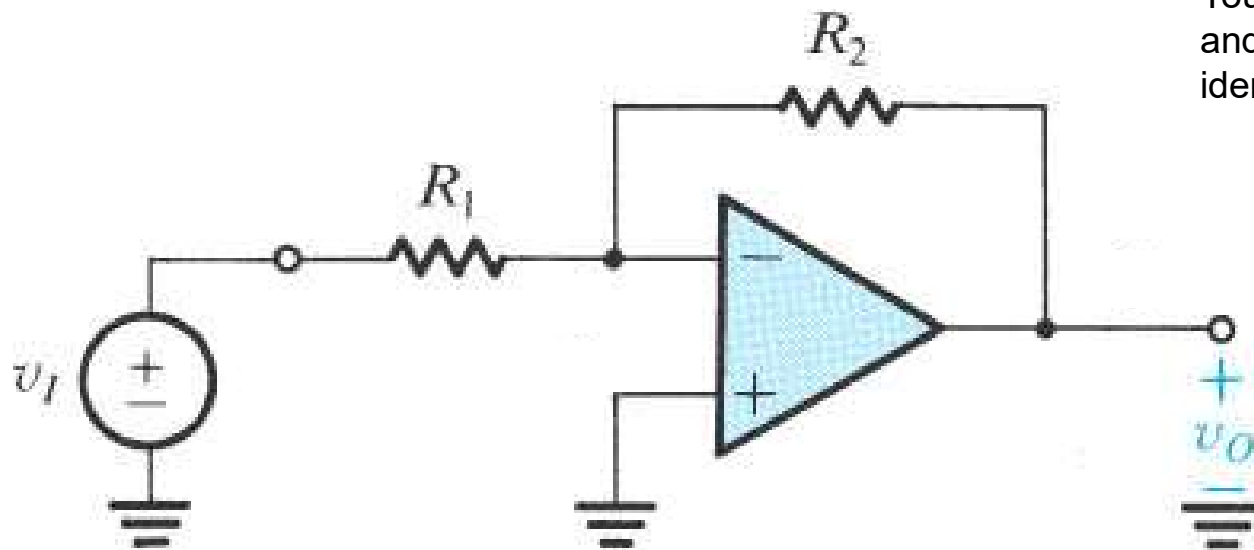
- Build an inverting and non inverting amplifier based on TL081 op-amp
 - Use NI myDAQ integrated instrument to interact with the breadboard
 - Use Digilent MyProto breadboard to build and play with the circuit

- Play with the circuits to verify their behavior
 - Use NI Elvis Software for preliminary circuits evaluation
 - Use Lab Instruments (signal generators, oscilloscope) for deeper investigation of circuit frequency response

- Build a Labview virtual instrument and use it to acquire the signal
 - Use the virtual instrument to measure: amplitude, average, rms value

Inverting Amplifier Schematic

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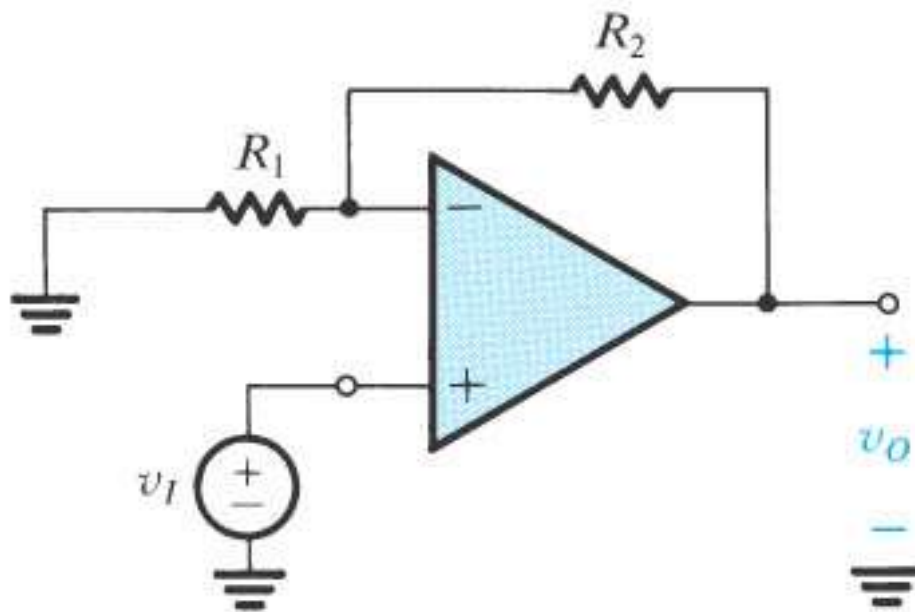
You may use ELVIS multimeter and/or color representation to identify suitable resistors

$$\frac{v_o}{v_I} = -\frac{R_2}{R_1}$$

- A reasonable gain for this activity is -10: (for instance $R_1=1\text{k}\Omega$, $R_2=10\text{k}\Omega$)
- Usually input current is negligible, anyway it can be compensated: how?

Non Inverting Amplifier Schematic

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You may use ELVIS multimeter for DC voltage measurements

$$\frac{v_o}{v_I} = 1 + \frac{R_2}{R_1}$$

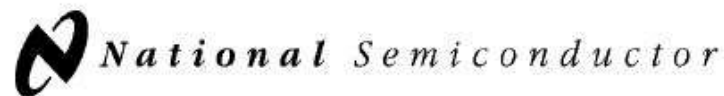
Does it Exist ?



- A reasonable gain for this activity is 10: (for instance $R_1=1\text{k}\Omega$, $R_2=9\text{k}\Omega$)
- Gain in both configurations may be affected by resistors value tolerance

TL081 Datasheet

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December 1995

TL081 Wide Bandwidth JFET Input Operational Amplifier

General Description

The TL081 is a low cost high speed JFET input operational amplifier with an internally trimmed input offset voltage (BI-FET II™ technology). The device requires a low supply current and yet maintains a large gain bandwidth product and a fast slew rate. In addition, well matched high voltage JFET input devices provide very low input bias and offset currents. The TL081 is pin compatible with the standard LM741 and uses the same offset voltage adjustment circuitry. This feature allows designers to immediately upgrade the overall performance of existing LM741 designs.

The TL081 may be used in applications such as high speed integrators, fast D/A converters, sample-and-hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth. The device has low noise and offset voltage drift, but for applications where these requirements

are critical, the LF356 is recommended. If maximum supply current is important, however, the TL081C is the better choice.

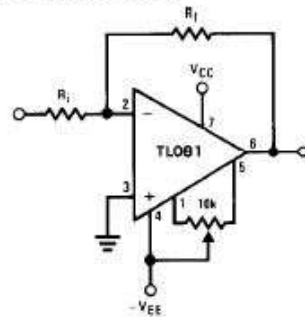
Features

- Internally trimmed offset voltage 15 mV ←
- Low input bias current 50 pA ←
- Low input noise voltage 25 nV/√Hz
- Low input noise current 0.01 pA/√Hz
- Wide gain bandwidth 4 MHz ←
- High slew rate 13 V/μs ←
- Low supply current 1.8 mA
- High input impedance 10¹²Ω ←
- Low total harmonic distortion $A_V = 10$, $R_L = 10k$, $V_O = 20$ Vp-p, $BW = 20$ Hz–20 kHz <0.02%
- Low 1/f noise corner 50 Hz
- Fast settling time to 0.01% 2 μs

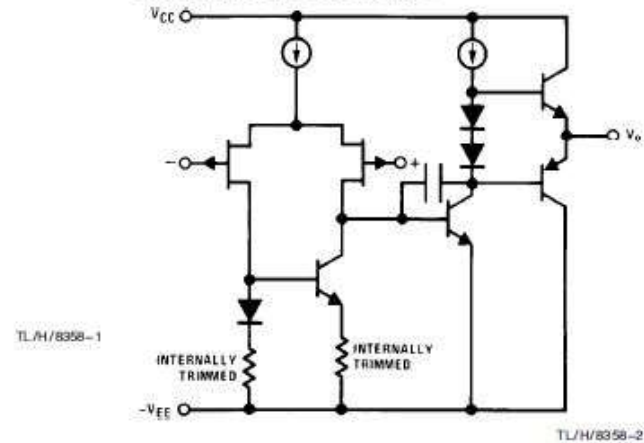
TL081 Datasheet

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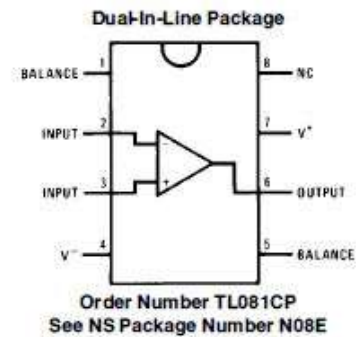
Typical Connection



Simplified Schematic

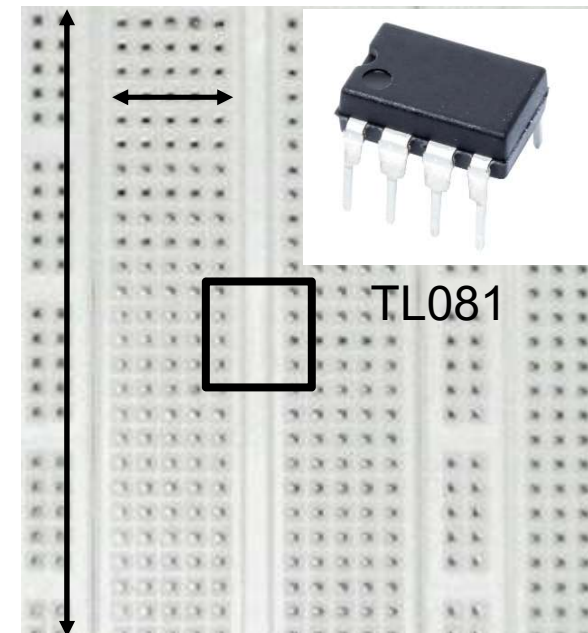
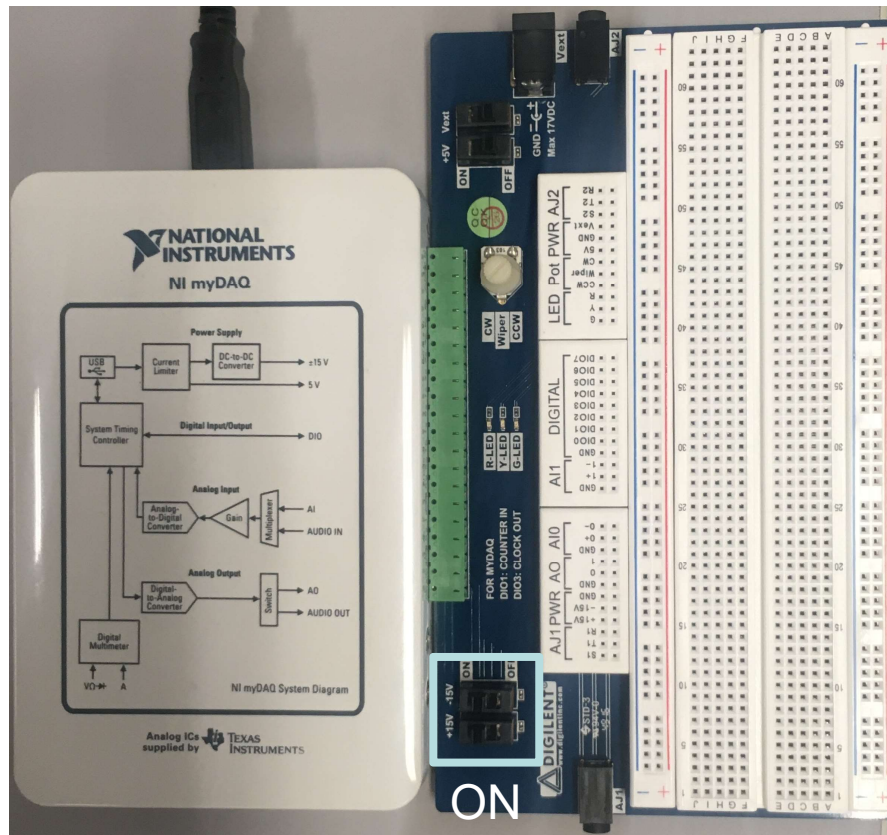


Connection Diagram



Suggestions on Circuit Building

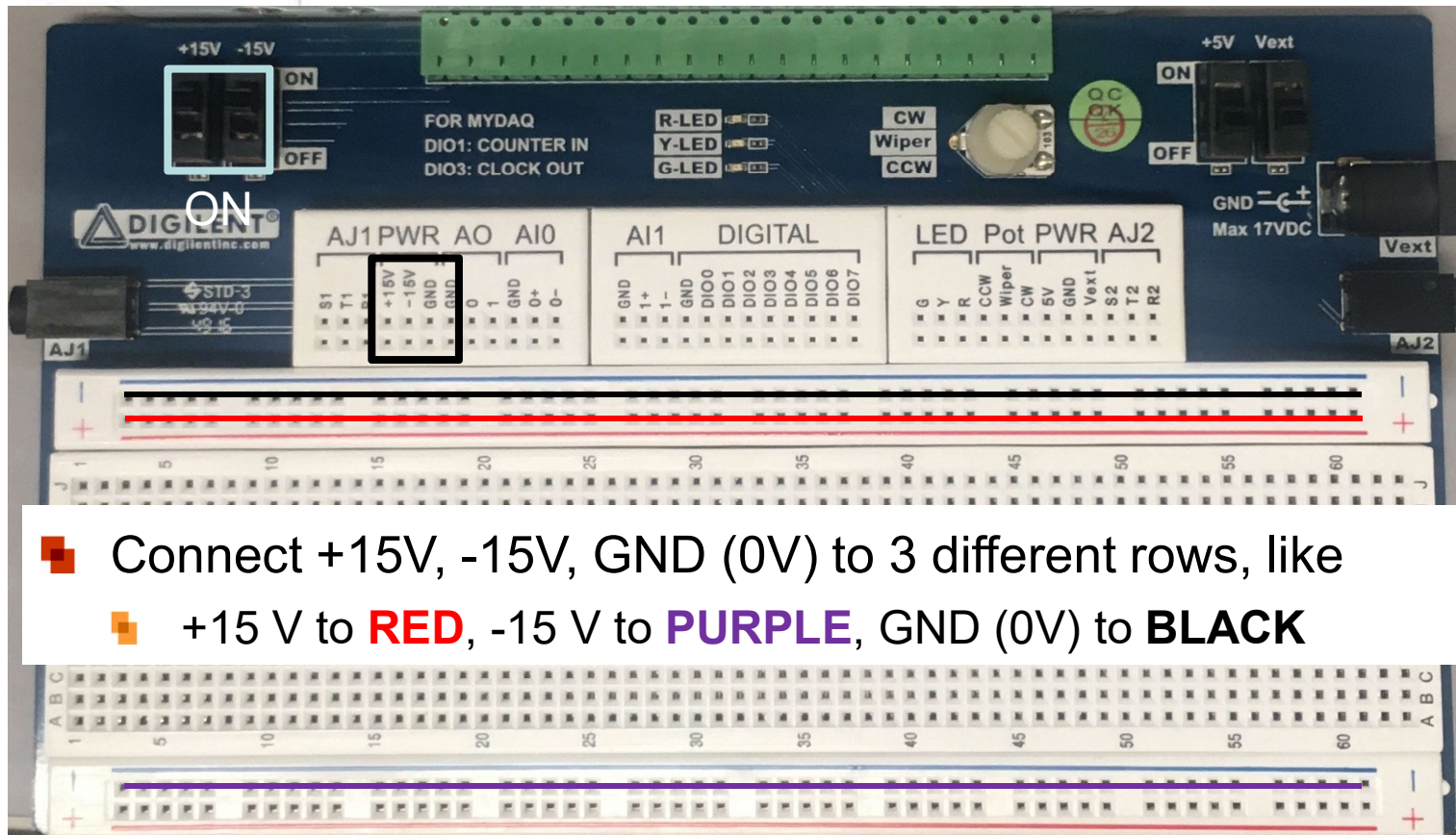
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- Five holes in a row are shorted

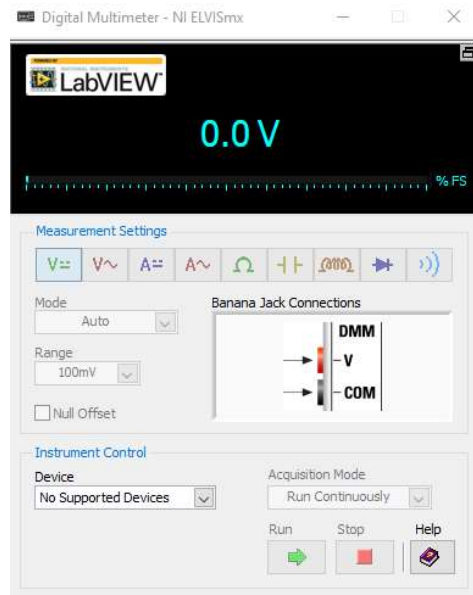
Suggestions on Circuit Building

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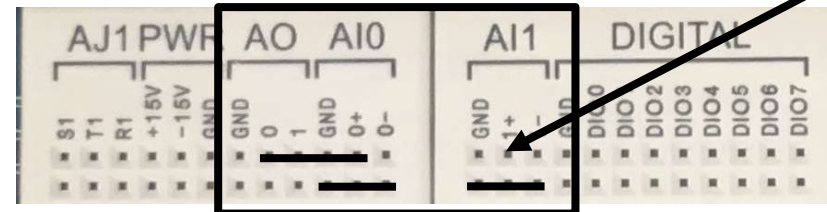


NI Labview Virtual Instrumentation

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Elvis Multimeter

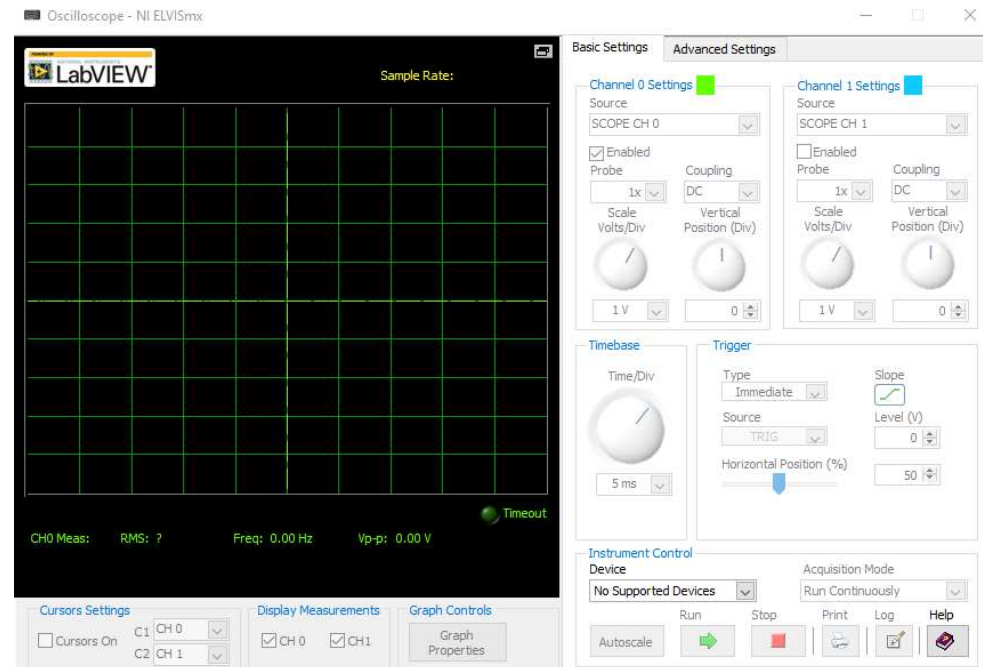
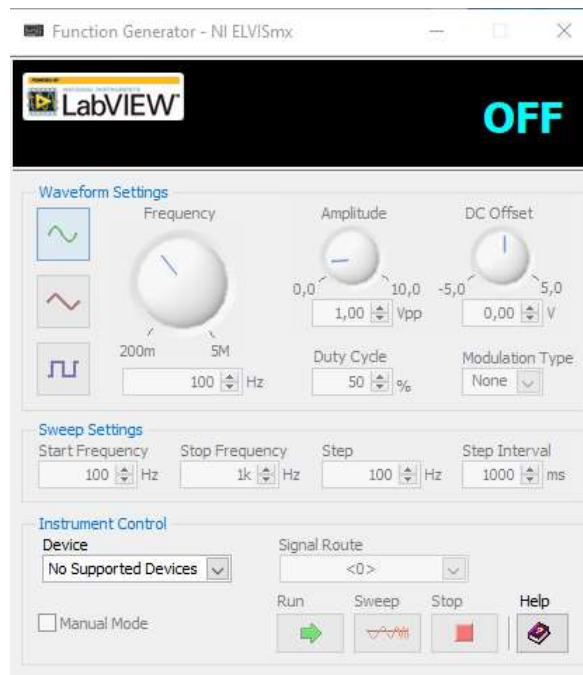


op-amp
output

- Single-Ended Analog Outputs (AO)
- Differential Analog Inputs (AI0, AI1)
 - For Single Ended use connect negative inputs (AI0-, AI1-) to GND

NI Labview Virtual Instrumentation

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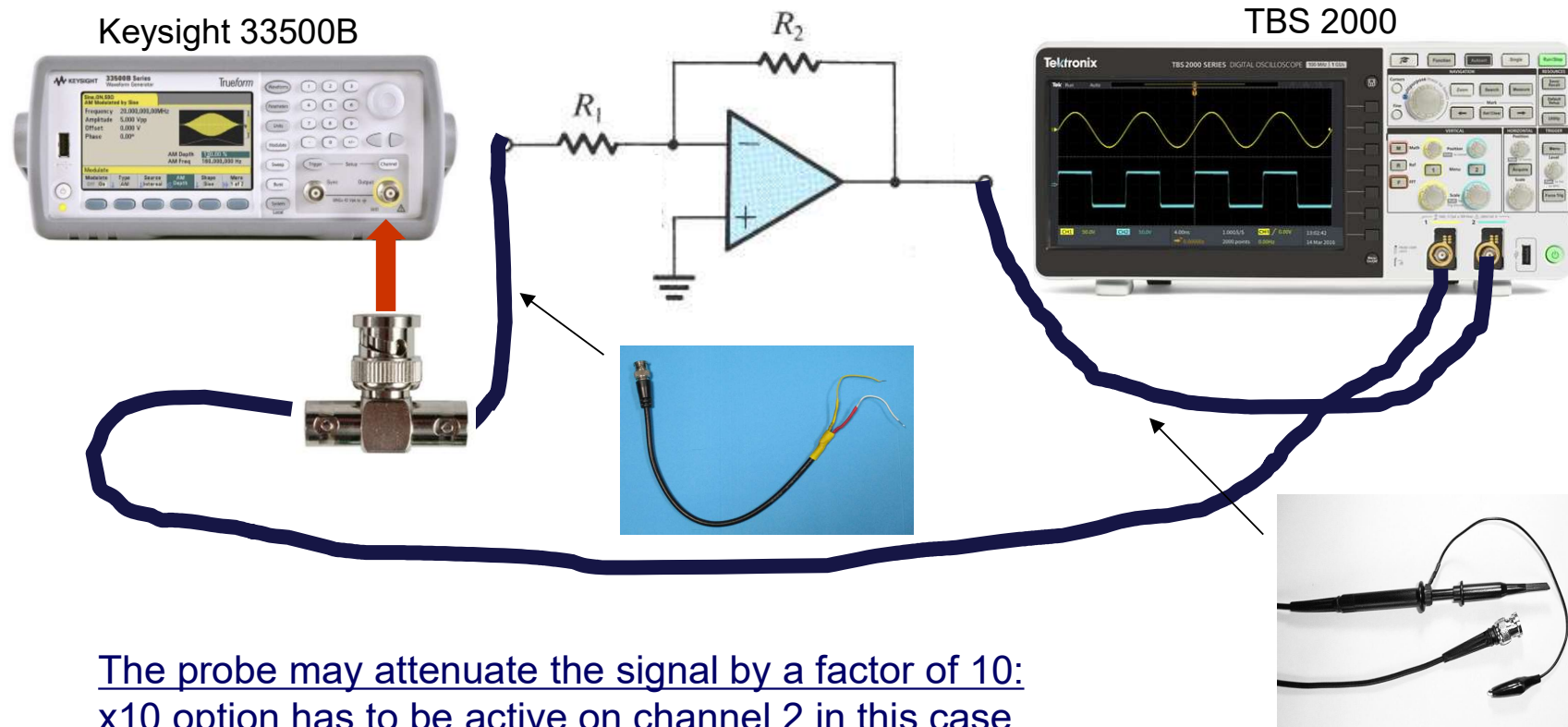


Elvis Function Generator

Elvis Oscilloscope

Laboratory Instrumentation

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Qualitative Response of the OP-Amp

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- Quick overview at low frequency of the op-amp behavior using ELVIS
 - Open Elvis Function Generator
 - Select Analog Output (AO) as Elvis Function Generator Module
 - Open Elvis Oscilloscope
 - Select Analog Input 0 (AI0) as Elvis Oscilloscope Channel 0
 - Select Analog Input 1 (AI1) as Elvis Oscilloscope Channel 1
 - Connect Analog Output (AO) of the BreadBoard to circuit input
 - Connect AO also to AI0+ of the breadboard (Single-Ended mode)
 - This means you should connect AI0- to GND
 - Connect the output of the circuit (op-amp) to AI1+ of the breadboard (SE mode)
 - This means you should connect AI1- to GND
- Play with the circuit to verify its behavior (vary amplitude and frequency)
 - Please note that ELVIS can easily handle frequencies up to max few kHz



Response of The OP-Amp Measurements



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Use the available laboratory instrumentation to evaluate op-amp behavior

- Send a sinusoidal signal to the amplifier input using Keysight 33500B
 - Measure the amplitude of the output signal when the input signal has a frequency of 1kHz and/or 10 kHz and an amplitude of 0.5V and 1V. Verify that the amplifier gain is about -10 for the inverting configuration and about 10 for the non-inverting one [**standard operation**]
 - Measure the amplitude of the output signal when the input signal has a frequency of 1kHz and/or 10 kHz and an amplitude of 1.5V and 2V. What happens? Can you explain it? [**clipping (saturation)**]
 - Measure the amplitude of the output signal when the input signal has an amplitude of 1V and a frequency of 10 kHz, 100 kHz, 1 MHz and 10 MHz. What happens when the frequency of the input signal is equal to or larger than 1 MHz? Can you explain it? [**(Gain) · Bandwidth limitation**]



Response of The OP-Amp Measurements



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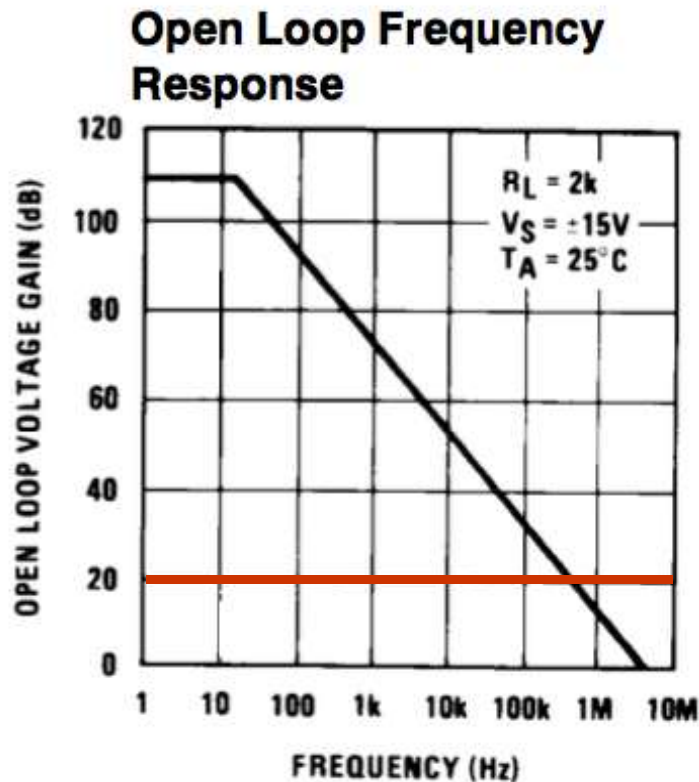
Use the available laboratory instrumentation to evaluate op-amp behavior

- Send a square signal with a 1V amplitude to the input of the amplifier
 - Look at the output signal when the frequency is 10 kHz, 100 kHz, 1 MHz and 10 MHz. Does the signal change shape when the frequency increases? Can you explain why? [**Slew Rate Limitation**]
 - Try this effect also with a sinusoidal signal of the same frequencies

- Can you think about a way to measure the offset voltage?
 - After having a look at the data sheet and to the chosen components, do you think that the bias current can have a significant effect on the output?
 - Where does the residual offset (even after eventual compensation of bias current, if really necessary..., come from) ?

Open Loop Gain - Bandwidth

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- Please note that the product of voltage gain and its associated bandwidth is constant
- When the gain is divided by K , the bandwidth is multiplied for the same factor K
- For the inverting amplifier, the actual bandwidth can be found graphically just tracing the line gain of closed loop horizontally over the open loop graph

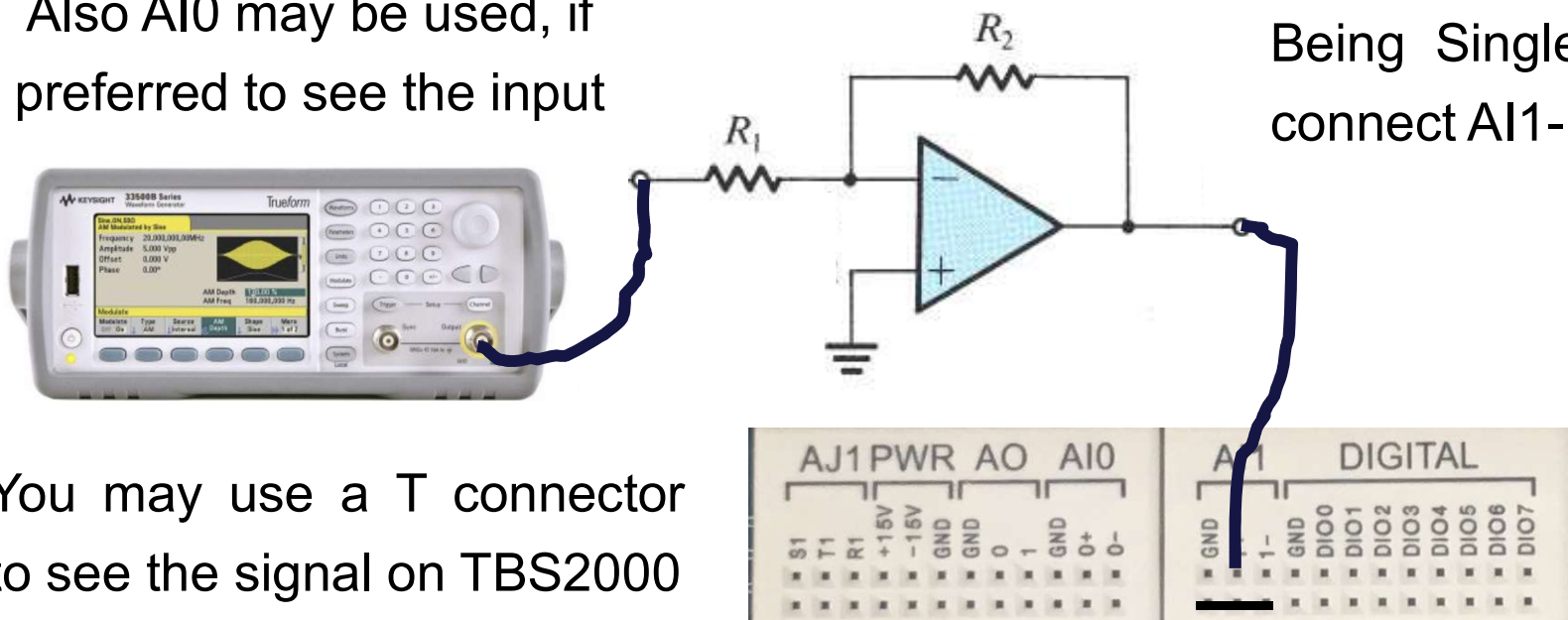
Signal Acquisition Setup

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For analog signal acquisition of the output of the opamp use the identical configuration used for qualitative study using ELVIS oscilloscope (AI1+)

Also AI0 may be used, if preferred to see the input

Being Single Ended connect AI1- to GND

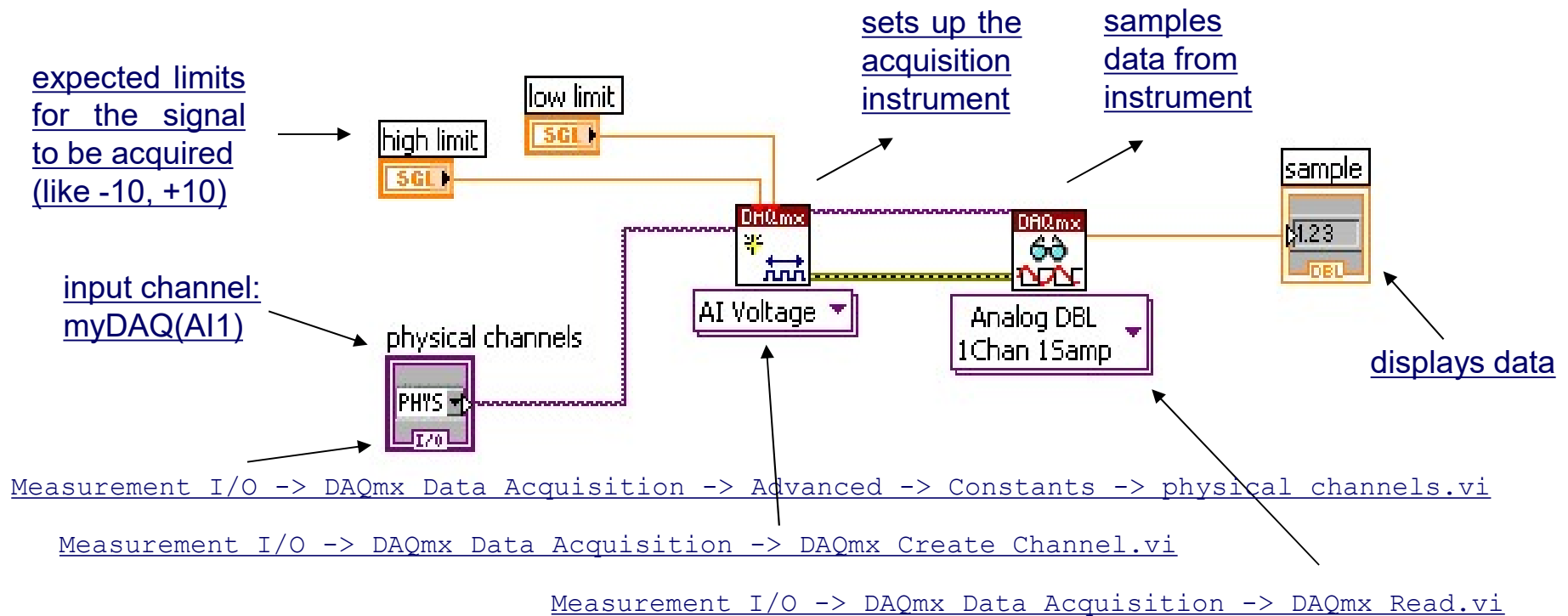


You may use a T connector to see the signal on TBS2000

Signal Acquisition Virtual Instrument

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Physical channel approach to implement a Virtual Instrument for acquisition

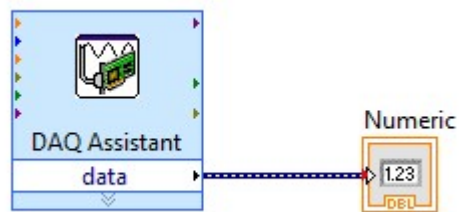


Signal Acquisition Virtual Instrument

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DAQ Assistant approach to implement a Virtual Instrument for acquisition

[Measurement I/O -> DAQmx Data Acquisition -> DAQ Assistant.vi](#)



Previous physical channel solution is strongly suggested for data post-processing VIs

- Click on the assistant icon to open the wizard guide
- Select: Acquire Signal -> Analog Input -> Voltage -> MyDAQ AI1
- Insert: Voltage limits (+10, -10), Differential Mode, Continuous ACQ
- Set: Number of samples and sample frequency (Default are 100, 1kHz)

Virtual Instrument Loop Function

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- Needed for continuous acquisition of the signal (use a very low frequency for the input op-amp signal, like 1 Hz or few more). A “stop” button should be included in the virtual instrument to stop the acquisition

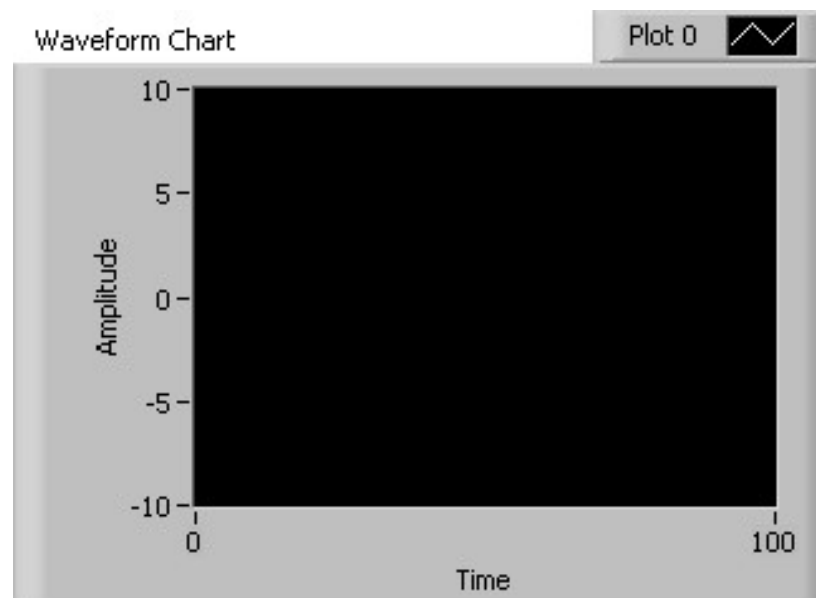
You may use WHILE for generic master loop and FOR for averaging purpose over N samples



Waveform Chart Output for VI

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- You can use a waveform chart for a graphical representation of the acquired data (“Graph” menu of the Controls palette, from the front panel window) – the acquired sample can be directly fed to the waveform chart



Measurements on The Acquired Data

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Previous physical channel solution is strongly suggested for these data post-processing VIs

- Send a sinusoidal signal with an amplitude of 1V and a very low frequency of 1 Hz or few more to the input of the amplifier
 - Measure the instant amplitude of the acquired (slow) signal
 - Measure the average value of the acquired signal - change the DC value of the signal from the waveform generator and check that the measured average value is the one you expect. Select the number N of samples for averaging
 - Measure the RMS (effective) value of the acquired signal – you can then use the RMS value of the acquired waveform to obtain the peak amplitude (amplitude= $V_{\text{RMS}} \times \text{sqrt}(2)$). What if DC is not zero ?
 - Measure the maximum and minimum value since the beginning of measure