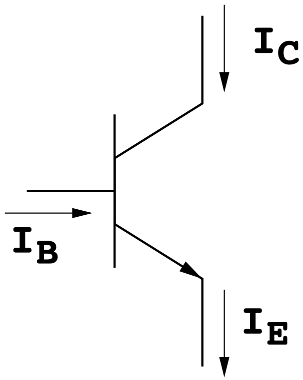
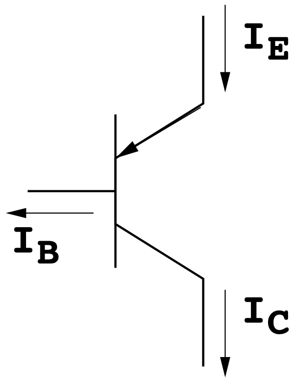
UNIVERSITÀ DEGLI STUDI DI PAVIA

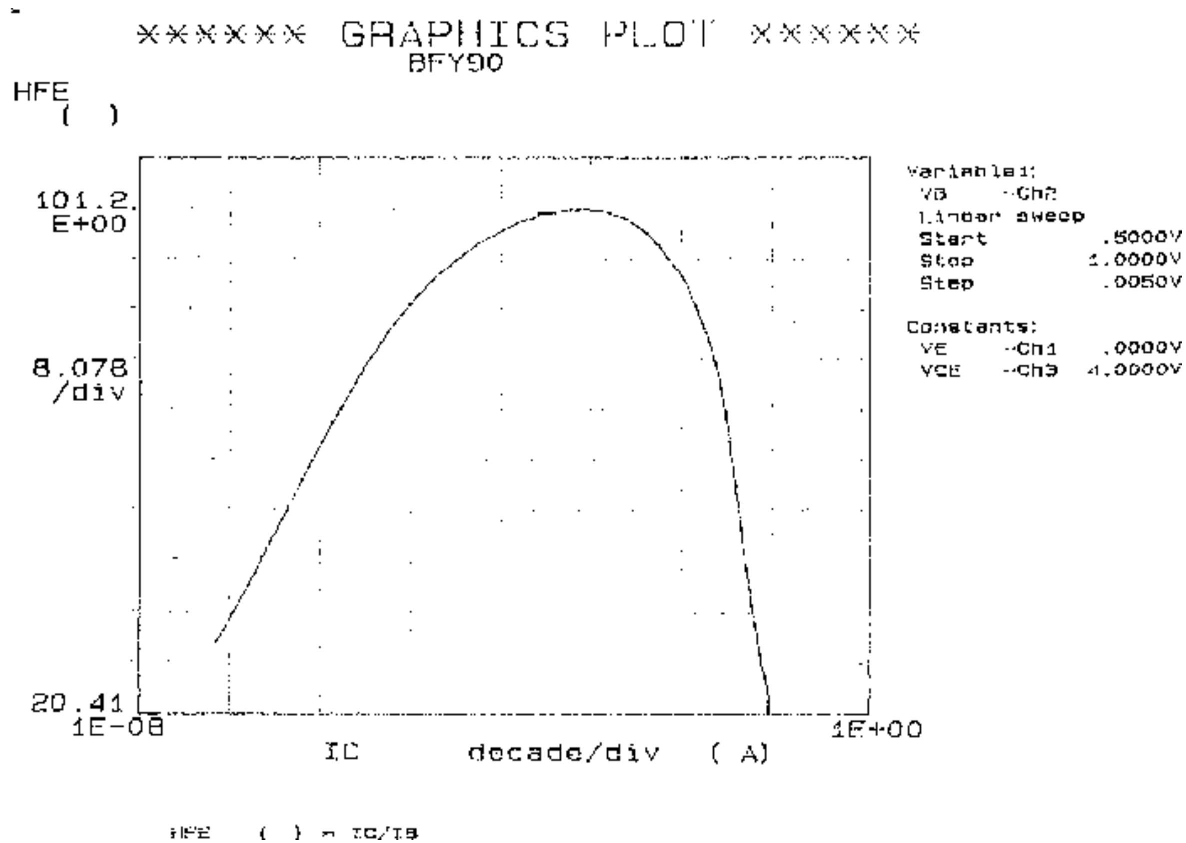
Dept. of Electrical, Computer and
Biomedical Engineering

Measuring the common emitter current gain β in a bipolar junction transistor

Measuring β





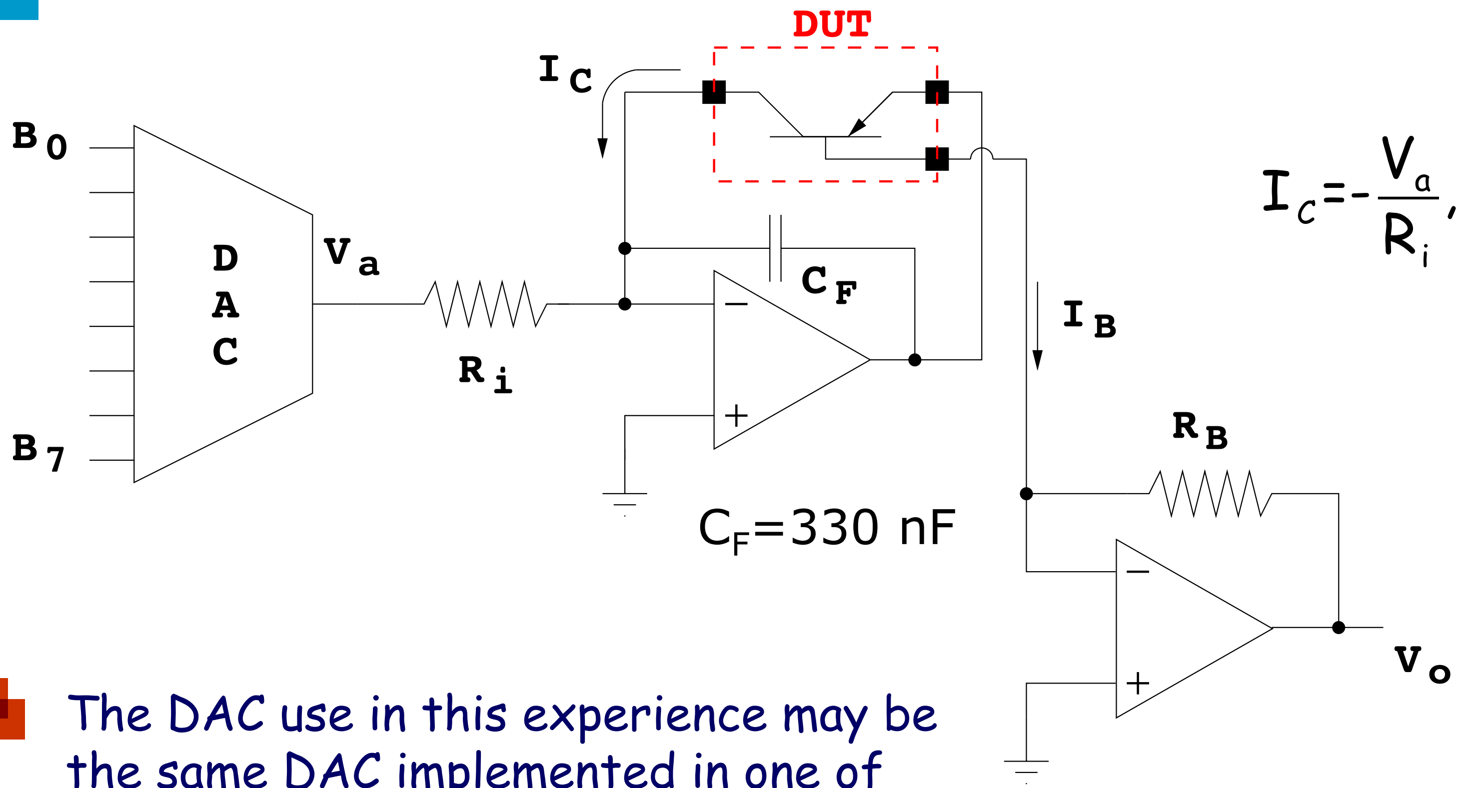


$$\beta(I_C, V_{CE}) = \frac{I_C}{I_B}$$

Purpose of the experiment

- Implementing a system allowing the user to measure the common emitter current gain β in NPN and PNP bipolar transistors. The system should include
  - a weighted resistor DAC controlling the collector current in the DUT (device under test)
  - a circuit setting the collector current of the transistor under test and $V_{CB}=0$ (transistor in a diode connection)
  - a virtual instrument allowing the user to control the DAC, acquire the data relevant to the collector and base current in the DUT, compute β and represent it as a function of I_C
- The virtual instrument should represent β as a function of I_C in graphical form and save the relevant data in the form of a table (I_C, β) in a text file

Measuring β



$$I_C = -\frac{V_a}{R_i}, \qquad I_B = -\frac{V_o}{R_B}$$

$$\beta = \frac{V_a}{V_o}\frac{R_B}{R_i}$$

- The DAC use in this experience may be the same DAC implemented in one of the previous experiences

- R_i should be chosen in such a way to have a maximum collector current of 10 mA; R_B should be chosen so that the voltage V_o at the output of the second amplifier covers the input dynamic range of the data acquisition board on the PC (±10 V)

TL081 JFET input OpAmp

National Semiconductor

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.

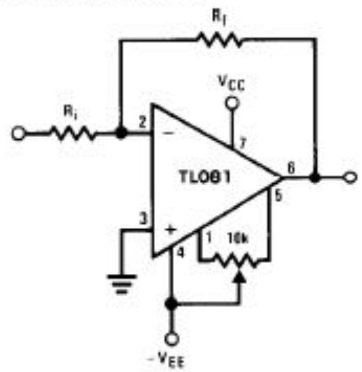
The TL081 may be used in applications such as high speed integrators, fast D/A converters, sample-and-hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth. The devices has low noise and offset voltage 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/$\sqrt{Hz}$
- Low input noise current — 0.01 pA/$\sqrt{Hz}$
- Wide gain bandwidth — 4 MHz
- High slew rate — 13 V/μs
- Low supply current — 1.8 mA
- High input impedance — $10^{12}\Omega$
- 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

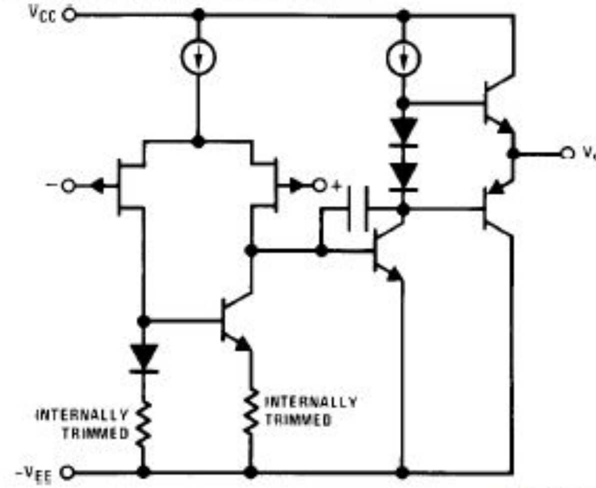
TL081 JFET input OpAmp

Typical Connection



TL/H/8358–1

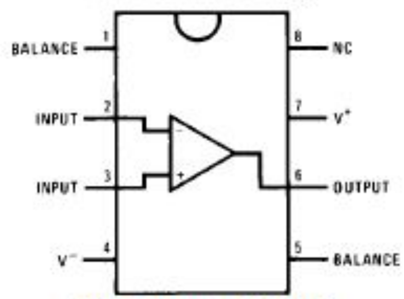
Simplified Schematic



TL/H/8358–2

Connection Diagram

Dual-In-Line Package

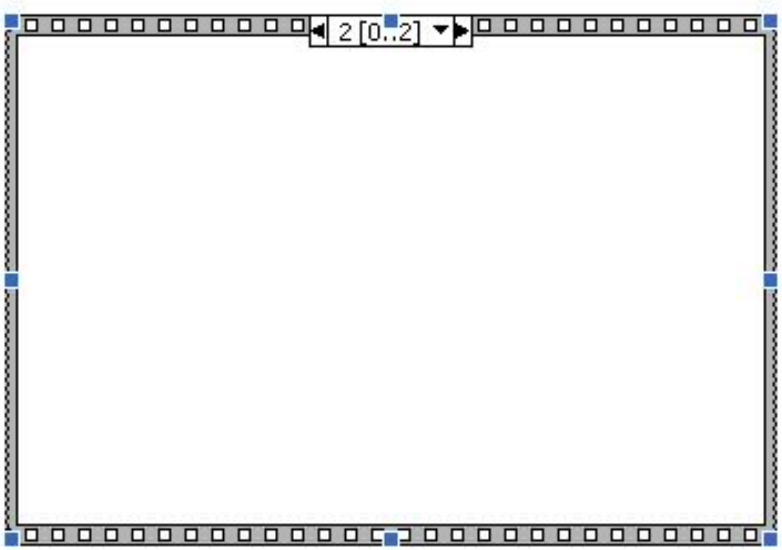


TL/H/8358–4

Order Number TL081CP
See NS Package Number N08E

Virtual Instrument

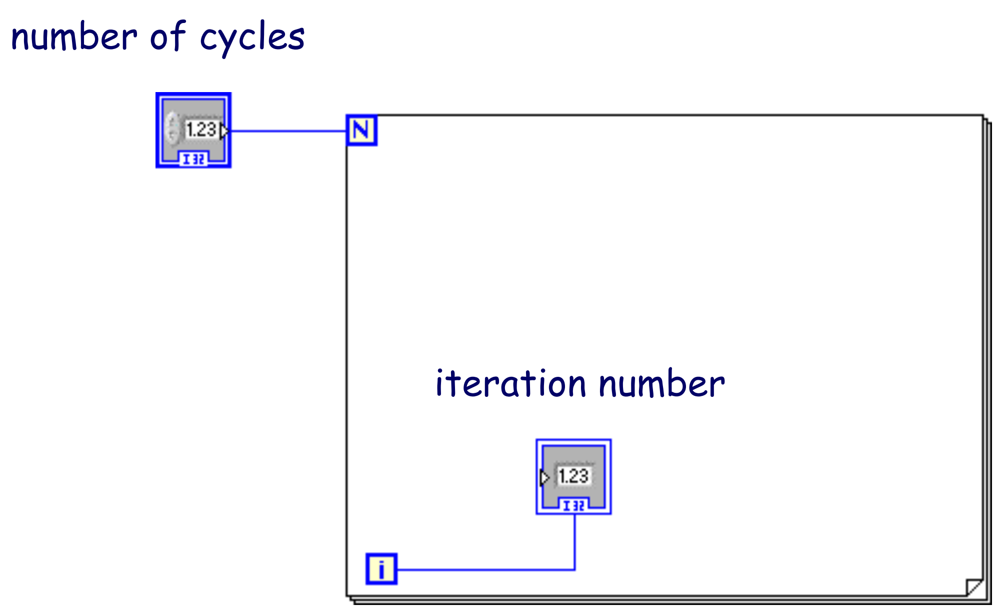
- As far as the block diagram is concerned, the LabVIEW VI can be implemented by means of a sequence structure including 4 frames (to add a frame, right click on the frame of the structure and select "Add Frame After"). The sequence structure makes it possible to execute a set of instructions according to a user defined time sequence (first the instructions included in frame 0 are executed, then those included in frame 1, etc.)



- The only purpose of using this structure is that of introducing a clear time separation between the four tasks of the program:
  - **DAC programming** (frame #0)
  - **acquisition of V_a** (frame #1)
  - **acquisition of V_o** (frame #2)
  - **calculation and graphical representation of beta** (frame #3)

Measuring β as a function of I_C

- In order to measure the value of beta for different values of the collector current, the sequence structure can be included in a for loop with 256 iterations, one for each of the possible DAC output levels



DAC programming (frame #0)

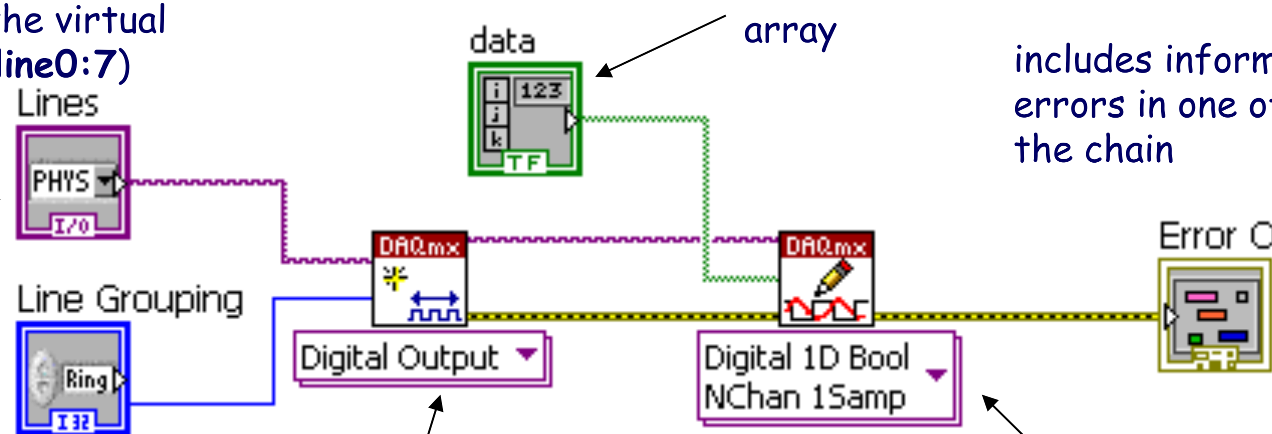
- DAQmx Create Channel.vi is used to configure the digital channel of the data acquisition board (DAQ, on the PC)
- DAQmx Write.vi is used to set the value at the digital output channels configured by the previous function

specifies the name of the digital lines or the ID number of the ports used to create the virtual channel (**Dev1/port0/line0:7**)

Boolean control array

includes information on possible errors in one of the blocks in the chain

grouping of the digital lines in one or more virtual channels **(one channel for each line)**

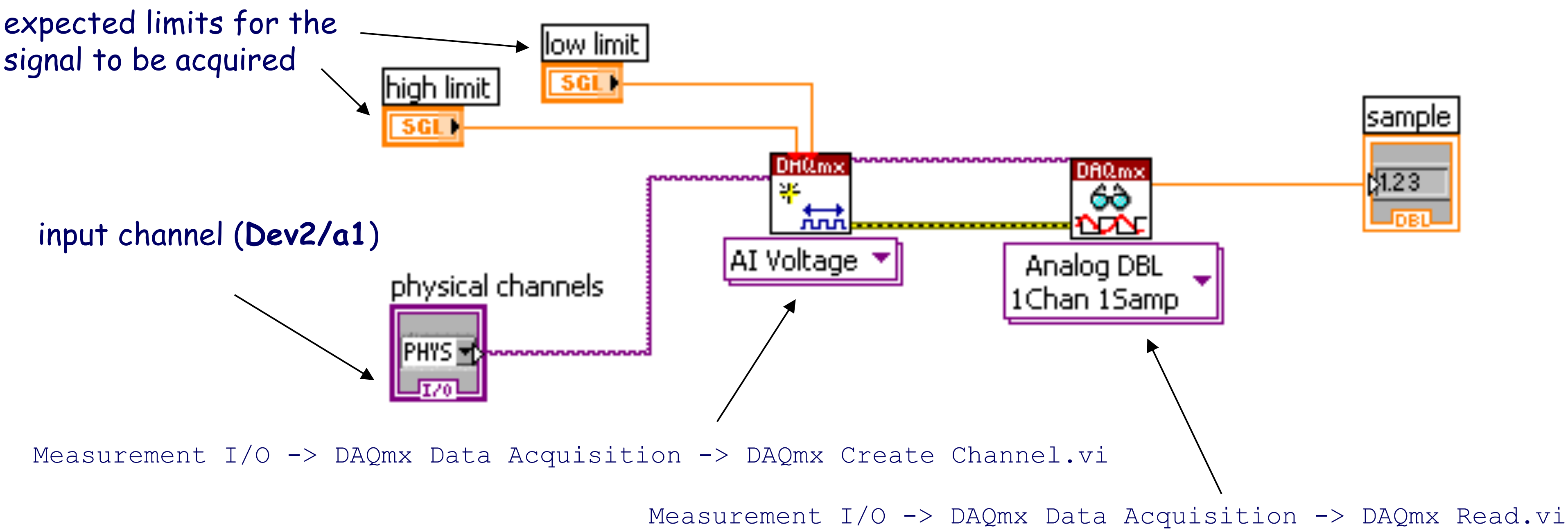


`Measurement I/O -> DAQmx Data Acquisition -> DAQmx Create Channel.vi`

`Measurement I/O -> DAQmx Data Acquisition -> DAQmx Write.vi`

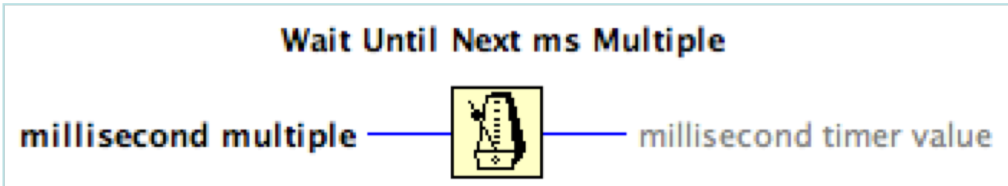
Acquiring V_a e V_o (frame #1 and #2)

- DAQmx Create Channel.vi provides the acquisition board with information about the type and range of the signals to be acquired and about the input channel
- DAQmx Read.vi samples the signal from the specified channel and yield the measured value

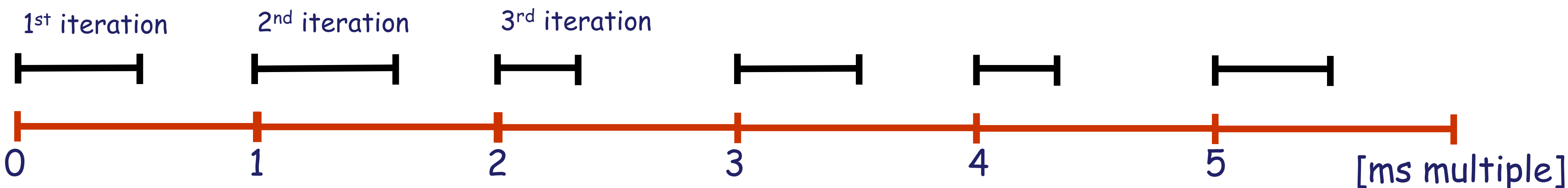


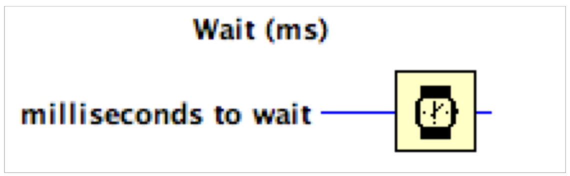
Acquisition Timing

- Before acquiring V_o, one should wait for the currents in the DUT to reach the regime conditions. For this purpose, a timing function should be used in the first frame of the sequence structure

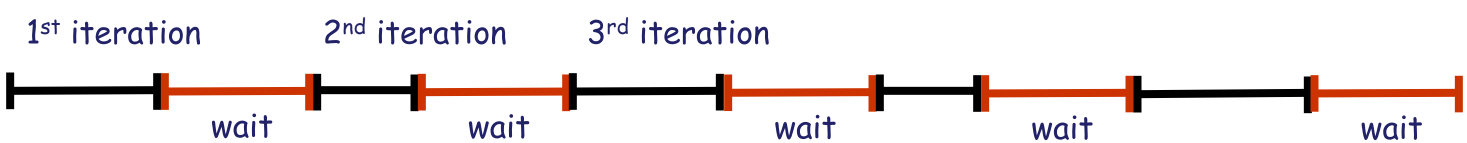


Waits until the timer content is a multiple of "millisecond multiple" before starting an iteration – generally used to synchronize the loop execution with the system clock



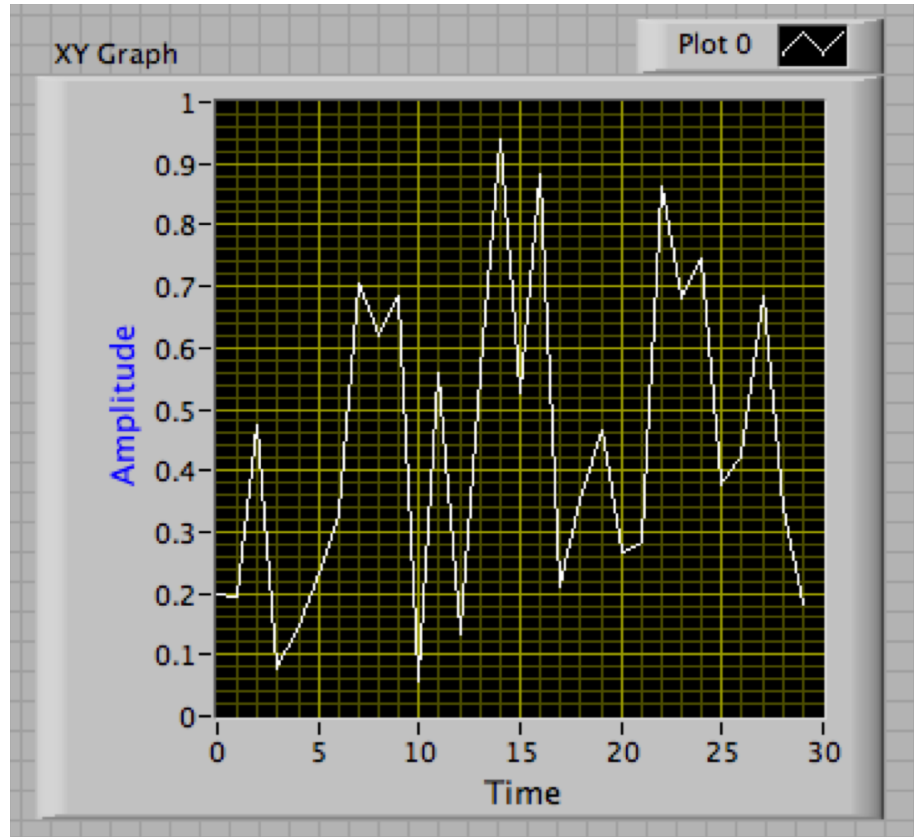


Waits for the specified number of milliseconds before starting an iteration

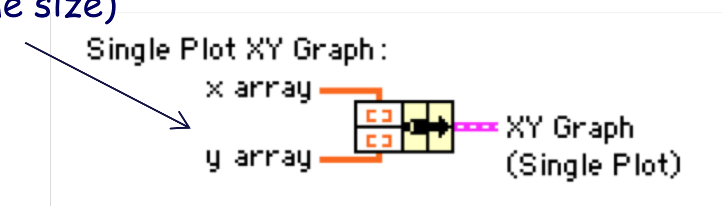


Graphical representation of β(I_C)

- XY graph (Modern-> Graph -
>XY Graph o Classic ->Classic Graph
->XY Graph)
- A Bundle function is required (Programming-> Cluster, Class & Variant-> Bundle) to group the independent (X) and dependent (Y) variables in a single array

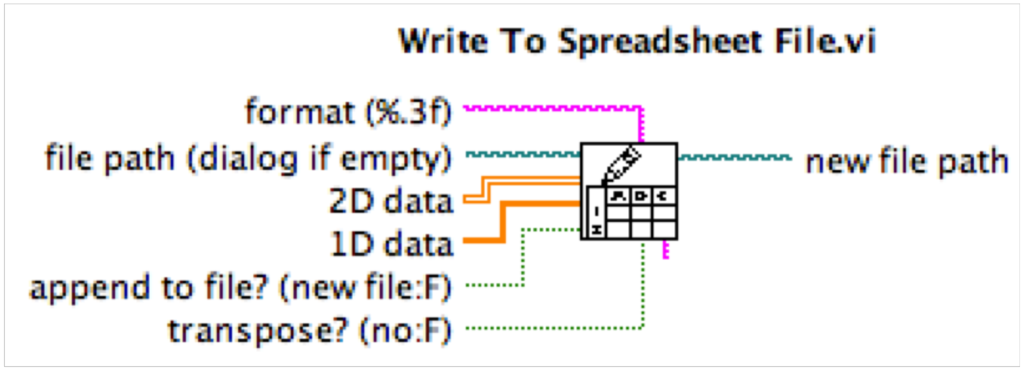


Input data in the form of vectors (same size)



Suggestion: to generate the data vectors one could use tunnels in "indexed" modes in a for structure

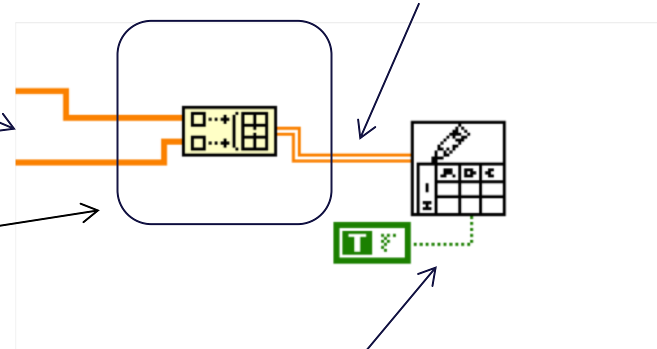
Writing a file



Programming-> File I/O->
Write To Spreadsheet File.vi

output: 1 2D array (2 column data table)

input: 2 1D arrays

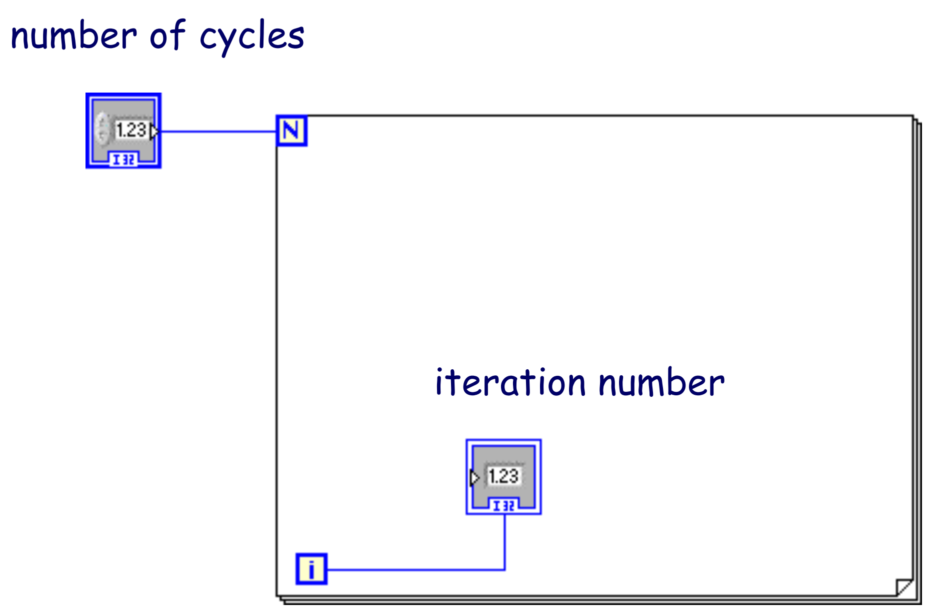


Programming-> Array-> Build Array

2D array transpose? yes

FOR cycle for noise rejection

- We can use a for cycle to reduce the effects of zero average disturbances, therefore improving the measurement accuracy



- Instead of representing (in the graph or in the numeric indicator) each individual acquired sample of the signal, we can represent the average value of N samples – the speed at which the measurement result is represented on the graph will decrease by a factor of N