Università degli Studi di Pavia

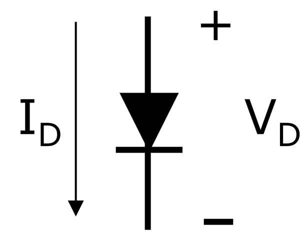
Dept. of Electrical, Computer and Biomedical Engineering

Data acquisition from a photodiode

Photodiodes

- Photodiodes are semiconductor devices with PN or PIN structure typically used as radiant power transducers
- The energy transferred by the electromagnetic radiation, absorbed in the depletion or in the intrinsic region is responsible for the generation of electron/hole pairs, eventually contributing to the formation of a current
- The voltage/current characteristic of a photodiode is therefore the same as in a diode, with the addition of a photo-generated current term I_{ph}

$$I_D = I_0\left(e^{V_D/V_T} - 1\right) - I_{ph}$$



where I_0 is the diode leakage current, V_D is the voltage across the device and V_T is the thermal voltage. Note that, in reverse bias operating conditions (V_D<0), the first term in the expression reduces to I_0, while for V_D=0, I_D=-I_{ph}.

Photodiodes

- The photo-generated current I_{ph} is proportional to the incident radiant power, i.e., to the flux of photons hitting the device:

$$I_{ph} = S \cdot P = \frac{\eta e}{h\nu} P, \quad \frac{P}{h\nu} = \#\ \text{fotoni al sec.}$$

- where S is the spectral (or radiometric) sensitivity, η is the quantum efficiency, **e** is the elementary charge (1.602 10^{-19} C), **P** is the power of the incident electromagnetic wave, **h** is the Plank's constant (6.625 10^{-34} J·s) and ν is the electromagnetic wave frequency

- Other characteristic parameters of a photodiode are the linearity, the dark current, the junction capacitance, the breakdown voltage and the response time

Main uses of thermistors

Application field	Use or device
Cameras	Light intensity measurement, automatic control of the shutter, auto-focus, flash unit control
Medical instrumentation	TAC scanner, X-ray detection, biological analysis (e.g., blood), oximetry
Safety devices	Smoke and flame detectors, X-ray systems for airplane inspection, intrusion detectors
Automotive	Headlight dimmer, sun light detector (for air conditioning)
Communications	Opto-electronic converters, remote optical control
Industry	Bar code readers, encoders, position detectors, toner density measurement in printers

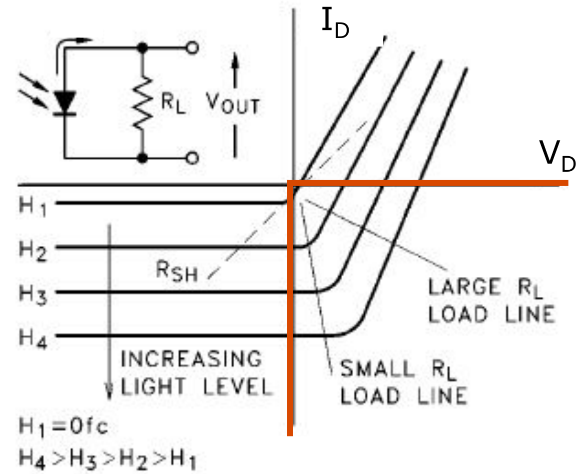
Purpose of the experiment

- Implement a system for data acquisition from a radiant power transducer, in particular from a photodiode. The system should include
  - a conditioning circuit for the signal coming from the photodiode
  - a virtual instrument implemented in the LabView programming environment serving as an interface between the acquisition system and the user
- The virtual instrument should take care of acquiring the room radiant power and representing the time evolution of the measured voltage and the instantaneous value of the radiant power

Operating modes for the photodiode

- Photovoltaic mode: the photodiode is operated with no bias voltage applied and can supply electrical power (in the passive sign convention, $V_D I_D < 0$, with $I_D \leq 0$ and $V_D > 0$); in particular, for $I_D = 0$, the photodiode behaves like a voltage source

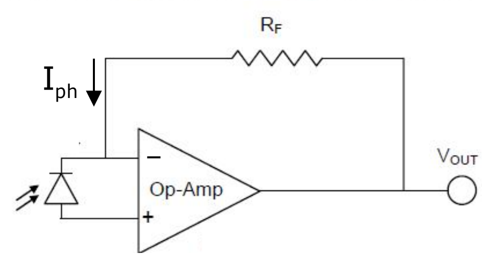
$$V_D = V_T \ln\left(\frac{I_{ph}}{I_0} + 1\right)$$

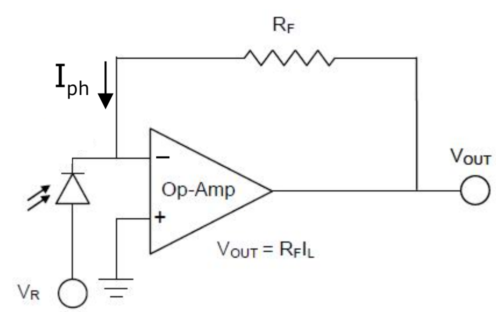


Current/Voltage Characteristics - Photovoltaic Mode

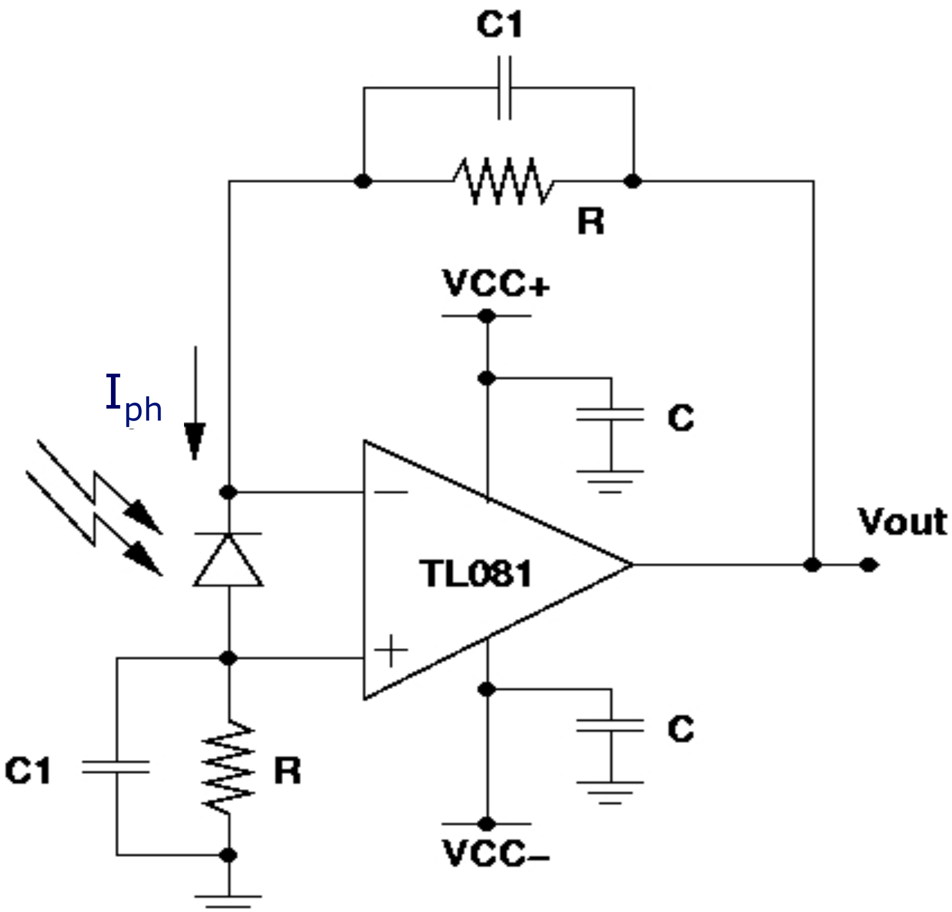
- Photoconductive mode: the photodiode is operated in reverse or zero volt bias conditions, $V_D \leq 0$, and behaves like a current source; in particular, if the potential difference across the device is close to zero

$$I_D = -I_{ph}$$





Conditioning circuit



- R=1 MΩ
- C=100 nF
- C1=15 nF
- VCC^{+}=+15 V
- VCC^{-}=-15 V
- PD: VTB8440B

Conditioning circuit

- The proposed scheme, in principle, makes it possible to cancel the dark current contribution (current flowing through the diode when $V_D=0$)

$$V_{out} = 2 \cdot R \cdot I_{ph} = 2 \cdot S \cdot R \cdot P$$

voltage at the amplifier output

spectral sensitivity

incident light power

- Another advantage of the proposed conditioning circuit lies in the reduction of the effects of the input bias currents on the output of the operational amplifier

$$V_{out} \big|_{I^+, I^-} = -I^+R + I^-R = -R\Delta I$$

where $\Delta I = I^+ - I^-$ is the offset of the input bias currents of the operational amplifier

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.

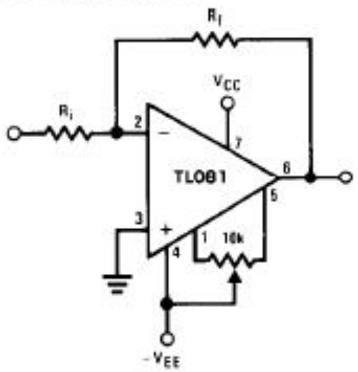
The TL081 may be used in applications such as high speed integrators, fast D/A converters, sample-and-hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth. The devices has low noise and offset voltage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

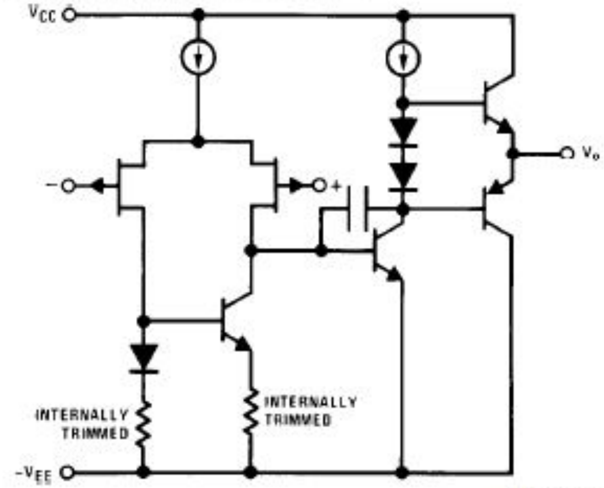
TL081 JFET input OpAmp

Typical Connection



TL/H/8358–1

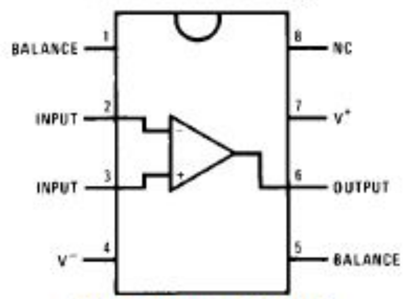
Simplified Schematic



TL/H/8358–2

Connection Diagram

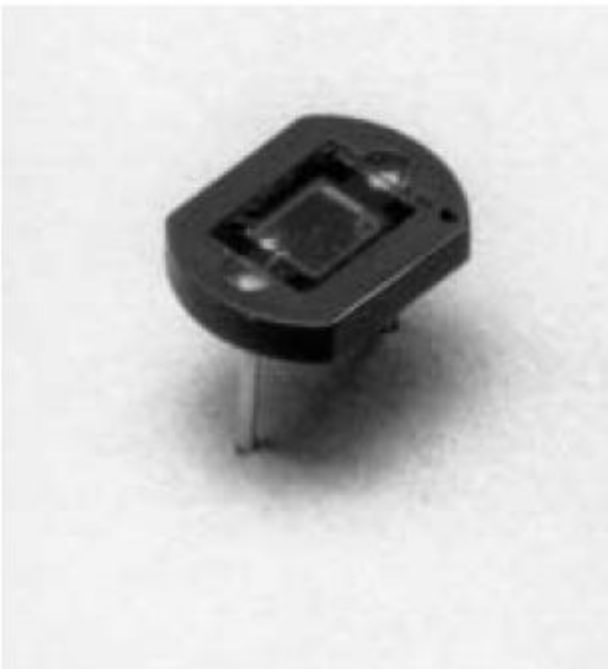
Dual-In-Line Package



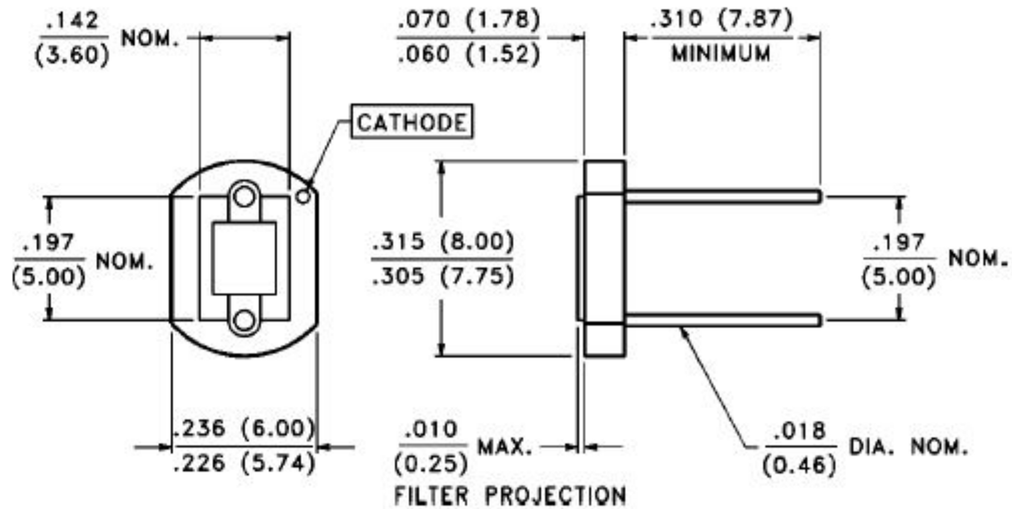
TL/H/8358–4

Order Number TL081CP
See NS Package Number N08E

VTB8440B photodiode



PACKAGE DIMENSIONS inch (mm)



CASE 21F 8 mm CERAMIC

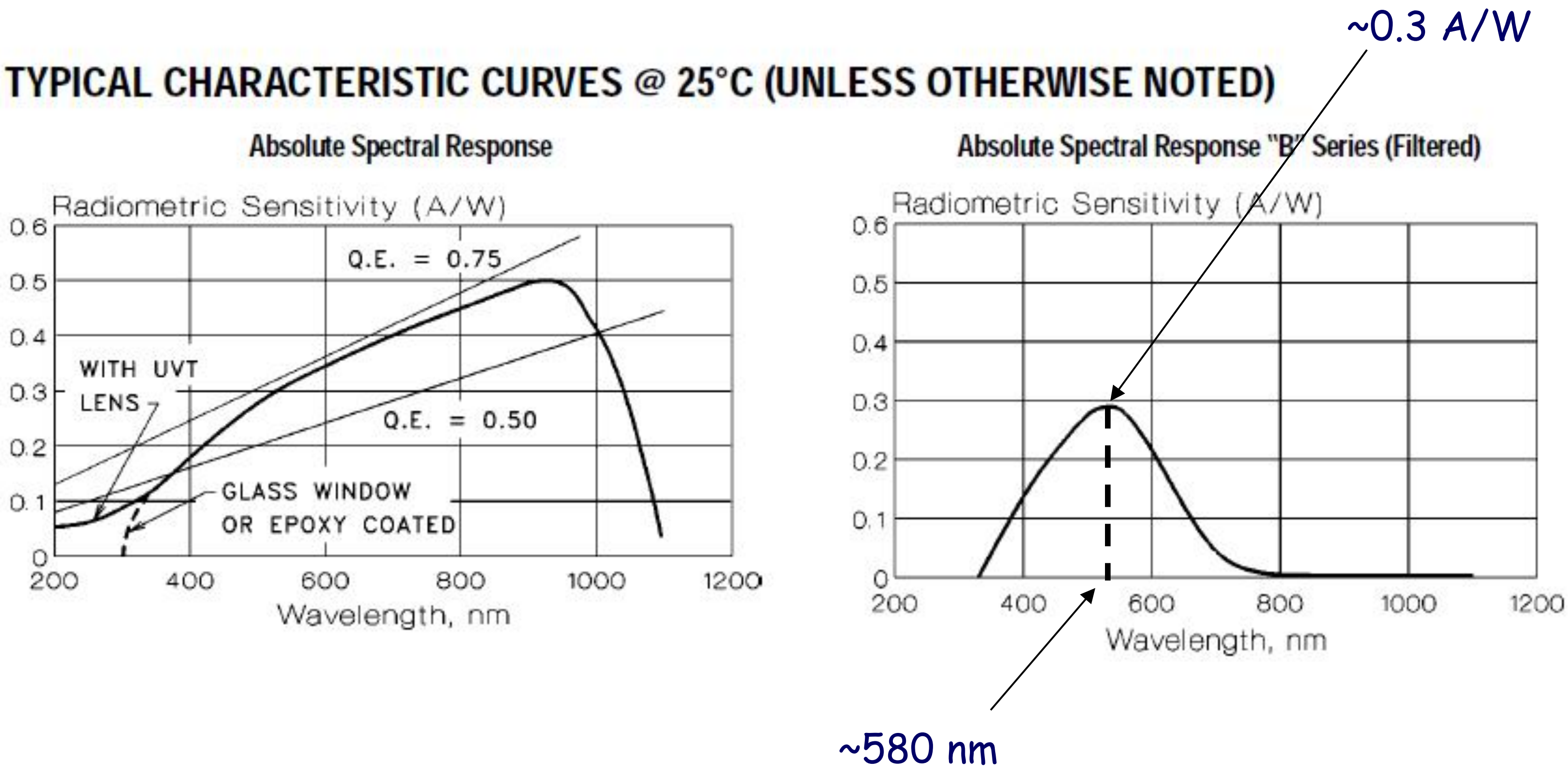
CHIP ACTIVE AREA: .008 in^2 (5.16 mm^2)

VTB8440B photodiode

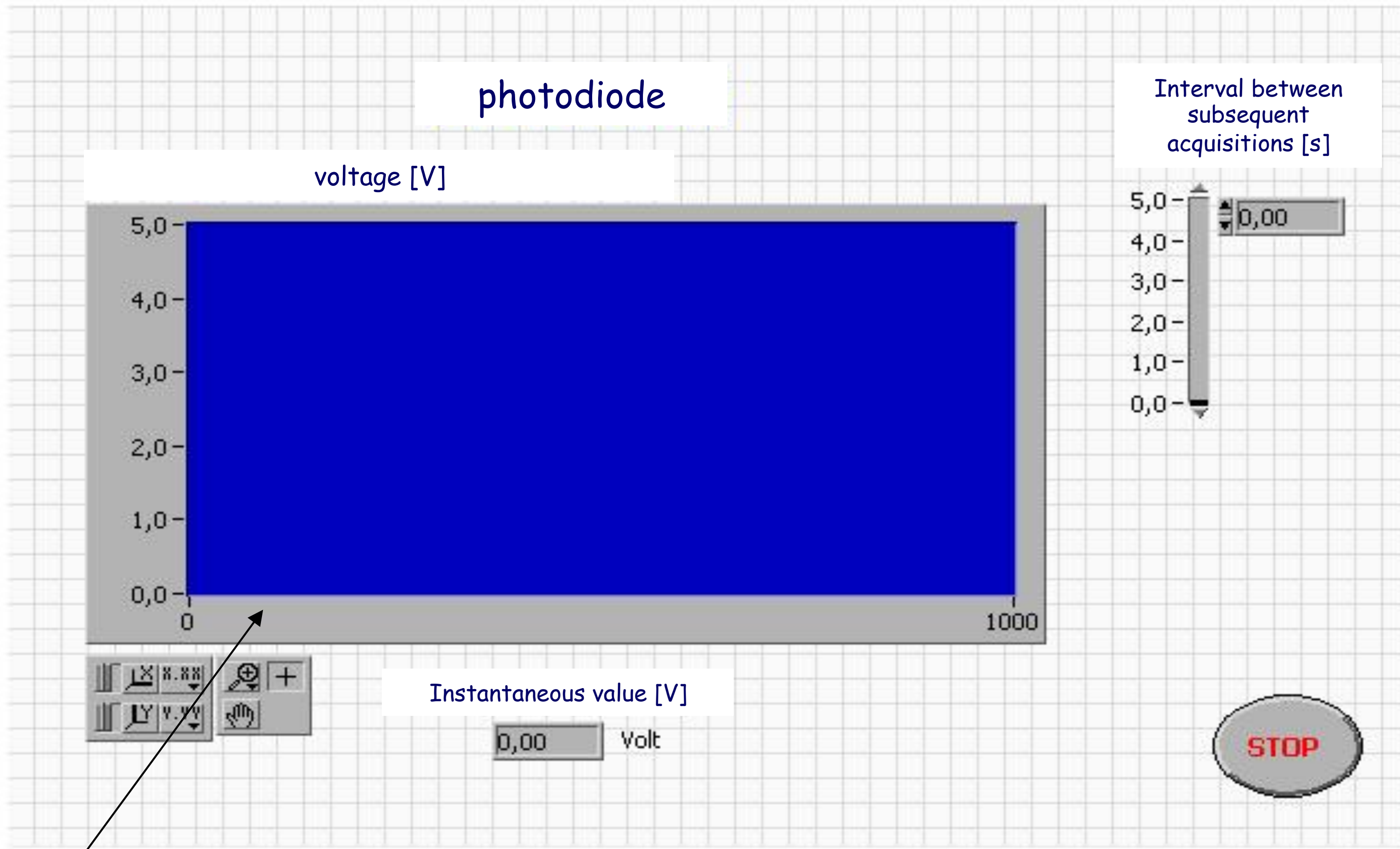
ELECTRO-OPTICAL CHARACTERISTICS @ 25°C (See also VTB curves, pages 21-22)

SYMBOL	CHARACTERISTIC	TEST CONDITIONS	VTB8440B			VTB8441B			UNITS
			Min.	Typ.	Max.	Min.	Typ.	Max.	
I_{SC}	Short Circuit Current	H = 100 fc, 2850 K	4	5		4	5		µA
TC I_{SC}	I_{SC} Temperature Coefficient	2850 K		.02	.08		.02	.08	%/°C
V_{OC}	Open Circuit Voltage	H = 100 fc, 2850 K		420			420		mV
TC V_{OC}	V_{OC} Temperature Coefficient	2850 K		-2.0			-2.0		mV/°C
I_D	Dark Current	H = 0, VR = 2.0 V			2000			100	pA
R_{SH}	Shunt Resistance	H = 0, V = 10 mV		.07			1.4		GΩ
TC R_{SH}	R_{SH} Temperature Coefficient	H = 0, V = 10 mV		-8.0			-8.0		%/°C
C_J	Junction Capacitance	H = 0, V = 0		1.0			1.0		nF
λ_{range}	Spectral Application Range		330		720	330		720	nm
λ_p	Spectral Response - Peak			580			580		nm
V_{BR}	Breakdown Voltage		2	40		2	40		V
$\theta_{1/2}$	Angular Resp. - 50% Resp. Pt.			±50			±50		Degrees
NEP	Noise Equivalent Power		1.1×10^{-13} (Typ.)			2.4×10^{-14} (Typ.)			$W/\sqrt{Hz}$
D*	Specific Detectivity		2.2×10^{12} (Typ.)			9.7×10^{12} (Typ.)			$cm\sqrt{Hz}/W$

VTB8440B photodiode



Front panel



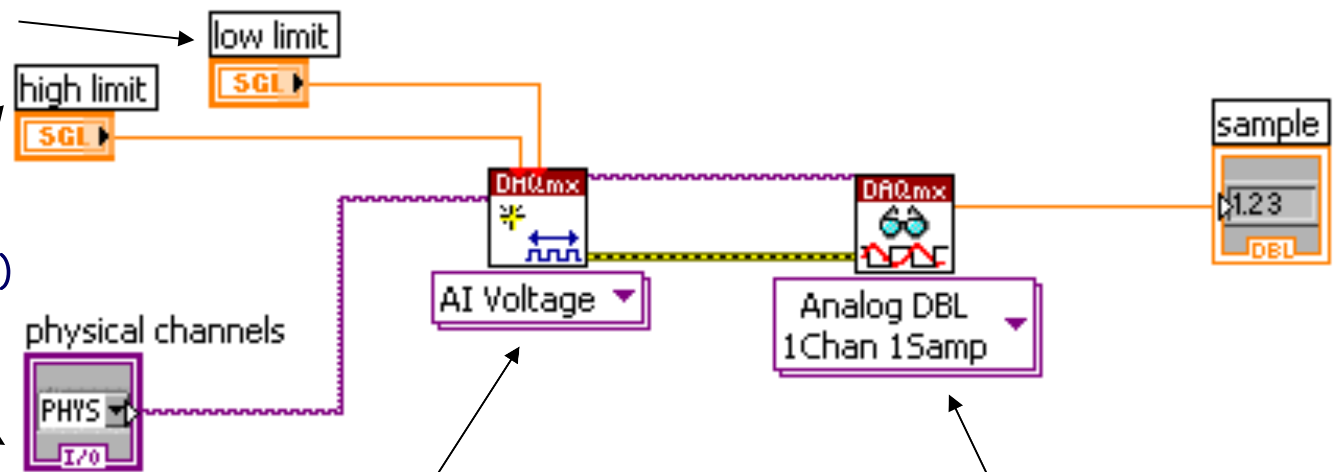
Waveform chart

DAQmx Create Channel.vi and DAQmx Read.vi

- 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

expected limits for the signal to be acquired

input channel (**Dev2/a1**)

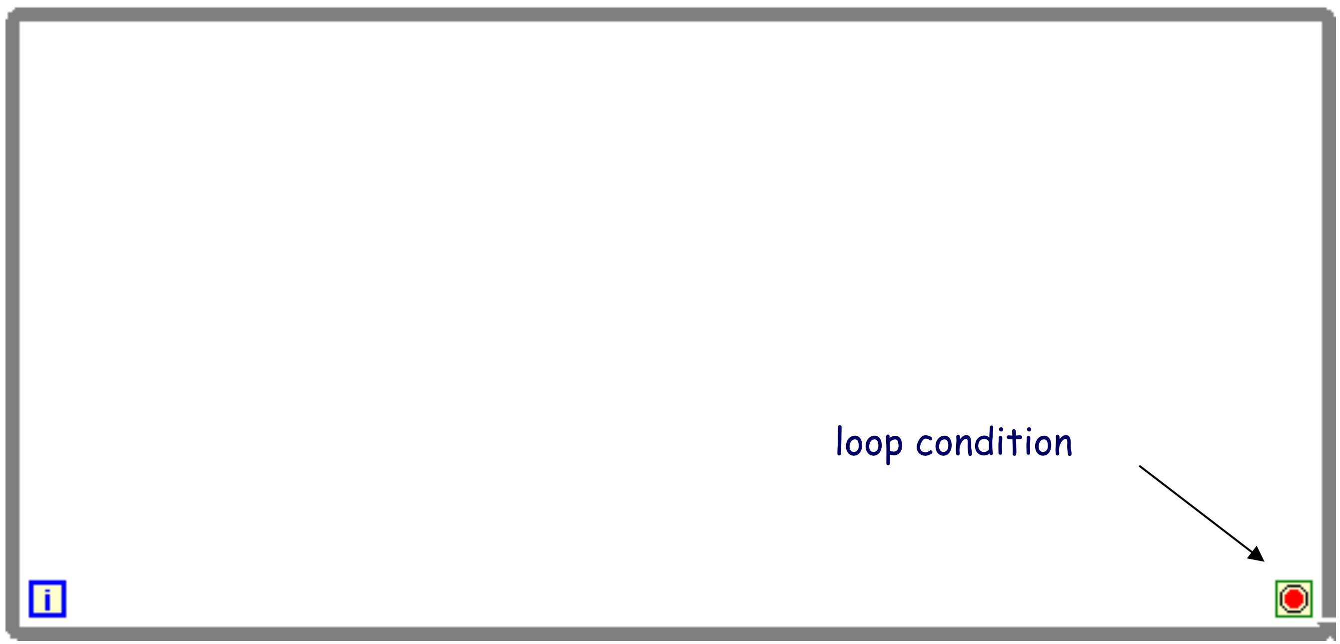


Measurement I/O -> DAQmx Data Acquisition -> DAQmx Create Channel.vi

Measurement I/O -> DAQmx Data Acquisition -> DAQmx Read.vi

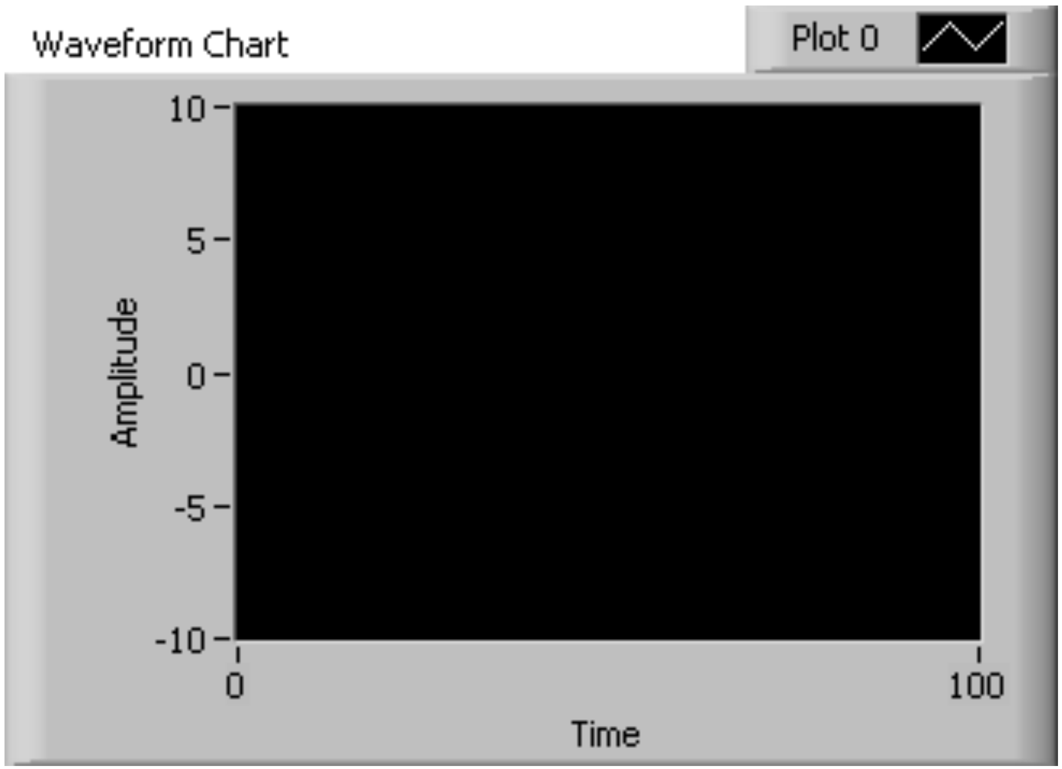
While loop

- Needed for continuous acquisition of the signal coming from the conditioning circuit (you can find it in the Structures menu from the Functions palette) – a “stop” button should be included in the virtual instrument to stop the acquisition



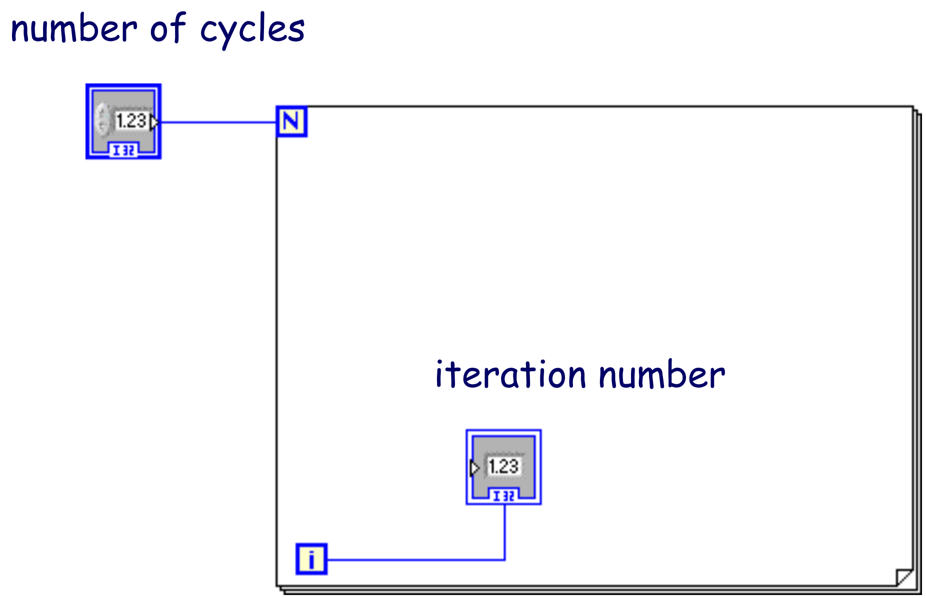
Waveform chart

- 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



For cycle

- 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