How to measure...

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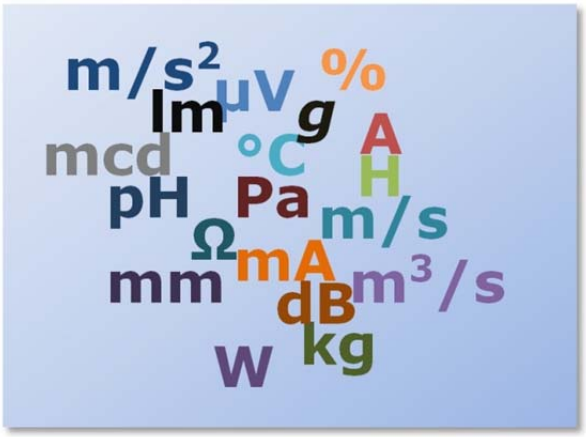

1. Acceleration

Pico products for measuring acceleration

- PicoScope 4224 Oscilloscope: The most popular product for measuring acceleration. Most moving-coil and piezo sensors (see below) can be plugged directly into the PicoScope. Silicon sensors are often 10 V bridge-type sensors that require a 10 V excitation voltage and produce a millivolt output. An additional precision 10 V power supply is required when using silicon sensors with Pico products.
- PicoScope 4224 IEPE Oscilloscope: The ideal instrument for use with a phantom-powered accelerometer, as it has a built-in IEPE power output. Just plug in the accelerometer and use like a normal scope. We can supply a suitable accelerometer—the TA095—with a ±50 *g* measurement range.

Other Information

There are several types of accelerometer:

- piezoresistive
- piezoelectric
- silicon bridge
- micromachined silicon
- voice coil

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Piezo resistor

A piezoresistive sensor uses a piece of material whose resistance changes when it is compressed, attached to a weight. When the weight is accelerated, it exerts a force on the piezoresistor. If a constant current is passed through the piezoresistor, the voltage changes. Current is about 4 to 8 mA and voltage is 8 to 24 V. Typical sensitivity is about 100 mV/*g* over the range 0 to 50 *g*. This type of sensor responds to frequencies up to 10 kHz.

Piezoelectric

A piezoelectric sensor generates charge when it is accelerated: typically 50 pC per *g*. It is necessary to integrate the charge to give a voltage which is related to the acceleration: this means that it is not suitable for low-frequency work, but piezoelectric sensors respond to frequencies up to 30 kHz.

Silicon bridge

A silicon bridge sensor is a piece of silicon that has been etched to leave a block of silicon at the end of a beam. When subjected to acceleration, the block exerts a force on the beam and the resistance of the beam changes. Maximum frequency is about 5 kHz. The sensor is a bridge, and so it requires an excitation signal of 5 to 10 V. Temperature compensation is required.

Micromachined silicon

Micromachined silicon accelerometers are a form of differential capacitor. One of the advantages of this type of sensor is the ability to measure DC acceleration (and consequently tilt). The maximum frequency is about 1 kHz. The popular Analog Devices ADXLxxx range of single and dual-axis sensors have built-in signal conditioning circuits that produce a voltage output suitable for use with our data loggers and oscilloscopes.

Voice coil

Voice coils work on the same principle as microphones, hence the name.

2. Audio Signals

Pico products for measuring audio signals

For measuring high-quality audio signals and for audio spectrum analysis the PicoScope 4000 Series precision oscilloscopes are ideal. For less demanding applications, the lower cost PicoScope 3000 Series can also be considered.

Other Information

The PicoScope software includes common audio measurements such as THD, SINAD and SFDR. It is included with all our oscilloscopes and data loggers.

We also have the following application notes on audio measurement:

- Audio Spectrum Analysis: Introduction and testing a CD player
- Audio Spectrum Analysis: Testing power amplifiers
- Audio Spectrum Analysis: Designing audio amplifiers using spectrum analysis
- High Resolution Oscilloscopes

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3. Automotive Signals

Please visit our automotive diagnostics website for more information.

4. Battery Discharge

Pico products for measuring battery discharge

Pico has several products suitable for recording battery discharge. They all connect to a USB port on the computer.

- **PicoLog 1210:** This 12 analogue input channels. The input voltage range is 0 to 2.5 V and the resolution is 2.5 mV. This device is suitable for measuring multiple channels at higher speed.
- **PicoLog 1216:** This has 16 analogue input channels. The input voltage range is 0 to 2.5 V and the resolution is 625 µV.
- **ADC-20:** This has 8 single-ended or 4 differential high-resolution analogue inputs. The input voltage range is -2.5 V to +2.5 V and the resolution is about 5 µV. This device should be used if more precise measurements are required at a slower speed.

Other Information

Terminal connector boards are available for the PicoLog 1000 Series and ADC-20 data loggers.

We also have the following application note on battery discharge:

- Using an ADC-16 to monitor battery discharge

5. Current

Pico products for measuring current

Pico has several products suitable for measuring and recording current.

The Pico range of current clamps allow current to be measured without having to break into the circuit. All of them can be used with any of our data logging or oscilloscope products:

- The **PP179 and PP266 current clamps** can measure AC or DC currents up to 600 A.
- The **PP218 and PP264 current clamps** can measure AC or DC current signals from 10 mA to 60 A.
- The **PP253 current clamp** can measure AC current signals up to 1500 A and DC current up to 2000 A.

The Pico Current Monitoring Kit contains current clamps, power monitor, data logger and everything else you need to start logging currents from up to three separate circuits. It is ideal for measuring and balancing 3-phase power supplies as well as machine monitoring and energy efficiency studies.

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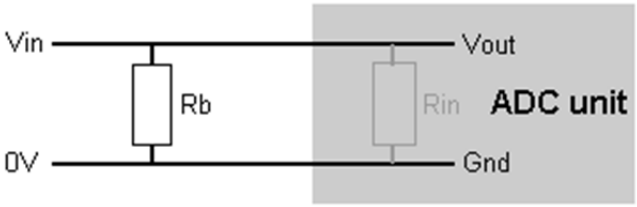
For small currents, a simple shunt resistor can be used to convert the current into a voltage, which the ADC can then measure. This can be done providing the signal can be grounded.



The resistor value can be calculated using the formula below:

$$R_b = \frac{V_{max}}{I_{max}}$$

where V_{max} is the maximum input voltage of the ADC, I_{max} is the maximum measured current and $R_b << R_{in}$.

WARNING: This method is NOT suitable for monitoring mains currents.
To monitor mains currents with data acquisition or oscilloscope products, use a current clamp.

Pico has four products where this resistor can easily be placed on a terminal board:

- **ADC-20 or ADC-24** and **terminal board:** can monitor 8 channels with high accuracy
- **PicoLog 1012 or 1216** and **terminal board:** can monitor 12 or 16 channels at higher speed

6. The Beating of a Bird's Wing

Equipment required:

- A high-power radar installation (ex-military is ideal)
- PicoScope 2000, 3000 or 4000 Series Oscilloscope
- Some birds

This application note looks at tracking migratory birds using radar. Using a PicoScope spectrum analyser it is possible to measure the frequency of the beating of the bird's wings and from this identify the type of bird.

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7. Flow

Pico products for measuring flow

There is a wide variety of flow sensors that can be used with Pico products.

Flow is commonly sensed by measuring differential pressure across two points in a pipe. This can be done using the Venturi effect (by placing a restriction in the flow). An alternative approach is to use a Pitot tube. The main advantage of this type of approach is that disturbance of the flow can be kept to a minimum. One disadvantage is that two holes are usually required in the pipe, making cleaning difficult. Also be aware that many differential pressure sensors are intolerant to aggressive gases and chemicals. The method for measuring these sensors is described in the section on pressure sensors.

For applications where pipes regularly need cleaning, consider using a bending vane type of sensor. As the name suggests, this consists of a vertical vane that deflects as flow increases. This deflection is measured using a strain gauge. The method for measuring such sensors is covered in the section on strain.

'Paddle wheel' sensors rotate in proportion to flow. The rotation is detected by either optical or magnetic means. These sensors produce a pulsed output. The main advantage of such sensors is low cost, and some are also suitable for measuring aggressive gases and liquids. The main disadvantage is disruption to the flow. For information on interfacing to such sensors, see Measuring frequency.

Ultrasonic and magnetic flow sensors allow flow to be measured with no moving parts. This minimises (or eliminates) disturbance to flow and provides for increased reliability. The main disadvantage is cost. These sensors tend to have built-in signal conditioning with either voltage or 4 to 20mA current loop outputs.

8. Food Temperature

Pico products for measuring food temperature

Pico has several products suitable for monitoring food temperature.

EnviroMon is a complete monitoring and recording system than can keep records and plot trends over many years. It is designed as an expandable system for permanent installation in buildings but is flexible enough to be used in many other areas. It is currently being used in large warehouses and supermarkets to monitor food storage conditions and also in factories and houses to monitor a variety of parameters from room temperature to humidity and power usage. Starter kits are available which contain the components required to monitor 3 temperatures, and extra components can be added at any later date. EnviroMon connects to the PC's RS-232 port to download the stored data. It does not require a PC to collect the data.

Several types of sensor can be used with the EnviroMon system:

- Our standard precision thermistor - for ambient and low-temperature monitoring
- PT100 RTD - for high-temperature monitoring
- Type K Thermocouple – temperature range depends on the thermocouple in use

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The USB TC-08 is our dedicated thermocouple unit. It accepts up to 8 thermocouples using standard Miniature Thermocouple connectors. It can accept all the standard thermocouple types: B, E, J, K, N, R, S and T. The channels can also be used as voltage inputs with a range of ±70 mV. It connects to the PC via a USB port and up to 20 USB TC-08 units can be used on a PC at once.

Other Information

We also have the following application notes available:

- Monitoring temperatures in the food industry - an actual installation
- Monitoring energy efficiency in the home - using EnviroMon
- Advice on choosing and using PT100 sensors
- Advice on choosing and using thermocouples

9. Frequency

Pico products for measuring frequency

Many Pico products can be used to measure frequency. The choice of device is dependent on the frequency range, the voltage input range and the number of channels required.

There are four possible measurement requirements:

- Logging frequency variations over time:
  PicoLog can be used to record fluctuations in frequency over time.
- Measuring spot frequencies:
  PicoScope's automatic measurements can be used to take spot frequency measurements and to show variation statistics.
- Investigating the frequency components of a signal:
  PicoScope's spectrum analyser shows the frequency spectrum of a signal, allowing the measurement of any frequency component within the signal.
- Viewing frequency variations over time:
  When used with the PicoScope 4000 Series 12-bit scopes, PicoScope can be used to graph fluctuations in frequency over time.

10. Humidity

Pico products for measuring humidity

- EL026: used with EnviroMon for stand-alone remote humidity measurement, or where a number of humidity readings need to be taken over a wide area.
- HumidiProbe: simply plugs into the USB port of a PC and uses internal sensors to give accurate humidity and temperature measurements.
- DrDAQ data logger: a low-cost option for humidity measurement using the optional humidity sensor.

11. Liquid Level

This topic is discussed in our science experiment 'measuring rainfall'.

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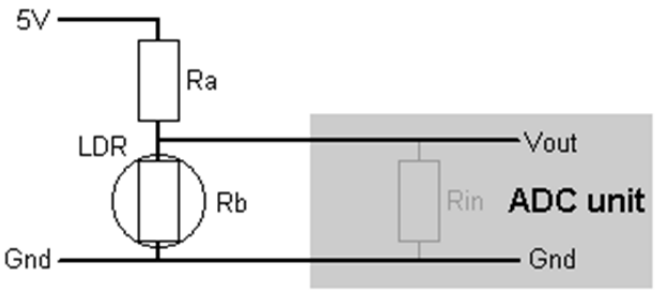
12. Light Level

Pico products for measuring light

The DrDAQ Data Logger has a built-in light sensor, so can be used as a low-cost light meter or light-level data logger. In addition, the light sensor has a fast response time so can be used to investigate fast-changing light signals such as those produced by tube lights.

The circuit on the right can be used with any of our oscilloscope or data logging products to measure light levels. The circuit uses an LDR to sense light level and converts this to a voltage using a potential divider network.



R_a should be around 1 MΩ.

13. The Swing of a Pendulum

This topic is covered in the following application note. It makes an ideal physics teaching experiment.

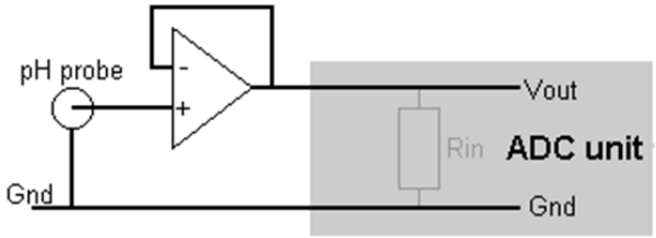
14. pH

Pico products for measuring pH

The DrDAQ data logger has a dedicated pH input. Optional pH electrodes are also available. DrDAQ measures pH over the full 0 to 14 range with a resolution of 0.02 pH.

Despite the low cost of DrDAQ, options are provided for calibration and temperature compensation, allowing very accurate pH measurements.

The circuit on the right allows any of our oscilloscope and data logging products to monitor signals from pH probes. The op-amp needs to have a very high input impedance - an LT1114 is suitable.



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15. Oxygen in Air

Pico products for measuring oxygen in air

The DD103 oxygen sensor can be connected to the external sensor sockets on the DrDAQ data logger to measure oxygen in air.

Unlike previously available oxygen sensors, the DD103 oxygen-in-air sensor can measure the full 0 to 100% range. This makes it ideal for many chemistry, biology and physics experiments.

16. Pressure

Pico products for measuring pressure

Most pressure sensors are '10 V bridge' type that require a 10 V excitation voltage and produce millivolt outputs. An additional precision 10 V power supply is required to provide this excitation voltage when using this type of pressure sensor with any of our products.

- For accurate measurement of up to 8 slowly changing signals, use the ADC-20 or ADC-24 data logger, or the TC-08 thermocouple and voltage data logger.
- For rapidly changing pressure signals, use one of our precision oscilloscopes such as the 12-bit PicoScope 4224.

Note that some pressure sensors have signal conditioning built in. These sensors usually have a voltage output or a 4-20 mA output. See the appropriate sections in this guide for information on measuring these signals.

17. Strain, Force and Load

Pico products for measuring Strain, Force and Load

The strain gauge is perhaps the most popular sensor for measuring force and deflection. As a strain gauge is stretched or compressed, its resistance changes. By mounting the strain gauge on a calibrated carrier, force can be indirectly measured. Such a sensor is commonly referred to as a load cell. Load cells consist of one or more strain gauges configured in an industry-standard '10 V bridge' arrangement. Sensitive load cells are used in weighing scales, while at the other extreme heavy industrial load cells can be used to measure loads of several tonnes.

As mentioned, most load cells are '10 V bridge' types that require a 10 V excitation voltage and produce millivolt outputs. An additional precision 10 V power supply is required to provide this excitation voltage when using this type of pressure sensor with any of our products.

- For accurate measurement of up to 8 slowly changing signals, use the ADC-20 or ADC-24 data logger, or the TC-08 thermocouple and voltage data logger.
- For rapidly changing pressure signals, use one of our precision oscilloscopes such as the 12-bit PicoScope 4224.

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18. Rainfall

This topic is covered in the following application note.

19. Resistance

Pico products for measuring resistance

Pico has two products that can be used for measuring and recording resistance:

- **USB PT-104 data logger:** can be used for high-accuracy (20 ppm) and high-resolution (1 µΩ) resistance measurement.
- **DrDAQ data logger:** can directly measure resistance over the 0 to 1 MΩ range.

Other Information

Other Pico products can also be used to monitor resistance. This is achieved using a precision voltage reference and a known resistance. The two resistances are connected in series and fed by the precision voltage source. The voltage developed across the unknown resistor can then be measured and used to infer the resistance.

Pico has two products where the resistors and voltage source can easily be placed on a terminal board:

- ADC-20 with terminal board: can monitor 8 channels with high accuracy.
- PicoLog 1000 Series with terminal board: can monitor 12 or 16 channels at higher speed.

20. Sound Level

Pico products for measuring sound level

- The DrDAQ data logger has a built-in microphone that can directly measure sound level over the 55 to 100 dB range. The low cost of DrDAQ makes it ideal as either a sound-level meter or sound-level data logger.
- PicoScope 4224 IEPE Oscilloscope: The ideal instrument for use with a phantom-powered, calibrated microphone, as it has a built-in IEPE power output. Just plug in the microphone and use PicoScope like a normal scope.

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21. Temperature

Pico products for measuring temperature

Temperature is the most commonly measured real-world signal. We have several products dedicated to measuring temperature. In addition, if you wish to monitor a mix of temperatures and other parameters, our data logging products provide a simple plug-and-play solution.

Other Information

We also have the following application notes available:

- Advice on choosing and using thermocouples
- Advice on choosing and using PT100 sensors
- Monitoring temperatures in the food industry
- Environmental monitoring at the Olympics

See also:

- Food temperature monitoring

22. Video Signals

Pico products for measuring video signals

For measuring video signals, consider one of our high-speed oscilloscopes such as the PicoScope 3000A and 3000B Series.

Other Information

We also have this application note on video measurement.

23. Voltage

Pico products for measuring voltage

The majority of Pico products can be used for data logging. To ensure you choose the correct product you must consider the following:

- How many voltages (channels) need to be measured
- How big (or small) the voltages are
- How fast the signals change
- How long you wish to record the voltage for

How many voltages (channels) need to be measured?

If your requirement is to measure a large number of channels, then consider the PicoLog 1012 (12 channels) or the PicoLog 1216 (16 channels). If more channels are required then it is possible to use multiple ADC units on the same PC to give very high channel counts. If you have a number of voltages to record over a wide area, then the EnviroMon networked data logging system can measure up to 30 channels per logger.

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How big (or small) are the voltages?

Most of our data logging products have fixed input ranges (2.5 V or 5 V). These can be easily increased through the use of simple potential divider circuits. Our oscilloscope products have software selectable ranges (10 mV to 100 V).

If you wish to measure high voltages then the range of our oscilloscope products can be extended to 1000 V using suitably rated x10 scope probes. For higher voltages, and high-current supplies such as mains (house current), we recommend the use of one of our oscilloscope products with an isolating x100 differential scope probe.

If you wish to measure small voltages, you need to consider the input range of the device and also the resolution:

Products	Input Range	Resolution	Sampling rate	LSB Voltage *
PicoLog 1012	0 to 2.5 V	10 bits	1 MS/s	2.5 mV
PicoLog 1216	0 to 2.5 V	12 bits	1 MS/s	625 µV
USB TC-08	±70 mV	20 bits	10 S/s	0.067 µV
ADC-20	±2.5 V	20 bits	16 S/s	4.8 µV
ADC-24	±2.5 V	24 bits	16 S/s	0.298 µV
USB PT-104	0 to 2.5 V	24 bits	1 S/s	0.156 µV

* Smallest detectable change

How fast the signals change

If your signals have frequency components above 1 kHz then consider our oscilloscope products. If all your signals are lower than 1 kHz you can use either our data logging or oscilloscope products.

How long you wish to record the voltage for

If you wish to record voltages for long periods of time (more than say 5 minutes), then use one of our data loggers or, if you need a stand-alone system, use EnviroMon.

24. WBGT (Wet Bulb Globe Temperature)

Pico products for measuring WBGT

WBGT is used to measure the heat load that the environment places on humans and animals. To calculate WBGT it is necessary to measure ambient temperature, humidity and solar radiation. This can be done using the EnviroMon data logger. The equations needed to calculate WBGT are built into the logger. If you have an interest in WBGT measurement, please contact Pico technical support for more information.

Other Information

We also have the following application note showing the use of the WBGT index during the Atlanta Olympics.

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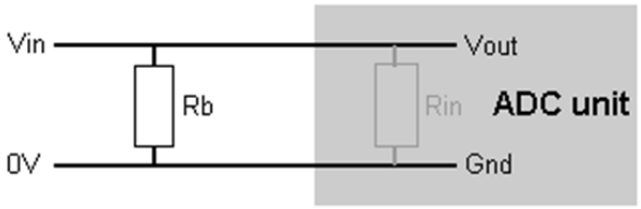
25. 4-20 mA Signals

Pico products for measuring 4-20 mA signals

Pico has several products suitable for measuring and recording 4-20mA signals, but the input circuit has to be slightly modified.

A simple shunt resistor can be used to convert the current in the loop to a voltage that is suitable for the ADC to measure. A 250 ohm resistor will give a voltage output of 1 to 5 V. This method can be used in systems where the signal can be grounded.



Other resistor values can be calculated using the formula below:

$$R_b = \frac{V_{max}}{I_{max}}$$

where V_{max} is the maximum input voltage of the ADC, I_{max} is the maximum measured current and $R_b << R_{in}$.

Other Information

Pico has four products where this resistor can easily be placed on a terminal board:

- **ADC-20 or ADC-24 and terminal board:** can monitor 8 channels with high accuracy.
- **PicoLog 1012 or 1216 and terminal board:** can monitor 12 or 16 channels at higher speed.

26. Speed of Sound

This topic is covered in the following application note. It makes an ideal physics teaching experiment.

27. Speed of Light

This topic is covered in the following science experiment. It makes an ideal physics teaching experiment.

28. Output of a Dynamo

One of our series of educational technical notes, this experiment looks at measuring the output of a bicycle dynamo.

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29. Speed of a Car

One of our series of educational technical notes, this experiment looks at measuring the speed of a car. (Unfortunately, due to budget restrictions, a rather small car had to be used!)

30. Other Measurements

Many different types of sensors are available to measure numerous variables, and we have been unable to discuss them all on this page.

If you have an interface solution for a sensor we haven't listed here, then please e-mail us and we will add it to this page.

Downloads

Download oscilloscope data sheets, User's Guides, Programmer's Guides, drivers and example source code from:

www.picotech.com

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