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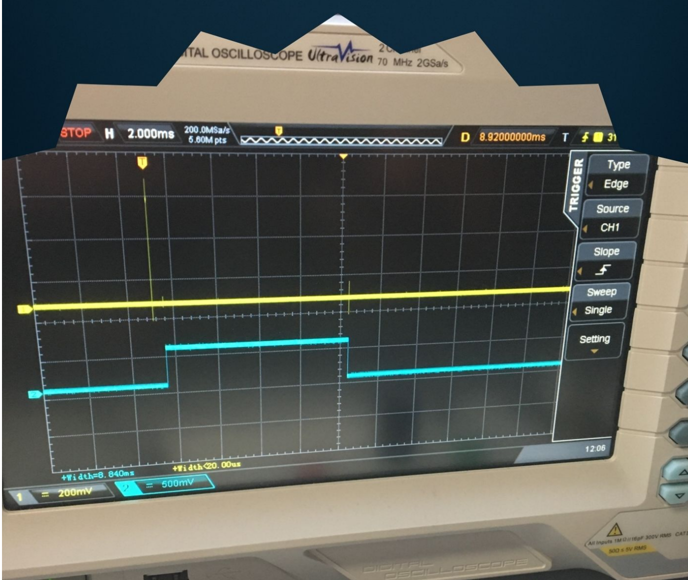
OSCILLOSCOPES

A “GETTING STARTED” GUIDE



Peter Dalmaris, PhD

Oscilloscopes

Getting Started

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What is an oscilloscope?

Oscilloscopes For Busy People guide series

What is an oscilloscope?

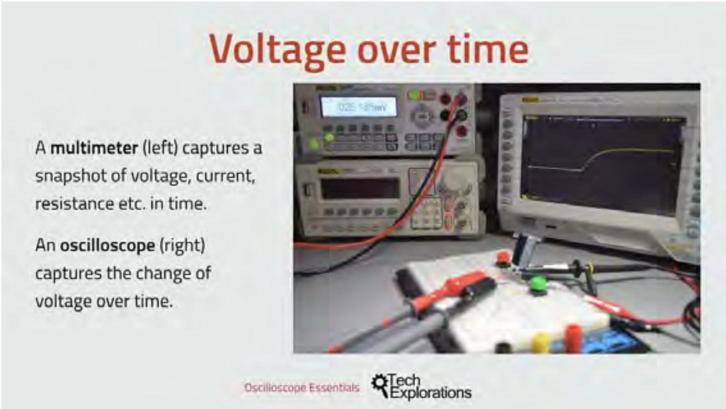
In this introductory article, I’ll explain what an oscilloscope is, what we use oscilloscopes for, and what kinds of oscilloscopes there are.

An oscilloscope is a test instrument that displays a waveform of voltage as it changes over time.

After the multimeter, it’s probably the instrument that most people that work with electronic circuits acquire, in one of its various forms.

In this section, I’ll talk about the various aspects of an oscilloscope, such as the most important features, functions, and controls.

But in this introductory article, I’ll explain what an oscilloscope is, what we use oscilloscopes for, and what kinds of oscilloscopes there are.



The oscilloscope and the multimeter.

While a multimeter gives you the ability to measure things like voltage, current, resistance and capacitance at a single moment in time, an oscilloscope allows you to capture information about voltage and how it changes over time.

Take the example in the image (above).

I have connected the multimeter (on the left) to measure the voltage across the pins of the capacitor.

I have also connected the oscilloscope to measure the same voltage.

When I press the green button to charge the capacitor, the multimeter will show me the current voltage on the capacitor. As the capacitor charges relatively quickly (at least in human terms), the multimeter will show me a quick jump from close to zero Volts to the 5V input that my power supply provides.

If I only have the multimeter to work with, the transition from 0V to 5V seems to have happened instantaneously.

With the oscilloscope measuring the same thing, however, this experiment teaches us a different lesson. Because the oscilloscope measures and records the voltage on the capacitor over time, it is able to draw a graph.

You can see the graph in the display of the oscilloscope in this photograph. It clearly shows the voltage being close to zero when the capacitor is discharged. It shows exactly when I pressed the green button and what happened immediately after that.

It shows how the voltage increased, edging closer to the supply voltage over time.

And now that I have captured this waveform, I can make very precise measurements to find out the exact rise time, among other things.

This is what I really find amazing about the oscilloscope. It helps me understand electronics because I can literally see them in operation, rather than through a series of "before" and "after" snapshots.

It's really the difference between still photography and videography. Each has its purpose, but videography allow you to tell a story in a way that photography can't.

The oscilloscope can show how voltage changes over time.

An oscilloscope stores a lot of data about a signal. For example, my lower-middle of the range oscilloscope can store 2 million samples and capture up to 2 billion samples per second. And this is per channel.

There’s a lot of data there that the oscilloscope and the user can use for signal analysis.

Most modern oscilloscopes can perform automatic measurements and decoding of the information that is encoded in a signal.

I’ll talk more about both capabilities later in this section and throughout the experiments in this course.

Measurement and decoding is the reason why you would want to use an oscilloscope, and again, both depend on the ability of the oscilloscope to capture a lot of data about the signal and how it changes over time.

In the photo in this slide, you see the same signal I captured as the capacitor in my test circuit charged. I asked the oscilloscope to give me the measurements for the rise time, the maximum and minimum voltages, and the peak-to-peak voltage, and it did. The measurements with additional statistics appear below the chart.

When I say “I asked”, I mean that I pressed a few buttons to bring up these measurements. But, these interments are become more clever all the time, so it is not long now before I will be able to talk to my oscilloscope, as I talk to my phone.

How amazing would that be?

At this point, let’s recap:

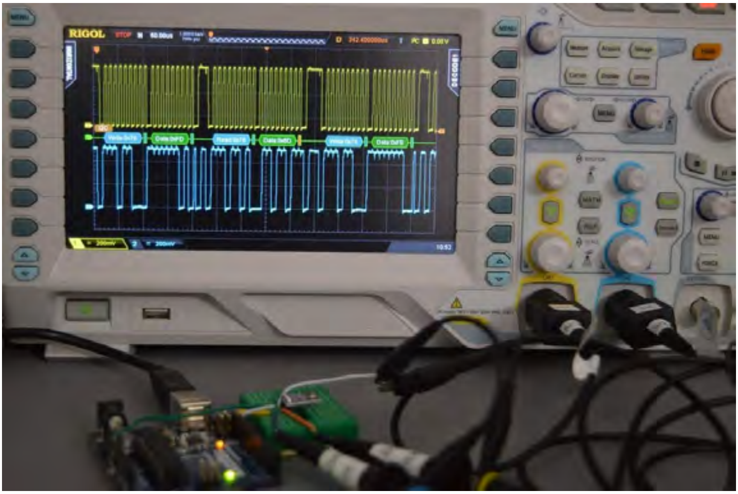
We use the oscilloscope to capture voltage over time for a signal, and then we use the data about the signal to analyse the signal and learn thing about it. We can measure many characteristics about the signal, and also extract any information that may be encoded in the signal. The later capability is called “decoding.”

Not surprisingly, oscilloscopes come in a few different types. There are many ways to create categories of things, but to keep things simple I have categorised them here based on their underlying technology and form factor.

The form factor controls most other aspects of how the oscilloscope works, so it seems like a reasonable choice.

An example of an analog oscilloscope (obsolete). By Elborgo – Own work, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=2841283

The first oscilloscopes were analog. The lack of digitisation meant that they could do only very basic signal analysis. Most of the measurements were done manually, using cursors and the display divisions. This is what oscilloscopes looked like when I started using them in engineering school. For all practical purposes, they are obsolete.

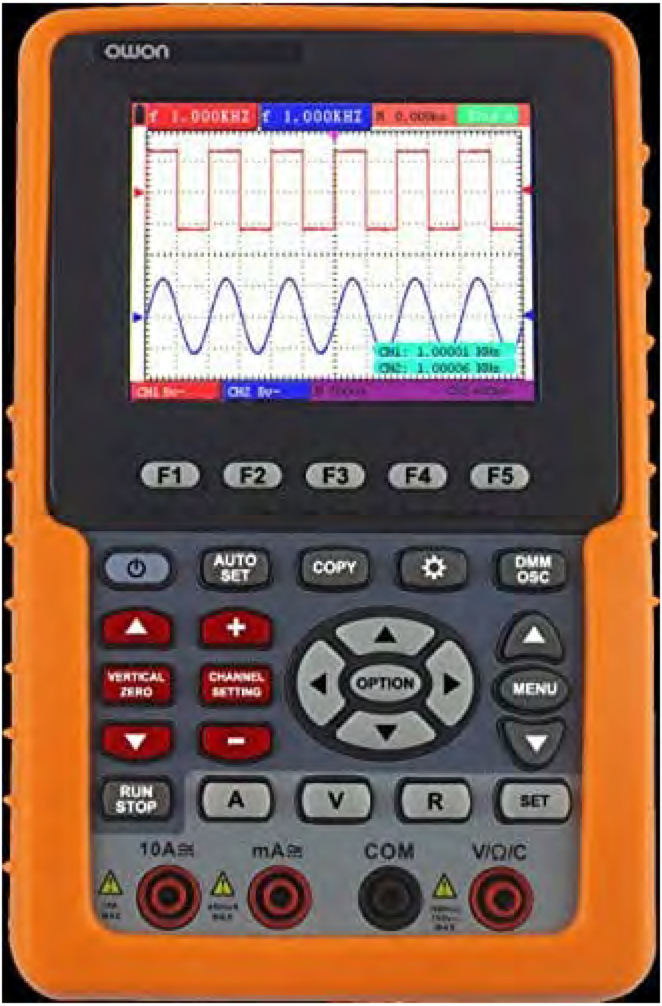


A modern digital bench-top oscilloscope.

Today, oscilloscopes are digital. The come in various form factors. In the middle photo, you can see my bench-top oscilloscope. It has is a fully sized instrument, with a decent size screen and a full array of buttons. It also contains a powerful microprocessor, memory and signal processor. These things combined, make work with this oscilloscope quick and enjoyable. This is an important factor when you are deciding on which tool to get. It has to work well in order to help you get your work done. It makes no sensor to get an instrument that delays you or just doesn’t work as it should.

A modern PC/USB oscilloscope.

In the right, you can see another modern digital oscilloscope. This one has no user interface, other then the connectors. This is a PC or USB oscilloscope, and it needs a computer. The USB oscilloscope uses the computer for the display, and the user interface. The cheaper USB oscilloscopes also use the computer for most or all of the processing. Their main function is to capture data from a source and then pass the data to the computer for display and analysis. The great advantage of a USB oscilloscope over other types is the price and the size. They can start at a lot less than $50, and they do provide basic oscilloscope capabilities. For not much more, you can even get decoding. I’ll show you how to use a low-cost USB oscilloscope along side my bench top oscilloscope in this course.



Owon HDS1021M portable oscilloscope

I also want to mention that there are oscilloscopes that are both tiny in size (like a USB oscilloscope) but don’t require a computer. What you are seeing here is an example of a portable oscilloscope. It has a screen to show waveforms, it can do measurements and even decoding, and it even has a few hardware buttons so you can be fairly productive.

People typically use a portable oscilloscope as a complement to a bench top instrument, for example, when they travel.

Oscilloscope specifications

With this article, you will learn the meaning of the most important specifications of an oscilloscope in a simple and practical way.

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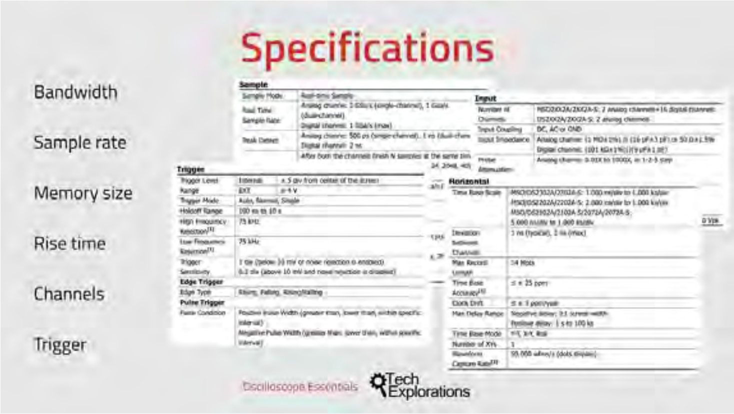
The technical specifications of an oscilloscope can easily fill several pages in table format. Similar to when you are looking for a new car or a new computer, you should focus on what is important first, because the details matter a lot less. Your objective is to find an oscilloscope that fits your budget, and allows you to measure the things that you want to measure.

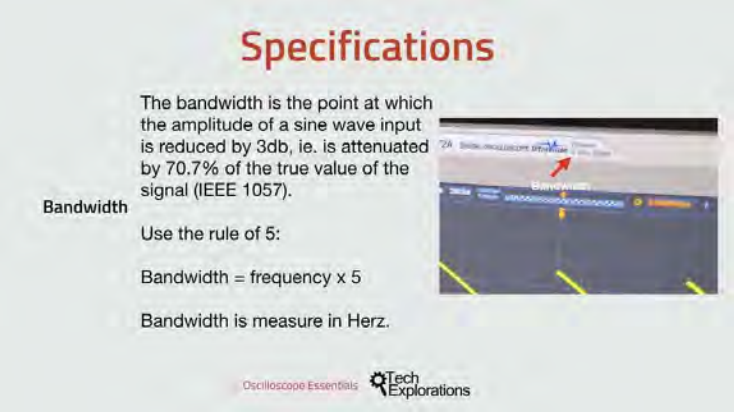


Oscilloscope specifications can be daunting

Bandwidth

Probably the most important specification of an oscilloscope is its bandwidth. The bandwidth of the the scope governs the maximum frequency of the signal that it can capture and analyse.

As the frequency of the signal gets closer to the maximum frequency that the oscilloscope can work with, its accuracy drops.



The bandwidth of the the scope governs the maximum frequency of the signal that it can capture and analyse

To figure out what bandwidth your oscilloscope should be, use the rule of 5:

> “figure out what is the highest frequency in a test signal you’d like to measure, and multiply it by 5.”

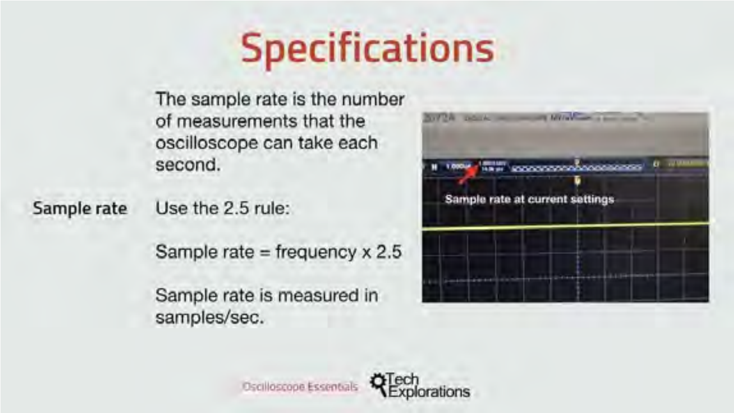
That’s your oscilloscope bandwidth.

For example, if you want to work with an at its’ maximum 20MhZ clock speed, you will need an oscilloscope that is rated at 100MhZ.

Beware though that this is the Arduino internal clock speed. If you want to work with Arduino PWM signals, then their frequency is just 490 Hz. Or if you want to work with I2C communications between an Arduino and a sensor, you will typically work at 100KHz. So, you can see that even at 20Mhz or 50Mhz of bandwidth, your oscilloscope is perfectly capable to work with most of the kind of signals you are likely to encounter.

Sample rate

The next important specification of an oscilloscope is its sample rate. The sample rate is the number of samples that the oscilloscope is capable of capturing per second. Obviously, the more, the better. But higher sample rates require more and faster memory to store, and faster electronics and processor to capture and process, driving up the price of the instrument.



The sample rate is the number of samples that the oscilloscope is capable of capturing per second.

As with the bandwidth and other technical decisions we are often called to make, we need to choose an instrument with a sample rate that is good enough for our purposes.

> A rule of thumb is to multiply the highest frequency you are likely to encounter in your work with the oscilloscope, and multiply by 2.5.

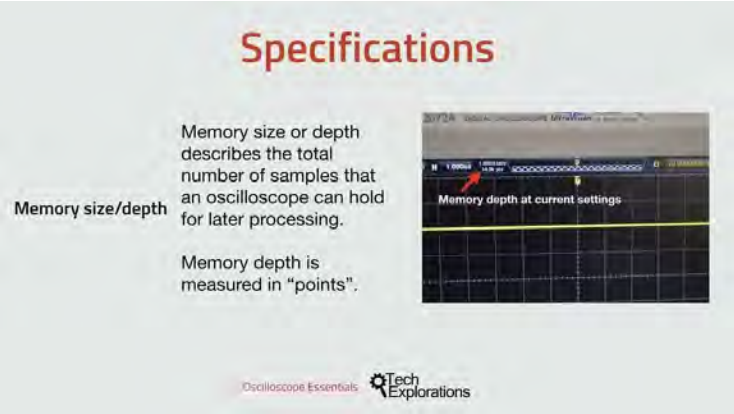
For example, if you want to work with an I2C signal at 100KHz, multiplying this frequency by 2.5 will give you a sample rate of 250,000 samples per second. Most digital oscilloscopes these days can easily handle this.

Memory size/depth

Very closely related to the oscilloscope sample rate is its memory size. As the oscilloscope samples the signal from the test circuit, it stores the waveform data in its memory.

Manufacturers report the memory size of their oscilloscopes using the term “memory depth”, and instead of using the regular byte unit, they use the “points” unit.

An oscilloscope that is quoted to have a memory depth of 54 Mpts can record a total of 54 million samples in its memory. This is divided among the input channels. So, if your oscilloscope has a memory depth of 54 million points, and you are recording on two channels, then each channel will have a memory depth of 54/2 = 28 million points.



Manufacturers report the memory size of their oscilloscopes using the term “memory depth”, and instead of using the regular byte unit, they use the “points” unit.

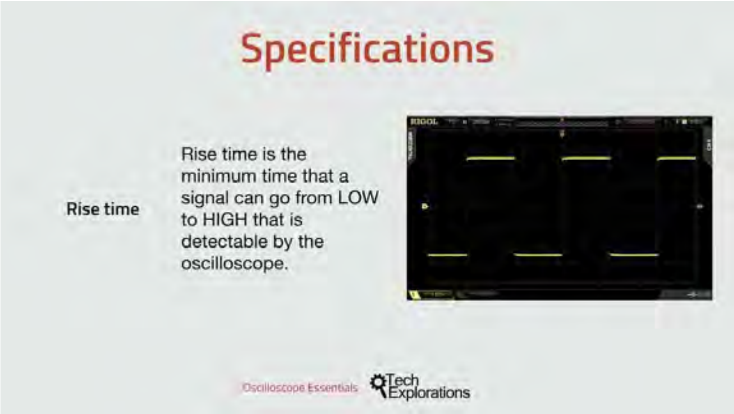
Of course, memory depth and sample rate go hand in hand. As the sample rate increases, the oscilloscope will need a larger memory to be able to record events that take place within a unit of time.

This about this: Say you want to record a waveform as it changes within 1 second. If your sample rate is 1000 samples per second, then you will need a memory with depth of 1000 points to store all samples. But if your oscilloscope is double as fast and can sample at 2000 samples per second, then you will need a memory depth of 2000 sample to do a full recording for the 1 second event.

Because of the close relation between the sample rate and the memory depth, modern oscilloscopes will automatically manage the sample rate depending on the time scale you have chosen so that the available memory is always filled.

Rise time

The Rise time of an oscilloscope describes the ability of the instrument to detect and capture rapidly rising and falling signals. This is particularly important when we work with square waves that have very sharp edges. A square wave can rise from 0V to 5V within nanoseconds.



The Rise time of an oscilloscope describes the ability of the instrument to detect and capture rapidly rising and falling signals.

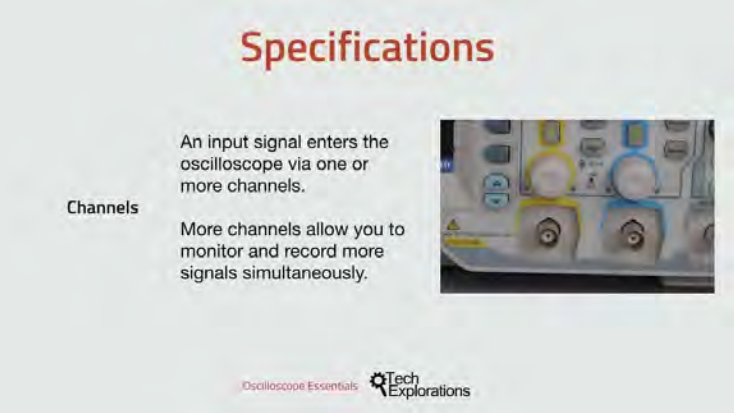
For the oscilloscope to be able to display the waveform of such signal precisely, it must be able to detect such rapid changes.

For example, my oscilloscope has a rise time of 5 nano seconds, which means that the fastest rise time it can detect is 5 nano seconds.

Channels

Oscilloscopes typically offer 2 or 4 channels.

Each channel has a separate connector where you can attach a probe, and through this probe to monitor a signal.



Each channel has a separate connector where you can attach a probe, and through this probe to monitor a signal.

An oscilloscope with 2 channels allow you to work with two signals at the same time, and decode data that flow in up to two wires (such as UART serial and I2C).

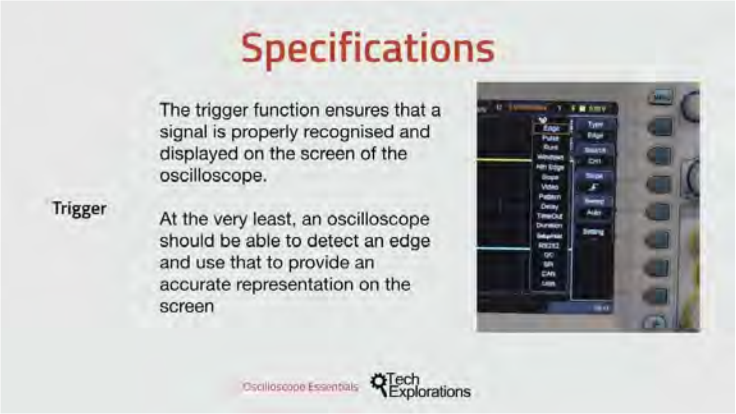
An oscilloscope with 4 channels allow you to work with up to four signals at the same time, and decode data that flow in up to four wires, such as SPI or a 4-bit parallel bus.

More channels can translate to a need for a larger memory depth and of course cost.

Trigger

The trigger of an oscilloscope is fundamental to its operation. The trigger is the mechanism through which the oscilloscope can recognise a specific attribute of the input signal. Based on this attribute, the oscilloscope can achieve synchronisation.

You know that the oscilloscope is in synch when the graphical representation of the signal on the screen is clear and stable.



The trigger is the mechanism through which the oscilloscope can recognise a specific attribute of the input signal.

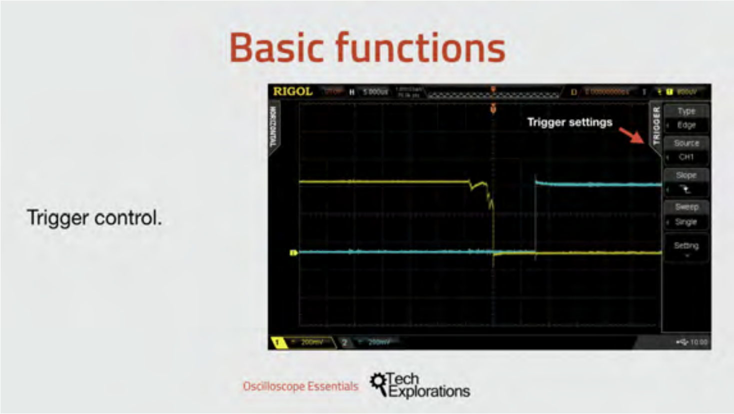
At the very least, a digital oscilloscope should be able to recognise an edge, upslope or downslope.

But in many cases, oscilloscopes can detect many different kinds of attributes of a signal.

For example, my oscilloscope can detect edges, pulses, and runts, among many others, all of them configurable to very precise specifications. You will be spending a lot of time to configure the trigger before each experiment in this course.

Basic functions

Let’s have a closer look at the basic functions on a digital oscilloscope.



An oscilloscope, really, does only one thing: it captures a representation of a live signal from a test circuit and displays it on a screen. Most often, this representation is the voltage of the signal as it changes over time.

Based on the information that the oscilloscope captures about the signal, modern digital oscilloscopes ofter two other important functions:

1. the automatic measurement of various parameters of the signal, like its frequency, peak-to-peak voltage, duty cycle and rise time, and

2. For signals that encode information, to decode that information and display it on the screen. For example, if the oscilloscope has captured the waveform that encodes serial UART information, we can set it so that this information is extracted from the waveform and displayed on the screen.

Almost all modern oscilloscopes offer these capabilities. The extend of their ability to automatically measure and decode differs between models and budgets.

Let’s have a closer look at the basic functions on a digital oscilloscope.

Plot signal waveform

The first and most important function of an oscilloscope is to display a signal, live, on its screen.

As the signal changes, the oscilloscope updates its display in close real time to reflect this change.

In this example, I’m chaining the duty cycle of a PWM signal using a potentiometer, and the oscilloscope is able to show the signal as it changes on the screen.

In this example, also notice the row of measurements below the graph. Those are also updated in real time.

Capture a waveform

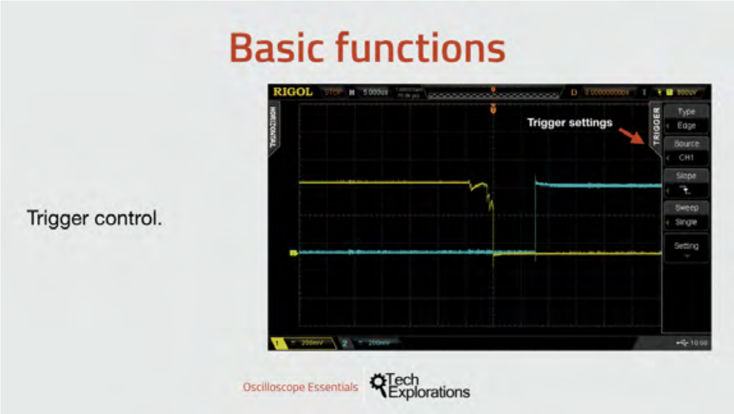
Often, we want to capture or “freeze” a waveform so that we can examine it more closely. This allows us use to use tools like the cursors or enable multiple automatic measurements to look at specific parts of the waveform that is of interest.

In this small example, which comes from one of the experiments in Oscilloscopes for Busy People, I have captured a single waveform that was produced by the press of a momentary button. With the waveform captured, I can then go ahead and use the cursors to make a measurement. At the top right corner of the oscilloscope, notice the red "Run|Stop" button, indicating that what I am looking at is the waveform captured and frozen in time, not a live waveform.

Trigger control

The trigger is a fundamental function of any oscilloscope. A trigger is defined by a full set of configurations that we use to prepare the oscilloscope to be able to recognise the waveform that we want to examine.

A trigger works by detecting a specific change in the signal it is monitoring, such as going from 0V to 5V within between 1 ms and 5 ms. Remember, triggering is all about change, and the type of change we expect in a signal.



A trigger works by detecting a specific change in the signal it is monitoring.

Modern oscilloscopes can detect many kinds of signals out of the box based on the changes in the voltage over time.

Most oscilloscopes have an automatic trigger function that can figure out how to capture regular, periodic signals without the user having to define its characteristics. This makes oscilloscopes user friendly so that people with no experience in using them can make simple measurements.

On top of this, oscilloscopes offer many types of signals that we can select and configure manually. In the screenshot in this example, I have set my oscilloscope to look for the most common kind of signal change, an Edge, coming from Channel 1, that goes from High to Low, and that is triggered when voltage drops below 800 microVolts (uV).

In the experiments in this course, I'll show you how to use a variety of triggers, like Edge, RS232 and I2C.

Measurements

Modern oscilloscopes can measure multiple parameters of a live signal, and show the results of the measurements on the screen.

In Oscilloscopes for Busy People, I'll show you many examples of measurements in each of the experiments in this course.

In this video clip, the oscilloscope is automatically measuring the frequency, period, and the maximum voltage of the waveform on the screen.

It's doing this "live" and updates these measurements multiple times per second. You can see the results of the measurements just below the graph. The measurements include the current measured value, the average, minimum and maximum values.

Decoding

A more advanced, but common, feature of modern digital oscilloscopes is the ability to decode a signal that contains information. When two devices communication, they use a specific protocol so that data can travel between them. For example, in micro controller and microcomputer applications, common protocols are serial UART, I2C, SPI, and CAN.

The protocol describes how a value, like a number or a character, is encoded into a waveform with a specific shape.The waveform, with this shape, contains information. At the receipt end, a device reverses the translation to extract the information contained in the waveform.

Oscilloscopes with decoding capability can eavesdrop in the communication between two devices, and extract the information that is contained in the waveform, as it travels through the wire.

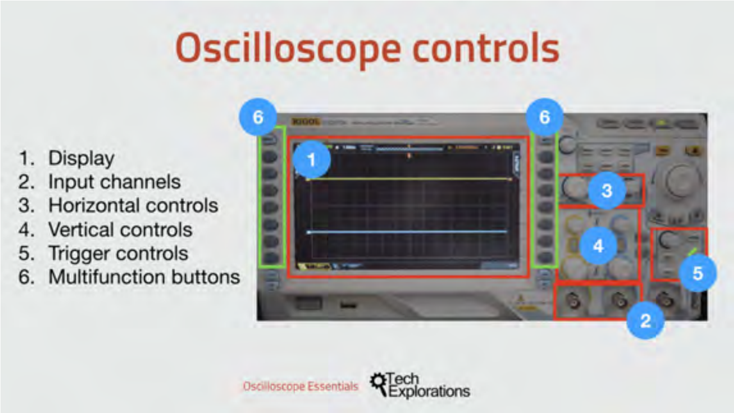
In this video clip, which I've taken from one of the experiments in this course, the oscilloscope is decoding serial UART communication between an Arduino and a computer.

By decoding communication between devices, you can troubleshoot problems and confirm that your hardware is working as expected.

Before I finish this lecture, I want to mention that although oscilloscopes can do decoding of signals, this is really an add-on feature. There are other instruments, called "logic analysers" that are specialised for this specific task.

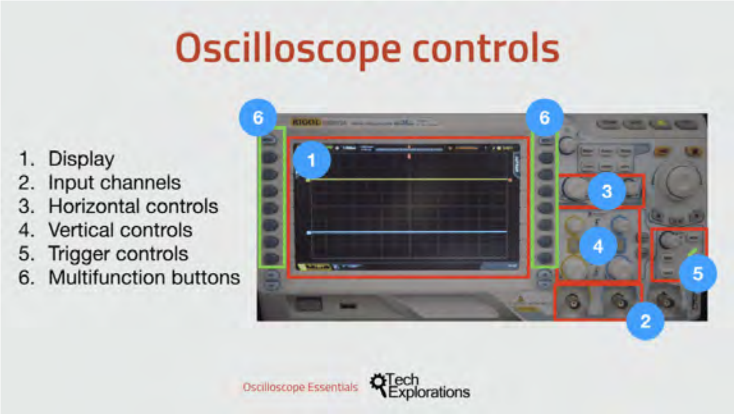
Basic controls

In this article, I write about the basic controls that you find on any oscilloscope and show a few examples of how these controls work on my oscilloscope.



At first glance, the oscilloscope looks like a very complicated instrument. Rest assured, there is a lot of logic and reason behind its design, and once this logic is exposed, you'll really enjoy working with it.

In this lecture, I'll talk about the basic controls that you'll find on any oscilloscope. I will also show you a few examples of how these controls work on my oscilloscope. Don't worry too much about the specifics of which knob and button does what, but pay attention to what the do. The specifics of "how" differ between oscilloscopes made by different manufacturers, but the "what" they do does not.



The basic controls of an oscilloscope.

The display

The display is where everything happens.

At the very least, it shows the signal waveform.

Virtual all modern oscilloscopes will also show the time (horizontal) scale, voltage (vertical) scale and trigger settings. They will also show automatic or manual measurements, any cursors you may have activated, and the position of the part of the waveform you are able to see in the display in the memory buffer.

Inputs

All oscilloscopes offer at least two inputs, where you can connect the probes that convey the signal from the test circuit. Once you connect the probe, and attach its tip and ground lead to the test circuit, you can setup your oscilloscope to receive the signal. Each input has its own independent set of parameters that you can set.

In this video, I’m browsing through some of the options available for Channel 1. I can set the the coupling to DC, AC, or Ground, the probe ratio, the probe input impedance, the polarity of the signal, and a few other parameters. Don’t worry about what each of these parameters do, for now. You will learn about them later in this course.

Horizontal controls

The horizontal controls allow you to play around in the time domain.

This means that you can control two things that belong to the horizontal axis in the display.

First, you can set how much time is represented by each horizontal division. You can turn the scale knob to increase or decrease the amount of time captured in each division. My oscilloscope, has a total of 14 horizontal divisions, so once you have set the time scale you can multiply it by 14 to work out how much time the screen contains.

Second, you can set the horizontal position of the waveform. Turn the position knob to move the waveform left or right.

Vertical controls

The vertical controls allow you to play around in the vertical (voltage) domain.

Just like with the horizontal controls, in the vertical dimension you can control two things:

First, you can set the voltage differential that is represented by each vertical division. You can turn the scale knob to increase or decrease the voltage per division. My oscilloscope, has a total of 8 vertical divisions, so once you have set the voltage scale you can multiply it by 8 to work out the voltage differential between the top and the bottom edge of the screen.

Second, you can set the vertical position of the waveform. Turn the position knob to move the waveform up or down.

Trigger controls

The trigger controls allow you to set the oscilloscope to be able to recognise the signal that you want to capture and measure.

Without a set trigger, the oscilloscope will not know what to do. Triggering depends on a change in the signal that can be treated like a signature. When the oscilloscope detects this change, it knows that this is the part of the signal that you want it to capture, so it starts recording immediately.

Let’s stop here with the discussion of oscilloscope controls. In the experiments that follow in this course, you will get a lot of practice on how to use each and every one of them, and quickly develop an intuitive sense of what they do.

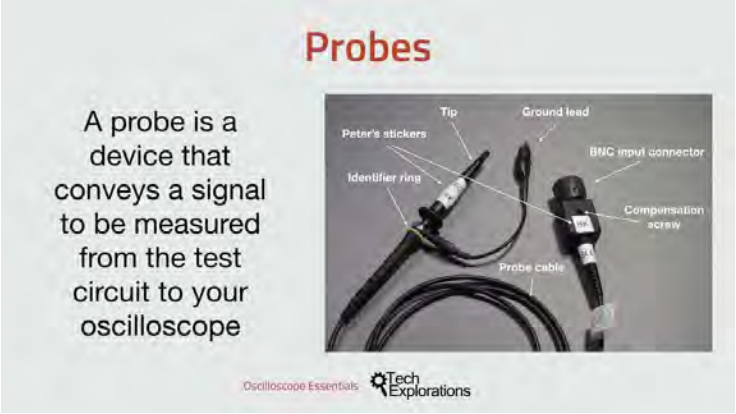
Let’s move over to the next lecture where I will talk about probes.

Oscilloscope probes

Oscilloscopes For Busy People guide series

Probes

In this article, I discuss the device that allows you to connect a circuit to your oscilloscope so that you can take measurements.

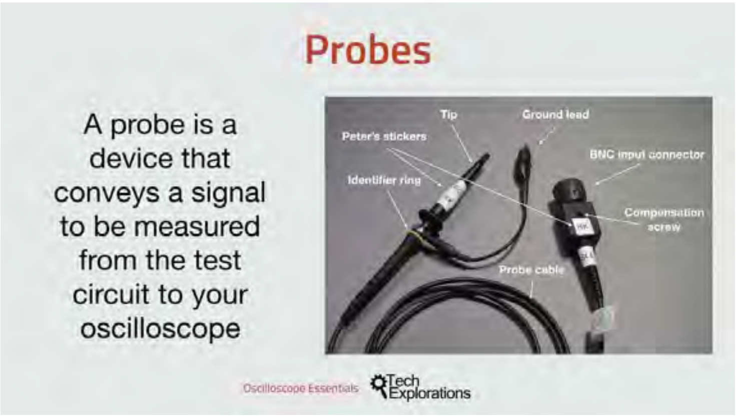


In this article, I discuss the device that allows you to connect a circuit to your oscilloscope so that you can take measurements.

We’ll have a look at the types of probes that are available, their most important specifications, and how to use them. Probes is a big topic on its own. In this lecture I am only covering the basic and most important concepts.

Your oscilloscope must be physically connected to your test circuit in order to make a measurements. This happens via a test probe. A probe is a device that conveys the signal to be measured from the test circuit to the oscilloscope.

Naturally, we want our measurements to be as accurate as possible, and therefore the probe is important to not modify the original signal in any way. Or at least, if it does modify it is some way, it should be done in a controllable and predictable way.



A passive probe, annotated.

In this image, you can see one of my probes. Let’s have a look at the parts that make up this probe.

At one end, on the left, you can see the probe tip. The tip comes in a few different types, like a hook (the type I use in this course), a point (I’ll show you an example shortly), or a spring. The tip is the part of the probe that we attached to the location of a circuit from where we want to take a measurement.

In the middle of this photo you can see the ground lead. The ground lead is physically attached to the handle of the probe, and usually is made up of a crocodile clip. We attach the clip to an appropriate ground point to provide a voltage reference for our measurement.

On the right of this photo, you can see the input connector. This is how we connect the probe to the oscilloscope. The connector comes in a variety of types. The one in this photo is a BNC connector, which is more common. There are also SMA connectors, similar to those used to connect an antenna to a radio modem.

The BNC input connector is attached to a small black box. In the back of this box is an opening that gives access to a screw. This is the compensation screw that allows us to improve the electrical characteristics of the probe so that it can convey a better signal from the test circuit to the oscilloscope. Hold on to that thought for now, I will talk more about attenuation in a minute.

Also notable in this photo are my stickers, and the identifier ring. I use stickers to clearly mark the role of a probe so that I don't make silly mistakes when I connect them to my circuit.

The hook

In this photo you can see the hook.

The hook is the most common mechanism for attaching the probe to a circuit.

The hook is contained inside a spring-loaded cover. Pull the cover down to expose the hook, and attach the hook to a wire or pin that you want to use as input. Then release the cover to reduce the amount of metal that is exposed, and secure the connection.

I'll be using the hook in the experiments in Oscilloscopes for Busy People because it is quick to snap on the circuit, and once is connected I don't have to continue to hold on to the probe.

The pin

If you need to measure a signal available through a really small surface, like a pad of an SMD component, you can use the pin. Expose the pin by removing the hook assembly.

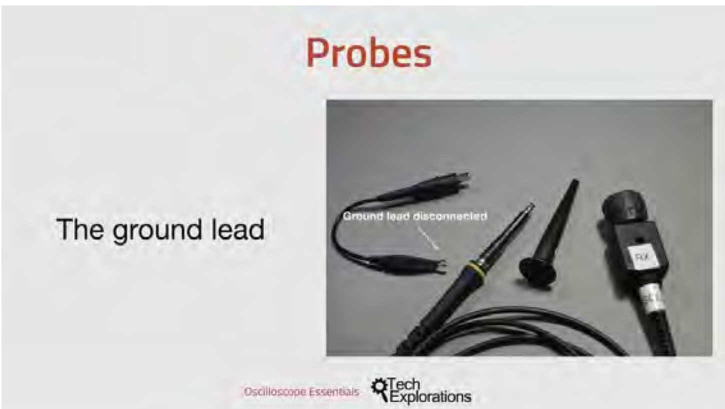
Most probes contain a pin under the hook cover.

In my probe, I can turn the hook assembly as if it was a screen to release it from the handle.

The pin allows you to connect the probe to very small places, by it's not a hands-free operation: you'll have to hold it in place.

The ground lead

In most probes, you can disconnect the ground lead and replace it with a different type. Perhaps you need a different way for the lead to latch on a ground source such as a spring, or a longer lead. Most probes make is easy to interchange these parts.



The ground lead is usually detachable.

Attenuation selector

Some probes include a switch on their handle. This is the attenuation selector. This switch allows you to change the range of the input voltage that the probe, and as an extension the oscilloscope, can work with.

For example, imagine that your oscilloscope is only rated to be able to safely measure signals from -5V to +5V.

If you use a 1X attenuation probe, then you must ensure that the part of the test circuit that you connect your probe to stays within this range.

But, what if you want to measure a signal that goes up to 20V?

This switch allows you to change the range of the input voltage that the probe

Just flip the red switch to 10X, and your oscilloscope can now (safely) measure a signal of up to 5V x 10 = 50V.

To make this work, you must also set the ratio or attenuation setting on the oscilloscope to match the value of the switch on the probe.

Compensation screw

Let's return to the reason of the existence of the compensation screw which I mentioned earlier.

By turning the compensation screw, we can achieve a better signal on the oscilloscope

The casing where the input connector is attached contains an RC network. We can adjust the properties of this RC network so that we can achieve a constant attenuation over the probe’s full bandwidth. In simple words, by turning the compensation screw, we can achieve a better signal on the oscilloscope.

A quick reminder here: attenuation is the effect the resistance and capacitance have over the strength of a signal.

Because a probe has both resistance and capacitance, the signal that flows through it is attenuated, that is, it looses some of its strength by the time it gets to the oscilloscope. As long as this attenuation is constant across the full bandwidth of the probe, that’s no problem. But if it isn’t, then we end up with a signal that is weakened at different rates across the bandwidth, and that is not ok as we end up with a signal in the oscilloscope that is very different to the original. This is why we need to compensate the attenuation before we start using the probe.

I’ll show you how to do this in the next section.

Types of probes

There are several different types of oscilloscope probes: Passive, active, differential, and current.

In Oscilloscopes for Busy People, I'll be using the passive probes that came with my oscilloscope. Nothing fancy, and great to work with all the typical circuits, like low speed electronics, voltages around 5V that microcontrollers work around and digital communications.

There are many kinds of probes.

A passive probe contains only passive components, like resistors and capacitors and usually an attenuation compensation circuit. They are cheap, and excellent for general purpose measurements.

Active probes contain active components, like amplifiers. They are better at measuring very small and weak signals, or high-speed signals, say above 500MHz.

Finally, differential probes are designed to measure the difference between two signals instead of their absolute values. They are typically used to measure high-frequency signals or signals with very low amplitude.

I also want to make a mention to current probes. A current probe allows us to measure current instead of voltage, using a Hall-effect sensor that can measure the magnetic field that is generated by a DC current as it passes through the probes ferrite core.

Ready for some serious learning?

Enrol to

Oscilloscopes for Busy People

Demystify the oscilloscope and learn how to use it in your projects.

This course is perfect for people who have never used an oscilloscope.Through a series of projects, this course will teach you how to use an oscilloscope to measure and decode signals in your electronics.Just click on the big red button to learn more.

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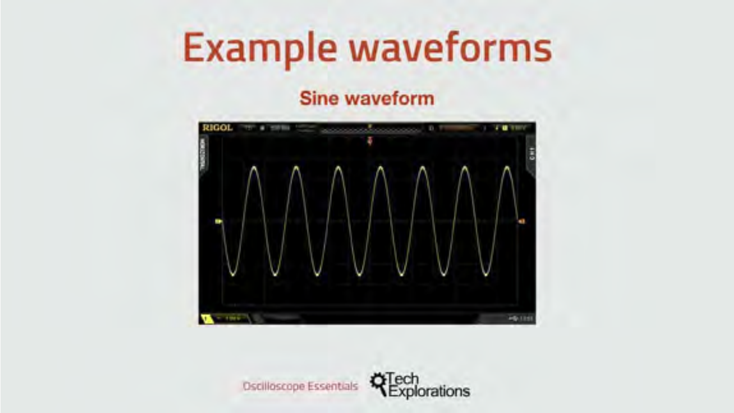
Example Waveforms

Oscilloscopes For Busy People guide series

Example Waveforms

In this article I’ll show you some of the waveforms that you will typically see with your oscilloscope. Sine, square, triangular and step waveforms are examples of signals that we commonly see.



In this article I’ll show you some of the waveforms that you will typically see with your oscilloscope.

There’s a few that you’ll see most often, but also some rare ones worth knowing about.

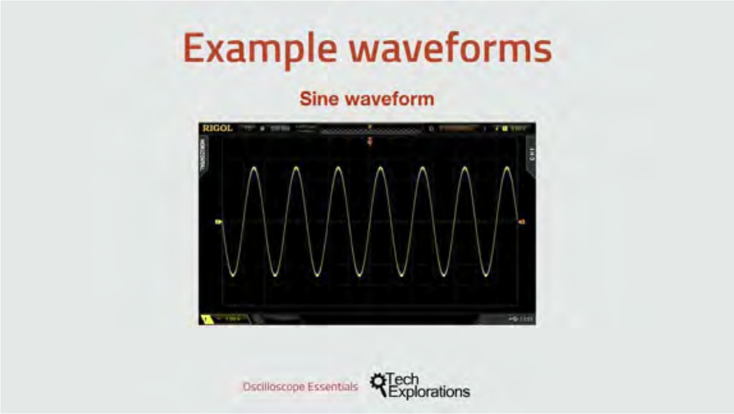
Oscilloscopes can display an infinite number of waveforms. All you have to do is to so supply it with some kind of voltage signal that changes over time, and it will display it on the screen.

However, there are certain waveforms that are regularly encountered in electronics.

Sine, square, triangular and step waveforms are examples of signals that we commonly see.

Let’s have a look at these, plus a few more.

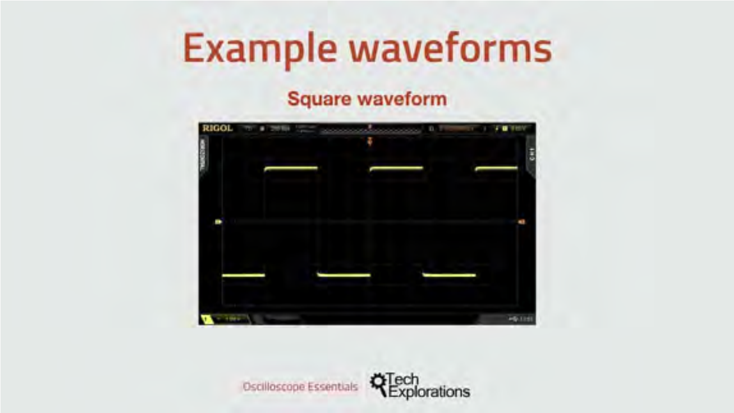
The sine wave



The sine wave is one of the most common waves you’ll see in an oscilloscope.

A sine wave is one of the most common waves you’ll see in an oscilloscope. A sine wave describes a continuous and smooth periodic oscillation. In comparison, the square wave, that you’ll see next, switches from one voltage level to another very abruptly.

The square wave



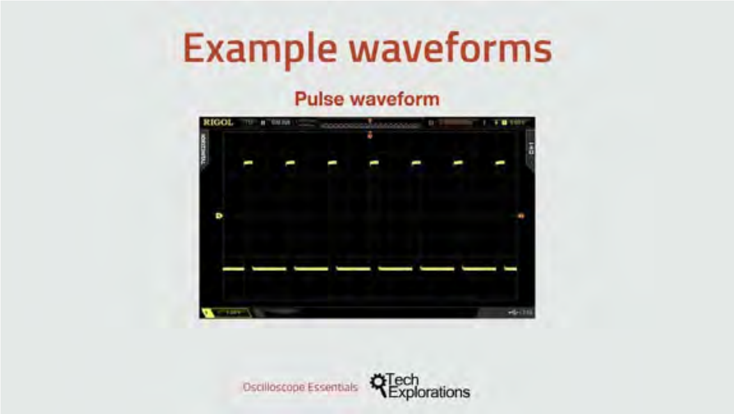
The square waveform (or is close relatives, such as the pulse), is the waveform that we work with the most

When we work with digital electronics, the square waveform (or is close relatives, such as the pulse), is the waveform that we work with the most. Digital electronics work with just a couple of voltage levels, high and low, and they tend to switch between these levels very quickly. Hence, in the oscilloscope they produce waveforms that look square.

The example you are looking at is almost perfect because it was produced by a signal generator. The signal generator is a device specifically designed to create very clear signals. As you'll see later in this course, real square waves are much noisier, but still work well for the purpose of transmitting information.

Let's have a look at an example of a relative to the square wave next…

The pulse wave

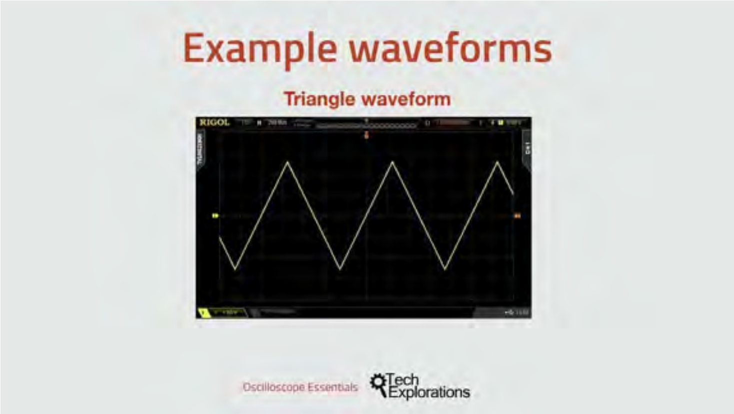


This is the pulse waveform.

This is the pulse waveform.

It’s called that because its voltage level is at low most of the time, and then is switches to High for a very brief amount of time before it goes back to Low. Of course, you can have the opposite, ie. a wave that spend most of its time at high and then switches to low for a brief amount of time.

The triangle wave



The triangular waveform.

The triangular signal has the voltage going up and down with a straight and regular slop. You can modify a triangular signal to produce a sawtooth or ramp waveform. I'll show you an example in a minute.

Noise

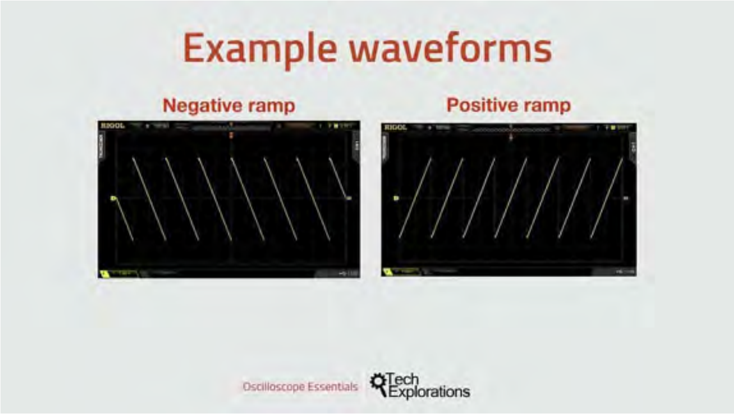
Noise.

Noise (not really a wave).

You can see something like this when the probes are connected to something that is noisy, or generates noise.

But you can also see a "noisy" signal if you are trying to display a non-noisy signal where the trigger is not properly set. The trigger is an important function and concept without which you cannot effectively operate your oscilloscope. You will learn about triggers later in this course.

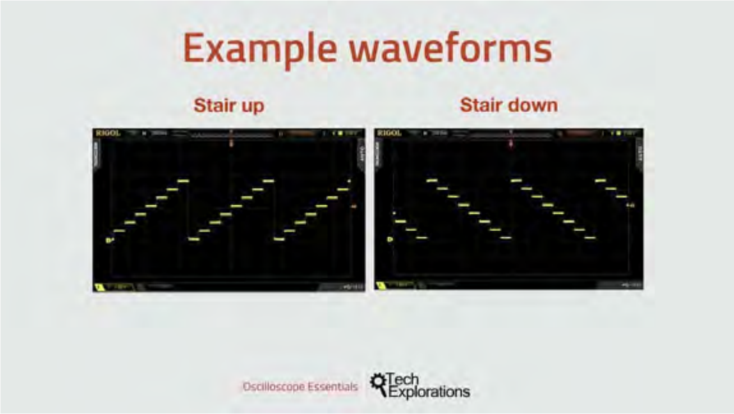
Ramp waveform



Ramp or Sawtooth waveform.

The Sawtooth (or ramp) is a relative of the triangular wave. Just remove one side of the triangle, and you get a ramp that is rising (positive) or falling (negative).

Stair waveform

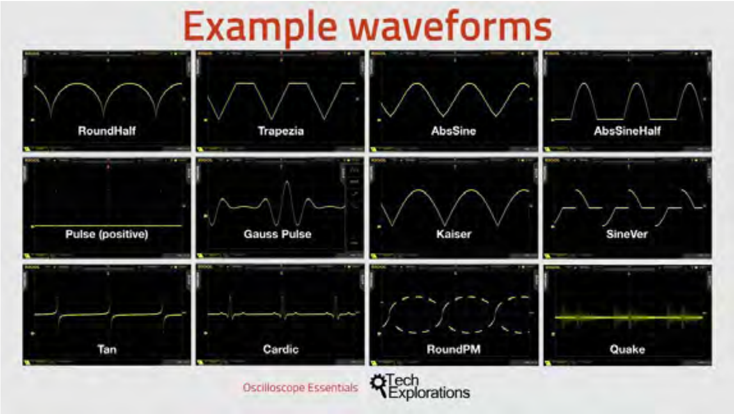


The stair waveform.

The stair waveform is a bit like the square waveform but instead of two levels, it has multiple. Like the ramp, we have stair waveforms that go up or down. In either case, the voltage level will switch to the very next level in the sequence.

You can also think of a stair waveform like a ramp. While a ramp is continuous (that is, it has an infinite number of in-between voltage levels), the stair has a finite number of voltage levels.

Other waveforms



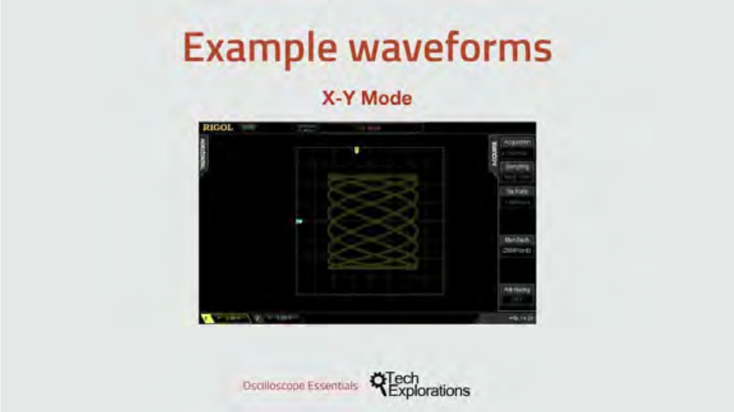
Other waveform examples.

In this slide I just want to show you some examples of the many other possible waveforms, and how they look in the oscilloscope. All of them are produced by the signal generator and are very rare in practice when you work with electronics, especially digital electronics (at least in my experience).

The one in the bottom right, the Quake waveform, depicts an actual earthquake. Your oscilloscope will be able to produce waveform is you connect appropriate probes that can detect earth tremors. Similarly, the second example in the bottom row, the Cardic waveform, is an actual waveform produced by the operation of a heart. Your oscilloscope can show your heart operation if you connect the appropriate probes .

Remember, any signal that changes over time, can be displayed by the oscilloscope.

X-Y waveform or “Lissajous figures”



Lissajous figures

Most of the time, you will be working in Y-T (Y over time) mode. That is the mode that you will use to display the waveforms you saw in the previous slides.

Most oscilloscopes, however, are also capable to operate in X-Y mode.

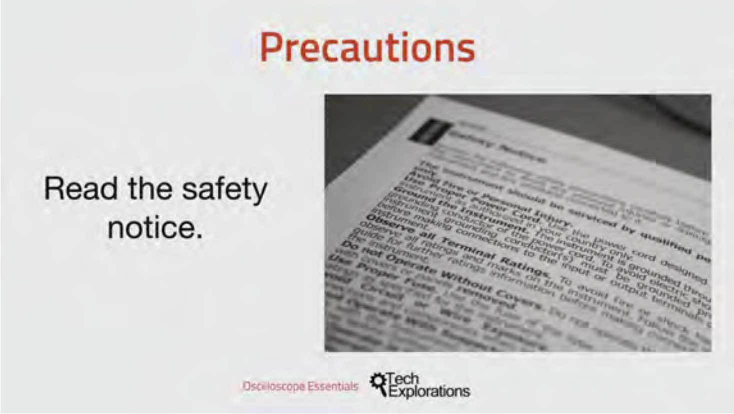
In X-Y mode, the oscilloscope takes input from both channels and creates a graph that combines the two signals in two dimensions. The signal coming through the first channel is used to control the X axis, while the signal from the second channel controls the Y axis.

In normal Y-T mode, the signal from either channel is used to control what is displayed in the Y axis whereas time controls what happens in the X (horizontal) axis.

The resulting graph is often called “Lissajous figures”. You are looking at an example in this slide. Later in this course, I will show you how to create such a figure.

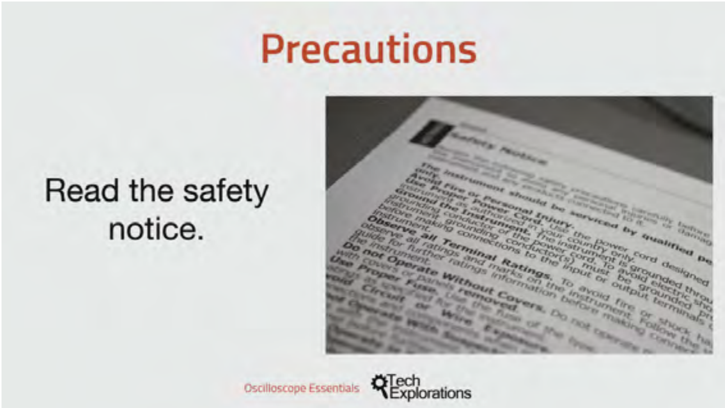
Precautions

In this article, I list a few simple ways by which you can protect your expensive oscilloscope from damage.



In this article, I list a few simple ways by which you can protect your expensive instrument from damage.

Read the manual



Always read the safety notice that is included in the user manual of your oscilloscope

Just like you do with all electrical appliances, always read the safety notice that is included in the user manual of your oscilloscope.

Much of the information in this notice is what you expect to see in any mains appliance:

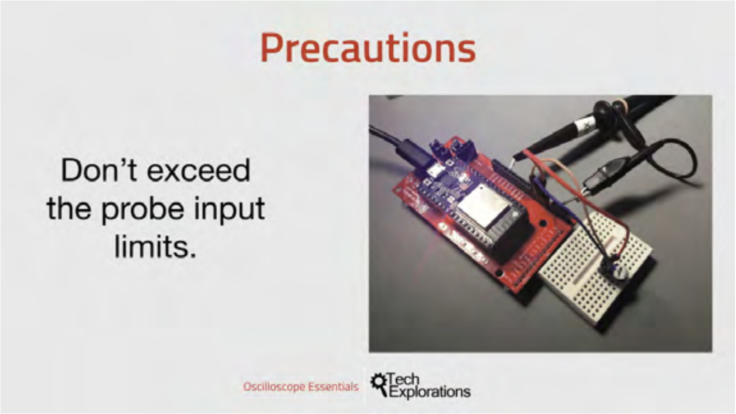
- Use the supplied power cord, which has a ground terminal and is appropriate for your country.
- Don’t operate it with the cover removed, that’s a big no-no.
- If you need to change the fuse, change it with one that has identical properties to the original
- Don’t operate the oscilloscope if it’s wet. This goes without saying, but there you go, I’ve said it!

Terminal ratings

Be sure it's ok to plug the power cord into the wall socket.

Observe the terminal ratings.My oscilloscope is rated for mains operation between 100 to 240 V and 45 to 440Hz so it is safe to plug into into practically any electrical outlet in the world. Yours might be different, so check first before you plug it into mains.

Input probe limits



Probes are rated to work within specific input voltage ranges.

Probes are rated to work within specific input voltage ranges.

For example, if your oscilloscope is rated for input voltages between -5V and +5V, don't provide input beyond these values.

These days, most decent oscilloscopes have build-in over-voltage protection so that the device can survive 5, 10, or even 100 times the voltage limit, but why risk it?

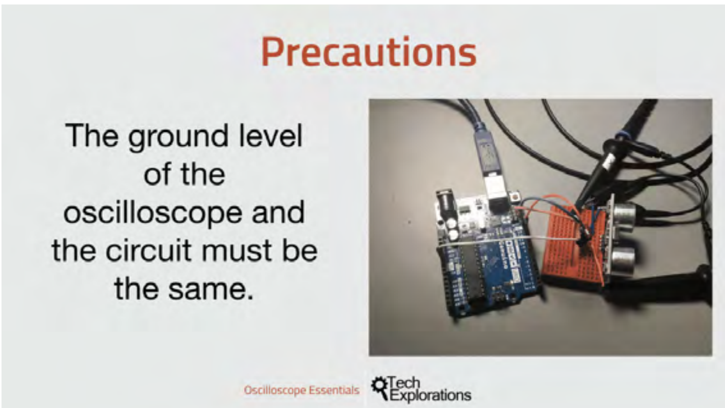
You can, in fact, use an oscilloscope with input range of, say, +-5V, to measure an input signal that goes far beyond that, say 500V. But the only way to do this safely, is to use a probe that is rated for the input voltage.

For example, you can use a 10X probe to measure input signals that are 5V*10 = 50V. A 1X probe allows you to measure input signals that fall within the actual input rating of your oscilloscope.

At this point, I must stress that I have personally never worked with such high voltages, and that doing so is very risky. I strongly advise you that you don't even try without the assistance and guidance of a qualified person.

Typical values for USB/PC oscilloscopes are +-5V, and for desktop oscilloscopes 40V.

Ground should be the same



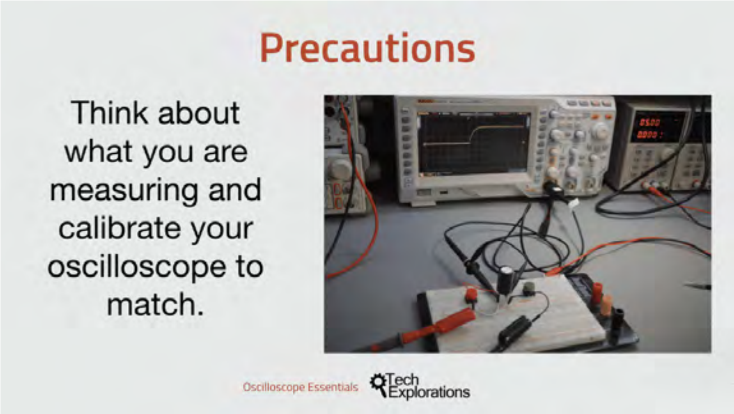
Your oscilloscope and whatever you are measuring must share the same ground level voltage.

Your oscilloscope and whatever you are measuring must share the same ground level voltage. Without a common ground, your measurements will not be reliable, and damage to your equipment and your circuit is also possible.

If you are using a USB powered oscilloscope, make sure that the computer that is powering the oscilloscope and the circuit you are measuring are properly grounded.

A tricky situation, especially for USB oscilloscopes, is when the computer is a laptop powered by its battery, and not connected to mains power and ground. In that case, the laptop ground and USB oscilloscope ground are floating. This is not a problem, and you can still take measurements reliably, but be very careful that the ground clip of the probe does not touch anything that is not in the same floating ground level. If it does, you will have a short circuit and damage will probably be the result of this.

Think before you measure



Before you connect the probes and turn on your oscilloscope, take a few moments to think about what is it that you want to measure.

Before you connect the probes and turn on your oscilloscope, take a few moments to think about what is it that you want to measure.

Then, make sure that your oscilloscope can actually make those measurements.

Finally, think about the calibrations you will need to make on the oscilloscope, and ensure that your probes or probe are appropriate for the task.

- Is your probe suitable for the input signal voltage and frequency?
- Is your probe compensation appropriate?
- How can you set the oscilloscope to capture the best representation of the signal that is

possible? What should the voltage and time scale be, as well as the trigger?
- Is the oscilloscope bandwidth appropriate?

Ask these question, get your answers, and your work with your oscilloscope will be a breeze. Through the experiments later in this course, you'll get a lot of practice to help you do just that.