




» 12 THINGS  
TO CONSIDER WHEN CHOOSING  
AN OSCILLOSCOPE

## 12 things to consider when choosing an oscilloscope

This is a quick guide to the most important criteria for choosing your next scope.

For a scope with a bandwidth above 1 GHz, or if you need one for special-purpose testing, you should probably talk to an applications engineer to help you make the right choice.

### There are several ways to navigate this interactive PDF document:

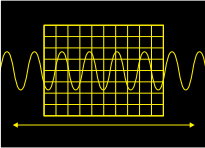
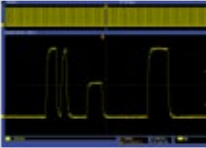
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- Use the navigation at the top of each page to jump to sections or use the page forward/back arrows
- Use the arrow keys on your keyboard
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- Click on the icon  to enlarge the image.

Mouse over the page example to see the navigation.

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# #7

## LONG RECORD LENGTHS

Record length is the number of points in a complete waveform record. A scope can store only a limited number of samples so, in general, the greater the record length the better.

**What you need**

Time captured = record length/sample rate. So, with a record length of 1 Mpoints and a sample rate of 250 MS/sec, the oscilloscope will capture a signal 4 ms in length.

Today's scopes allow you to select the record length to optimize the level of detail needed for your application.





A good basic scope will store over 2,000 points, which is more than enough for a stable sine-wave signal (needing perhaps 500 points). But to find the causes of timing anomalies in a complex digital data stream you should consider, for example, a DPO (Digital Phosphor Oscilloscope) with a record length of 1 Mpoints or more.

To search for infrequent transients such as jitter, runt pulses and glitches, select at least a mid-end scope that combines long record length with a high waveform capture rate.

Since an oscilloscope can store only a limited number of samples, the waveform duration (time) will be inversely proportional to the oscilloscope's sample rate. **Time Interval = Record Length / Sample Rate**

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## The digital storage oscilloscope: a brief introduction

Oscilloscopes are the basic tool for anyone designing, manufacturing or repairing electronic equipment. A digital storage oscilloscope (DSO, which this guide concentrates on) acquires and stores waveforms. It can show high-speed repetitive and single-shot signals across multiple channels to capture elusive glitches and transient events.

A scope shows the signal's frequency, whether a malfunctioning component is distorting the signal, how much of the signal is noise, whether the noise changes with time, and much, much more.

**In short, whatever scope you choose it must** not only match how and where you work but also:

- Accurately capture your signals.
- Have features that expand your capabilities and save you time.
- Offer guaranteed not just typical specifications.

**Accuracy.** You will need a pretty good idea of what signals you're going to need to look at: whether (analog) audio and transducer signals or (digital) pulses and steps. If you're looking at digital signals, will you be measuring rise times, or just looking at approximate timing relationships? Will you use the scope to qualify elements of your design, or mostly for debugging? Either way, accurate signal capture at the outset is more important than any later signal processing – your decisions rely on accurate information, and you can always process the information on a computer.

**Capability.** You need to consider not just your present generation of designs, but future generations too. A high-quality scope will give you many years' reliable service.

**Guaranteed specs.** Ensure that all the parameters you need to measure are detailed as "guaranteed specifications" in the oscilloscope datasheet. Parameters listed as "Typical" are simply an indication of oscilloscope performance, and cannot be used to make meaningful measurements that comply with recognised quality standards.



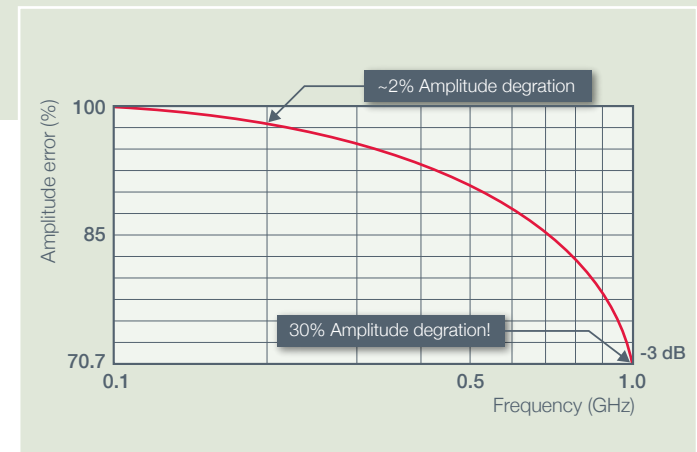


# BANDWIDTH

System bandwidth determines an oscilloscope's fundamental ability to measure an analog signal - the maximum frequency range that it can accurately measure.

## What you need

- Entry level scopes will often have a maximum bandwidth of 100 MHz. They can accurately (within 2%) show the amplitudes of sine-wave signals up to 20 MHz.
- For digital signals, oscilloscopes must capture the fundamental, third and fifth harmonics or the display will lose key features. So, the bandwidth of the scope **together with the probe** should similarly be at least **5x the maximum signal bandwidth** for better than  $\pm 2\%$  measurement error – **the 'five times rule'**. This is also needed for accurate **amplitude** measurements.
- High-speed digital, serial communications, video and other complex signals can therefore require scope bandwidths of 500 MHz or more.

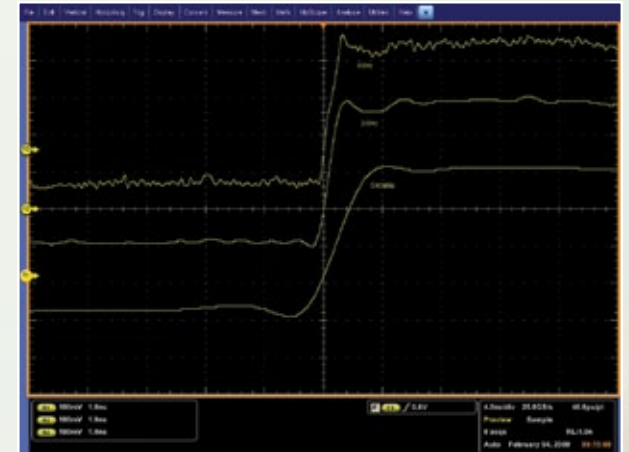


Bandwidth is defined as the frequency at which a sine-wave input signal is attenuated to 70.7% of its true amplitude (the -3 dB or 'half-power' point, shown here for a 1 GHz scope).

## Remember the 'five times rule'

When selecting bandwidth, use the 'five times rule'. If bandwidth is too low, your oscilloscope will not resolve high-frequency changes. Amplitude will be distorted. Edges will vanish. Details will be lost.

Signals captured at 250 MHz, 1 GHz and 4 GHz bandwidth.



# #2

## RISE TIME

While analog engineers look at bandwidth, digital engineers are more interested in the rise time of signals like pulses and steps.

### What you need

- The faster the rise time, the more accurate are the critical details of fast transitions. Fast rise time is also needed for accurate **time** measurements.
- Rise time is defined as,  $\frac{k}{\text{Bandwidth}}$  where k is between 0.35 (typically for scopes with bandwidth <1 GHz) and 0.40 to 0.45 (>1 GHz).
- Similar to bandwidth, **an oscilloscope's rise time should be < 1/5 x fastest rise time of signal.**  
E.g. a 4-ns rise time needs a scope with faster than 800 ps rise time. Note: As with bandwidth, achieving this rule of thumb may not always be possible.
- TTL and CMOS may need 400 to 300 ps rise times.

Specifications  
All specifications apply to all models unless noted otherwise.

Mixed Signal Oscilloscope

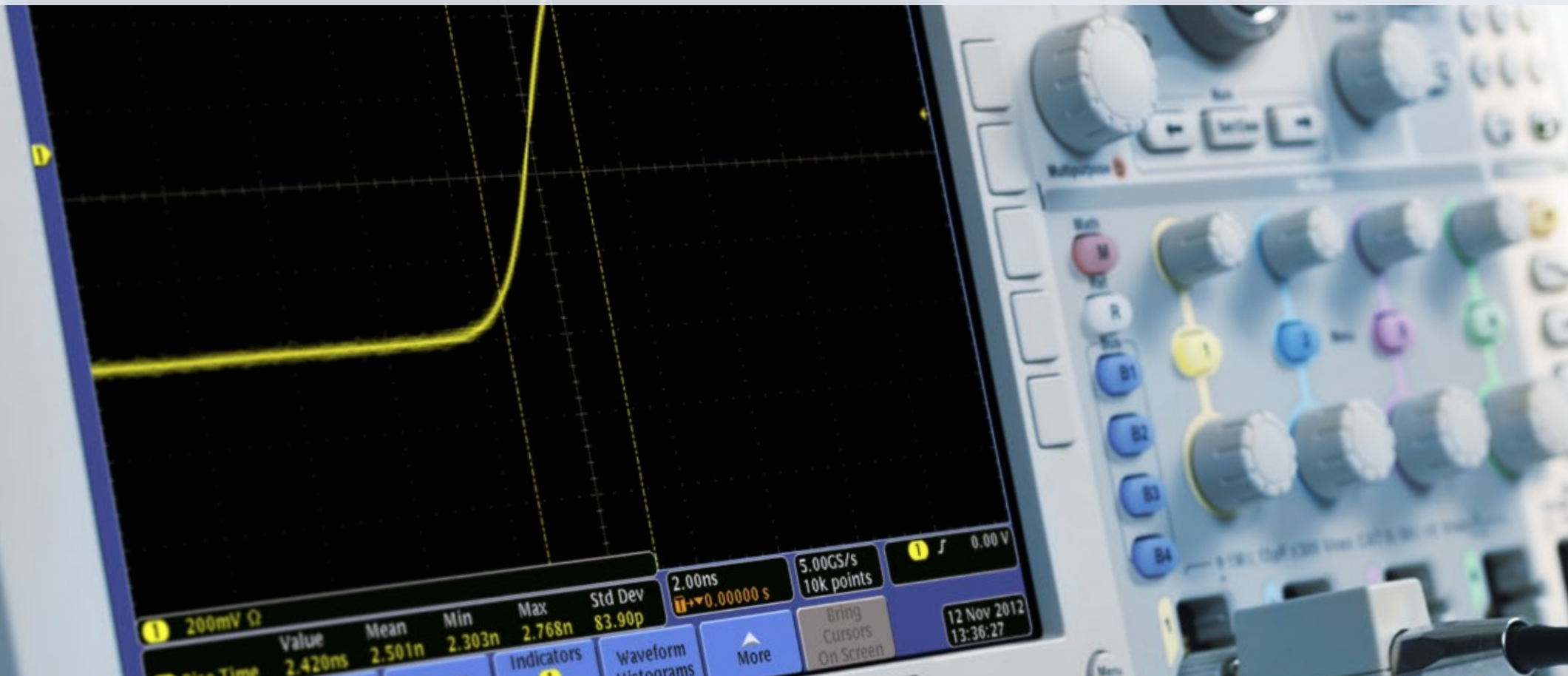
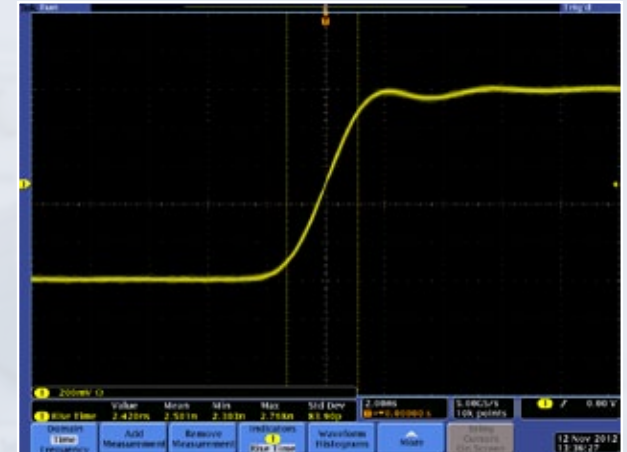
Model overview

	DPO4014B, MSO4014B	DPO4034B, MSO4034B	DPO4054B, MSO4054B	DPO4102B-L, MSO4102B-L	DPO4150B, MSO4150B
Analog channels	4	4	4	2	2
Bandwidth	100 MHz	350 MHz	500 MHz	1 GHz	1 GHz
Rise time	3.5 ns	1 ns	700 ps	350 ps	350 ps
Sample rate (1 ch)	2.5 GS/s	2.5 GS/s	2.5 GS/s	2.5 GS/s	5 GS/s
Wave rate (2 ch)	2.5 GS/s	2.5 GS/s	2.5 GS/s	2.5 GS/s	5 GS/s
Wave rate (4 ch)	2.5 GS/s	2.5 GS/s	2.5 GS/s	2.5 GS/s	5 GS/s
Wave rate (1 ch)	2.5 GS/s	2.5 GS/s	2.5 GS/s	2.5 GS/s	5 GS/s
Wave rate (2 ch)	20M	2.5 GS/s	2.5 GS/s	2.5 GS/s	5 GS/s

Your scope rise time must be fast enough to capture rapid transitions accurately.

## Accurate rise time measurements are key

Many logic families have faster rise times (edge speeds) than their clock rates suggest. A processor with a 20 MHz clock may well have signals with rise times similar to those of an 800 MHz processor. Rise times are critical for studying square waves and pulses. Square waves are standard for testing amplifier distortion and timing signals for TVs and computers. Pulses may represent glitches or information bits – too slow a rise time for the circuit being tested could shift the pulse in time and give a wrong value.







## MATCHING PROBES

Precision measurements start at the probe tip. The probe's bandwidth must match that of the oscilloscope (**the 'five times rule' again**), and must not overload the Device Under Test (DUT).

### What you need

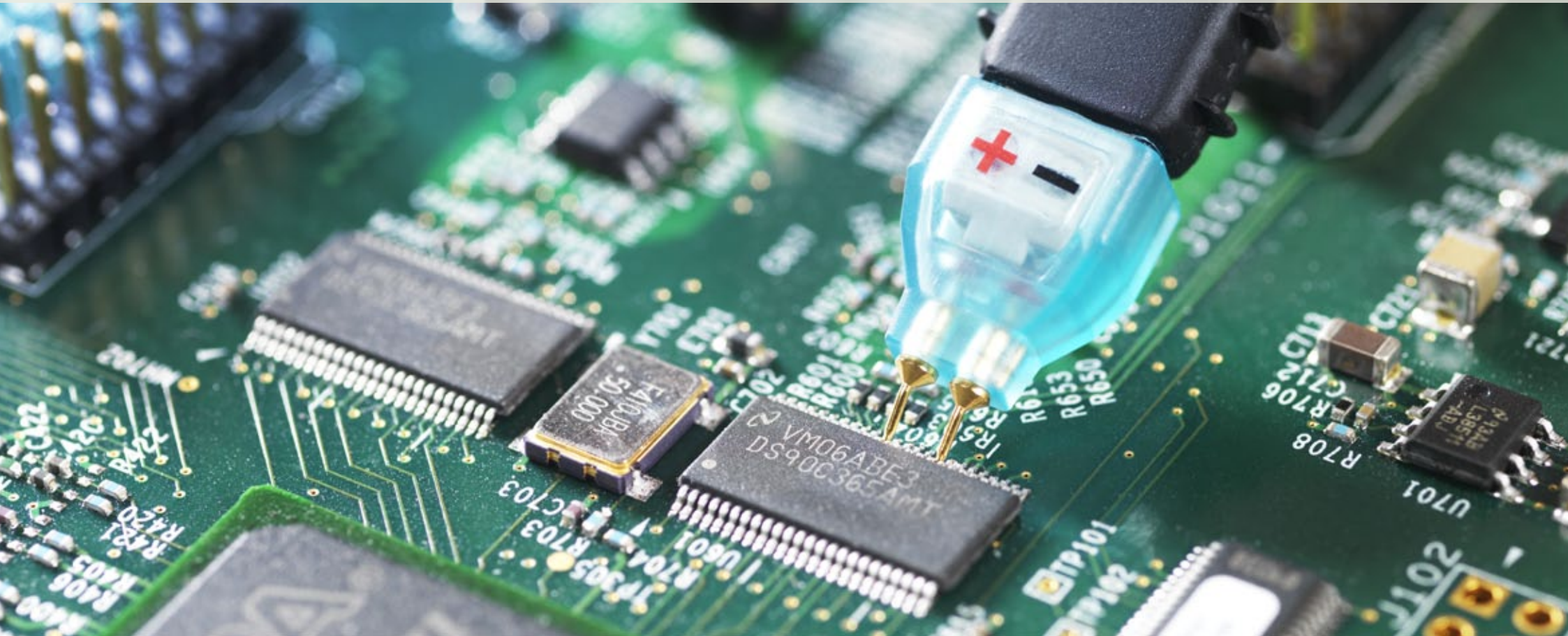
- Probes actually become a critical part of the circuit, introducing resistive, capacitive and inductive loading that alters the measurement. To minimize the effect it's best to use probes from the same manufacturer as the scope, forming an integrated solution.
- Loading is critical. Resistive loading of standard passive probes is usually an acceptable 10 M $\Omega$  or better. Capacitive loading of 10, 12 or even 15 picoFarads (pF) at high frequencies is a real problem though.
- When selecting a **mid-range scope choose probes with capacitive loadings of < 10 pF**. The best passive probes offer 1GHz bandwidth with a capacitive load <4 pF.



**Probing for answers:** Do you plan to measure voltage, current or both? What frequency is your signal? How large is the amplitude? Does the DUT have low or high source impedance? Do you need to measure the signal differentially? What you want to do determines the probes you need.

## Use a range of probes

To start with, select passive probes that have high bandwidth and low loading. Active ground-referenced probes offer 1 to 4 GHz bandwidth, and differential active probes 20 GHz or more. Adding a current Probe enables the scope to calculate and display instantaneous power, true power, apparent power, and phase. High voltage probes measure to 40 kV peak. Specialty probes include logic, optical and environmental types.





# ACCURATE INPUT CHANNELS ... AND ENOUGH OF THEM

Digital scopes sample analog channels to store and display them. In general, the more channels the better, although adding channels adds to the price.

## What you need

- Whether to select 2, 4, 8 or 16 channels depends on your application. Two or four analog channels will allow you to view and compare signal timings of your waveforms, while debugging a digital system with parallel data needs an additional 8 or 16 digital channels or more.
- A Mixed Signal Oscilloscope adds digital timing channels, which indicate high or low states and can be displayed together as a bus waveform. The latest Mixed Domain Oscilloscopes add a dedicated RF input for making high frequency measurements in the frequency domain.
- Whatever you choose, all channels should have good range, linearity, gain accuracy, flatness and resistance to static discharge.
- Some instruments share the sampling system between channels to save money. But beware: the number of channels you turn on can reduce the sample rate.
- Isolated channels simplify floating measurements. Unlike ground-referenced oscilloscopes, the input connector shells can be isolated from each other and from earth ground.



A mixed domain oscilloscope not only offers analog and digital channels, like an MSO, but also includes a dedicated RF input channel that behaves like a spectrum analyzer.

## Choose enough channels

The more time-correlated analog and digital channels your scope has, the more points in a circuit you can measure at the same time and the easier it is to decode a wide parallel bus, for instance. The example shows 2 analog, 8 digital and 1 decoded bus waveforms.

Analog

Digital

Bus



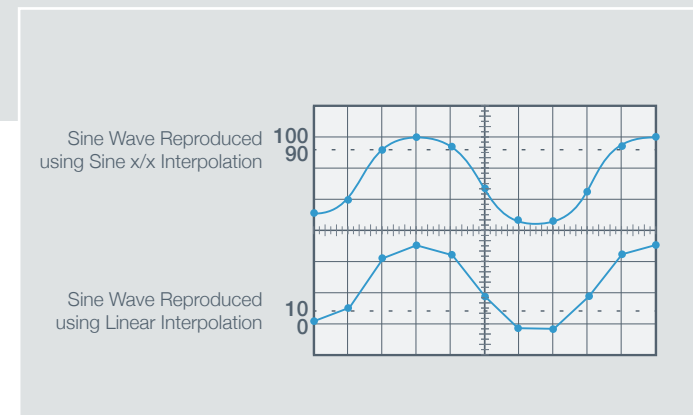
# #5

## FAST SAMPLE RATE

The sample rate of an oscilloscope is similar to the frame rate of a movie camera. It determines how much waveform detail the scope can capture.

### What you need

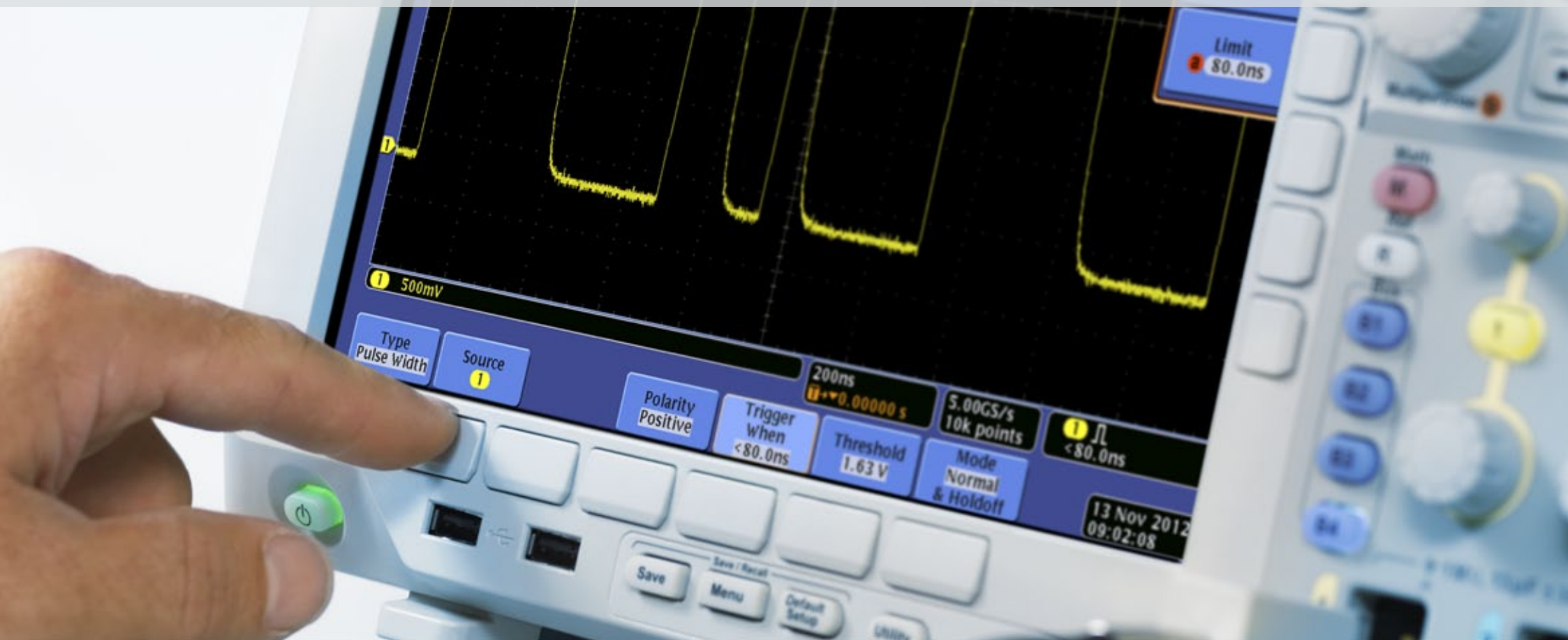
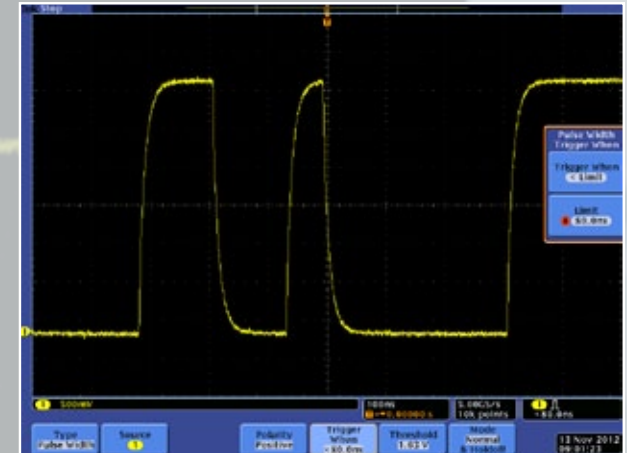
- Sample rate (samples per second, S/s) is how often an oscilloscope samples the signal. Again, we recommend a **'five times rule'**: use a sample rate of at least 5x your circuit's highest frequency component.
- The minimum sample rate may also be important if you need to look at slowly changing signals over longer periods of time.
- Most entry-level scopes have a (maximum) sample rate of 1 to 2 GS/s, while mid-range ones can have 5 to 10 GS/s.
- The faster you sample, the less information you'll lose and the better the scope will represent the signal under test. But the faster you will fill up your memory, too, which limits the time you can capture.



Accurate reconstruction of a signal depends on both the sample rate and the interpolation method used. Linear interpolation connects sample points with straight lines, but this approach is limited to reconstructing straight edged signals. Sin  $x/x$  interpolation is a mathematical process in which points are calculated to fill in the time between the real samples. This form of interpolation lends itself to curved and irregular signal shapes, which are far more common in the real world than pure square waves and pulses. Consequently, sin  $x/x$  interpolation is the preferred method for applications where the sample rate is 3 to 5 times the system bandwidth.

## To capture glitches you need speed!

Nyquist said that a signal must be sampled at least twice as fast as its highest frequency component to accurately reconstruct it and avoid aliasing (showing artefacts that are not actually there). Nyquist however is an absolute minimum – it applies only to sine waves, and assumes a continuous signal. Glitches are by definition not continuous, and sampling at only twice the rate of the highest frequency component is usually not enough. Conclusion: A high sample rate increases resolution, ensuring that you'll see intermittent events.



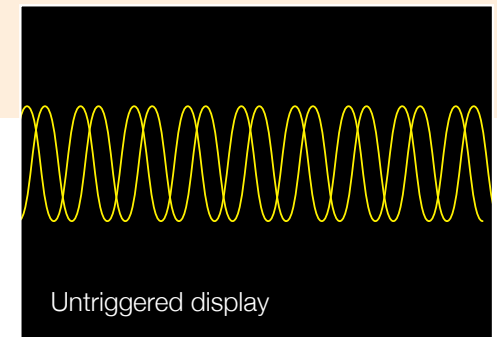
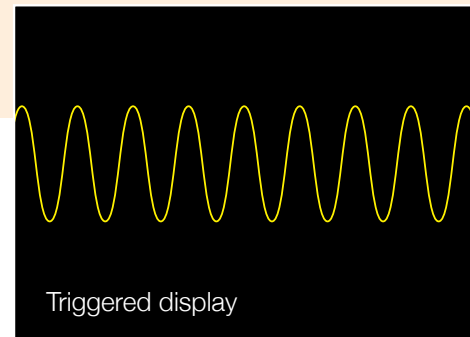
# #6

## VERSATILE TRIGGERING

Triggering gives a stable display and lets you zero in on specific parts of complex waveforms.

### What you need

- All oscilloscopes provide edge triggering, and most offer pulse width triggering.
- To acquire anomalies and make best use of the scope's record length, look for a scope that offers advanced triggering on more challenging signals.
- The wider the range of trigger options available the more versatile the scope (and the faster you get to the root cause of a problem!):
  - A & B sequence triggering; delay by time or delay by events
  - Video triggering on line/frame/HD signals, etc.
  - Logic triggering: slew rate, glitch, pulse width, time-out, runt, setup-and-hold
  - Communications triggers: embedded system designs use both serial (I<sup>2</sup>C, SPI,CAN/LIN, USB ...) and parallel buses.



[See how it works](#)

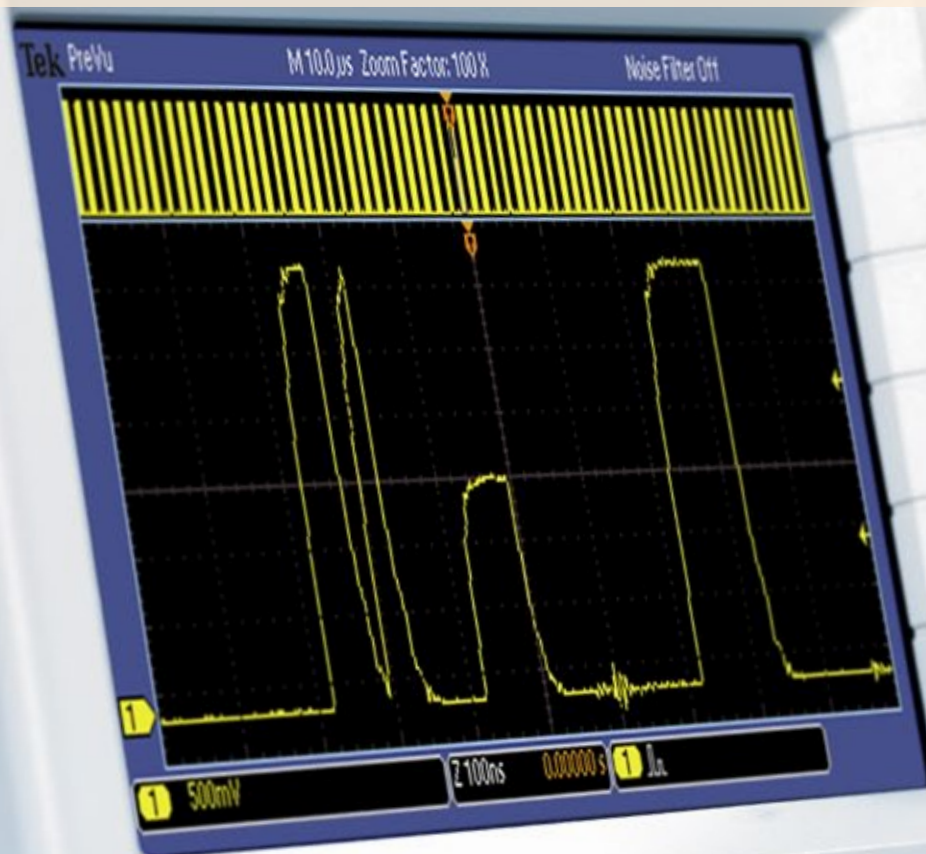
Triggering synchronizes the horizontal sweep at the correct point in the signal, rather than just starting the next trace at the point where the present trace happens to finish. A single trigger acquires all input channels simultaneously.

## Advanced triggers find the right information

Triggering lets you isolate a group of waveforms to see what is going wrong. Specialized triggers can respond to specific conditions in the incoming signal – making it easy to detect, for example, a pulse that is narrower than it should be.



Tektronix TDS 2024C FOUR CHANNEL DIGITAL STORAGE OSCILLOSCOPE 200MHz 2GS/s





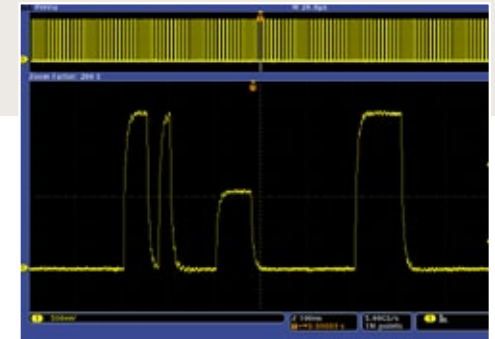
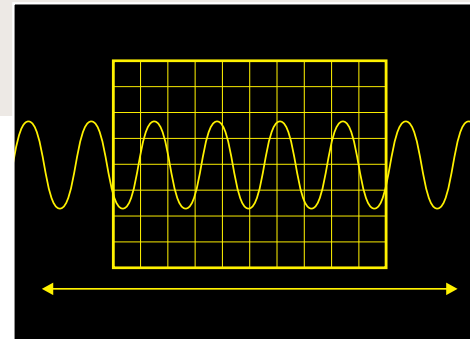
# #7

## LONG RECORD LENGTHS

Record length is the number of points in a complete waveform record. A scope can store only a limited number of samples so, in general, the greater the record length the better.

### What you need

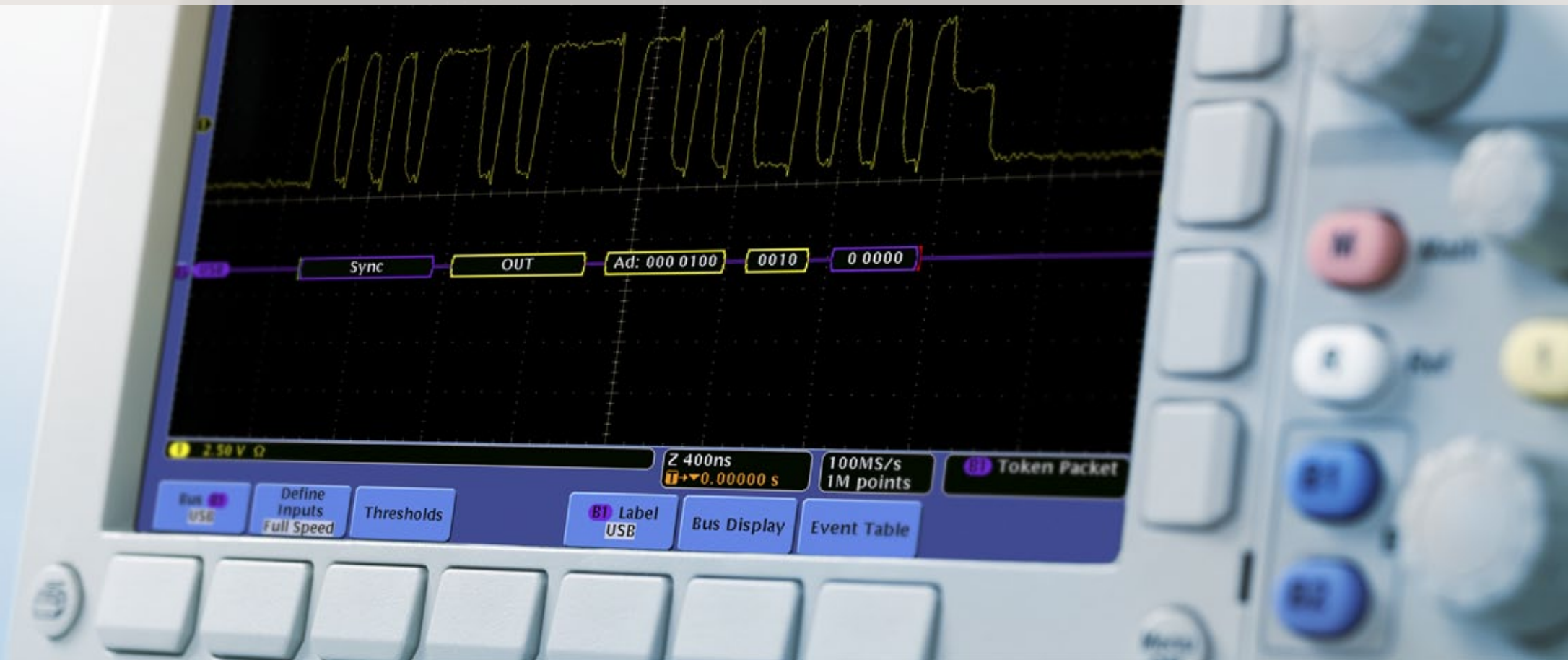
- Time captured = record length/sample rate. So, with a record length of 1 Mpoints and a sample rate of 250 MS/sec, the oscilloscope will capture a signal 4 ms in length.
- Today's scopes allow you to select the record length to optimize the level of detail needed for your application.
- A good basic scope will store over 2,000 points, which is more than enough for a stable sine-wave signal (needing perhaps 500 points). But to find the causes of timing anomalies in a complex digital data stream you should consider, for example, a DPO (Digital Phosphor Oscilloscope) with a record length of 1 Mpoints or more.
- To search for infrequent transients such as jitter, runt pulses and glitches, select at least a mid-end scope that combines long record length with a high waveform capture rate.



Since an oscilloscope can store only a limited number of samples, the waveform duration (time) will be inversely proportional to the oscilloscope's sample rate. **Time Interval = Record Length / Sample Rate**

## See the bigger picture

Capturing enough detail to decode this USB serial data stream requires high resolution sampling (200ps). Capturing multiple packet contents needs a long time (200 $\mu$ s). An oscilloscope with long record length (1 Mpoints) is needed to display both.



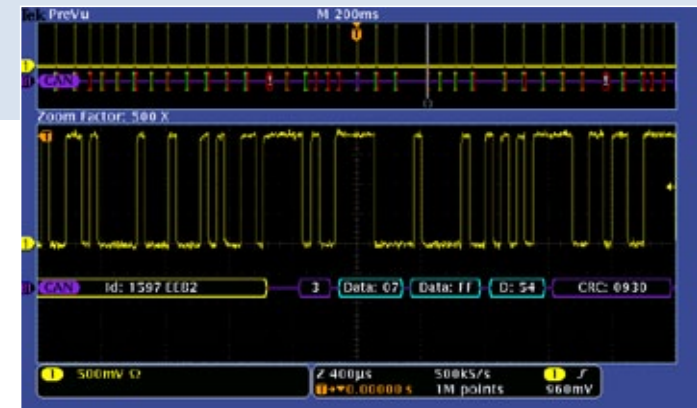
# #8

## POWERFUL WAVEFORM NAVIGATION AND ANALYSIS

Searching for specific waveform errors can be like searching for a needle in a haystack. You need tools that automate the process and accelerate the “time to answer”.

### What you need

- **Zoom & Pan** allows you to zoom in on an event of interest, and pan the area backwards and forwards in time.
- **Play & Pause** automatically pans the zoom window across the waveform. That allows hands-free playback so you can concentrate on what’s important – the waveform itself.
- **Marks** lets you mark events of interest while you’re looking for a problem. You can use front-panel controls to rapidly jump between each mark for quick and easy timing measurements (see panel).
- **Search & Mark** lets you search through the entire acquisition and automatically mark every occurrence of a user-specified event.
- **Advanced search** lets you define various different criteria, similar to trigger conditions, which will be automatically detected and marked in the captured waveform.

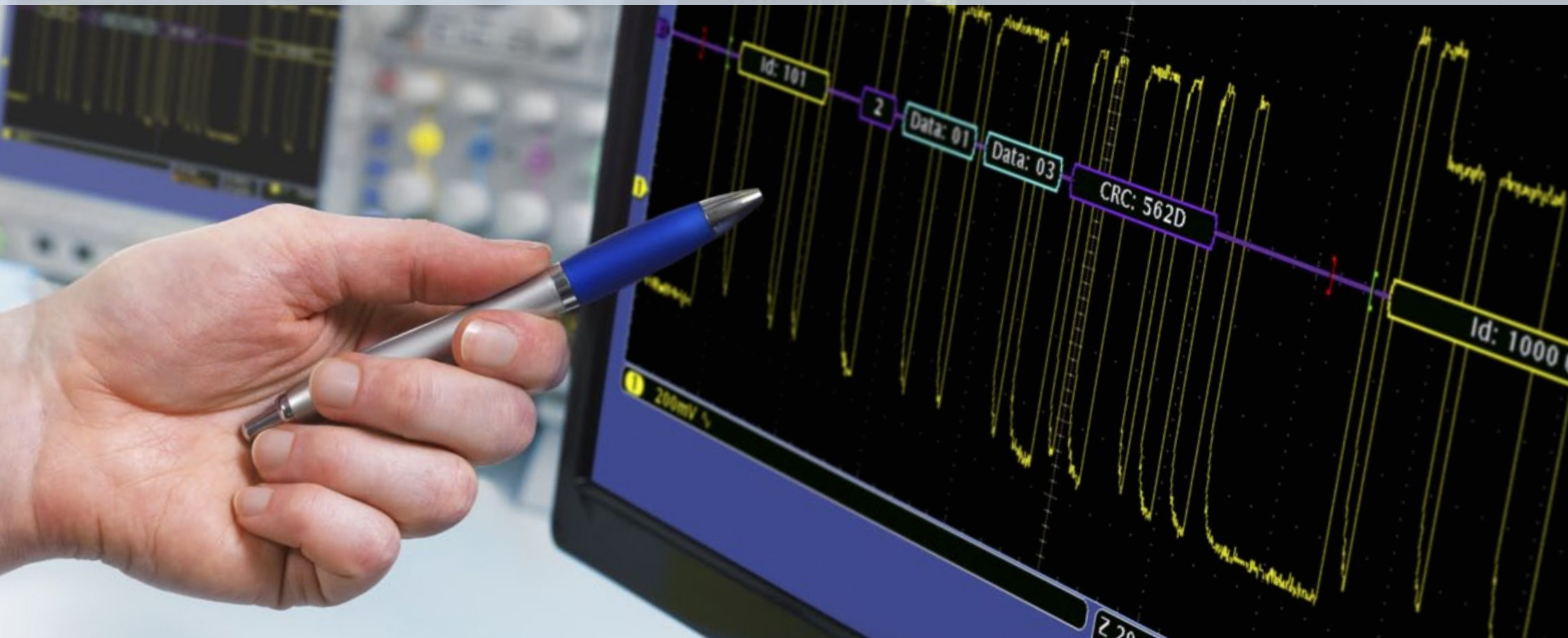
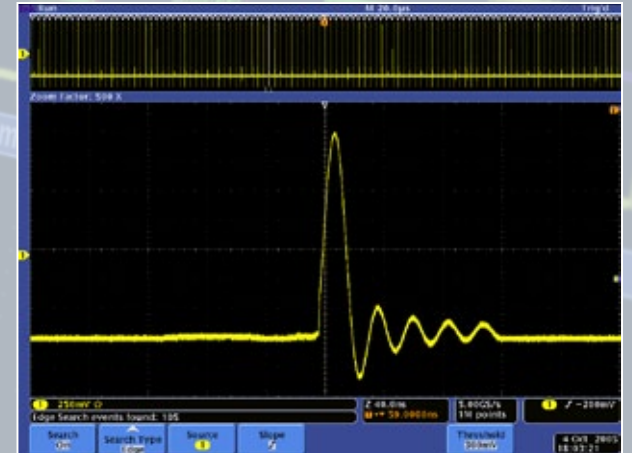


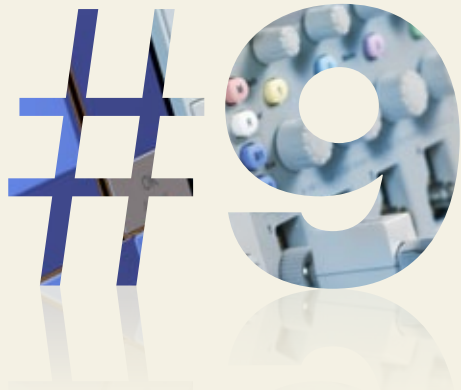
Oscilloscopes with record lengths in the millions of points can show thousands of screens worth of signal activity, essential for examining complex waveforms. Placing **marks** on the waveform assists in latency measurements on a CAN bus, for example.

## Consider advanced search tools

The industry's fastest tool for automated navigation, search and analysis is Wave Inspector®, a proprietary technology. It allows you to specify search criteria to automatically find every occurrence in an acquisition that violates some specified criteria such as setup and hold time.

Wave Inspector®  
marking every  
pulse that crosses  
300mV in a long  
acquisition.





# AUTOMATED WAVEFORM MEASUREMENTS

Automated waveform measurements make it easier to obtain accurate numerical readings.

## What you need

- Most scopes offer front-panel buttons and/or screen-based menus to take accurate automated measurements.
- Basic choices on most scopes include amplitude, period and rise/fall time.
- Many digital scopes also provide mean and RMS calculations, duty cycle, and other maths operations.
- Advanced mathematics functions are found on some scopes, improving the 'time to answer' even further. Some examples:
  - FFT, Integrate, Differentiate, Logarithm, Exponent, Square root, Absolute
  - Sine, Cosine, Tangent, Radians, Degrees
  - Scalars, with user-adjustable variables and results of parametric measurements.

### Examples of fully automated waveform measurements:

- |                      |                |               |
|----------------------|----------------|---------------|
| ■ Period             | ■ Duty Cycle + | ■ High        |
| ■ Frequency          | ■ Duty Cycle - | ■ Low         |
| ■ Width +            | ■ Delay        | ■ Minimum     |
| ■ Width -            | ■ Phase        | ■ Maximum     |
| ■ Rise time          | ■ Burst width  | ■ Overshoot + |
| ■ Fall time          | ■ Peak-to-peak | ■ Overshoot - |
| ■ Amplitude          | ■ Mean         | ■ RMS         |
| ■ Extinction ratio   | ■ Cycle mean   | ■ Cycle RMS   |
| ■ Mean optical power | ■ Cycle area   | ■ Jitter      |

Automated measurements appear as on-screen alphanumeric readouts, and are more accurate than direct graticule interpretation.

## Look for fast answers

Once again, extra functions shorten the time to answer. Digital Signal Processing techniques can automate measurements – making them faster, more accurate and more repeatable than is possible with cursors. You can even write your own formulae for specific maths functions.





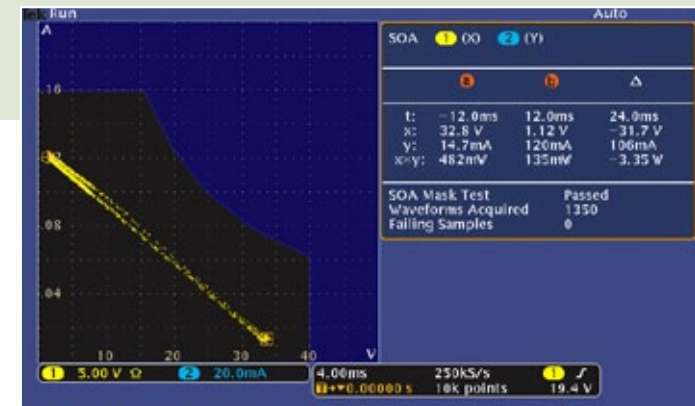
# ADVANCED APPLICATION SUPPORT

Advanced scopes have application software for optical and electrical design troubleshooting and standards compliance.

## What you need

- Signal integrity and jitter measurement packages: provide insight into signal integrity-related problems in digital systems, their causes, characteristics and effects.
- RF applications: view signals in the frequency domain and analyze using spectrograms, amplitude, frequency and phase versus time traces.
- Support for debug of embedded systems with mixed analog & digital, parallel & serial technologies such as CAN/LIN, I<sup>2</sup>C, SPI, FlexRay, MOST and others.
- Education: electrical engineering students need to understand complex circuits and electronic designs to develop next generation technologies.
- Power measurement (SMPS, for example): automated measurements for power quality, switching loss, harmonics, safe operating area, modulation, ripple, slew rate and more.

Others include optical communications, memory system verification, communications standards testing, disk drive measurements, video measurements, and more.

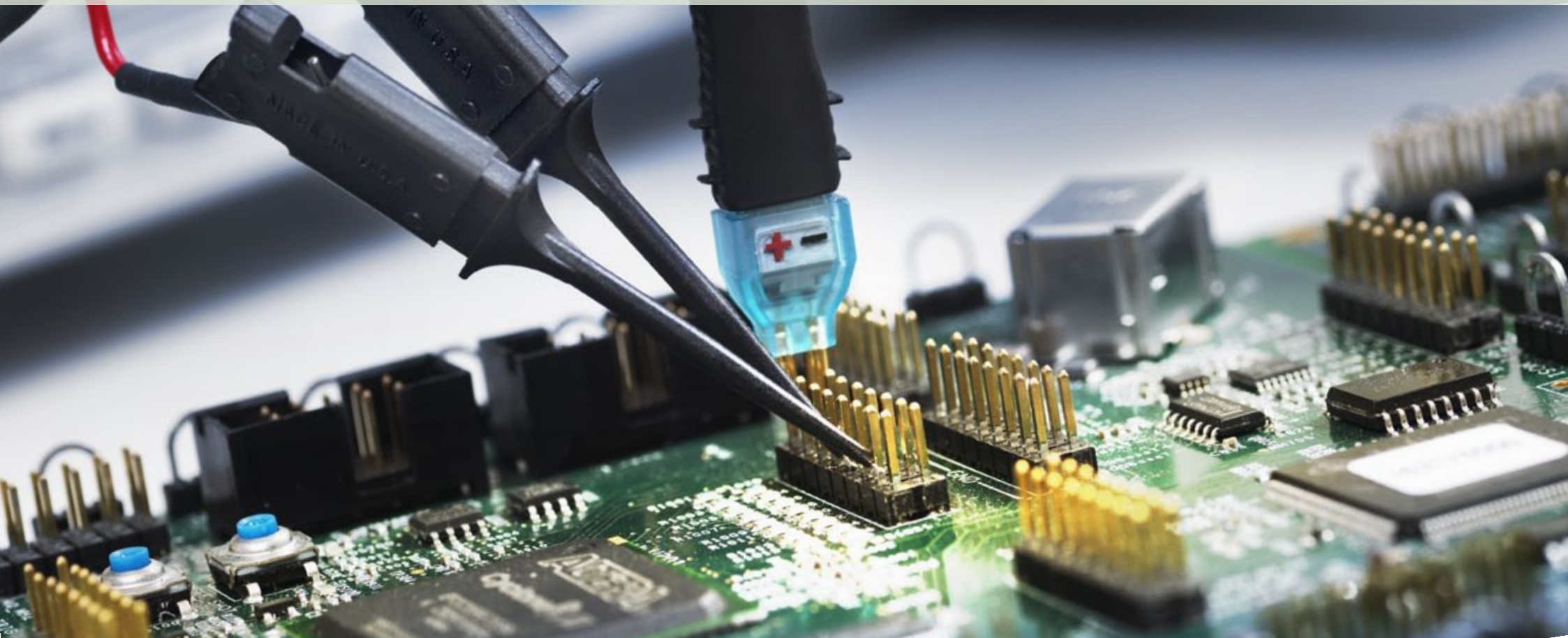
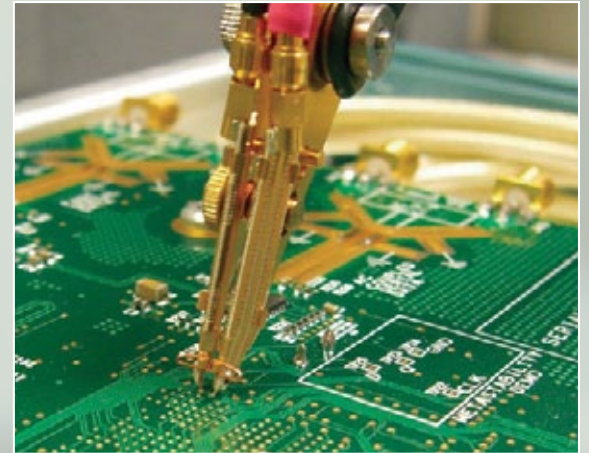


Is your SMPS switching device operating within safe limits?

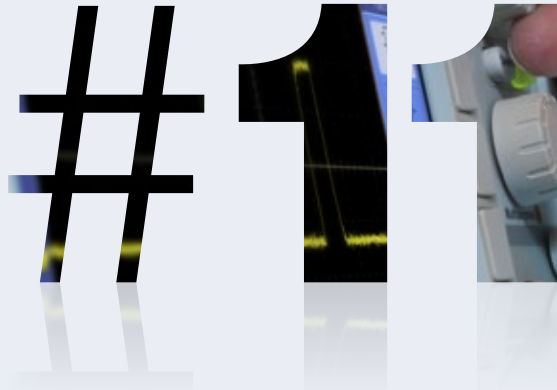
Automated analysis tools provide power measurements at the touch of a button, enabling quick and accurate analysis of safe operating area (SOA), power quality, switching loss, harmonics, modulation, ripple, and slew rate (di/dt, dv/dt).

## Think about your future needs

Complex electronic designs are driving innovation across many industries today. Your scope should have all the features your application needs – now and in the future.







## EASY, RESPONSIVE OPERATION

Oscilloscopes should be easy to operate, even for occasional users. The user interface is a large part of the ‘time to answer’ calculations.

### What you need

- Frequently used adjustments should have dedicated knobs.
- AUTOSET and/or DEFAULT buttons will make for instant setup.
- The scope should be responsive, reacting quickly to changing events.
- There should be support for your own language, with templates for the dials.

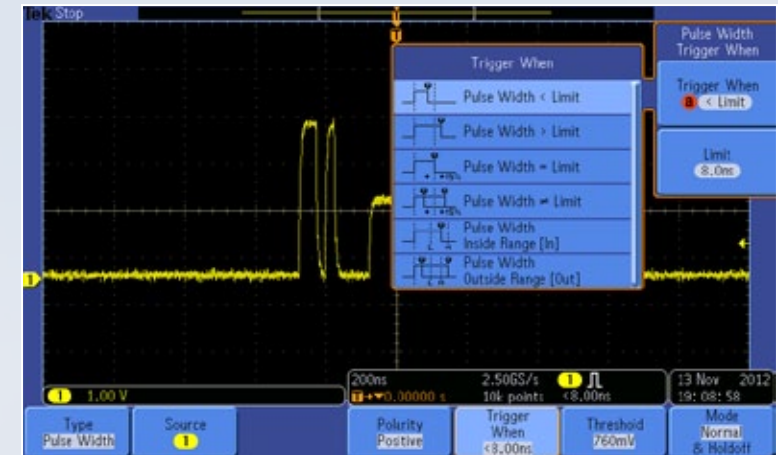


Many people don't use a scope every day. Intuitive controls allow even occasional users to feel comfortable with the scope while giving full-time users easy access to the most advanced features. Many oscilloscopes are portable – for use in the lab or in the field.

## Controls that match your way of working

Oscilloscopes should give you different ways to operate the instrument. Built-in help can provide a convenient, built-in reference manual, while smart menus give easy access to multifunction, context-sensitive commands.

An icon-rich graphical user interface helps you understand and intuitively use advanced capabilities.



# #12

## CONNECTIVITY AND EXPANSION

Connecting a scope to a computer directly or transferring data via portable media allows advanced analysis, and simplifies documenting and sharing results.

### What you need

- Consider a scope that allows you to access a Windows desktop and provide network printing and file sharing resources.
- Check if it can run third-party analysis, documentation and productivity software.
- Is it helpful to provide internet access, and share measurements with colleagues real-time?
- Can it meet your needs as they change? For example, can you add:
  - Memory to channels to analyze longer record lengths
  - Application-specific measurements and application modules
  - A full range of probes and modules
  - Accessories like battery packs and rack mounts
  - Software to control the scope from your PC, take automated measurements, waveform data logging and export waveforms live.



Standard interfaces can include GPIB, RS-232, USB, Ethernet and LXI, and links to network communication modules. USB is useful for USB flash drives to store waveforms, captures and settings. PictBridge lets the scope act like a digital camera. VGA connects to an external monitor.

## Ask about interfaces

LAN, Display, and Printer interfaces enable you to integrate your oscilloscope with the rest of your working environment:

- Ethernet port for network connectivity, plus compatible software to capture screen-shots, waveform data and measurement results
- USB Host port: quick & easy data storage, printing, and connecting a USB keyboard
- USB device port for easy connection to a PC or direct printing to a printer
- Video port to export the oscilloscope display to a monitor or projector



# ... AND FINALLY, CONSIDER LOW COST OF OWNERSHIP AND PEACE OF MIND!

In the end, the scope you choose will have a price tag – but what is the real cost of ownership? Check out the manufacturer's support options to see how far they add value to your purchase and contribute to extending your scope's useful life. For example, on-site education and training, as well as design, system integration, project management, and other professional services can help you maximize your productivity and ensure accurate and reliable measurements. High-value support packages such as these, along with options like extended warranty can save money in the long term, and bring peace of mind.

**For Further Information**

To access product information and related literature please visit [www.tek.co.uk](http://www.tek.co.uk)

**Freephone Number: 00800 2255 4835\***

(available in Austria, Belgium, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden, Switzerland, UK)

\* If Freephone numbers are not accessible from your phone, or for any other countries, dial: +41 52 675 3777

**Literature reference number:**

“12 Things to Consider When Choosing an Oscilloscope”.  
48X-28633-0

