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The Digital Oscilloscope, Part I

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Overview

The oscilloscope is a ubiquitous tool in engineering and physical-science laboratories. It is used for measuring and visualizing voltage versus time, or in some cases, one voltage versus another. Modern digital oscilloscopes can preserve a display for an arbitrary length of time, allowing an experimenter to perform any number of measurements at their leisure, and often allowing the experimenter to print or save the trace on the screen as well.

Principles

All modern oscilloscopes are digital, which means they consist of a set of analog-to-digital voltage converters connected to an elementary computer. Most controls are universal to all oscilloscopes (**Figure 1**). Different models might have different locations for certain features, but all oscilloscopes have a single screen for output; a vertical group of controls (specifically the vertical-scale knob); a horizontal group of controls (specifically the horizontal-scale knob); trigger controls; an acquire group/autoset button; channel selector buttons; soft keys; an on/off button. The oscilloscope also has a network connection for communication and printing.

To get the most use out of an oscilloscope, or "scope" for short, it is essential to understand triggering and how to set the scale.

Triggering is analogous to tripping the shutter on a camera. It determines the exact moment when the scope "takes a snapshot" of the voltage, and thus, captures exactly what part of the voltage appears on the screen. The scope can be triggered manually, but more often it is programmed to monitor the signal and to take a snapshot (*i.e.*, draw the screen) when certain conditions are met, specifically when the voltage on a particular channel (that the user selects) rises or falls through a predetermined value. For periodic signals, triggering off a certain point allows multiple traces to be displayed with the same starting point, or horizontal alignment.

"Scale" refers to the range of values that the screen displays, both in the vertical and horizontal axes. A signal varying between +1 and -1 V, for example, is best displayed on a screen covering that range. Similarly, the horizontal scale should be set so that the screen shows the relevant variations of the signal. Most scopes can vary their scales over many orders of magnitude, making it easy to use the wrong scale (*e.g.*, using a scale too small for a large range and vice versa).

This experiment~~ lab will also~~ also~~make~~ utilizes~~se of~~ a function generator, a device for producing electronic signals where the user specifies properties, such as the frequency (how many times the signal repeats per second) or period (time between successive peaks in the signal, equal to the inverse of the frequency), amplitude (height of the signal), and shape (sine, square wave, triangle, etc.). Operation of most function generators is usually very straightforward, unlike oscilloscopes.

In most laboratory settings, electronic signals are transmitted along coaxial cables, which consist of an inner wire conductor surrounded by a flexible, insulating material and ~~then~~ an outer~~,~~ conducting "sheath" that is connected to ground and ~~thus~~ maintained at a potential of zero volts. Connections are usually made using bayonet-type connectors~~, as shown in~~ (**Figure 2~~1~~**).

Many cable and connection types are available, and a survey of the different models and designs is beyond the scope of this video. The most common combination in a laboratory setting is ~~probably~~ RG-58U cable and BNC connectors. Runners-up are typically similar enough that the similar principles, characteristics, and modes of operation apply.

Procedure

1. Turn on the scope and the function generator.

Commented [A1]: Talk about this in the Principles section. What it does, how it's used in conjunction with the oscilloscope, etc.

2. Program the function generator to produce~~Select~~ a sine wave with a frequency of 1 kHz and an amplitude of 1 V.

Commented [A2]: On the oscilloscope, or function generator?

~~3.~~ Connect the output of the function generator to the input (Ch1) of the scope.

~~6.1.~~3.1. Take an intact cable with BNC connectors on both ends. Plug one end into the SIG-OUT port of the function generator and the other into Channel 1 of the oscilloscope. Note how the slots in the BNC connectors line up with the pegs on the ports, and that the connectors are locked into place by pushing in and turning.

~~7.~~4. Set the vertical scale of the scope to 1 V/div and the horizontal scale to 1 ms/div.

~~8.~~5. Do the appropriate calculation to show the relation between the frequency and period of a sine wave (1/1 kHz=1 ms) (**Figure 3**).

~~9.~~6. Push the manual trigger button. The scope should draw a representation of the signal on the screen. Observe that the period and amplitude agree with ~~our~~ the expectations (1 V & 1 ms).

Commented [A4]: Need to define in the Principles section.

~~10.~~7. Push the manual trigger button again, and repeat three or four times. Notice how the horizontal alignment changes with each trigger.

~~11. Program the scope to trigger automatically and consistently at a certain point, relative to the signal, by setting the following options, Source, Level, and Slope.~~

Commented [A5]: Explain this process in more detail.

~~14.1.~~8.1. Type: Edge

~~14.1.1.~~8.1.1. For Type, there are two choices, Edge and Video. Video is only used to diagnose signals meant for a CRT screen, such as an old, analog TV or VGA computer monitor. Neither is widely used today, so ignore this option and stick with Edge.

~~14.2.~~8.2. Mode: Normal

~~14.2.1.~~8.2.1. This mode option is like setting an attention span. Under Normal, it has an infinite attention span and waits as long as necessary for the trigger conditions to be met before drawing the screen. If the conditions are never met, the scope never triggers, and the display on the screen remains frozen at whatever it drew last. Under Auto, the scope has a finite attention span. It only waits for so long before triggering and drawing the signal on the screen. If ~~the scope~~this waiting time ends~~runs out~~ before the trigger conditions are met, the scope~~it~~ just draws whatever voltage it happens to find on the input at that time.

Commented [A7]: Explain what exactly this means.

~~14.3.~~8.3. Source: Ch1

~~14.3.1.~~8.3.1. Source refers to which channel the scope uses to look for its trigger conditions to be met.

~~14.4.~~8.4. Coupling: DC

~~14.4.1.~~8.4.1. Coupling gives the user the option of filtering the signal before using it to trigger the scope. DC means no filtering, where the signal is used as-is. Other options allow the removal of high-frequency noise, low-frequency drift, or a DC offset.

~~14.5.~~8.5. Slope: Falling (Negative)

~~14.5.1.~~8.5.1. Slope is whether the signal is rising or falling through the level set.

~~14.6.~~8.6. Level: 0 V

~~14.7.~~8.7. Single Sequence: Off

~~15.~~9. Observe the display.

~~16.~~10. Measure the amplitude and period of the trace given. These should be in agreement with the settings on the function generator.

~~17.~~11. Adjust the amplitude of the sine wave using the signal generator.

~~18.~~12. Observe how the oscilloscope trace responds. Its amplitude should respond to changes made on the function generator.

~~19.~~13. Switch to Single Sequence mode.

~~20.~~14. Again, adjust the amplitude of the sine wave, using the signal generator. Note that trace does not change now, even if the signal generator is turned off. The first trace is frozen on the screen until manually triggering it or turning Single Sequence off.

Representative Results

The screenshot in **Figure 4~~5~~** represents the desired result. Note the orange tab at the top of the screen with a capital letter "T" in it. This identifies the trigger point, which is the point in the signal where the scope triggered (in this case, at the center of the screen). There are, of course, eleven points on this trace where the scope could have triggered, but because the signal is periodic, there would be no discernable difference in the resulting trace.

Applications

While the oscilloscope can be used as a primary data-acquisition device, it is more often used as a diagnostic tool. Signals are examined at various points in a circuit to verify that they are doing what they are supposed to be doing. If a signal that is supposed to be a sine wave is clipping, for example, this will be immediately obvious upon inspection with the oscilloscope.

Oscilloscopes are widely used in science and engineering wherever a time-varying signal must be examined. Examples include physics experiments, electronic engineering, communications technology, and computer science, where digital signals moving from one component to another need to be examined to verify that they fall within expected norms.

Legend

Figure 1: A depiction of a modern digital oscilloscope.

Figure 2: A coaxial cable cut in two. The inner conductor carries the signal voltage, and the outer sheath serves as ground.

Figure 3: The calculations needed to show the relation between the frequency and period of a sine wave.

Figure 4~~5~~: A screenshot of the collected data from a digital oscilloscope. The orange tab a "T" represents the trigger point. At the bottom of the screen is a row of boxes listing trigger parameters. From left to right: "Type: Edge," "Source: Ch1," "Coupling: DC," "Slope: (Rising)," "Level: 20mV," "Mode: Auto & Holdoff." Above this are scale settings, 1.00 V for Channel 1 and a timebase of 1.00 ms.

Photo or Graphic File

Click here to download Photo or Graphic File: Eric Black_Digital Oscilloscope_Figure 1.jpg

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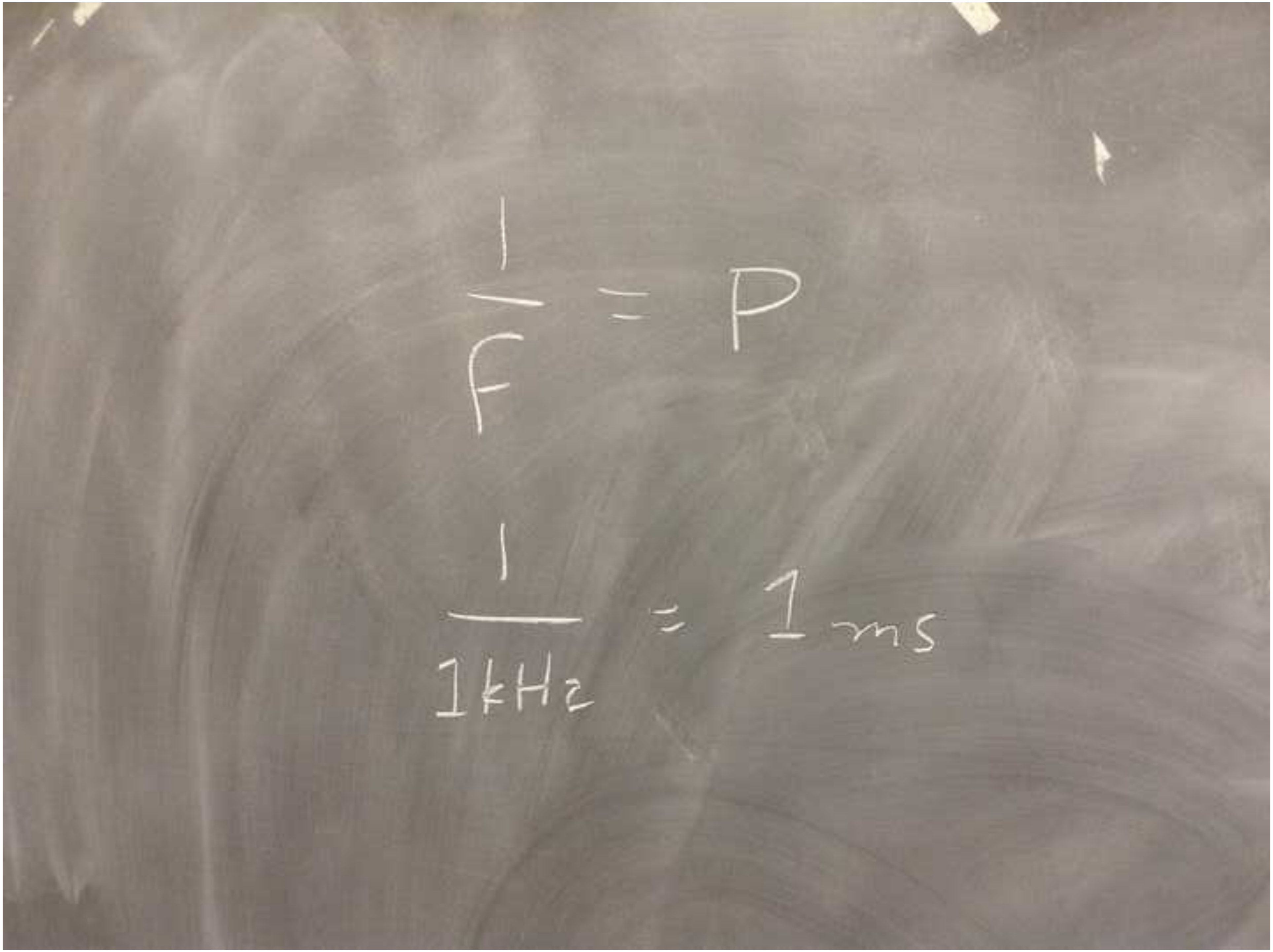

Photo or Graphic File

Click here to download Photo or Graphic File: Eric Black_Digital Oscilloscope_Figure 4.jpg