**A-8.**

**The Oscilloscope**

**READING**

None

**OBJECTIVES**

After performing this experiment, you will be able to:

1. Explain the four functional blocks on an oscilloscope and describe the major controls within each block.

2. Use an oscilloscope to measure ac and dc voltages.

**MATERIALS NEEDED**

None

**SUMMARY OF THEORY**

The oscilloscope is an extremely versatile instrument that lets you see a picture of the voltage in a circuit as a function of time. There are two basic types of oscilloscopes—analog oscilloscopes and digital storage oscilloscopes (DSOs). DSOs are rapidly replacing older analog scopes because they offer significant advantages in measurement capabilities including waveform processing, automated measurements, waveform storage, and printing, as well as many other features. Operation of either type is similar; however, most digital scopes tend to have menus and typically provide the user with information on the display and may have automatic setup provisions.

There is not room in this Summary of Theory to describe all of the controls and features of oscilloscopes, so this is by necessity a limited description. You are encouraged to read the Oscilloscope Guide at the beginning of this manual, which describes the controls in some detail and highlights some of the key differences between analog scopes and DSOs. You can obtain further information from the User Manual packaged with your scope and from manufacturers’ websites.

Both analog and digital oscilloscopes have a basic set of four functional groups of controls that you need to be completely familiar with, even if you are using a scope with automated measurements. In this experiment, a generic analog scope is described. Keep in mind, that if you are using a DSO, the controls referred to operate in much the same way but you may see some small operating differences.

Although the process for waveform display is very different between an analog oscilloscope and a DSO, the four main functional blocks and primary controls are equivalent. Figure 1 shows a basic analog oscilloscope block diagram which illustrates these four main functional blocks. These blocks are broken down further in the Oscilloscope Guide for both types of scope.

Controls for each of the functional blocks are usually grouped together. Frequently, there are color clues to help you identify groups of controls. Look for the controls for each functional group on your oscilloscope. The display controls include intensity, focus, and BEAM finder. The vertical controls include input coupling, volts/div, vertical position, and channel selection (ch1, ch2, dual, alt, chop). The triggering controls include mode, source, trigger coupling, trigger level, and others. The horizontal controls include the sec/div, magnifier, and horizontal position controls. Details of these controls are explained in the referenced reading and in the operator’s manual for the oscilloscope.

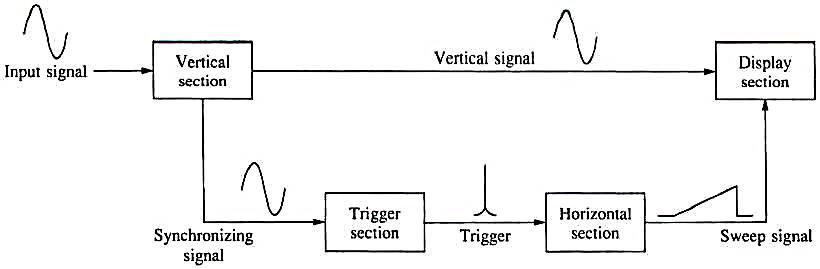


Figure 1

With all the controls to learn, you may experience difficulty obtaining a trace on an analog oscilloscope. If you do not see a trace, start by setting the sec/div control to 0.1 ms/div, select auto triggering, select ch1, and press the beam finder. Keep the beam finder button depressed and use the vertical and horizontal position controls to center the trace. If you still have trouble, check the intensity control. Note that it’s hard to lose the trace on a digital scope, so there is no beam finder.

Because the oscilloscope can show a voltage-versus-time presentation, it is easy to make ac voltage measurements with a scope. However, care must be taken to equate these measurements with meter readings. Typical digital multimeters show the rms (root-mean-square) value of a sinusoidal waveform. This value represents the effective value of an ac waveform when compared to a dc voltage when both produce the same heat (power) in a given load. Usually the peak-to-peak value is easiest to read on an oscilloscope. The relationship between the ac waveform as viewed on the oscilloscope and the equivalent rms reading that a DMM will give is illustrated in Figure 2.

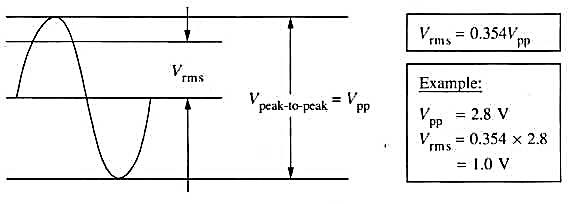


Figure 2

Many automated oscilloscopes can measure peak-to-peak or even rms readings of waveforms directly on the screen. They may include horizontal and vertical cursors. Be careful using an automated rms measurement of a sine wave. It may include any dc offset present. If you want to avoid including the dc component, ac couple the signal.

Waveforms that are not sinusoidal cannot be directly compared with an oscilloscope and DMM except for the dc component. The dc level of any waveform can be represented by a horizontal line which splits the waveform into equal areas above and below the line. For a sinusoidal wave, the dc level is always halfway between the maximum and minimum excursions. The dc component can be correctly read by a DMM no matter what the shape of the wave when it is in the DC volts mode.

The amplitude of any periodic waveform can be expressed in one of four ways: the peak-to-peak, the peak, the rms, or the average value. The peak-to-peak value of any waveform is the total magnitude of the change and is independent of the zero position The peak value is the maximum excursion of the wave and is usually referenced to the dc level of the wave. To indicate that a reported value includes a dc offset, you need to state both the maximum and minimum excursions of the waveform.

An important part of any oscilloscope measurement is the oscilloscope probe. The type of probe that is generally furnished with an oscilloscope by the manufacturer is called an attenuator probe because it attenuates the input by a known factor. The most common attenuator probe is the 10X probe, because it reduces the input signal by a factor of 10. It is a good idea, before making any measurement, to check that the probe is properly compensated, meaning that the frequency response of the probe/scope system is flat Prohes have a small variable capacitor either in the probe tip or a small box that is part of the input connector. This capacitor is adjusted while observing a square wave to ensure that the displayed waveform has vertical sides and square comers. Most oscilloscopes have the square-wave generator built in for the purpose of compensating the probe.

**PROCEDURE**

1. Review the front panel controls in each of the major groups. Then turn on the oscilloscope, select CHl, set the sec/div to 0.1 ms/div, select auto triggering, and obtain a line across the face of the CRT. Although many of the measurements described in this experiment are automated in newer scopes, it is useful to learn to make these measurements manually
2. Turn on your power supply and use the DMM to set the output for 1.0 V. Now we will use the oscilloscope to measure this dc voltage from the power supply. The following steps will guide you:
3. Place the vertical coupling (ac-gnd-dc) in the gnd position. This disconnects the input to the oscilloscope. Use the vertical position control to set the ground reference level on a convenient graticule line near the bottom of the screen.
4. Set the chI volts/div control to 0.2 V/div. Check that the vernier control is in the cal position or your measurement will not be accurate. Note that digital scopes do not have a vernier control. For fine adjustments, the volts/div control can be changed to a more sensitive setting that remains calibrated.
5. Place the oscilloscope probe on the positive side of the power supply. Place the oscilloscope ground on the power supply common. Move the vertical coupling to the DC position. The line should jump up on the screen by 5 divisions. Note that 5 divisions times 0.2 V per division is equal to 1.0 V (the supply voltage). Multiplication of the number of divisions of deflection times volts per division is equal to the voltage measurement.
6. Set the power supply to each voltage listed in Table 1. Measure each voltage using the above steps as a guide. The first line of the table has been completed as an example. To obtain accurate readings with the oscilloscope, it is necessary to select the volts/div that gives several divisions of change between the ground reference and the voltage to be measured. The readings on the oscilloscope and meter should agree with each other within approximately 3%

**Table 1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Power  Supply  Setting | VOLTS/DIV  Setting | Number of Divisions of Deflection | Oscilloscope  (measured  voltage) | DMM  (measured  voltage) |
| 1.0 V | 0.2 V/DIV | 5.0 D1V | 1.0 V | 1.0 V |
| 2.5 V |  |  |  |  |
| 4.5 V |  |  |  |  |
| 8.3 V |  |  |  |  |

1. Before viewing ac signals, it is a good idea to check the probe compensation for your oscilloscope. To check the probe compensation, set the volt/div control to 0.1 V/div, the ac-gnd-dc coupling control to DC, and the sec/div control to 2 ms/div. Touch the probe tip to the probe comp connector. You should observe a square wave with a flat top and square comers. If necessary, adjust the compensation to achieve a good square wave.
2. Set the function generator for an ac waveform with a frequency of 1.0 kHz. Adjust the amplitude of the function generator for 1.0 Vrms as read on your DMM. Set the sec/div control to 0.2 ms/div and the volts/div to 0.5 V/div. Connect the scope probe and its ground to the function generator. Adjust the vertical position control and the trigger level control for a stable display near the center of the screen. You should observe approximately two cycles of an ac waveform with a peak-to-peak amplitude of 2.8 V. This represents 1.0 Vrms, as shown in Figure 3.

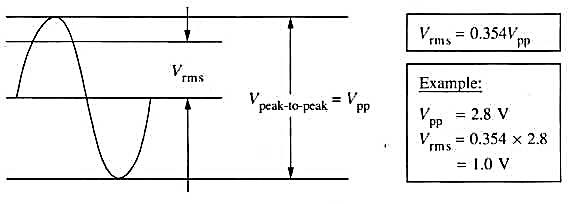


Figure 3

1. Use the DMM to set the function generator amplitude to each value listed in Table 2. Repeat the ac voltage measurement as outlined in step 5. The first line of the table has been completed as an example. Remember, to obtain accurate readings with the oscilloscope, you should select a volts/div setting that gives several divisions of deflection on the screen.

Table 2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Signal  Generator  Amplitude | VOLTS/DIV  Setting | Number of Divisions  (peak-to-peak) | Oscilloscope  Measured  (peak-to-peak) | Oscilloscope  Measured  (rms) |
| 1.0Vms | 0.5 V/DIV | 5.6 DIV | 2.8 Vpp | 1.0 Vms |
| 2-2Vms |  |  |  |  |
| 3.7Vms |  |  |  |  |
| 4-8Vms |  |  |  |  |

1. Do this step only if you are using an analog oscilloscope. You can observe both the power supply and the function generator at the same time. Select both channels (marked DUAL on some scopes). Each channel can be displayed with its own ground reference point. You will need to leave the trigger SOURCE on channel 2 because the ac waveform is connected to that channel. You can select either ALTemate or CHOP mode to view the waveforms. To really see the effects of this control, slow the function generator to 10 Hz and change the horizontal SEC/DIV control to 20 ms/div. Compare the display using ALTemate and CHOP. At this slow frequency, it is easier to see the waveforms using the CHOP mode; at high frequencies the ALTemate mode is generally preferred.

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| --- | --- |
| **Report for**  **Experiment A-8** | **Name**  **Date**  **Class** |

**ABSTRACT:**

**DATA:**

**Table 1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Power  Supply  Setting | VOLTS/DIV  Setting | Number of Divisions of Deflection | Oscilloscope  (measured  voltage) | DMM  (measured  voltage) |
| 1.0 V | 0.2 V/DIV | 5.0 D1V | 1.0 V | 1.0 V |
| 2.5 V |  |  |  |  |
| 4.5 V |  |  |  |  |
| 8.3 V |  |  |  |  |

Table 2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Signal  Generator  Amplitude | VOLTS/DIV  Setting | Number of Divisions  (peak-to-peak) | Oscilloscope  Measured  (peak-to-peak) | Oscilloscope  Measured  (rms) |
| 1.0Vms | 0.5 V/DIV | 5.6 DIV | 2.8 Vpp | 1.0 Vms |
| 2-2Vms |  |  |  |  |
| 3.7Vms |  |  |  |  |
| 4-8Vms |  |  |  |  |

**Table 3**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Power  Supply  Setting | VOLTS/DIV  Setting | Number of Divisions of Deflection | Oscilloscope  (measured  voltage) | DMM  (measured  voltage) |
| 1.0 V | 0.2 V/DIV | 5.0 D1V | 1.0 V | 1.0 V |
| 2.5 V |  |  |  |  |
| 4.5 V |  |  |  |  |
| 8.3 V |  |  |  |  |

Table 4

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Signal  Generator  Amplitude | VOLTS/DIV  Setting | Number of Divisions  (peak-to-peak) | Oscilloscope  Measured  (peak-to-peak) | Oscilloscope  Measured  (rms) |
| 1.0Vms | 0.5 V/DIV | 5.6 DIV | 2.8 Vpp | 1.0 Vms |
| 2-2Vms |  |  |  |  |
| 3.7Vms |  |  |  |  |
| 4-8Vms |  |  |  |  |

**RESULTS AND CONCLUSION:**

**EVALUATION AND REVIEW QUESTIONS:**

1. (a) Compute the percent difference between the DMM measurement and the oscilloscope measurement for each dc voltage measurement summarized in Table 1.

(b) Which do you think is most accurate? Why?

1. Describe the four major groups of controls on the oscilloscope and the purpose of each group.
2. If you are having difficulty obtaining a stable display, which group of controls should you adjust?
3. (a) If an ac waveform has 3.4 divisions from peak to peak and the VOLTS/DIV control is set to 5.0 V/div, what is the peak-to-peak voltage?

(b) What is the rms voltage?

1. If you wanted to view an ac waveform that was 20.0 Vrrns, what setting of the VOLTS/DIV control would be best?
2. Most analog oscilloscopes have a single beam, which is shared with two signals. If you are using an analog oscilloscope, when should you select ALTemate and when should you choose CHOP?