The Science of Measurements

Oscilloscopes

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Last month, we looked at digital and analog voltmeters and presented the advantages and disadvantages of each of the instruments. No one single instrument is designed to be able to analyze all aspects of an electronic circuit. The oscilloscope is probably the most versatile instrument that a ham can have in his radio shack. The scope presents an electronic picture of the voltage at a point in the circuit. From that picture, a ham can determine if the circuit is working properly or not. Voltmeter often have a single knob to select the range and function (voltage, ohms or milliamperes) as well as a simple display. The oscilloscope, on the other hand, has an array of knobs and switches and an X –Y graphic display screen.

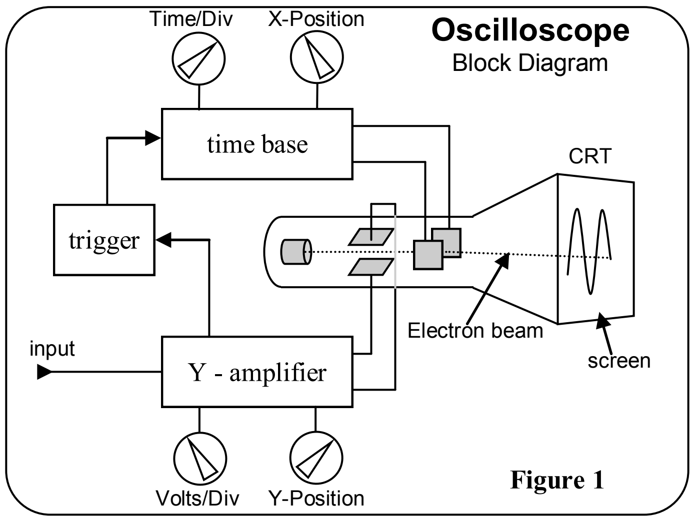


Figure 1

The design of the basic scope is to have a time presentation on the horizontal (X-) axis and have a voltage presentation on the vertical (Y-) axis . The block diagram to the right shows the basic sections of an oscilloscope. The line on the CRT (cathode ray tube) is the result of an electron beam being pulled by a set of deflection plates on either side of the horizontal axis. The rate of the sweep is set by the time base using a front panel control. When the beam reaches the far right side of the CRT, there is a blanking pulse that blanks out the CRT to allow the electron beam to reposition itself on the left hand side of the CRT. A trigger signal derived from the Y-amplifier is used to start the horizontal trace at the same position of the input signal for every sweep. An input signal is applied to a precision gain Y-amplifier. This gain is set by a front panel "volts/division" control. Both the sweep rate or time/division and the input gain or volts/division controls consist of a multi-position switch and a variable control. Usually the variable control is left in a "calibrate" position so that accurate readings can be taken from the CRT. A graticule on the CRT face allows the user to measure the deflection of the beam in both the X and Y directions.

Most of the scopes available to the ham community are great for troubleshooting HF rigs. The scope that I have is a 100 MHz dual trace scope. What that means is that at a 100 MHz signal will indicate a voltage that has been reduced by 3 dB. For my purposes, this scope is useable to cover the 10 meter band. The accuracy of a typical scope is about 3% in the useable band width. Some of the newer scopes have digital enhancements that make the scopes more accurate. For the average ham this is not necessary.

In figure 2, on the next page, the time base is set at 0.5 ms per division. There are two divisions from the peak of one cycle to the peak of the adjacent cycle. So the time for one complete cycle, the period, is 1 ms. Frequency is the inverse of the period: f = 1/t where "f" is frequency in Hz and "t" is time in seconds. The frequency of the waveform in figure 3 is 1 kHz (1000 Hz). The voltage is measured by counting the number of divisions on the vertical axis. In this case there are 6 divisions between the positive peak and the negative peak. Since the range switch is set at 0.5 V/division the result is $3V_{P-P}$. Not only have we measured the voltage and frequency of the input signal, but by observing it on the oscilloscope screen we see that it has the appearance of a pure sine wave uncorrupted by excess noise or distortion. There is a lot of information presented to us if we can interpret it.

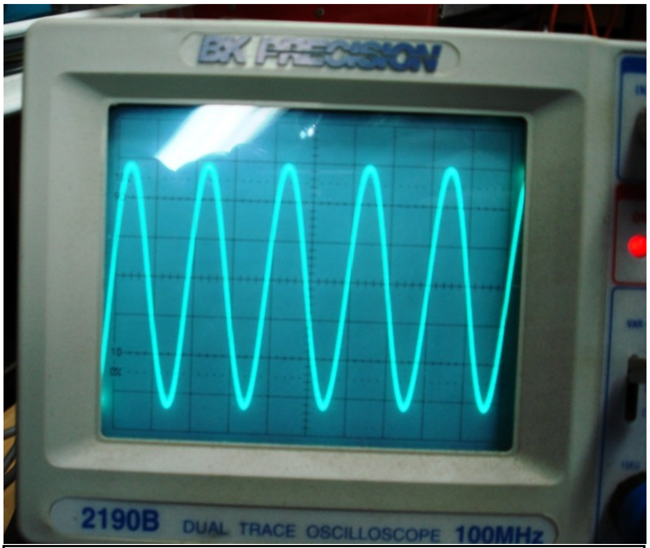


Figure 2
A 1000 Hz sine wave signal. The vertical display is set at 0.5V / div. The horizontal display is set at 0.5 ms / div.

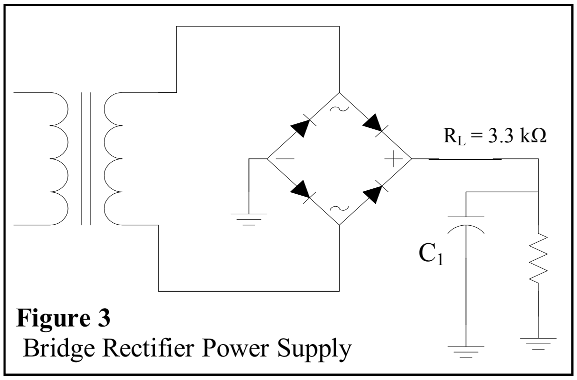


Figure 3
Bridge Rectifier Power Supply

Figure 3 is a schematic of a simplified bridge rectifier power supply. The scope pictures shown below are oscilloscope traces of the AC component of the power supply output, and they illustrate how it changes with the addition of filter capacitance.

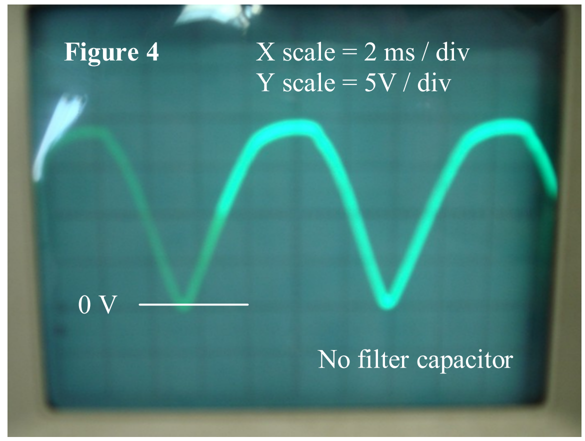
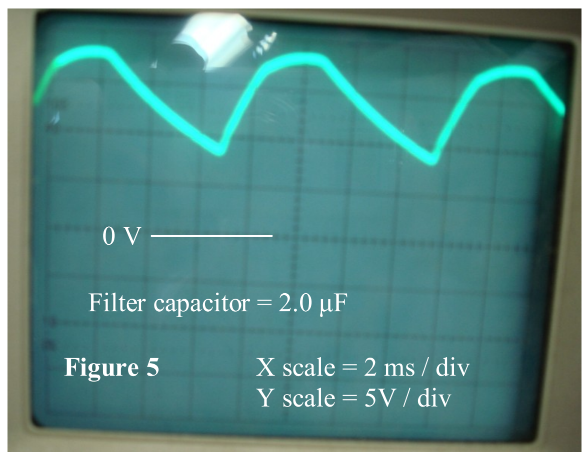
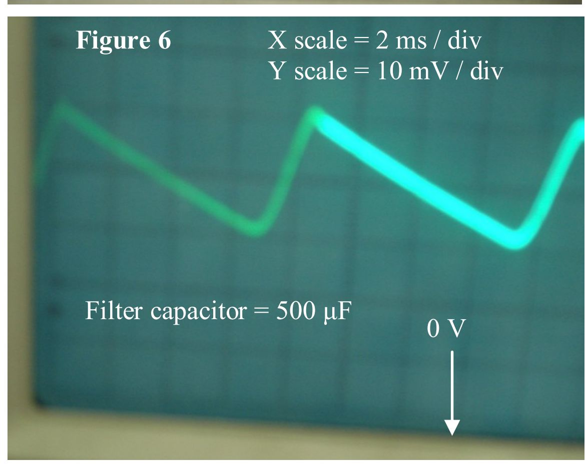


Figure 4 is a picture of the output of the bridge rectifier with no capacitor filtering to smooth out the AC component of the waveform. The vertical scale is 5V/div. There is approximately 20V of "pulsating DC". In the next pictures, capacitive filtering will be added to the circuit.



In figure 5 a 2.0 µF has been added to the output of the power supply. The peak voltage remains the same value (about 20 volts), and the voltage rises more rapidly than it falls. The capacitor is said to "Hold up the voltage." Let's see what the effect is of a significant increase in capacitance.



In the last figure the filter capacitance was increased to 500 µF. The vertical scale has been changed to 10mv to read the ripple voltage. The ripple voltage has been reduced to 20mv peak to peak at a frequency of 120Hz. While the DC level is not shown on the scope, it can be measured with a digital multimeter. This should be approximately 20V DC.

We can clearly see the effect of adding filtering capacitance to a simple power supply. The ripple is inversely proportional to the capacitance. (The ripple is also affected by the amount of current that is drawn from the supply — but more about that at some other time.)

If you have any questions or comments, please feel to drop me a note at WB6WXO@SOARA.org