8. Signal Generators and Oscilloscopes

Introduction

Signal generators produce alternating currents (and voltages) or AC and signal generators play the role of batteries for AC circuits. Oscilloscopes are basically voltmeters to measure alternating voltages. Since the voltage is changing, oscilloscopes are more complicated devices that digital voltmeters and they are also more complicated to operate.

Signal Generators

The picture below is of a typical signal generator we have in Electronics Lab. There are several controls on the front:
1. **ON/OFF** switch is obvious.
2. **MODE** switch is for choosing Sine, Square, or Triangular shape wave output.
3. **FREQUENCY**: This controlled with a COARSE push button which picks the major frequency range and a FINE control knob for adjustments within the range. The frequency $f$ is given in Hertz or cycles per second on a signal generator. The higher frequencies of kilohertz ($10^3$ cycles/sec) or kHz and the highest frequencies are megahertz ($10^6$ cycles/sec) or MHz.
4. **AMPLITUDE**: This adjusts the maximum value of the output voltage. The typical output voltage is millivolts-1 volt range.

Also, there is typically a BNC connector for attaching a coaxial cable output wire which in this lab will run to the oscilloscope. Coaxial cable has a center conducting wire on the axis and this is surrounded by a shield and is the second conductor to complete the circuit. Coaxial cable is used because the inner conductor is naturally shielded from outside, extraneous AC sources coming from for example, radio stations of even the AC from the Con Edison wall socket. The outer shielded part of the coaxial cable is usually automatically grounded inside the device like the signal generator. The grounding allows the shielding to work properly as a shield. Sometimes the output connector on the signal generator is different from BNC.
Oscilloscopes

The picture below is of a typical oscilloscope found in Electronics Lab. The "scope" or small TV screen is on the left and this is where the voltage (or current) is measured or viewed.

The oscilloscope is used for measuring AC voltages and as a result, the voltage is not constant but varying in time. Typically what you will see on the oscilloscope screen is a Sine wave function like \( \sin(\omega t) \) where \( \omega \) is the angular frequency in radians. In electronics, the frequency \( f \) in Hertz (or cycles per second) of the voltage is usually measured instead of \( \omega \) and as you know \( \omega = 2\pi f \). Actually, since what we see on the screen of the oscilloscope is typically a Sine wave, what is measured directly is the period \( T \) or repeat time in seconds of the wave and you recall, \( T = \frac{1}{f} \).

A block diagram of the connection between the oscilloscope and signal generator is simple:

![Block Diagram of Oscilloscope and Signal Generator](image)

**DUAL CHANNEL OSCILLOSCOPE:** Typically, the signal measured is input into the oscilloscope using a coaxial cable connected to a BNC connector. Most oscilloscopes today have the ability to measure two different input signals (on the same viewing screen) so there are TWO input connectors on the front of the oscilloscope one for **CHANNEL 1** and one for **CHANNEL 2**.

There are several controls on the front of the typical oscilloscope:
- **ON/OFF** switch which again is obvious.
- **VOLTAGE SCALE ADJUST:** This is similar to the voltmeter scale adjust on a digital voltmeter. If this scale is too low (in comparison with the voltage measured) the Sine wave will be too large to display on the screen. If the scale is adjusted to large, the measured voltage will appear as too small a Sine wave to be seen. Quite often the center of the Voltage Scale Adjust contains a fine adjust knob. Make sure this knob is in the **calibrate** position if you want use the known calibrated scale. In dual channel oscilloscopes, there is a voltage scale adjust for each channel.
HORIZONTAL POSITION adjust: This knob should be about midway in the range so that the Sine wave appears center horizontally in the output screen.

VERTICAL POSITION adjust: This knob should be about midway in the range so that the Sine wave appears center vertically in the output screen. Sometimes when using the dual channel feature, you want the two Sine waves measured to be separated in the output screen (one above and one below). Sometimes when comparing the two Sine waveforms you want to superimpose the two waves to examine the relative amplitude of phase shift for example.

INPUT CHANNEL KNOB: You can select which channel the oscilloscope views. You can view channel 1 or channel 2 separately. (Make sure you select the same channel (1 or 2) as you connect the coaxial cable to the BNC connector from the signal generator.) You can also view them together in alternate or in chop modes. Finally you can add the two input channels together in the sum mode.

HORIZONTAL TIME/DIVISION: This adjust the horizontal time scale on the oscilloscope and this must roughly match the period $T = \frac{1}{f}$ output from the signal generator. You know the signal generator output frequency $f$ so you can calculate the period $T$ measured on the oscilloscope. This period $T$ should roughly match the TIME/DIVISION scale selected. If the Time/Division scale is too small, the waveform measured will appear too big on the oscilloscope screen. Alternatively, if the Time/Division scale is too large, the waveform measured will appear too fine to see the sine wave shape. If you do not know the frequency $f$ of the signal measured, you must adjust the TIME/DIVISION scale until the output waveform appear right.

AC/DC/GROUND KNOB: Typically you will have this in the AC position and all the AC voltage input through the BNC connector appears on the oscilloscope screen. When in the AC position, there is a capacitor placed in the input inside the oscilloscope and this "blocks" DC voltages from appearing on the oscilloscope screen. If this knob is in the DC position, there is no capacitor in the input and the total input voltage appears on the screen. This could be a problem if there is a DC voltage (5 volts) added to a small AC voltage (say 2 millivolts) because the DC voltage will take the waveform off screen above. If this knob is in the grounded position, the input voltage is shorted out and does not appear on the oscilloscope screen.

TRIGGER MODE: The most difficult part to adjust on an oscilloscope is the trigger and there are several knobs that control the trigger. First make sure one knob is in the INTERNAL trigger position. Another knob should be placed in the AUTOMATIC position. Also, another know selects the TRIGGERING CHANNEL (make sure the channel selected here is the same channel as connected the BNC coaxial cable from the signal generator). Finally, adjust the TRIGGERING know until the waveform is stationary (no moving) on the screen. This knob synchronizes the internal trigger with the input signal voltage.

Laboratory Exercises

Adjust the signal generator so that the voltage output is say 10 kiloHertz and the waveform is a sine wave. $T=0.1$ millisecond calculated from $T = \frac{1}{f}$ so the time scale on the oscilloscope should be adjusted
properly to view this according to the above instructions. Try several different frequency outputs from the signal generator and make sure you can view each on the oscilloscope. Do the same with the square wave and make sure you understand which is considered the period in this case. Also, view the triangular wave output.