

EXPERIMENT 5

The Oscilloscope and Applications

Object

The primary purpose of this experiment is for you to become familiar with how to operate an oscilloscope, and then, how to use it in various applications. Basically, the oscilloscope is an X-Y plotter displaying 'Voltage vs Time' or 'Voltage vs Voltage'. You will learn to display various electrical signals and to measure such quantities as voltage, time, frequency, and phase. The reason for so much importance in studying the oscilloscope is that it will be an invaluable tool in electronic laboratory work.

Background

The basic constituent of an oscilloscope is the cathode ray tube (CRT) as shown in Figure 1. This highly evacuated tube contains an electron gun, two sets of deflection plates (X-plates, Y-plates), and a fluorescent screen at the enlarged end. The purpose of the gun is to produce an electron beam by evaporating electrons off the cathode and focusing them into a narrow stream. The electrons are accelerated to a high velocity and strike the fluorescent screen, leaving a bright spot where they hit. The electron beam traces out a pattern on the screen - depending on the potential difference across the plates. This same principle is used in producing a pattern on a TV screen!

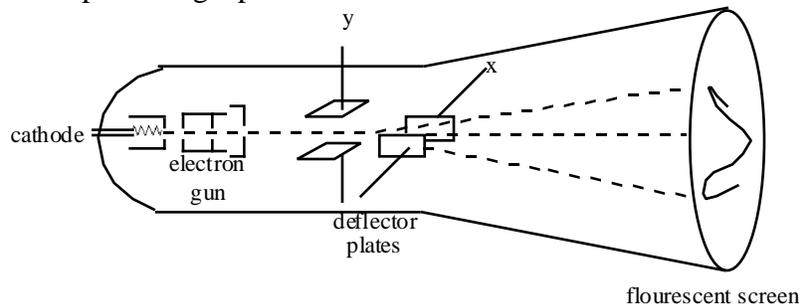


FIGURE 1: Cathode Ray Tube

The oscilloscope has connections which permit potential differences (voltages) to be applied across the X-plates and Y-plates. If a voltage V is applied across the plates, it produces an electric field $E = V/d$ which deflects the electron beam (recall $F = qE$). The amount of deflection is directly proportional to the amplitude of the applied voltage. If $V_1(t)$ is applied to the Y-plates and $V_2(t)$ is applied to the X-plates, the electron beam plots a graph of " V_1 versus V_2 " on the screen.

Although the scope will graphically display two voltages " V_1 versus V_2 ", the most common application is that of displaying a time-varying voltage $V(t)$ as a function of time t . The time-axis is produced by the scope's *HORIZONTAL SWEEP* circuit which generates a linear voltage (ie. $v_x \propto t$) across the X-plates. This feature enables the oscilloscope to plot

very quick variations in the instantaneous voltage. On the other hand, a voltmeter only provides an “average” value of the voltage and cannot measure instantaneous voltage.

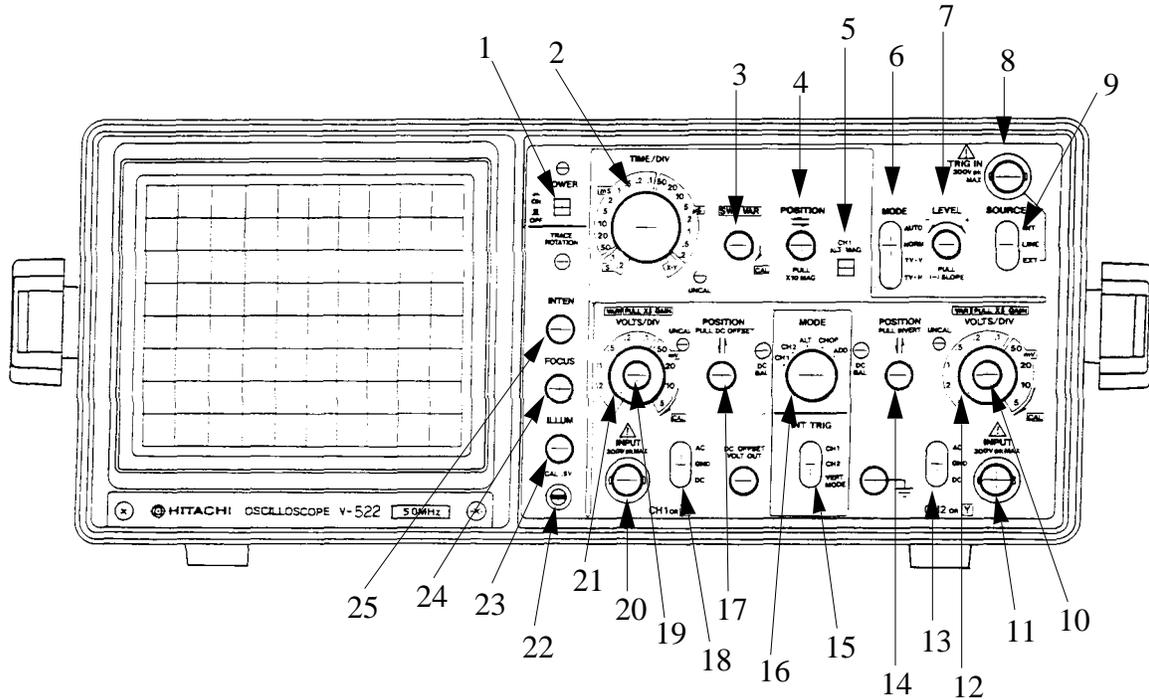


FIGURE 2: Front View of the V-522 HITACHI Oscilloscope

Procedure/Results

Starting with part (2) sketch the observed waveform, tabulate any data/results, show sample work, and answer the questions as you progress through each new part of the experiment.

1. Preliminary Set-up to Obtain a Free-Running Trace

Although you will be using the HITACHI oscilloscope, all models of oscilloscopes (like TV models) perform the same basic functions. The numerous controls may seem confusing, but these can be simplified by grouping them into 4 functional areas: power, vertical, horizontal, and trigger controls.

In this exercise, you will set the controls to obtain the simplest display - a free running horizontal trace due to the electron beam sweeping across the screen. This also shows whether your oscilloscope is working. The numbers in brackets refer to the controls labeled in Figure 2.

Basic Power Controls

- (1) **POWER** button - depress to turn on the oscilloscope
- (25) **INTEN**sity control - keep 'low' so the screen is not damaged by the electron beam

(24) **FOCUS** control - adjust for a sharply defined trace

Vertical Display Controls (CH1 and CH2 inputs)

- (16) **MODE** display switch - set to **CH1**
- (21,12) **VOLTS/DIV** switch for CH1 & CH2 - set to **1 volt/cm** (Note: 1Div = 1cm)
- (19,10) **VARIABLE** (center knob of **Volts/Div**) - set to **CALibrate** (**UNCAL** light off)
- (17,14) **POSITION** control for CH1 & CH2 - pushed in and set to the middle
- (18,13) **AC-GND-DC** input coupling switch - set to **GND** (**GND** \equiv Ground \equiv 0 volts)

Horizontal Sweep Controls (Time-Base system)

- (2) **TIME/DIV** switch - set to **1 ms/cm** (Note: 1Div = 1cm)
- (3) **SWP VARIABLE** control - set to **CALibrate** (**UNCAL** light off)
- (4) **POSITION** control - pushed in and set to the middle
- (5) **CH1 ALT MAG**nification switch - **x1magnification** (blue button out)

Trigger Controls (Synchronization system)

- (6) Trigger **MODE** switch - set to **AUTO**
- (7) Trigger **LEVEL** control - pushed in and set midway between '-' and '+'
- (9) Trigger **SOURCE** switch - set to **INT**
- (15) **INT TRIG**ger switch - set to **CH1**

(a) Obtaining a Single Trace

A horizontal trace should appear on the screen with the preliminary settings. If not, turn the beam **INTENS**ity clockwise to obtain a display of reasonable brightness and adjust the **FOCUS** for a sharp trace. Do not make the beam too bright or the screen will become permanently damaged.

NOTE: If no trace appears on the screen, adjust the *POSITION* and *INTEN* controls slowly . If that fails ask for assistance.

b) Obtaining Two Traces

To obtain a trace using the second channel, set the display **MODE** switch to **CH2**. What happens if the **INT TRIG** switch is set to **CH1** or **CH2**? After obtaining a trace using either channel, set the display **MODE** switch to **ALTE**rnate and you should see two traces on the screen.

(c) Observing the Horizontal Sweep (or Time-Base)

Inside the oscilloscope there is a special electronic circuit (called the sweep circuit or time-base) which generates a voltage proportional to time and applies it across the horizontal deflection plates. Such a voltage (Figure 3 & 4) causes the electron beam to

"sweep" at a constant speed from left to right across the screen, and then to quickly return and proceed again. During the return or "flyback", the beam is temporarily blanked out.

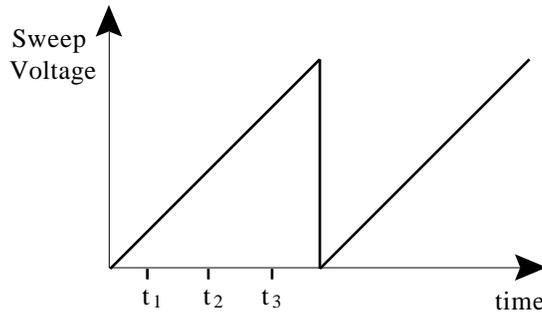


FIGURE 3: Sweep Voltage Applied to the Horizontal Plates

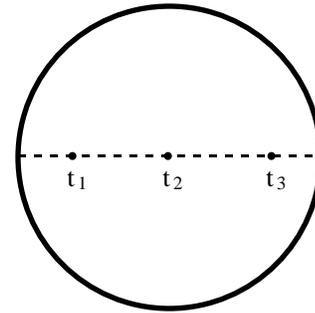


FIGURE 4: Motion of Beam due to Horizontal Sweep

Reset the oscilloscope to use only the **CH1** trace. Examine the motion of the beam spot on the screen by slowly adjusting the **TIME/DIV** control from its slowest to fastest sweep. When the sweep rate is sufficiently fast, the "spot" on the screen becomes a "line" due to persistence of vision and persistence of phosphorescence.

2. Measurement of Voltage and Frequency

Detailed variations in instantaneous voltage can be studied by displaying "voltage" on the Y-axis and "time" on the X-axis. The voltage signal under examination is connected to the **INPUT** of the scope and the time-axis is established by the **TIME/DIV**. To ensure proper calibration of the display, variable time/div and volts/div controls must be at **CAL**.

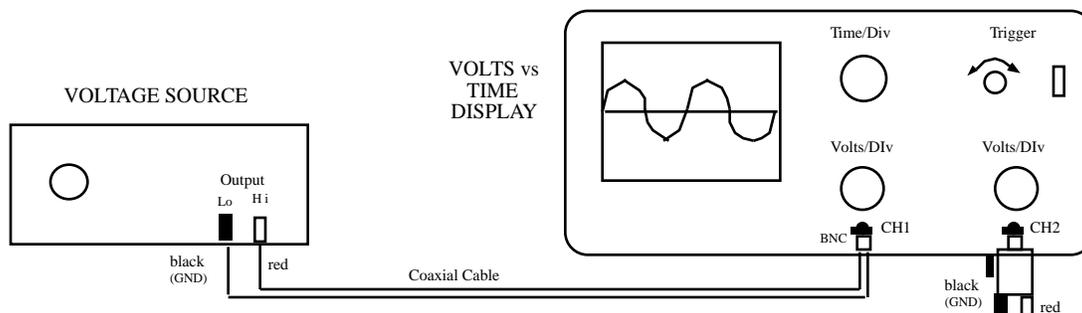


FIGURE 5: Connection of Scope to Display "Voltage versus Time"

Connect the BNC terminal of the coaxial cable to the **CH1 INPUT** of the scope and investigate the following voltage signals. Perform the relevant measurements, sketch a representative diagram of the observed waveform, and tabulate any data or results.

(a) Voltage of a DC Battery

Establish a "zero-volt" reference by setting the *CH1 AC-GND-DC* switch to *GND*. Adjust the *POSITION* control to center the trace on the screen. Set the *CH1 VOLTS/DIV* switch to *1 volt/cm*. Connect the leads across the terminals of the battery then set the *AC-GND-DC* switch to *DC*. Note the vertical displacement of the trace on the screen. To calculate the measured voltage, multiply the vertical displacement of the trace measured in *cm* by the *VOLTS/DIV* setting. What is the uncertainty due to error in reading the screen? Repeat this measurement with decreasing *VOLTS/DIV* settings.

Question 1: To make the most accurate measurement of the battery voltage, where would you position the "0 V" reference? What oscilloscope *VOLTS/DIV* setting would you use?

(b) Sinusoidal Voltage Signal

Set the *AC-GND-DC* switch to *AC* and connect the output of the 3311A function generator to the *CH1* input of the scope. Observe the effects of changing the waveform, frequency, amplitude of the generator. Using the scope, measure the peak-to-peak voltage V_{pp} and frequency f of a sinusoidal waveform for a chosen dial-setting on the generator. Determine the period T of the displayed signal by adjusting the *TIME/DIV* control so that one wavelength occupies most of the screen. Measure the wavelength λ (*cm*) and use the *TIME/DIV* setting to give the period T . Compare the measured frequency $f = 1/T$ with the dial setting on the generator. Do they compare?

(c) Electrical Noise Pick-up by a Wire

Attach a BNC-to-Banana plug  to the *CH1* input of the scope. Connect a loose wire to one of the banana terminals and measure the frequency of the radiation picked up by the wire from the AC power lines. What happens when your hand touches the wire?

3. Measurement of Phase Difference

Connect a variable capacitor C and resistance $R = 5\text{K}\Omega$ in series across the output of the 3311A function generator as shown in Figure (6). Connect V_G to the *CH1* input and V_R to the *CH2* input of the scope. Display both signals on the screen at the same time by selecting the *ALT* position on the *MODE* display switch.

If two signals have the *same* frequency but *different* phase, the two waves will be separated from each other by a phase difference ϕ which can be measured using the time-base of the scope as shown in Figure (7). Set both signals to have the same 0-volt reference position by setting the *AC-GND-DC* switches to *GND* and centering each trace. Set the switches back to *AC*.

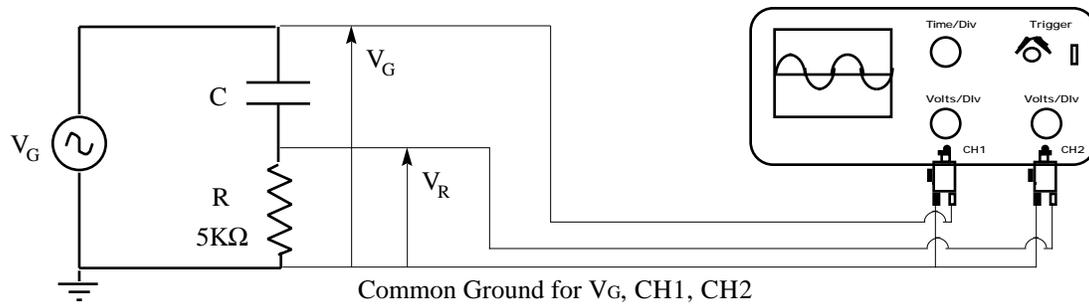


FIGURE 6: R-C Circuit

Use the oscilloscope to adjust the output of the generator to a 10Khz sine wave. Measure the phase difference ϕ between the generator voltage V_G and the resistor voltage V_R as the capacitance C is varied from $0.002\mu\text{F}$ to $0.010\mu\text{F}$ in $0.002\mu\text{F}$ steps. Compare your measured results to theoretically predicted values of ϕ for an RC circuit.

4. Internal Impedance of the 3311A Function Generator

According to Thevenin's theorem every active linear device can be represented by series combination of a generator E (of zero Impedance) and an

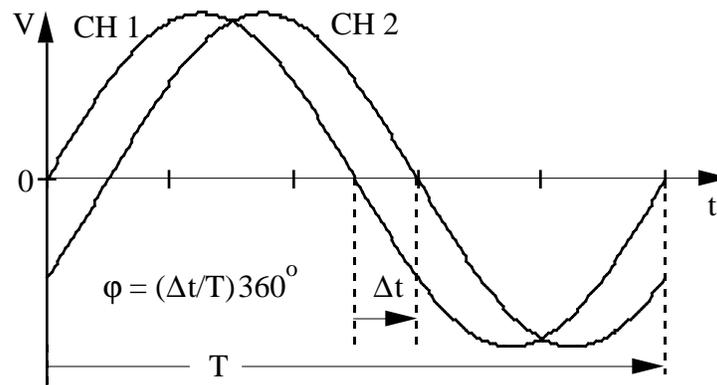


FIGURE 7: Phase Difference

impedance Z . Determine the values of E and Z of the 3311A function generator by connecting a known variable resistance R across its terminals and measuring the output voltage V using the oscilloscope. The schematic diagram is shown in Figure (8).

Initially set the variable resistor R to 100Ω and increase its value to 1000Ω in 100Ω steps. Then increase R in 1000Ω steps up to $10,000\Omega$. Although it is possible to determine Z and E from two independent measurements of V and R , a graphical method is preferable. HINT: Using Kirchoff's Law, derive a linear relation between V and I where $I = V/R$.

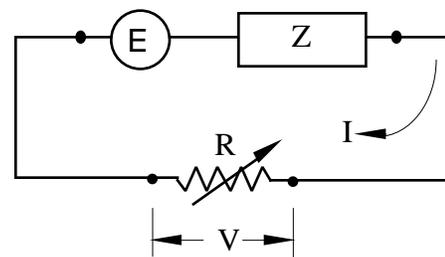


FIGURE 8

Question 2: Calculate the ratio V/E when $Z = R$ for the circuit shown in Figure (8). Do your experimental results agree with this value?

