

# Experiment 1      The Dual-Beam Oscilloscope and the Digital Multimeter

## The dual-beam oscilloscope

The cathode ray oscilloscope, CRO, is a versatile instrument which may be used as a high impedance DC or ACO voltmeter or for measuring the frequency and shape of electrical oscillations. The instrument consists essentially of a narrow beam of electrons which gives rise to a bright spot when it impinges on a fluorescent screen. Two pairs of plates enable the beam to be deflected either horizontally (x-plates) or vertically (y-plates) when a voltage is applied to them. In normal operation, an internally generated saw-tooth waveform is applied to the x-plates, causing the beam to be deflected horizontally at a constant rate in a repetitive fashion; this results in a horizontal line across the screen if no voltage is applied to the y-plates. If a time-varying voltage is applied to the y-plates, the electron beam is deflected by the resulting electric field, thus giving a display of voltage versus time on the screen.

The dual-beam oscilloscope used in this course (Figure 1.1) has two inputs (CH1 and CH2) so that the two signals can be displayed simultaneously, allowing direct comparisons to be made.

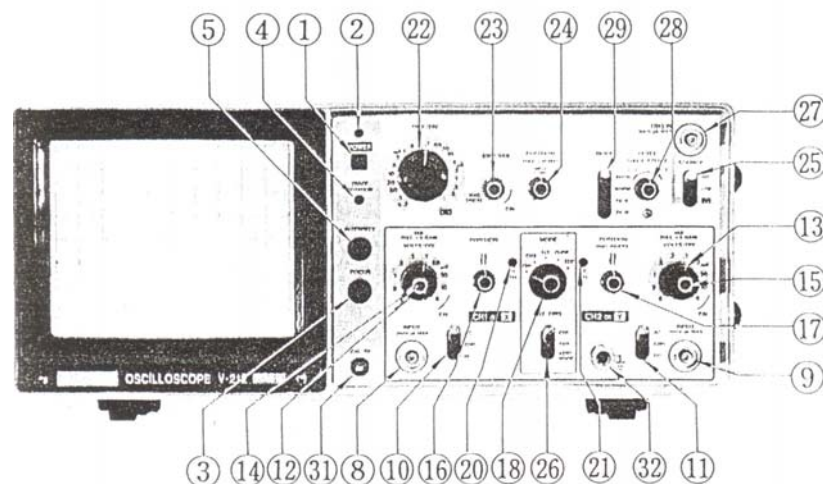


Figure 1.1: The cathode ray oscilloscope

The functions of the various controls will become familiar with use. The brightness and sharpness of the beams are determined by the INTENSITY (5) and FOCUS (3) controls, respectively. The speed at which the beams are deflected horizontally (time base) is determined by the TIME/DIV control knob (22). For normal operation the red SWP VAR control knob (23) should be fully clockwise; only in this situation is the time base calibrated correctly. The POSITION controls (16, 17, 24) are used to position the trace on the screen. Electrical signals to be investigated are applied to the y-plates via the input connectors CH1 (8) and CH2 (9) through amplifiers of variable gain. The VOLTS/DIV control knobs (12, 13) select the appropriate gain of these amplifiers. The red VAR controls (14, 15) must be fully clockwise if the VOLTS/DIV scales are to be used for measurement.

**CAUTION:** *The 0 V side of the input connectors is joined to earth. If the generator of the signal under investigation also has an earthed terminal this must be connected to the oscilloscope earth, otherwise the signal source would be short-circuited.*

When an AC-GND-DC switch (10, 11) is in the DC position, the input is connected directly to the amplifier. In the AC position the input signal is first fed through a capacitor; this is useful for observing small AC signals superimposed on a large DC background, since the DC part of the signal will not be coupled through the capacitor. For many applications, the trigger MODE select switch (29) may be set in the AUTO position. The trigger LEVEL control (28) may be used to obtain a steady trace on the screen. The lower centre MODE select switch (18) enables the signal on CH1 or on CH2 or both (ALT position) to be observed.

## The digital multimeter

The digital multimeter, DMM, (Figure 1.2) is a versatile instrument, which may be used to measure DC and AC voltages, currents and resistance. It complements the oscilloscope and must always be used when accurate (i.e. better than 5%) measurements are required. When used to measure voltage the DMM has an input impedance of 10 M $\Omega$ .

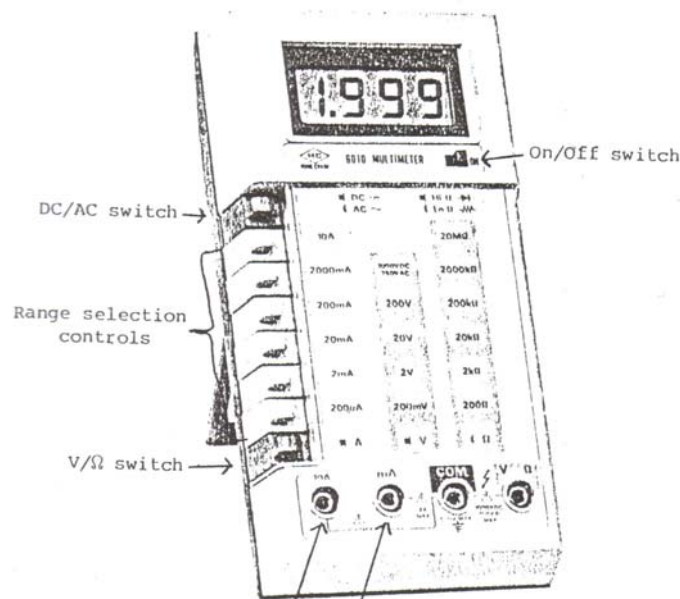


Figure 1.2: The digital multimeter.

## Part 1: To measure a DC voltage using a CRO

To illustrate the use of the oscilloscope as a d.c. voltmeter, set up the circuit indicated in Figure 1.3, with  $R' = 2.2 \text{ k}\Omega$ . Initially, set  $R = 1000 \Omega$ .

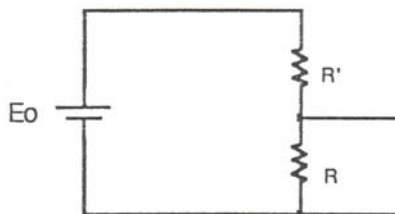


Figure 1.3: A potential divider.

Connect one of the y-inputs of the CRO across the resistor,  $R$ , and note the deflection of the trace. Change the volts/cm control knob to get maximum sensitivity. Measure the potential difference across  $R$  (remember to record the maximum error). Decrease  $R$  in steps of  $100 \Omega$  and record the potential difference,  $V_R$ , across the resistance,  $R$ , in each case.

Resistance, $R (\Omega)$	Error in $R$	Voltage, $V_R$ (V)	Error in $V_R$
1000			
900			
800			
700			
600			
500			
400			
300			
200			
100			

Also, use the oscilloscope to measure the e.m.f.,  $E_0$ , of the power supply. Show that each of the measured values of  $V_R$  are consistent with the theoretical value, calculated assuming that the power supply has negligible internal resistance, viz.

$$V_R = \frac{RE_0}{R + R'} \quad [\text{prove this relationship}]$$

The circuit under study here is called a potential divider and has many important applications e.g. to produce stable voltage references, to set the dc bias of a common emitter amplifier, etc.

Finally, switch the AC-GND-DC switch to the AC position and satisfy yourself that the introduction of the capacitor blocks the DC signal.

## **Part 2: To measure the amplitude and frequency of an AC signal**

The signal to be investigated is that produced by the variable frequency signal generator. Output sockets, one of which is earthed, are at the lower right of the panel. The knob below the dial knob is the frequency range selector switch and the knob at the lower right controls the output amplitude.

Set the frequency control on the signal generator to around 1 kHz and the output amplitude to about half maximum.

Make sure the SWP VAR and VAR controls on the oscilloscope are fully clockwise (CAL position). Apply a sinusoidal signal from the signal generator to one input of the oscilloscope with the AC-GND-DC switch in the DC position. Obtain a sharp steady trace and measure the peak-to-peak voltage,  $V_{pp} = V/2$ , (where  $V$  is the amplitude of the signal) and period of the waveform. Draw a scale diagram of the trace for inclusion in your report. Calculate the rms voltage,  $V_{rms} = V/\sqrt{2}$  for the observed signal. Repeat for a number of other frequency ranges (say, approximately 100 Hz, 10 kHz and 100 kHz).

Repeat the experiment using the square waves from the signal generator. Finally, switch the AC-GND-DC switch to the AC position and observe the effect of introducing the capacitor in this case.

## **Part 3: To investigate the trigger LEVEL facility of the CRO**

To enable a stationary pattern to be observed on the screen the start of the x-sweep must be synchronized with the signal being observed. The trigger LEVEL control allows the sweep to start on the appearance of either a positive going or negative going (knob pulled out) signal; the sweep is started only when the signal being observed exceeds some preselected amplitude determined by the control setting.

Apply a sinusoidal signal from the signal generator to one input of the oscilloscope. With the trigger level control in the AUTO position the sweep should start at the zero level of the sine wave. Set the trigger MODE switch to the NORM position and slowly turn the LEVEL control clockwise. Note how the starting point of the sweep moves up or down the sine wave depending on the level set. Draw a number of scale

diagrams to illustrate the effect observed. Repeat the procedure with the LEVEL control pulled out.

#### Part 4: To use a digital voltmeter as (a) an ohmmeter and (b) a voltmeter

- (a) To familiarise yourself with the digital multimeter used as an ohmmeter set the switches to ohms ( $\Omega$ ), 20 k $\Omega$  and DC and connect a resistance box between the ohms ( $\Omega$ ) and common (COM) terminals of the DMM. Measure the resistance of the box for some (four) different settings of the dials between 9999  $\Omega$  and 0  $\Omega$ , switching ranges as convenient. Check that your measurements agree with the dial readings.
- (b) Connect the signal generator to the oscilloscope and adjust to give about 1 V peak-to-peak sine wave at 1 kHz. Use the oscilloscope to measure the peak-to-peak voltage of the signal and, hence, calculate the corresponding rms voltage. Now measure the AC and DC voltages with the DMM. Tabulate the results as indicated below. Switch to square waves and repeat the measurements. How do they compare?

	OSCILLOSCOPE		DIGITAL MULTIMETER	
	$V_{pp}$ (Volts)	$V_{rms}$ (Volts)	DC Voltage (Volts)	AC Voltage (Volts)
Sine wave				
Square wave				

With the signal generator set to give sine wave output increase the frequency of the signal generator to the maximum possible, and then decrease to the minimum, while checking the AC voltages recorded by the DMM and the oscilloscope display. Over what frequency range will the DMM operate satisfactorily in this mode?

#### Part 5: Measurement of the output impedance of the signal generator

When a voltage source supplies current to a load,  $R_L$ , the voltage across the terminals may drop below the unloaded value. This is exactly analogous to the effect of the internal resistance of a DC power supply. The output stage may be represented as an ideal voltage source,  $V_0$ , in series with an impedance,  $R_i$  (c.f. Figure 1.4). This predicts that the observed output voltage will be given by:

$$V = \frac{R_L}{R_L + R_i} V_0.$$

Set up the circuit in Figure 1.4. The points A and B represent the terminals of the signal generator. Measure the observed output voltage when there is no load and when  $R_L = 3 \text{ k}\Omega$ . Hence, calculate  $R_i$ . Repeat for  $R_L = 1 \text{ k}\Omega$  and, again, calculate,  $R_i$ .

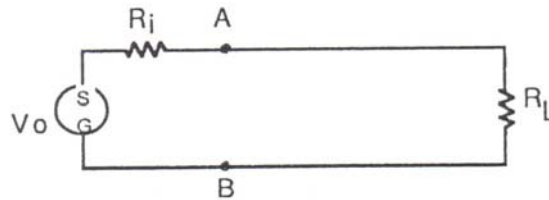


Figure 1.4: Circuit to measure the output impedance of a signal generator.