

# Appendix G

## Displaying I–V Curves on an Oscilloscope

### G.1 Introduction

When observing the behaviour of various electronic devices, it is often useful to view their *I–V curves*; i.e. the relationship of their current to the voltage applied across them. With an oscilloscope, curves of this sort can be observed easily.

#### G.1.1 Wiring

The characteristic curve for a device can be determined using the circuit shown in Figure G.1.

With the oscilloscope in the x–y mode, the voltage across the device is  $V_A$ . The current can be determined from the voltage drop across  $R_M$ , and is:

$$I = \frac{V_B - V_A}{R_M} \quad (\text{G.1})$$

#### G.1.2 Oscilloscope Settings

To get  $V_B - V_A$  we can use “-” and “ADD” which actually gives  $V_A - V_B$ , so B channel is “upside down”. To see the I–V curve, use *x via A* mode; thus we get –I vs V (again, it’s upside down) and remember, the current is actually the voltage on the vertical axis divided by  $R_M$ .

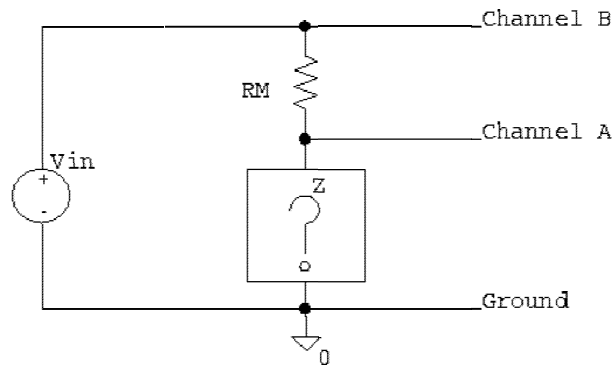


Figure G.1: Circuit to Measure I-V Curve of a Device

Make sure you have the same settings on both channels when you add or subtract them; otherwise you are trying to combine apples and oranges.

### G.1.3 Input Voltage

If we provide  $V_{in}$  with a wave generator set for sine or sawtooth, we will see whole graph at once.

Q: What should we set the trigger to?

A: Trigger is irrelevant in x via A mode!

## G.2 Phase Difference of Waveforms

If we have two sinusoidal waveforms on an oscilloscope in timebase mode, it is easy to measure the phase difference as follows. (See Figure G.2.)

In this case, the phase difference,  $\delta$ , is given by

$$\delta = \frac{t_d}{T} \times 360^\circ$$

where  $t_d$  is the delay time and  $T$  is the period.

Another way to measure the phase difference between two signals in  $x-y$  (X VIA A) mode is to measure the angle between the maximum  $x$  voltage and the maximum  $y$  voltage. This is shown in Figure G.3.

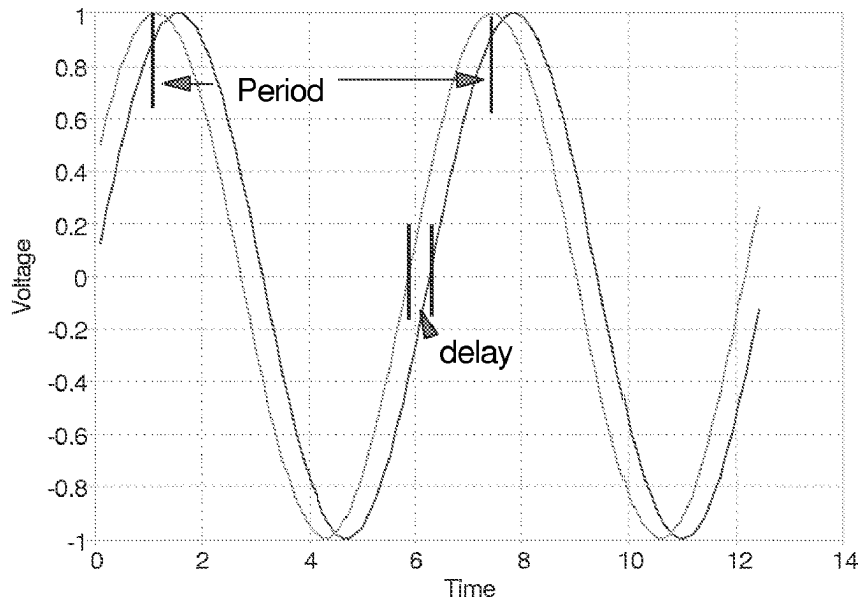


Figure G.2: Phase Difference of Two Waveforms

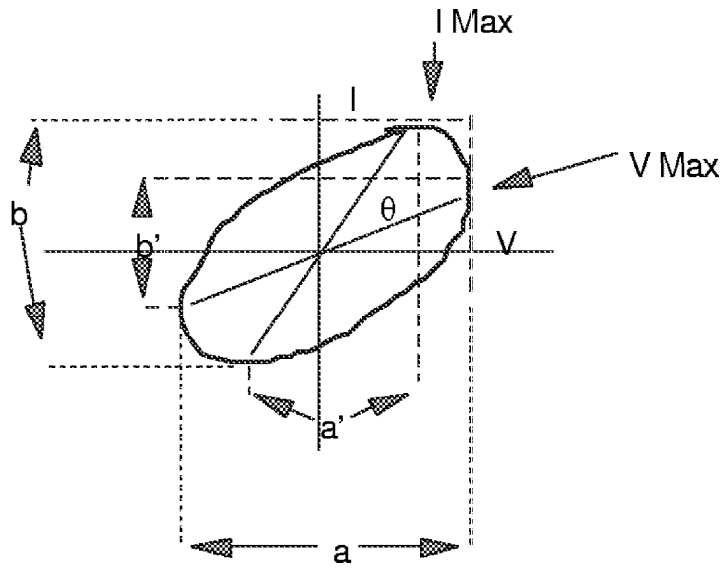


Figure G.3: Phase Difference in X-Y Mode

By measuring from one side of the ellipse to the other, we eliminate the need to worry about whether it is centred on the screen. In this case,

$$\theta = \arctan \left( \frac{ab - a'b'}{aa' + bb'} \right)$$

(This is simply an application of the equation for the angle between two lines.) This will only tell the phase difference between the two signals, not which one leads. To determine that, you can try to operate at a very low frequency and see whether the ellipse is traced out clockwise or counterclockwise. From that you can determine which leads. Note that the ellipse you will see will be upside down compared to this one, so you will have to make the appropriate changes.

### G.3 Measuring Impedance with the Oscilloscope

There are two cases to consider; reactive and non–reactive devices. For the latter, where there is no loop in the I–V curve, then the impedance is simply the resistance, and is calculated as usual. See Figure G.4..

In the diagram it is clear that at the point noted, the DC and the AC resistances are not equal. The **DC resistance** is given by  $R = V/I$  and the **AC resistance** is given by  $r = \frac{dv}{di}$  and both can be calculated from the inverses of the slopes of the lines shown.

For a reactive device, it simplifies matters to think of the **impedance** as being the ratio of the difference between the *maximum* and *minimum* voltages to the difference between the *maximum* and *minimum* currents. Thus if the I–V curve is an ellipse, the impedance is given by the ratio of the width to the height. See Figure G.5.

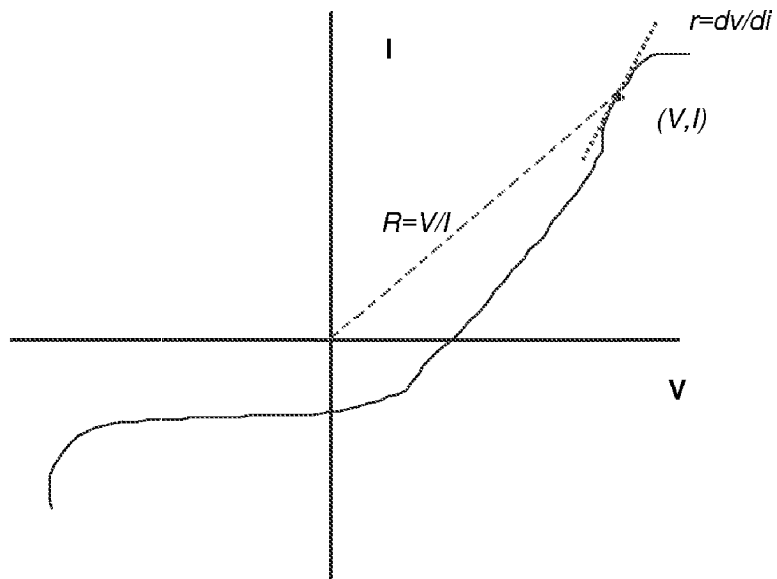


Figure G.4: I-V Curve of Non-reactive Device

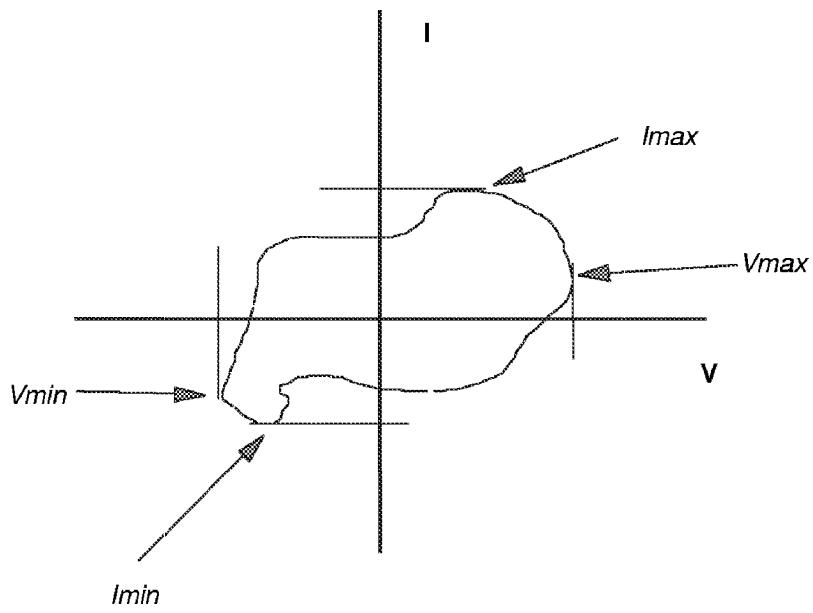


Figure G.5: I-V Curve of Reactive Device