LAB 1: Familiarity with Laboratory Equipment (_/10)

PURPOSE

To gain familiarity with basic laboratory equipment – oscilloscope, oscillator, multimeter and electronic components.

EQUIPMENT

(i) Oscilloscope – Tektronix 3012.
(ii) Oscillator – Wavetek 182A.
(iii) Multimeter – Wavetek DM15XL.
(iv) Prototyping board.
(v) 22 kΩ resistor.
(vi) 0.01 μF capacitor.

BACKGROUND

Part 1. Prototyping Board

To construct the circuits required in this and subsequent labs, a prototyping board is used. Figure 1 shows the top view of a prototyping board. The individual holes allow one to insert components such as resistors, capacitors, wires, integrated chips, etc. The board itself has internal connections to interconnect components without wires. Figure 2 shows the bottom view of the board, with the internal connections visible. As can be seen from the two figures, the entire top row of holes is connected together. The same applies to the second top row of holes and the two rows at the bottom. Moreover, the middle section of the board is divided into columns, each column consisting of five interconnected holes.

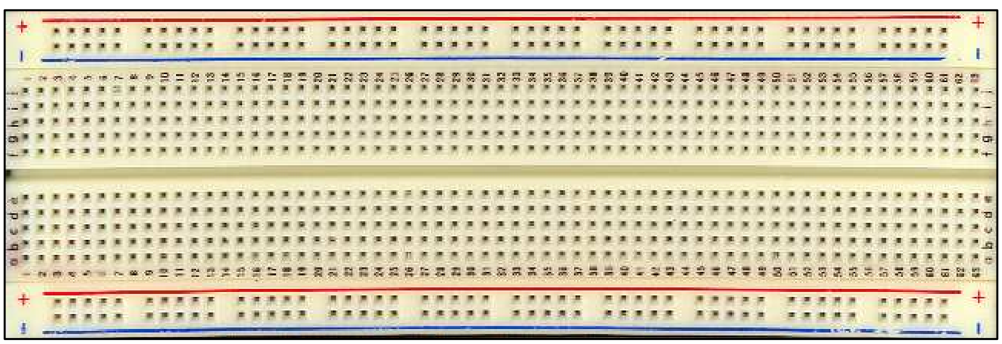


Figure 1. Prototyping board – top view.

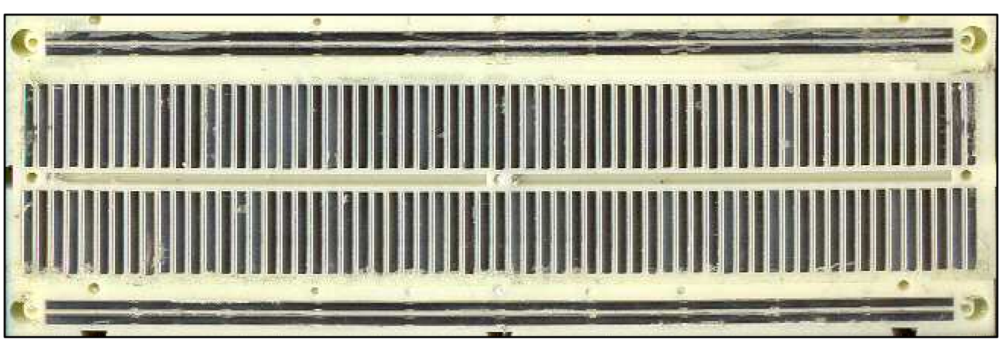


Figure 2. Prototyping board – bottom view.

Visualization of the internal connections in the board will allow you to properly construct the circuit. For example, normally the two ends of a resistor are connected to two distinct nodes in a circuit. Therefore, when a resistor is inserted into a prototyping board, its two connections should be placed into non-interconnected holes.

It is usually convenient to use the long interconnected rows for power and ground. For example, one usually connects the top row marked by a (+) sign (and a red line visible on the actual board) to the positive power, and the bottom row marked by a (–) sign (and a blue line) to the ground connection. In larger circuits, numerous components may make connections to the ground. These connections can tap into the long (–) marked row and thus avoid unnecessary wires.

Part 2. Resistor Identification

To allow for identification of values, resistors are marked with colored bands. Often referred to as color codes, these markings are indicative of the resistance and tolerance values. Figure 3 shows the position of the bands and their meaning.

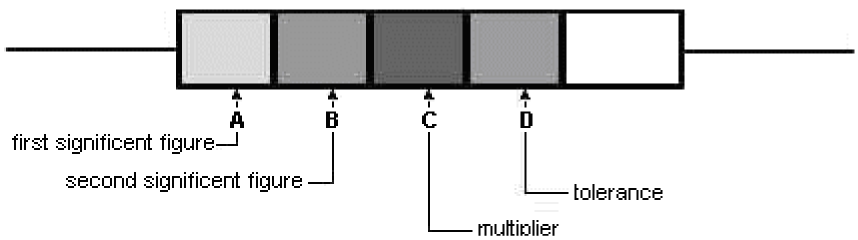


Figure 3. Resistor identification bands.

Band A: The first significant figure of the resistance value.

Band B: The second significant figure of the resistance value.

Band C: The multiplier, i.e. the factor by which the two significant figures are multiplied to yield the nominal resistance value.

Band D: The resistor's tolerance.

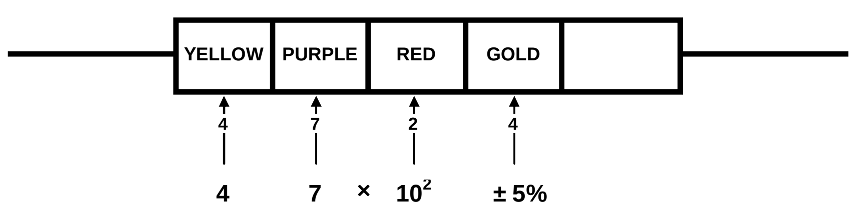
The colors of the first three bands correspond to the following values:

COLOR	BLACK	BROWN	RED	ORANGE	YELLOW	GREEN	BLUE	PURPLE	GRAY	WHITE
VALUE	0	1	2	3	4	5	6	7	8	9

while the colors of the last band correspond to:

COLOR	SILVER	GOLD	RED	NONE
VALUE	± 10%	± 5%	± 2%	± 20%

For example, a resistor with the following bands:



has the nominal value 4.7 kΩ and a tolerance of ± 5% (i.e. its actual value can range between 4.465 kΩ and 4.935 kΩ).

Part 3. Capacitor Identification

There exist many types of capacitors with different labeling systems. Two types of capacitors that are used in this course are polyester (typically orange, larger components) and ceramic (typically blue or beige, and smaller). Both of these capacitors are unpolarised, that is they can be connected either way around.

The polyester capacitors usually have their value printed on the component itself without any multiplier. When the printed number is smaller than 1, the value is in microfarads (10^{-6} F). For example, a capacitor with 0.047 printed on it has the value 0.047 μF or 47 nF.

The ceramic capacitors are usually very small, which makes printing on them difficult. Therefore, usually three numbers are printed: the first two numbers are the two most significant figures of the capacitance value, and the third number is the multiplier, i.e. the factor by which the two significant figures are multiplied to yield the nominal capacitance value in picofarads (10^{-12} F). For example, a capacitor with 473 printed on it has the value of 47×10^3 pF or 47 nF.

For more information on the different types of capacitors and their identification, refer to the 'Resistor Colour Code / Capacitors / Diodes' identification boards posted on both sides of the lab, near the component drawers.

PRELAB (_/2)

1. (_/0.5) Obtain a proof, perhaps from your lecture notes, that for a sinusoidal waveform, V_{PEAK} (the peak value of the wave) and V_{RMS} (the root-mean-square value of the wave) are always related through the relationship given in equation (2) in Part 1 below. Start your proof from the definition of V_{RMS} given in equation (1).

2. (_/0.5) Derive a similar relationship between V_{PEAK} and V_{RMS} for a *square wave* signal, ranging from $-V_{PEAK}$ to $+V_{PEAK}$.

3. (_/0.5) Figure 4 shows two sinusoidal waveforms. Calculate the phase difference between the two waveforms using equations (3) – (5) given in Part 2. By how much does wave 1 lead wave 2?

4. (_/0.5) Carefully read the *Background* section above before coming to the lab. Sketch how you would construct the circuit given in Figure 7 on the prototyping board, including the placement of the resistor, the capacitor and the oscillator.

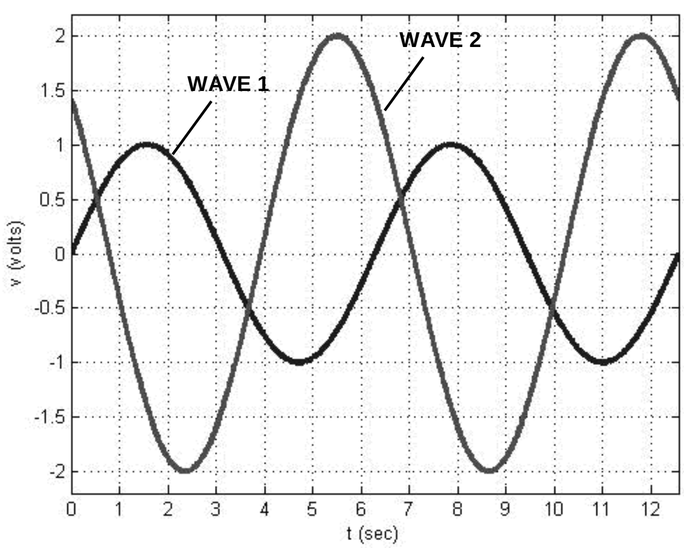


Figure 4. Sinusoidal waveforms for question 3.

PROCEDURE (_/8)

Part 1. Measurement of Waveforms

1.1 Study the layout of the controls of the oscilloscope:

- Waveform intensity – controls the intensity of the displayed signal.
- Vertical settings – control the choice of input, vertical scale and vertical position.
- Horizontal settings – control the horizontal scale and horizontal position.
- Trigger settings – determine when the oscilloscope starts tracing the input signal on the screen.
- Autoset button – automatically adjusts the vertical, horizontal and trigger settings.
- Cursors – used to measure horizontal or vertical offsets between two points on the screen.

1.2 Connect the oscillator, oscilloscope (channel 1) and voltmeter as shown in Figure 5. Connect the oscillator output cable to the 'HI' output port, and adjust it to give 5 volts RMS sine wave on the voltmeter at approximately 1 kHz. Note that the oscilloscope ground is *always* connected to the ground node of the circuit because it is internally connected to hydro ground.

Adjust the time base and vertical scale settings such that the waveform is well displayed on the oscilloscope. Why is it important to make this adjustment?

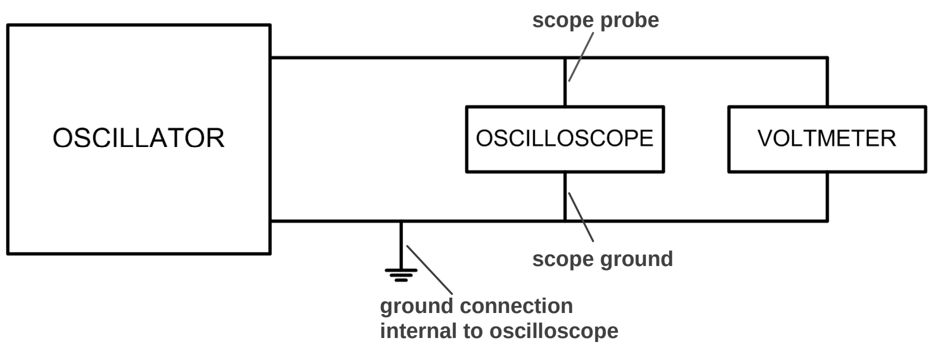


Figure 5. Circuit configuration for step 1.2.

1.3 (Table _/1) Note the peak-to-peak voltage as indicated on the oscilloscope. The voltmeter is calibrated, *for sine waves only*, to read the RMS value of the sinusoidal voltage, given by:

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T v^2(t)dt} \qquad (1)$$

where $v(t)$ is a periodic voltage and T is the period of the waveform.

Take three readings of voltages between 100 mV and 1 V RMS on both the oscilloscope and the voltmeter.

When taking readings on the oscilloscope, use the 'cursors' menu to obtain precise measurements:

- Press 'cursors' button on the top of the oscilloscope panel.
- Select 'H bars' for horizontal cursors or 'V bars' for vertical cursors.
- Use the dial on the top left of the oscilloscope panel to move the cursors on the screen, and the 'select' button to switch between the two cursors.
- The values of the two cursors and the difference between the cursors are indicated on the screen by @ and Δ symbols, respectively.

Demonstrate from these observations that when the waveform is sinusoidal, the following relationship holds:

$$V_{RMS} = \frac{V_{PEAK}}{\sqrt{2}} \qquad (2)$$

where V_{PEAK} is the peak value of the sine wave.

1.4 (_/1) Change the waveform of the oscillator to a square wave and repeat step 1.3. Use the square wave relationship between V_{PEAK} and V_{RMS} as derived in the prelab.

1.5 (_/1) Change the waveform to a sine wave and set the frequency of the oscillator to three different values between 100 Hz and 10 kHz. Adjust the horizontal scale such that you can view an entire period of the waveform on the oscilloscope screen. For each frequency setting do the following:

(a) Measure the period of the waveform as given by the oscilloscope. Use the ‘cursors’ menu or the ‘measure’ menu.

(b) Calculate the period of the waveform from the oscillator frequency. The Wavetek oscillators in our lab have custom retrofitted digital frequency meters, which measure in kHz and are accurate to ±0.05%.

What conclusion can you draw?

1.6 (_/1) Repeat step 1.5 using a square wave.

Part 2. Measurement of Phase Angles

2.1 Two sinusoids of the same frequency are said to have a phase difference when their peak values occur at different times, as shown in Figure 6.

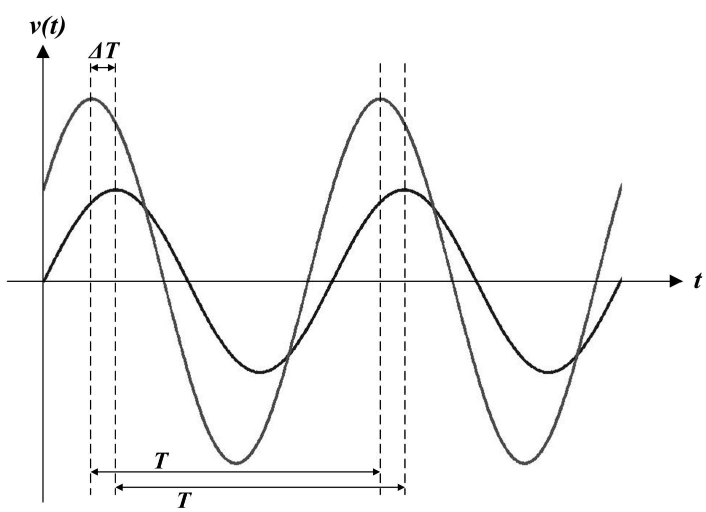


Figure 6. Phase difference between two sinusoidal signals.

The period (T) of a signal, as well as the time difference (ΔT) between two signals, can be measured using the oscilloscope. Since the frequency and the radian frequency are given by:

$$f = \frac{1}{T} \qquad \text{[Hz]} \tag{3}$$

$$\omega = 2\pi f \qquad \text{[rad/sec]} \tag{4}$$

the phase difference can be calculated as follows:

$$\theta = \omega \Delta T = \frac{2\pi}{T} \Delta T \qquad \text{[rad]} \tag{5}$$

To obtain two sinusoids with a phase difference, connect the circuit shown in Figure 7 on your prototyping board. Verify that the nominal values of the resistor and the capacitor are correct using the guidelines in the *Background* section. Set the oscillator to a 2 V peak-to-peak sinusoidal signal of frequency 1 kHz.

Connect channel 1 of the oscilloscope to measure the voltage v_1, as specified in Figure 7. Similarly, connect channel 2 of the oscilloscope to measure the voltage v_2. Display both v_1 and v_2 on the oscilloscope screen simultaneously.

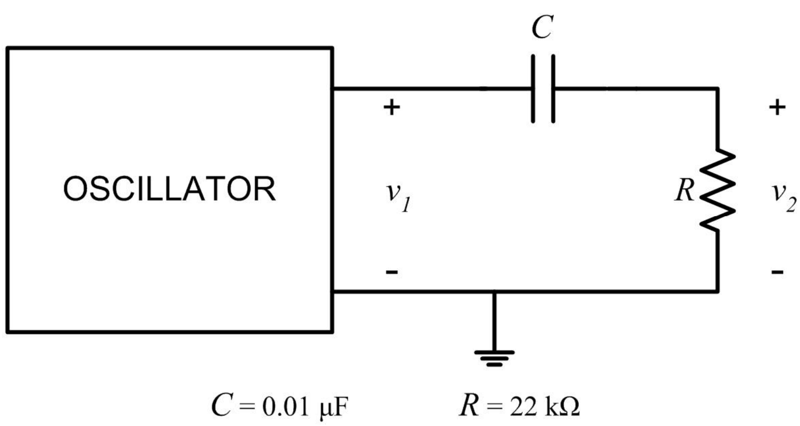


Figure 7. Circuit configuration for step 2.1.

2.2 (Table _/3 & Conclusion _/1)The RC circuit in Figure 7 produces voltages v_1 and v_2, which are out of phase:

$$v_1 = V_{PEAK} \sin(\omega t) \tag{6}$$

$$v_2 = V_{PEAK} \sin(\omega t + \theta) \tag{7}$$

Calculate the phase angle between v_1 and v_2 using the relationship given in (5), and fill in the required parameters in the table below. After calculating the phase angle, measure it on the oscilloscope using the 'phase' button from the 'measure' menu:

- Press 'measure' button on the top of the oscilloscope panel.
- Select 'phase' from the list of parameters that can be measured.

Verify that the calculated and measured values of the phase angle are reasonably close to each other.

Repeat the process for the three additional frequencies listed in the table below.

f	T	ΔT	$\theta_{calculated} = \frac{2\pi}{T}\Delta T$	$\theta_{measured}$	
			(in radians)	(degrees)	(radians)
200 Hz					
1 kHz					
2 kHz					
4 kHz					

Look at the data in the table above. What is the relationship between f and θ?