LAB 2: Thévenin Equivalent Source and Superposition

PURPOSE

(a) To construct the Thévenin equivalent source for the laboratory oscillator and test its validity.
(b) To demonstrate an application of the Superposition theorem.

EQUIPMENT

(i) Oscilloscope – Tektronix 3012.
(ii) Oscillator – Wavetek 182A (Oscillator 1).
(iii) DOE Electronics FG515 – Oscillator and DC power supply (Oscillator 2).
(iv) Multimeter – Wavetek DM15XL.
(v) Prototyping board.
(vi) Resistors: 22 Ω, 47 Ω, 100 Ω, 220 Ω

PRELAB (_/2)

0. Starting with Lab 2, the work that you are expected to complete during the lab period is significant, and therefore requires understanding of the lab procedure *before* coming to the lab. Read thoroughly through the procedure, understand the requirements and know how to connect the required circuits on the prototyping board.

1. The analysis of the circuit shown in Figure 2 is given in equations (1) – (3) in Part 1. How can a graph of v_S/v_0 against $1/R_L$ be used to obtain the value of the source resistance, R_S?

2. Divide a sheet of graph paper into three parts. On the top part, draw a square wave, symmetric around zero volts.

3. On the middle part of the same graph paper, draw a sine wave of frequency three times that of the square wave. Keep the amplitudes of the waveforms in the ratio 3:2 (square wave:sine wave).

4. On the bottom part of the same graph paper, draw a third waveform by *graphically adding the square wave to the sine wave*; i.e. for each point in time, add the numerical values of the two waves and draw the resulting waveform.

PROCEDURE (_/8)

Part 1. Thévenin Equivalent Source for the Laboratory Oscillator

1.1 Construct the circuit shown in Figure 1. Set the Wavetek oscillator to a sine wave at a frequency of 1 kHz. Adjust the output to give a reading of 5 volts on the voltmeter. Since the voltmeter has a very high input impedance, this reading can be considered to be the open-circuit voltage of the oscillator, v_S.

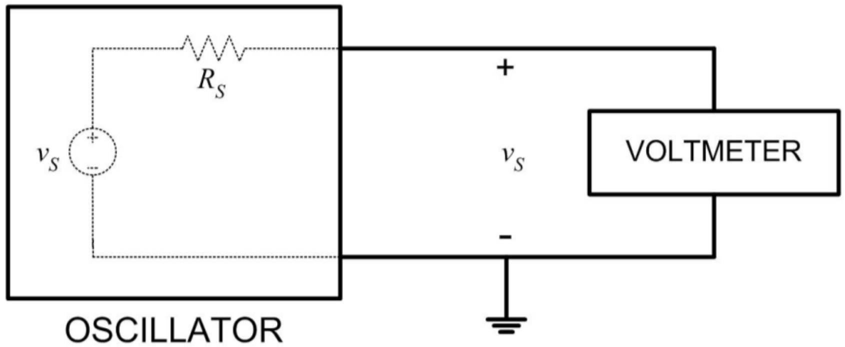

Figure 1. Circuit configuration for step 1.1.

1.2 (Table & 1.3 _/2) Choose a load resistance (R_L) of nominal value 47 Ω. Measure the exact resistance value on the multimeter and use this value in your calculations. Connect the load resistor to the circuit, as shown in Figure 2, and measure the voltage v_0 across it.

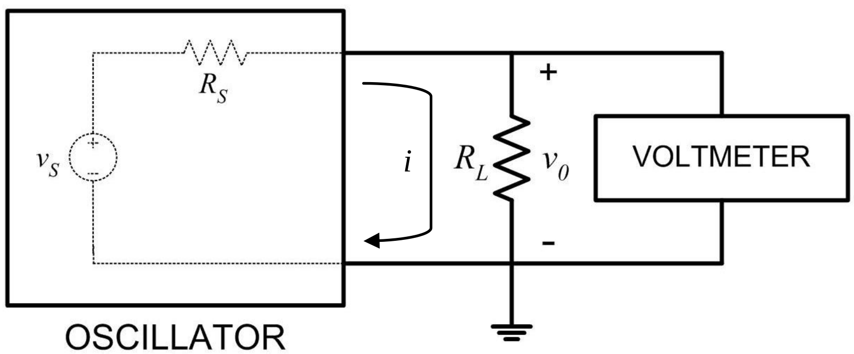

Figure 2. Circuit configuration for step 1.2.

If the current in the loop in Figure 2 is i, KVL analysis can be applied to get:

$$v_S - iR_S - iR_L = 0 \tag{1}$$

Using Ohm's law, the voltage across the load resistor is:

$$v_0 = iR_L \tag{2}$$

Substituting for i in (1) results in:

$$v_S = \frac{v_0}{R_L}(R_S + R_L) \tag{3}$$

All the terms in equation (3), except for R_S, are known. Using your measured values, solve for R_S, the Thévenin equivalent resistance of the oscillator.

1.3 The value of R_S obtained in step 1.2 is valid for a single value of the load R_L. Use the table below to determine the value of R_S for a range of values of the load resistor by repeating the experiment with three additional values of R_L.

Frequency f (KHz)	v_S (Volts)	nominal R_L (Ω)	measured R_L (Ω)	measured v_0 (Volts)	v_S/v_0	calculated R_S $R_S = R_L\left(\frac{v_s}{v_o} - 1\right)$ (Ω)	$1/R_L$
1	5	47 Ω					
1	5	22 Ω					
1	5	100 Ω					
1	5	220 Ω					

Complete the above table by calculating v_S/v_0 and $1/R_L$. Does R_S remain constant with the changing load resistance R_L?

1.4 (_/1) Plot a graph of v_S/v_0 against $1/R_L$ based on the values recorded in the above table. Obtain the value of R_S from this graph. Is the obtained value of R_S more accurate compared to the values obtained in steps 1.2 and 1.3?

1.5 (_/1) Using the open-circuit voltage v_S measured in step 1.1 and the value of R_S obtained in step 1.4, draw the Thévenin equivalent of the laboratory oscillator. Using this model, calculate the load voltage v_0 across each of the resistors used in step 1.3. Compare these calculated values to the measured values in step 1.3 and comment on your results.

R_L (Ω)	v_0 (Volts)	Calculate, $v_o = \left(\frac{R_L}{R_L + R_s}\right)(v_s)$
(measured in section 1.3)		In this case, use the value of R_s found from graph in step 4.

Part 2. Superposition Theorem (Sinusoidal Source – Oscillator # 1 and DC Source – Oscillator # 2)

2.1 In Part 1 of the experiment, the internal resistance R_{S1} of the first oscillator was obtained. In this experiment, we use two oscillators and need to find the internal resistance of the second oscillator, R_{S2}.

2.2 In Part 2 we use the DC power supply as oscillator #2. Since the internal resistance of the DC sources used in our lab is very small, for simplicity we will assume it to be zero. Connect the circuit shown in Figure 3, with the DC power supply as oscillator #2. Include the two resistors R_{S1} and R_{S2}, which are approximately equal to the internal resistances of oscillator #1 and oscillator #2, respectively.

When the power is off, an electronic source will have a different output resistance than when it is on. Thus, for superposition, when a source is switched off, the R_{S1} or the R_{S2} resistance is used to replace that source's internal resistance in order to maintain the same resistive load on the other source.

2.3 Connect A to B and X to Z. Redraw the circuit, omitting any components that do not contribute to the circuit's functionality.

2.4 Adjust oscillator #1 to give a sinusoidal signal of amplitude 2 V peak-to-peak on the oscilloscope at a frequency of 3 kHz.

2.5 Remove the links A to B and X to Z. Connect X to Y and B to C. Redraw the circuit, omitting any components that do not contribute to the circuit's functionality.

2.6 Adjust oscillator #2 to give a 2 V DC signal on the oscilloscope.

2.7 Remove the link B to C, and reconnect A to B. Redraw the circuit, omitting any components that do not contribute to the circuit's functionality.

2.8 (_/2) Draw the waveform obtained on the oscilloscope accurately to scale on a piece of suitable graph paper. Note: x and y axes must be marked properly with units to get the full 2 marks.

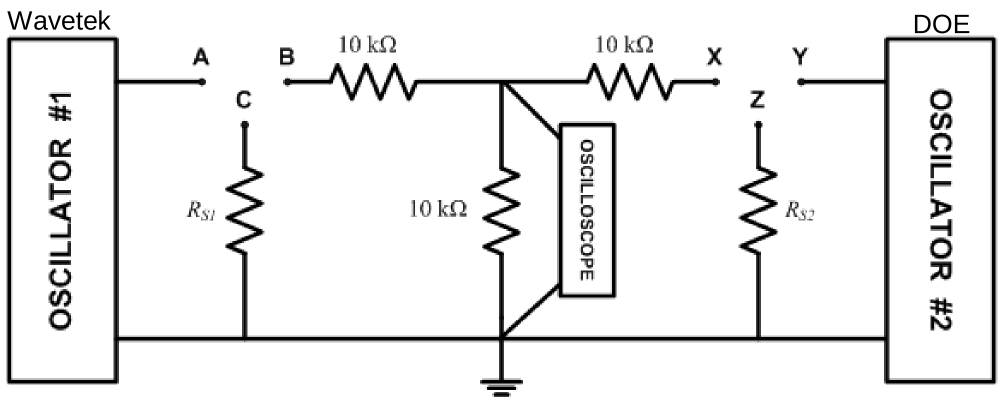

Figure 3. Circuit configuration for Parts 2 and 3.

Part 3. Superposition Theorem (Square wave Source - Oscillator # 1 and Sinusoidal Source - Oscillator # 2)

3.1 In the previous experiment, the superposition was of a DC source and a sinusoidal source. In this experiment, the superposition is of a sinusoidal source and a square wave. Use the Wavetek <u>182A</u> as oscillator #1, and the DOE Electronics FG515 frequency <u>generator as oscillator #2</u>, as shown in Figure 3. Note that the internal resistance of the DOE Electronics FG515 oscillator used as a sinusoidal source is 50 Ω. The internal resistance of the Wavetek 182A oscillator was found in Part 1 of this lab.

3.2 Connect A to B and X to Z. Adjust <u>oscillator #1</u> to give a <u>square wave</u> signal of amplitude <u>3 V peak-to-peak on the oscilloscope at a frequency of 1 kHz.</u>

3.3 Remove the links A to B and X to Z. Connect X to Y and B to C. Adjust <u>oscillator #2</u> to give a to give a <u>sinusoidal signal</u> of <u>amplitude 2 V peak-to-peak on the oscilloscope at a frequency of 3 kHz</u>.

3.4 (_/1) Remove the links B to C, and reconnect A to B. Make slight adjustments to the frequency of oscillator #2 to obtain a somewhat steady trace on the oscilloscope. External triggering has been added which reduces the need to use trigger knob. Use the "Single seq" button on the oscilloscope to make it steady. Draw the waveform accurately to scale on a piece of suitable graph paper. Note: x and y axes must be marked properly with units to get the full marks.

3.5 (_/0.5) Compare the waveform obtained in step in 3.4 to the waveform drawn <u>in question 5 in the prelab.</u>

3.6 (_/0.5) Explain the need for the resistors R_{S1} and R_{S2} in the circuit in Figure 3.