Sirindhorn International Institute of Technology
Thammasat University at Rangsit
School of Information, Computer and Communication Technology

COURSE **:** ECS 204 Basic Electrical Engineering Lab
INSTRUCTOR : Asst. Prof. Dr. Prapun Suksompong (prapun@siit.tu.ac.th)
WEB SITE : http://www2.siit.tu.ac.th/prapun/ecs204/
EXPERIMENT : 04 AC Measurements

I. OBJECTIVES

1. To study how to use a cathode-ray tube oscilloscope and a function generator.
2. To learn and verify the relationship among instantaneous, peak, and rms values of ac voltages and currents.
3. To manually measure frequency by using a cathode-ray tube oscilloscope.
4. To measure phase shifts and power consumed in ac circuits.

II. BASIC INFORMATION

1. **A cathode-ray oscilloscope (CRO)** is one of the most versatile instruments in electronics. An oscilloscope (abbreviated sometimes as scope or O-scope) displays the **instantaneous amplitude of a voltage waveform versus time** on the screen. A dual-trace oscilloscope makes it possible to observe two time-related waveforms simultaneously at different nodes in a circuit.
2. A **function generator** is also one of the most versatile instruments in electronics. It generates various waveforms of basic signals at various frequencies and amplitudes.
3. The dc voltage can be identified by a single value. However, the ac voltages are time-varying and there are many values that can be used to specify ac voltages: the peak, the rms, the average, and the instantaneous values. All of these values are related. **Peak value** means the maximum value of an ac voltage. **Rms value** is the value of the ac voltage that will produce the same power as the equivalent dc level. **Instantaneous value** is the value of voltage at any particular time. Integrating the instantaneous value over the time of one

period and dividing it by the period yields the **average value**. In the design of ac circuits, voltage and current measurements are usually made in rms values.

4. In this experiment, the time-varying ac signals are of the form $A\cos(2\pi ft+\theta)$.

> For a signal of the form $A\cos(2\pi ft+\theta)$, the ***peak value*** is given by its amplitude *A*. Its ***peak-to-peak (p-p) value*** is $2A$. The ***rms value*** is given by $\frac{A}{\sqrt{2}}$.

Note that $1/\sqrt{2}$ is approximately 0.707.

5. The oscilloscope can measure frequency of periodic signals. If the time base of the scope is calibrated in time units per division, then the horizontal divisions covered by one cycle of any periodic signal will represent the signal period. The **period** T is the reciprocal of the **frequency** *f* which can be calculated by using the formula *f* = 1/*T*.
6. **In resistive circuits, voltages and currents are in phase, while in non-resistive circuits, voltages and currents may not be in phase. For a pure inductor, the current "lags" the voltage by 90 degrees. For a pure capacitor, the current "leads" the voltage by 90 degrees.** Using a dual-trace oscilloscope, the phase difference between two waveforms can be calculated.

II.1 The passive circuit elements in the phasor domain

Inductors are circuit elements based on phenomena associated with magnetic fields. The source of the magnetic field is the charge in motion, or current. If the current is varying with time, the magnetic field induces a voltage in any conductor linked by the field.

Capacitors are circuit elements based on phenomena associated with electric fields. The source of the electric field is the separation of charge, or voltage. If the voltage is varying with time, the electric field is also varying with time, and a time-varying electric field produces a displacement current in the space occupied by the field.

When the circuit consists of passive circuit elements such as resistor, inductor, and capacitor, we can change the frequently used formula v = iR to the *phasor form*:

$$\mathbf{V} = Z\mathbf{I},$$

where **V** is the phasor voltage, **I** is the phasor current, and Z represents the ***impedance*** of the circuit elements. The above equation is the "**Ohm's law"** for ac circuits.

The impedance of a resistor, an inductor, and a capacitor are given by R, *jωL*, and 1/*jωC*, respectively, where R is the resistance of the resistor, L is the inductance of the inductor, and C is the capacitance of the capacitor. The angular frequency ω is $2\pi f$, where f is the frequency, and j = $\sqrt{-1}$. In all cases, the impedance is measured in ohms. The concept of impedance is crucial in sinusoidal steady-state analysis.

II.2 V-I relationship for a resistor

The phasor voltage at the terminals of a resistor is the resistance times the phasor current.

$$\mathbf{V} = R\mathbf{I}$$

Figure 4-1(a) depicts the phase relationship between the current and the voltage of a resistor R. It can be seen from Figure 4-1(a) that there is no phase difference between the current and voltage.

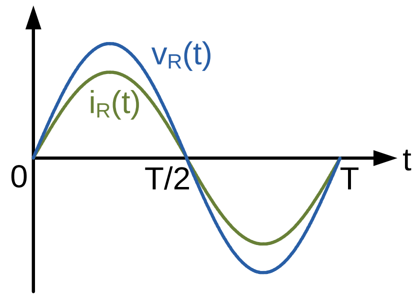


Figure 4-1(a): The voltage and current at the terminals of a resistor are in phase.

II-3 V-I relationship for an inductor

The phasor voltage at the terminals of an inductor (pure inductor) equals $j\omega L$ times the phasor current, i.e.,

$$\mathbf{V} = j\omega L\ \mathbf{I}.$$

In the phasor domain, "j" means $\angle 90°$ shift. Thus, the voltage and current are out of phase by exactly 90°. In particular, the voltage leads the current by 90° or, equivalently, the current lags behind the voltage by 90°, as shown in Figure 4-1(b)

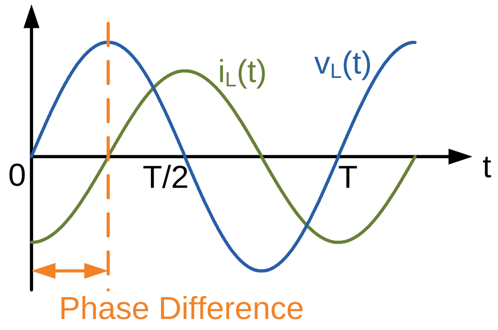


Figure 4-1(b): The voltage leads the current by 90° in the pure inductor circuit.

II.4 V-I relationship for a capacitor

Similar to the inductor circuit, the phasor voltage at the terminals of a capacitor equals $1/j\omega C$ times the phasor current. So,

$$\mathbf{V} = \frac{1}{j\omega C}\mathbf{I} = -\frac{j}{\omega C}\mathbf{I},$$

where -j means ∠-90° shift. Therefore, the voltage and current are out of phase by exactly 90°. However, in this case, the voltage lags the current by 90°, or the current leads the voltage by 90° as shown in Figure 4-1(c).

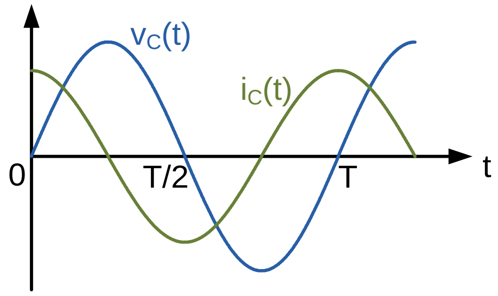


Figure 4-1(c): The voltage lags the current by 90° in the pure capacitor circuit.

III. (DUAL-TRACE) OSCILLOSCOPE

III.1 Front panel

To successfully accomplish this lab, the student has to be able to use an oscilloscope proficiently. Figure 4-2 shows the front panel of the oscilloscope used in this experiment.

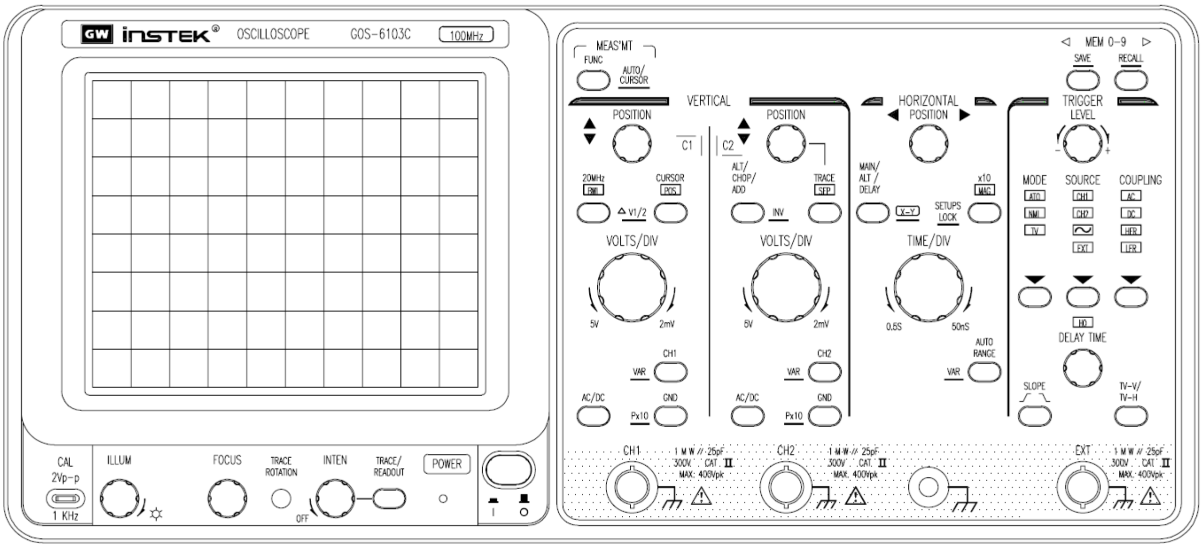


Figure 4-2: Front panel of an oscilloscope

III.1.1 DISPLAY CONTROLS

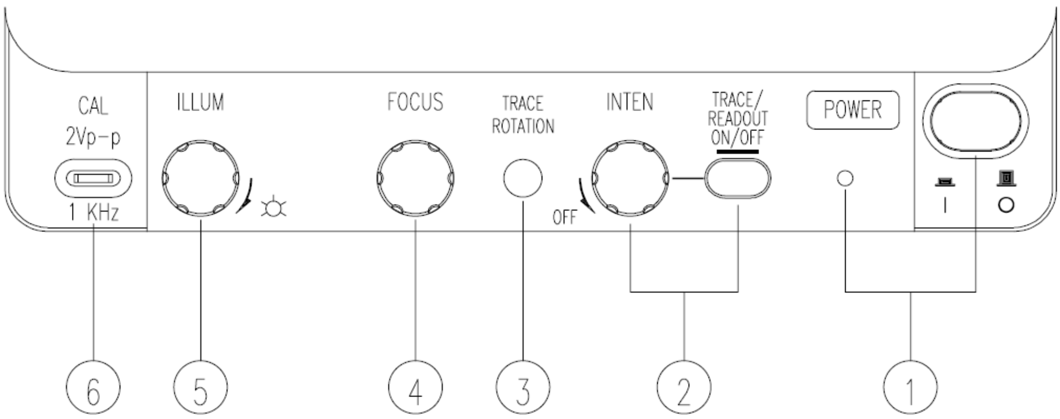


Figure 4-2a: Display controls of an oscilloscope.

Controls/Sockets	Functions
POWER (1)	Main power switch of the instrument. When this switch is turned on, the LED (1) is also turned on.

Controls/Sockets	Functions
INTEN (2)	Controls the brightness of the trace and the on-screen readout. Turning the knob clockwise to increase the intensity and turning it counterclockwise to decrease the intensity. Press the TRACE/READOUT pushbutton briefly to switch between trace intensity adjustment and readout intensity adjustment. Pressing and holding the TRACE/READOUT pushbutton to switch on or off the readout.
FOCUS (4)	For focusing the trace and the readout to the sharpest image.
CAL (6)	The terminal provides a reference signal of 2Vp-p at 1kHz for probe adjustment.

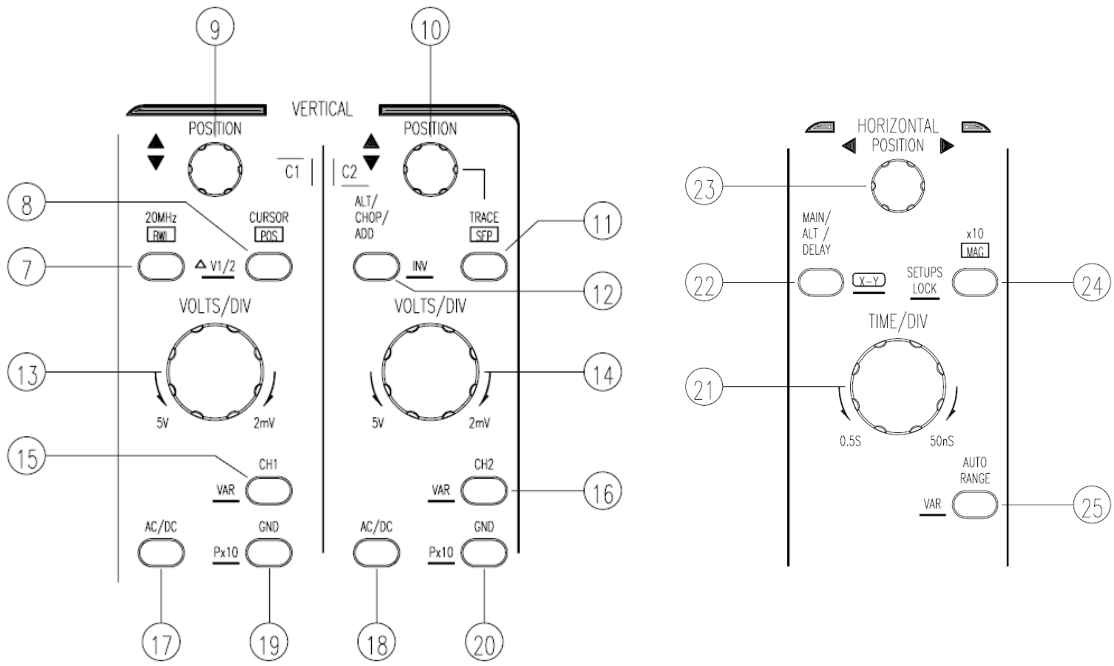


Figure 4-2b: Vertical and horizontal controls of an oscilloscope.

III.1.2 VERTICAL CONTROLS

The vertical controls select the displayed signals and control the amplitude characteristics.

Controls/Sockets	Functions
CH1 POSITION (9)	Vertical trace positioning control of channel 1.
CH2 POSITION (10)	Vertical trace positioning control of channel 2.

Controls/Sockets	Functions
ALT/CHOP/ADD-INV (12)	The pushbutton has several functions, which are required and available only when both channels are active. • ALT: Displays in the readout, indicates alternate channel switching. After each time base sweeps the instrument internally, switches over from channel 1 and channel 2 and vice versa. • CHOP: Indicates chopper mode. The channel switching occurs constantly between channel 1 and channel 2 during each sweep. • **ADD**: Displays in the readout, indicates additional mode. The algebraic sum (addition: CH1+CH2) of the signals is displayed. In general, for correct measurements, the deflection coefficients (VOLTS/DIV) for both channels must be equal. Subtraction (CH1-CH2) can be done with this operation is used with the invert function. • **INV**: Pressing and holding this pushbutton to set the channel 2 invert function on or off. The invert on condition is indicated with a horizontal bar above "CH2" in the readout. The invert function causes the signal display of channel 2 to be inverted by 180°.
CH1 VOLTS/DIV (13) CH2 VOLTS/DIV (14)	Turning the knob clockwise to increase the sensitivity in 1-2-5 sequence and turning it in the opposite direction (CCW) to decrease. The available range is from 2mV/div up to 5V/div. The deflection coefficients and additional information regarding the active channels are displayed in the readout. ie. "CH1=deflection coefficient, input coupling".
CH1 (15) CH2 (16)	Pressing briefly the CH1(CH2) button to set the channel 1 (channel 2) of the instrument on, the deflection coefficient will be displayed in the readout indicating the current conditions ("CH1…"/ "CH2…").
CH1 AC/DC (17) CH2 AC/DC (18)	Pressing the pushbutton briefly to switch over from AC (~ symbol) to DC (= symbol) input coupling. **AC : AC coupling** (Input signal is coupled via blocking capacitor and DC component is blocked.) **DC : DC coupling** (Input signal is directly coupled.) The setting is displayed in the readout with the deflection coefficient.
CH1 GND (19) CH2 GND (20)	Each time when the pushbutton is pressed briefly, the input of the corresponding vertical amplifier is grounded (and input terminal are

Controls/Sockets	Functions
	disconnected). It is displayed in the readout as an earth (ground) symbol.

III.1.3 HORIZONTAL CONTROLS

The horizontal controls select the time base operation mode and adjust the horizontal scale, position and magnification of the signal.

Controls/Sockets	Functions
TIME/DIV (21)	Select the sweep time. The time coefficient(s) will be displayed in the readout. In **MAIN time base (MTB)** mode, time deflection coefficients between 0.5s/div and 50ns/div can be chosen in 1-2-5 sequence.
MAIN/ALT/DELAY/X-Y (22)	Pushbutton for time base mode selection. The TIME/DIV control knob is operated only under the **MAIN** time base mode.
H POSITION (23)	Horizontal positioning control of the trace.
AUTO RANGE (25)	Each time when the pushbutton is pressed briefly the incoming signal is selected, then the time range would change automatically and approx. 1.6 to 4 waveforms are displayed on the screen. The AUTO RANGE does not function when the trigger is not obtained

III.1.4 TRIGGER CONTROLS

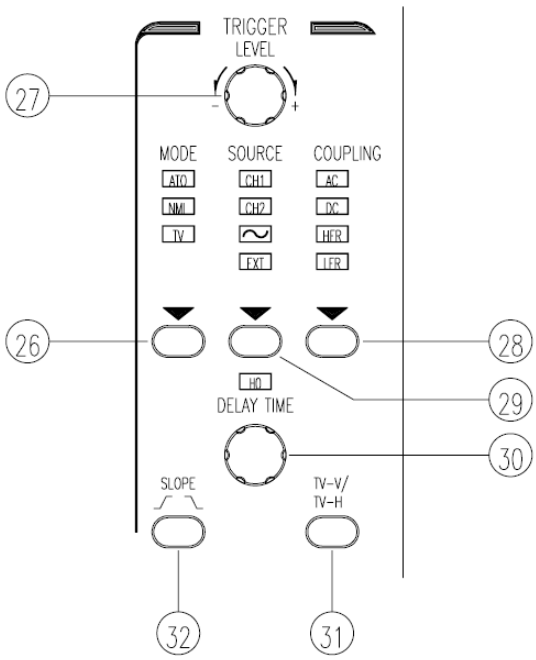


Figure 4-2c: Trigger controls of an oscilloscope.

The trigger controls determine the sweep start timing for both signal and dual trace operation.

Controls/Sockets	Functions
MODE (26)	Pressing the pushbutton to select the trigger mode. The actual setting is indicated by a LED. Each time when the MODE pushbutton is pressed the trigger mode changes in the sequence: ATO—NML—TV—ATO • **ATO** (Auto): Select the automatic mode, the sweep free-runs will display a baseline trace when there is no trigger signal or the frequency is below 10Hz. The setting of triggering level changed only when the TRIGGER LEVEL (27) control is adjusted to a new level setting. • **NML** (Normal): Select the normal mode, the input signal will trigger the sweep when the TRIGGER LEVEL control is set within the peak-to-peak limits of an adequate trigger signal. When the sweep is not triggered, no baseline trace will be displayed.
LEVEL (27)	Turning the control knob causes a different trigger input setting (voltage), and set to a suitable position for the starting of triggered sweep of the waveform. An approximate trigger level setting (voltage) value will be displayed in the readout.
COUPLING (28)	Pressing the pushbutton to select the trigger coupling. The actual setting is indicated by a LED and by the readout ("source, slope, AC"). Each time when the COUPLING pushbutton is pressed the trigger coupling changes in the sequence: AC—DC—HFR—LFR • **AC**: Attenuates trigger signal frequency components below 10Hz and blocks the DC component of the signal. • **DC**: Couples DC and all frequency components of a triggering signal to the trigger circuitry.
SOURCE (29)	Pressing the pushbutton to select the trigger signal source or the X signal for an X-Y operation. The actual setting is indicated in a LED and by the readout ("SOURCE", slope, coupling). • **CH1**: The signal applied to the channel 1 input connector is the source of the trigger signal. • **CH2**: The signal applied to the channel 2 input connector is the source of the trigger signal.
SLOPE (32)	Pushbutton for the triggering slope. If in the AUTO or NML trigger

Controls/Sockets	Functions
	mode, briefly pressing the pushbutton to select the slope of the signal which is used for triggering the time base generator. Each time when the pushbutton is briefly pressed, the slope direction will switch from falling edge to rising edge, and vice versa. The current setting is displayed in the readout under item “source, SLOPE, coupling”.

III.1.5 INPUT CONNECTORS

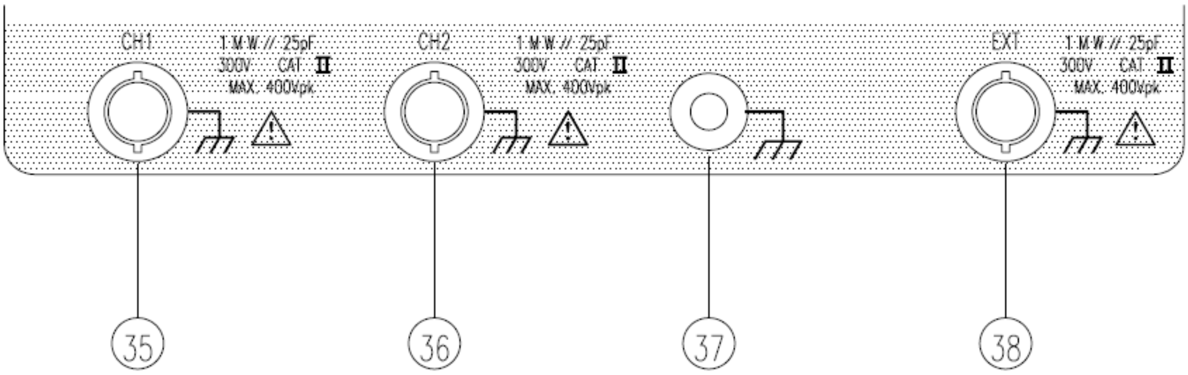


Figure 4-2d: Input connectors of an oscilloscope.

The input section is where the input signals are commonly connected to the oscilloscope.

Controls/Sockets	Functions
CH1 (35)	This BNC socket is the signal input for channel 1. The outer (ground) connection is galvanically connected to the instrument ground and consequently to the safety earth contact of the line/mains plug.
CH1 (36)	This BNC socket is the signal input for channel 2. The outer (ground) connection is galvanically connected to the instrument ground and consequently to the safety earth contact of the line/mains plug.
Ground socket (37)	Banana Socket galvanically connected to safety earth. This socket can be used a reference potential connection for DC and low frequency signal measurement purposes.

III.2 Rear panel

Figure 4-3 shows the rear panel of the oscilloscope.

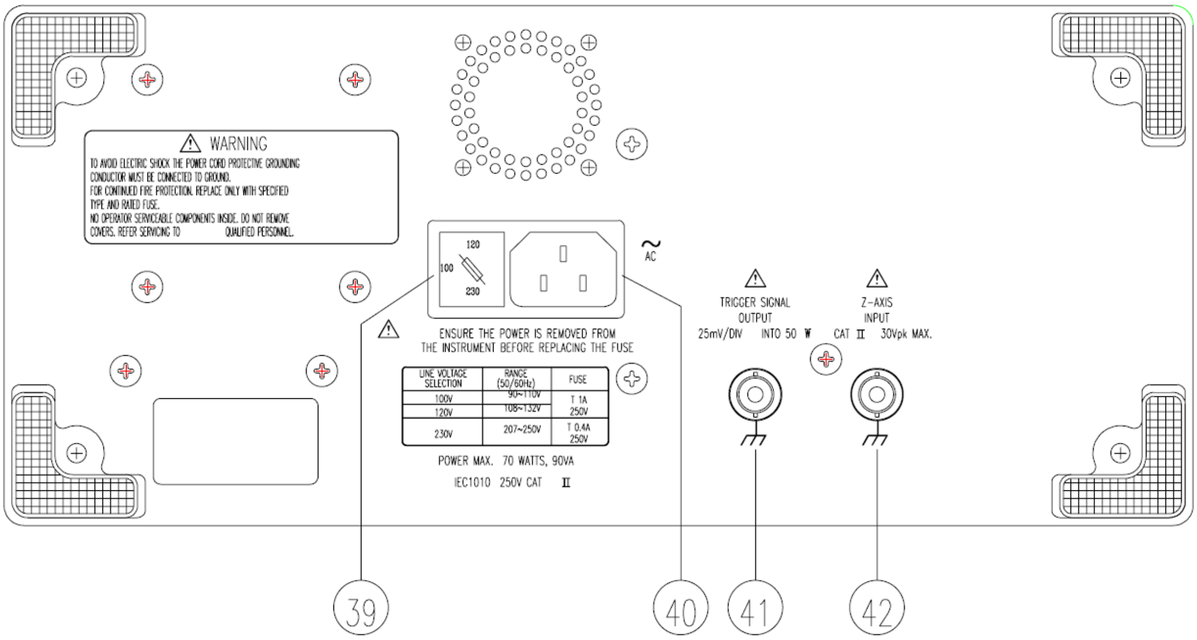


Figure 4-3: Rear panel of an oscilloscope

Sockets	Functions
AC Power input connector (40)	Connect the AC power cord to the power supply of instrument, the power cord protective-ground connection is connected to the exposed metal part of the instrument. The power cord must be connected to a proper grounded source for electrical-shock protection.

III.3 Oscilloscope Preparation

1. Engage the POWER (1) switch. When switch on, the oscilloscope has all LEDs lighted and the software version will be displayed on the screen. After the Internal test is completed successfully, the normal operation mode is present. Then the last settings become activated and the LED indicates the ON condition.
2. Adjust the trace to an ***appropriate*** brightness/sharpness using the INTEN control (2) and FOCUS control (4), respectively.
3. Set the oscilloscope to display both channel 1 and channel 2 (by briefly pressing the CH1 (15) button and/or the CH2 (16) button).
4. Set both CH1 and CH2 COUPLING to GND (by briefly pressing the Channel 1's GND (19) button and/or the Channel 2's GND (20) button).
5. Notice two green traces on the display. (Note that one many be hidden behind another.) Make sure that the TRIGGER MODE (26) is set to ATO mode, otherwise the trace will not be shown.
6. Use the CH1 and CH2 POSITION controls ((9) and (10)) to align both traces on the center graticule. Adjust the FOCUS control so that the trace image appears sharply.
7. Install the probes onto the oscilloscope (Press the BNC connector onto the channel input and rotate the connector to lock it into place).

III.4 Use of the Calibration Signal

1. Apply the steps given in Section III.3.
2. Connect the probe tips to the CAL test point (6) of the oscilloscope.
3. Use the following setting:

VERTICAL:	VOLTS/DIV ((13) and (14))	1V
	COUPLING ((17) and (18))	DC
	ALT/CHOP/ADD (12)	CHOP or ALT
HORIZONTAL:	MODE (22)	MAIN
	TIME/DIV (21)	0.5ms
TRIGGER:	MODE (26)	ATO
	SOURCE (29)	CH1
	COUPLING (28)	AC

The square wave of the calibrator signal will be displayed on the screen.

If necessary, reapply steps (4) to (7) in Section III.3.

III.5 Dual-channel operation

<u>STATIONARY DISPLAY OF BOTH CH1 AND CH2</u>

1. Continue from Section III.4. We have stationary display of both CH1 and CH2.

<u>STATIONARY DISPLAY OF CH1</u>

2. Disconnect the CH2 probe from the CAL test point (6) of the oscilloscope.
   At this state, the CH1 trace is the square wave of the calibrator signal (from Section III.4) and the CH2 trace is a straight line since no signal has been applied to the CH2 yet.
3. Because CH1 is used (to display the Calibrator Signal), selecting CH1 as the TRIGGER SOURCE (29) makes the Calibrator signal stationary in CH1.

<u>NON-STATIONARY DISPLAY OF CH1</u>

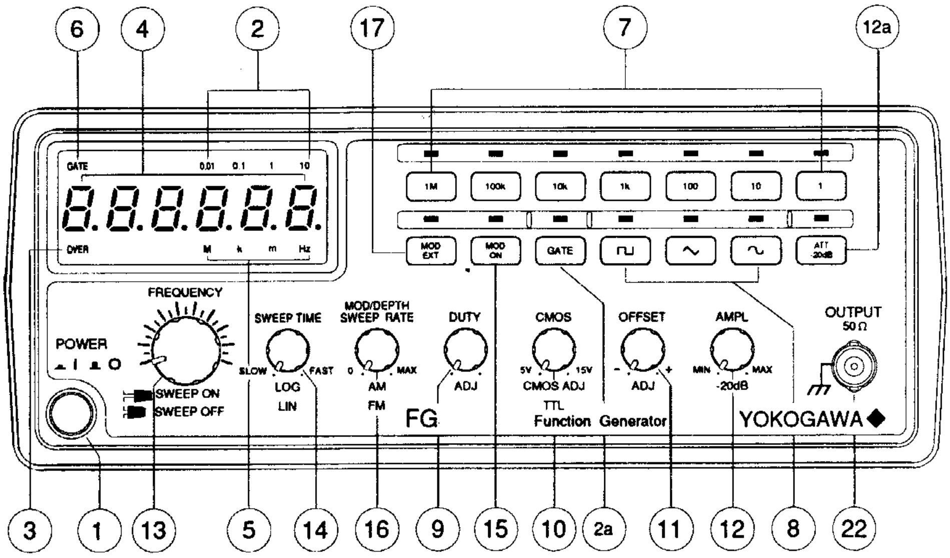
4. If CH1 is used (to measure the Calibrator Signal) but CH1 is not selected as the TRIGGER SOURCE, i.e. CH2 is selected, the signal in CH1 will not be stationary.

Note: For more advanced operations of the oscilloscope, please consult the instruction manual available on the course website.

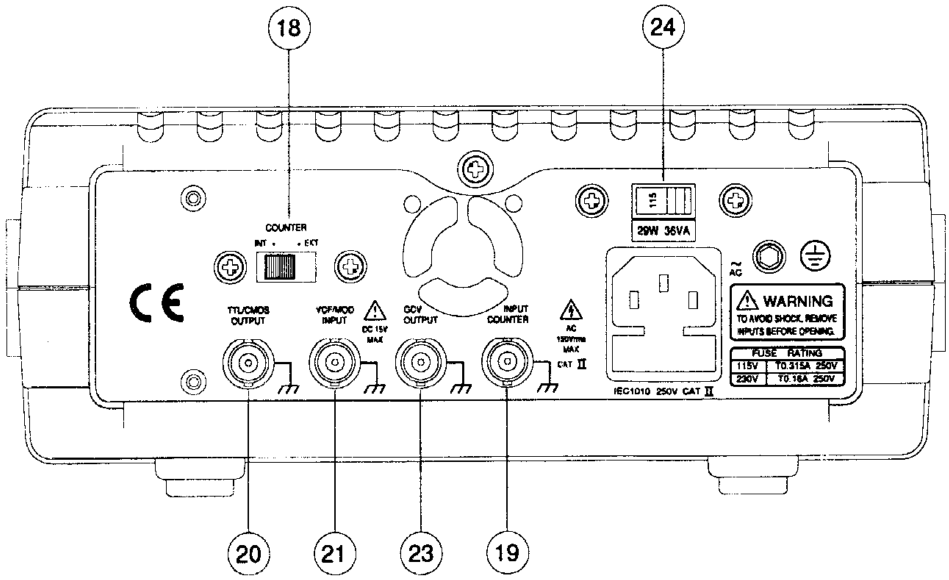
IV. Function generator

IV.1 Front and rear panels

To successfully accomplish this lab, the student has to be able to use a function generator proficiently. Figure 4-4 shows the front and rear panels of the function generator.



(Front panel)



(Rear panel)

Figure 4-4: Front and rear panels of a function generator

IV.2 Function description

<table>
<tr><th>Controls/Sockets</th><th>Functions</th></tr>
<tr><td>Power Switch (1)</td><td>Connect the AC power, then press power switch.</td></tr>
<tr><td>Frequency Indicator (5)</td><td>Indicates the current frequency value.</td></tr>
<tr><td>Gate Time Indicator (6)</td><td>Indicates the current Gate time (external counter mode use only)</td></tr>
<tr><td>Frequency Range Selector (7)</td><td>To select the required frequency range by pressing the relevant push button on the panel as shown in the table below:
<table>
<tr><td>Button</td><td>1</td><td>10</td><td>100</td><td>1k</td><td>10k</td><td>100k</td><td>1M</td></tr>
<tr><td>Freq.</td><td>0.5Hz
|
5Hz</td><td>5Hz
|
50Hz</td><td>50Hz
|
500Hz</td><td>500Hz
|
5kHz</td><td>5kHz
|
50kHz</td><td>50kHz
|
500kHz</td><td>500kHz
|
5MHz</td></tr>
</table></td></tr>
<tr><td>Function Selector (8)</td><td>Press one of the three push buttons to select the desired output waveform. Caution: Default waveform when the generator starts is triangular which you will never use in any ECS304 experiment. If you turn the generator off and then turn it back on again, do not forget to change it to sinusoidal or rectangular specified in the experiment.</td></tr>
<tr><td>Duty Function (9)</td><td>Pull out and rotate the knob to adjust the duty cycle of the waveform.</td></tr>
<tr><td>DC Offset Control (11)</td><td>Pull out the knob to select any DC level of the waveform between ±10V, turn clockwise to set a positive DC level waveform and invert for a negative DC level waveform.</td></tr>
<tr><td>Output Amplitude Control with Attenuation Operation (12)</td><td>Turn clockwise for MAX output and invert for a -20dB output. Pull the knob out for an additional 20 dB output attenuation.</td></tr>
<tr><td>MANU/SWEEP Selector and Frequency Adjustment [Sweep On/Off] (13)</td><td>Press and turn the knob clockwise for MAX frequency and invert for MIN frequency (keep the pointer within the scale range on the panel). Pull out the knob to start the auto sweep operation; the upper frequency limit is determined by the knob position.</td></tr>
<tr><td>Sweep Time Control and LIN/LOG Selector (14)</td><td>1. Rotate the knob clockwise to adjust sweep time for MAX, or invert for MIN.
2. Select linear sweep mode by pushing in the knob or select LOG sweep mode by pulling out the knob.</td></tr>
<tr><td>Main Output Terminal (22)</td><td>Main signal output.</td></tr>
</table>

IV.3 Use of a Function Generator

The function generator can provide versatile waveforms of high efficiency. **One of the best ways to observe waveforms is to connect the function generator to an oscilloscope**. Watch the effect in different control of waveforms on the oscilloscope carefully while proceeding as follows.

1. Press the PWR switch (1) and **ensure all the rotary controls are pushed in**.
2. Connect the output (22) of the function generator to the CH1 of the oscilloscope.
3. Select Function of desired waveforms (8) , e.g. a sinusoidal wave (or Triangle or Square Waves), and select Range (7). Rotate FREQ (13) to set the desired frequency (determine from display window).
4. Rotate AMPL (12) knob to obtain desired amplitude, e.g. 1 Vp-p.

Note: For more advanced operations of the function generator, please consult the instruction manual available on the course website.

V. MATERIALS REQUIRED

- Function generator
- Dual-trace oscilloscope
- Multi-meter
- Resistors (½ W): two 100-Ω, two 3.3-kΩ, and one 4.7-kΩ.
- Inductor: ≈5-mH
- Capacitor: 0.47-μF

VI. EXPERIMENTS

First, follow the steps in Section III.3 and II.4 to set and check the oscilloscope.

Part A: The relationships among instantaneous, peak, and rms values

1. **Connect the circuit** of Figure 4-5.

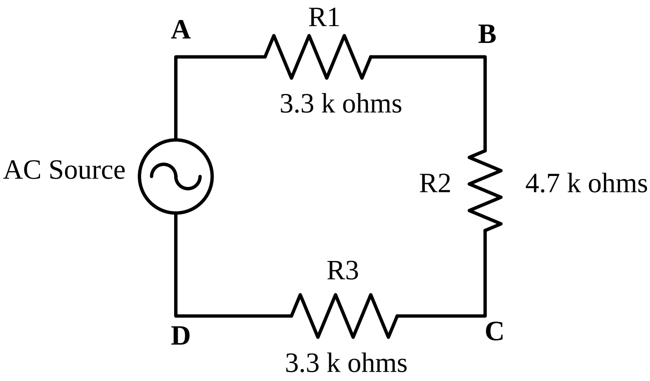


Figure 4-5: A circuit for measuring rms and peak values.

2. Connect the output of the sine-wave generator (AC source in Figure 4-5) to channel 1 of the dual-trace scope.
3. Turn on the generator. (Press the POWER (9) button.) Select sinusoidal waveform. Set the frequency to 1000 Hz. With a DMM (used as an AC voltmeter) connected across its output, adjust the signal generator output to 5 V (rms). Record the value in the "Voltage, rms, measured" column of Table 4-1.

   Caution:

   (i) Make sure that the DMM is in AC mode. In this mode, the value that you get for zero-mean waveform is the rms value.

   (ii) All measurement should be done with the AC generator still connected in the circuit.
4. Use the DMM to measure the rms voltage across each resistor, R1, R2, R3. Record the values in the "Voltage, rms, measured" column of Table 4-1.
5. Use the scope to measure the peak voltages across the generator, R1, R2 and R3. Record the values in the "Voltage, peak, measured" column of Table 4-1.

   Caution: If both channels of the oscilloscope are used, make sure that their ground probes are connected at the same nodes.
6. Use the DMM (as an AC ammeter) to measure current flowing through R1. Record the ammeter reading in the "current, rms, measured" column.

7. Similarly, measure currents in R2 and R3, and record the values in Table 4-1.
8. From the measured voltage value of the AC source and the measured resistance values, calculate rms currents, rms and peak voltages and record the values in the "calculated" columns of Table 4-1.

Part B: Frequency measurement

1. Set the output of the sine-wave generator to an arbitrary[1] frequency in the range of 1 kHz and 2 kHz. Record the value in Table 4-2.
2. Connect the output of the generator to channel 1 of the oscilloscope. Adjust the scope so that approximately **one cycle** of the waveform is displayed on the screen.
3. Measure the number of divisions spanned by one cycle. Record the value in Table 4-2. Record the Time-base/Div. setting.
4. Calculate the period of waveform, and record your answer in Table 4-2.
5. Calculate the frequency and verify it with the setting value on the generator.

Part C: Phase shifts and power consumed in ac circuits

<u>C.1 RESISTIVE CIRCUIT</u>

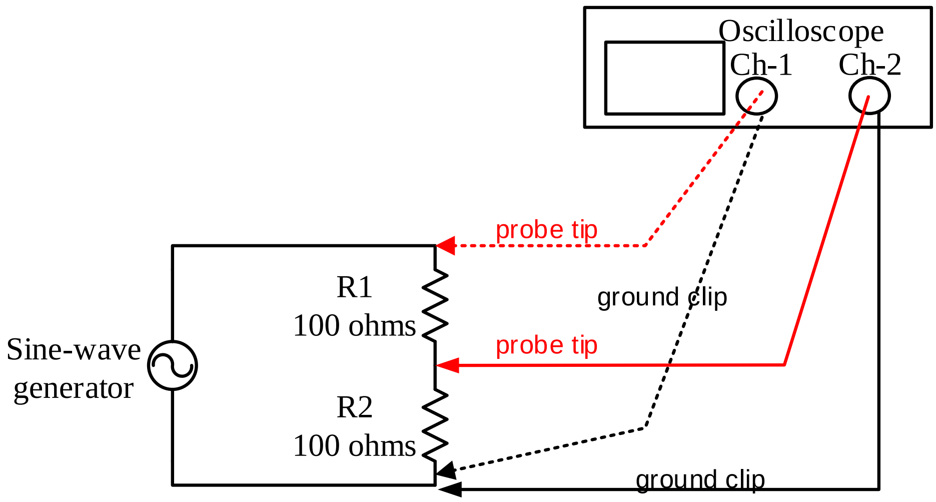


Figure 4-6: A circuit for measuring phase shifts.

1. Make sure that the generator is off. Connect the circuit of Figure 4-6. Channel 1 is connected to the output of the generator. Select channel 1 as the trigger source. Channel 2 is connected across resistor R2.[2]

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[1] "Arbitrary" means you may choose your own value within the specified range.

2. Turn on and adjust the generator to output 2 kHz ***sinusoid*** with output voltage of 2 V (**rms**).
3. Switch the Vertical Mode to channel 1; this will be the reference signal channel. Adjust scope (Volts/Div. Button) and output level of the generator until a single stationary sine wave is displayed on the screen for the entire width. Center the waveform. (See Figure 4-7)
4. Switch the Vertical Mode to the dual-trace mode to display both signals. Adjust the Volts/Div. Button to obtain the waveforms that are easy to draw. Draw the waveforms in Graph 4-1. Label channel 1 to represent *v* and channel 2 to represent *i*.

   In the lab report, find the relationship between the actual current and the *i* that you saw on the oscilloscope.

   Remark: The waveforms that you get from the scope are voltage waveforms. However, because R2 is a resistor, the voltage v_2 across its terminals and the current i_2 that passes through it are in phase. Therefore, we can tell the phase of the current i_2 from the voltage waveform v_2. Because the whole circuit is a single loop, the current i_2 is the same as the current *i* that passes through all the components.
5. Measure the horizontal distance D (in divisions, see Figure 4-7) for the voltage sine wave labeled *v*. Record the value in Graph 4-1. This is the period of the waveform.
6. Measure the horizontal distance d (in divisions, see Figure 4-7) between the two positive (or negative) peaks of the sine waves. Record the value in Graph 4-1. This is the phase difference between the two waveforms.
7. With reference to Figure 4-7, the phase shift θ (in degrees) is given by

$$\theta = \frac{360}{D} \cdot d$$

   where θ = phase shift

   D = period of the waveform (in divisions)

   d = phase difference (in divisions)

   Calculate the phase shift and record the value in Graph 4-1.
8. Use a DMM to measure the rms voltage across and the rms current through the generator. Calculate the average power P_G delivered by the generator.

---

[2] Channel 1 is (typically) connected to the input of the circuit. Channel 2 is (typically) connected to the output of the circuit.

Hint: $P = \underbrace{V_{rms} I_{rms}}_{\substack{\text{apparent} \\ \text{power}}} \underbrace{\cos\theta}_{\substack{\text{power} \\ \text{factor (pf)}}}$

In your lab report, explain how you can get the value of V_{rms} from the waveform v in Graph 4-1.

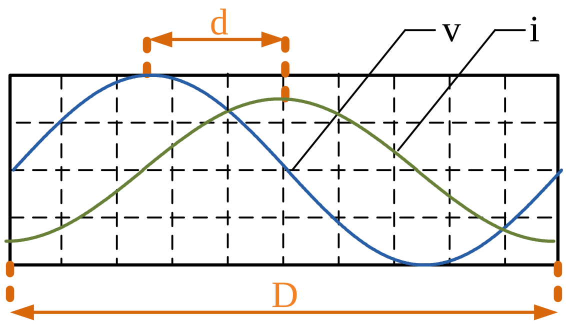


Figure 4-7: Output waveforms.

C.2 INDUCTIVE CIRCUIT

Repeat the steps given in Part C.1 with the following modifications.

1. Replace R1 in Figure 4-6 by the inductor.
2. Record the results in Graph 4-2.

C.3 CAPACITIVE CIRCUIT

Repeat the steps given in Part C.1 with the following modifications.

1. Replace R1 in Figure 4-6 by a 0.47-μF capacitor.
2. Record the results in Graph 4-3.

Do not forget to turn off the scope and the generator.

Note: Capacitance can be determined by the following methods:

- ✓ Measurement: Use the multi-meter in the capacitance measurement mode (-||- mark) with the SELECT button pressed to display the unit F (farad).
- ✓ Numerical code read from the capacitor body:

  For a code *abc*, *a* and *b* give the first two figures of the capacitance while *c* gives the value of multiplier (the number of 0's). The capacitance read from the code is set to have a unit of pF. Thus, 474 is equal to 470000 pF or 470 nF or 0.47 μF.

Table 4-1: The relationship between peak and rms values

	rms voltage, V		peak voltage, V		rms current, mA	
	Measured	Calculated	Measured	Calculated	Measured	Calculated
Sine wave generator output						
R1 = Ω						
R2 = Ω						
R3 = Ω						

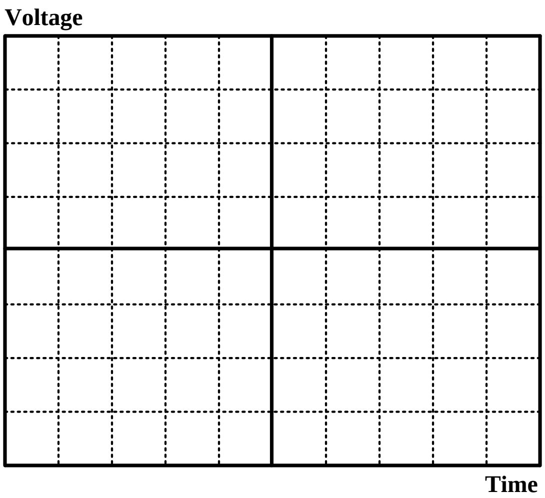
TA Signature:

Table 4-2: Frequency measurement

Frequency of wave (Hz) (Setting value)	Width of one cycle (div.)	Time-base setting (time units/div.)	Period of wave *T* (sec.)	Calculated frequency of wave f (Hz)

TA Signature:

Graph 4-1: Phase relationship in a resistive circuit



Channel 1: volts/div = ______________

Channel 2: volts/div = ______________

Time/div = ______________

R1 = ______________

R2 = ______________

V_{rms} = ______________

I_{rms} = ______________

Distance D from 0° to 360° for the voltage sine wave, *v* = ______ divisions.

Horizontal distance d between maximum points of *v* and *i* = ______ divisions.

Phase angle θ = (360/D)(d) = ________ degrees.

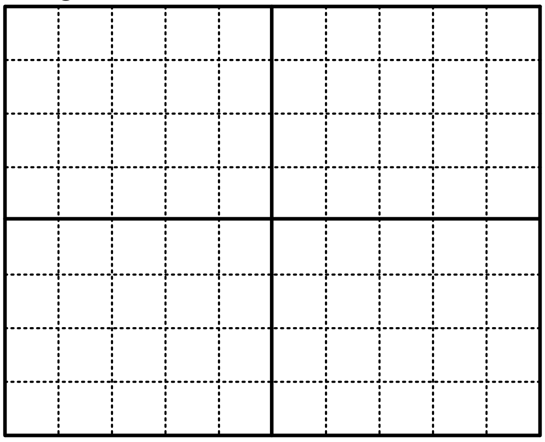
v leads *i* by _________ degrees. Power factor cos θ = ________ .

Average power delivered by the generator = _________ watts.

TA Signature:

Graph 4-2: Phase relationship in an inductive circuit

Voltage



Time

Channel 1: volts/div = ______________

Channel 2: volts/div = ______________

Time/div = ______________

L = ______________

V_{rms} = ______________

I_{rms} = ______________

Distance D from 0° to 360° for the voltage sine wave, *v* = ______ divisions.

Horizontal distance d between maximum points of *v* and *i* = ______ divisions.

Phase angle θ = (360/D)(d) = _________ degrees.

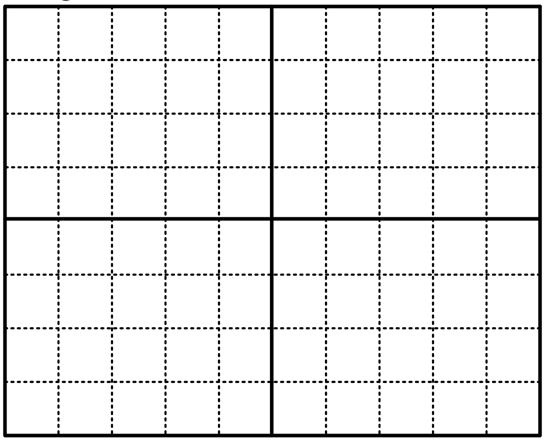
v leads *i* by __________ degrees. Power factor cos θ = _________ .

Average power delivered by the generator __________ watts.

TA Signature:

Graph 4-3: Phase relationship in a capacitive circuit.

Voltage



Time

Channel 1: volts/div = ______________

Channel 2: volts/div = ______________

Time/div = ______________

C = ______________

V_{rms} = ______________

I_{rms} = ______________

Distance D from 0° to 360° for the voltage sine wave, *v* = ______ divisions.

Horizontal distance d between maximum points of *v* and *i* = ______ divisions.

Phase angle θ = (360/D)(d) = _________ degrees.

v leads *i* by __________ degrees. Power factor cos θ = _________.

Average power delivered by the generator __________ watts.

TA Signature:

VII. QUESTIONS

Fill in the blanks.

1. A sine wave has a peak value of 100 V. Its average value is ____________, and the rms value is ____________.
2. The period of a sinusoidal radiation from a station FM100 at 100 MHz is _____________ seconds.
3. The measured average power, current, and voltage in a circuit are 880 W, 5 A_{rms}, and 220 V_{rms}, respectively. Determine the following.

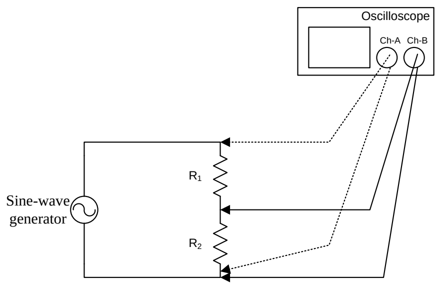
   Phase angle θ = ______________

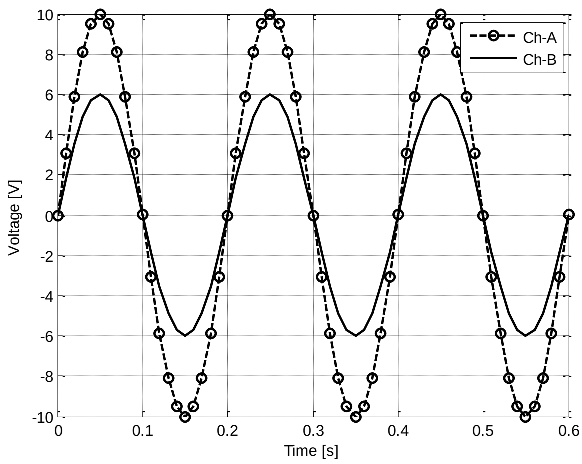
   Power factor $\cos\theta$ = ______________

Answer the following questions in detail. When possible, use drawing to illustrate your answers.

4. How can you make AC voltage measurement using the DMM?
5. How can you make AC current measurement using the DMM?
6. Can the oscilloscope do addition/subtraction? How?
7. Consider a 2 V_{p-p} 1 kHz sinusoidal signal. The oscilloscope is adjusted so that the signal's peak-to-peak voltage occupies exactly four divisions and the signal's period occupies exactly five divisions.

   What are the values of VOLTS/DIV and TIME/DIV of the oscilloscope?
8. Consider the circuit and its corresponding measurements below.





Note that Channel A of the oscilloscope displays the voltage across the generator. Channel B of the oscilloscope displays the voltage across R_2. The ground clips of both channels are connected to the same node.

a) Find the peak voltages and the peak-to-peak voltages across each component in the circuit. Put your answers in the table below. No explanation is needed.

	Peak voltage	Peak-to-peak voltage
Voltage across generator		
Voltage across R_2		
Voltage across R_1		

b) (Tricky) Suppose a student wants to simultaneously display (i) the voltage across R_1 on channel A of the oscilloscope and (ii) the voltage across R_2 on Channel B of the oscilloscope. The ground clip of Channel A is moved to the (middle) node between resistor R_1 and resistor R_2.

Carefully plot the waveforms (for both Channel A and Channel B) that will be displayed on the oscilloscope screen.