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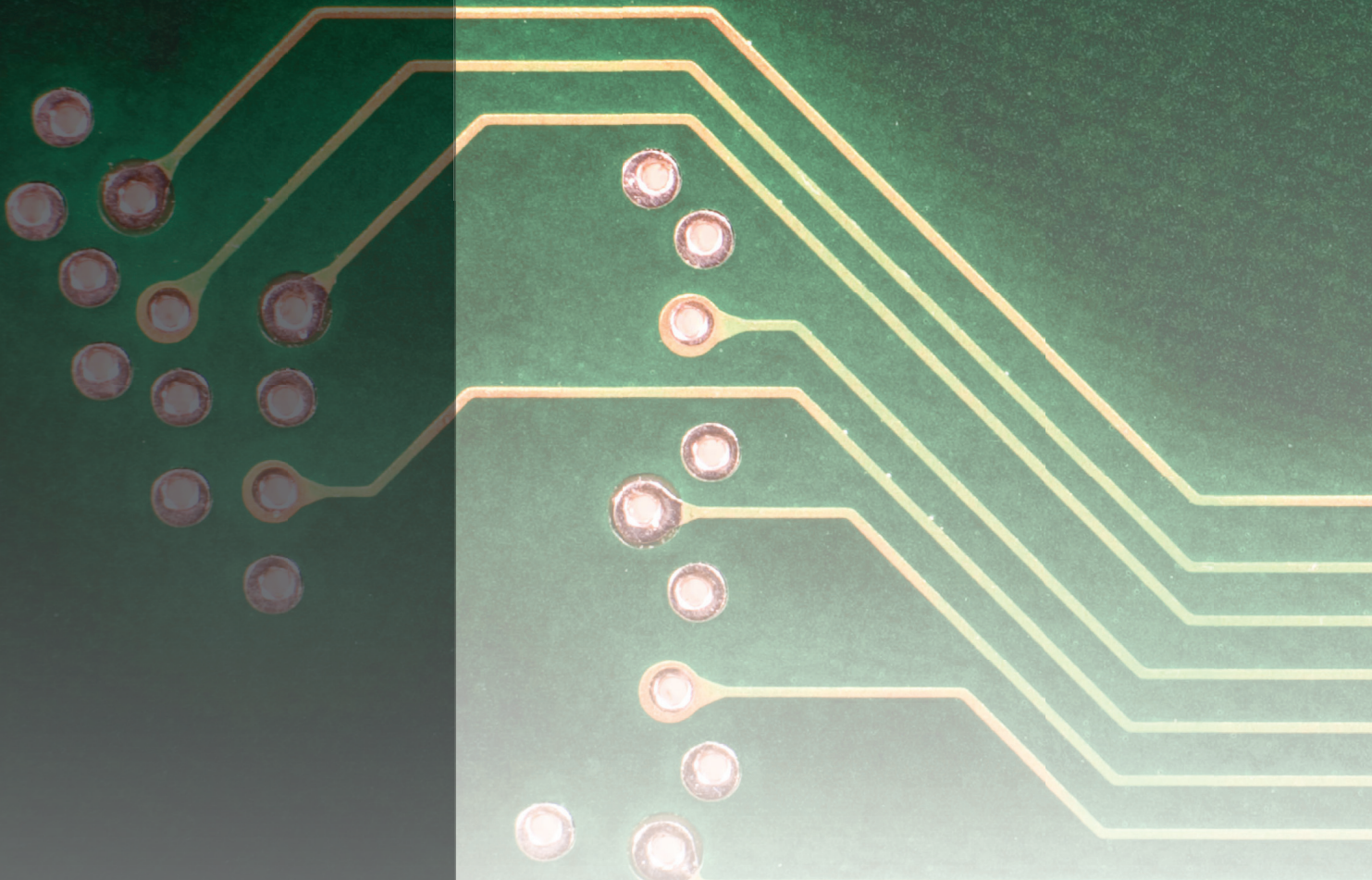
*Innovative Training Solutions*

**Student Lab  
Manual**

# **Electronics Fundamentals Courseware**

**Comprehensive Course  
in AC / DC Electronics**

**Second Edition**



# Electronics Fundamentals

## Student Lab Manual



*Innovative Training Solutions*

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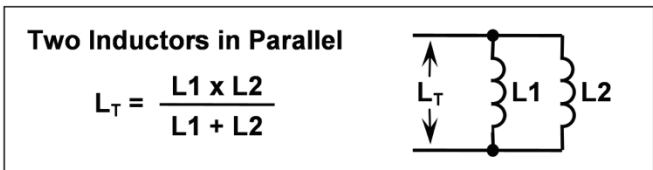
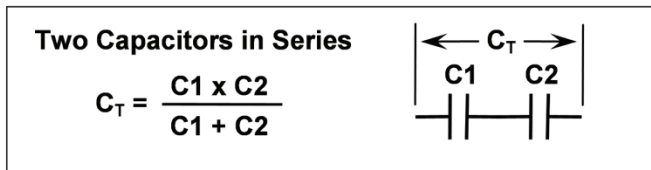
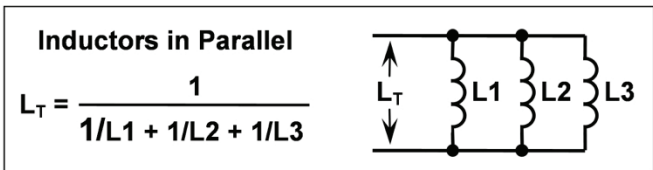
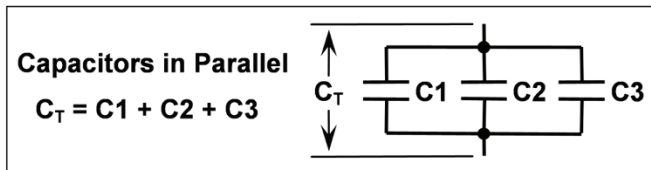
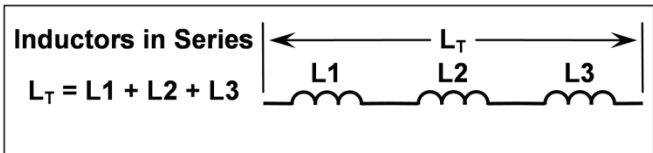
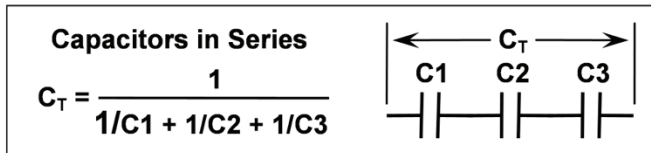
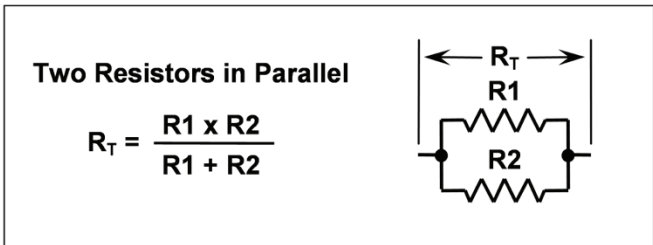
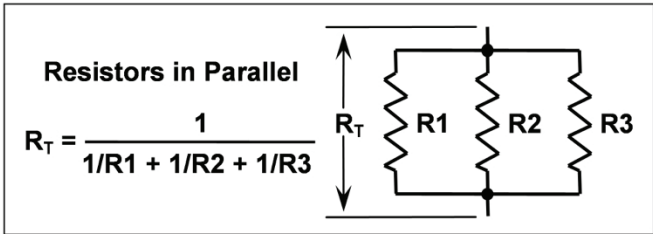
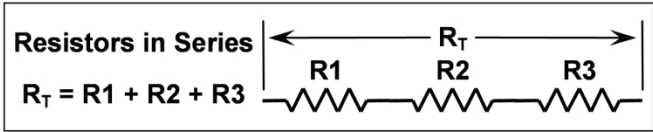
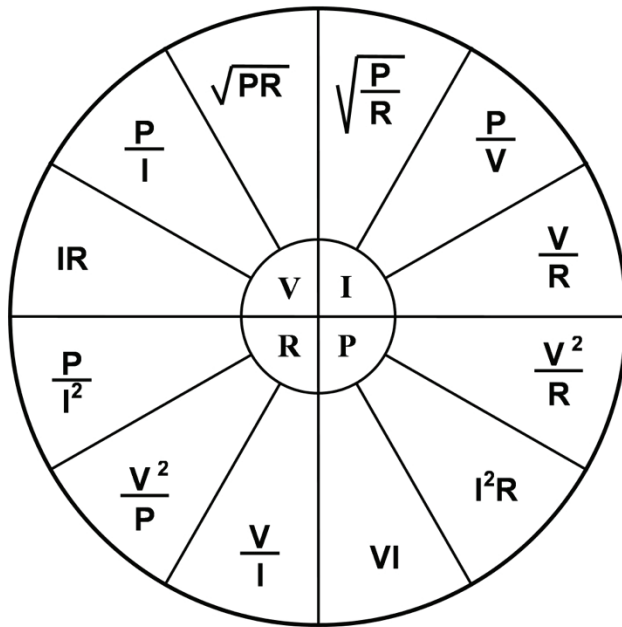
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## USE OF OHM'S LAW

A thorough understanding of Ohm's Law is necessary to complete the Lab Projects in this manual. If there is any uncertainty, review the formulas for calculating Resistance (R), Voltage (V), Current (I) and Power (P). This manual is furnished with formula and color code chart to help with calculations.



**Capacitive Reactance**

$$X_C = \frac{1}{2 \pi f C}$$

**Inductive Reactance**

$$X_L = 2 \pi f L$$

**Resonant Frequency**

$$f_R = \frac{1}{2 \pi \sqrt{LC}}$$

**Impedance Series**

$$Z = \sqrt{R^2 + X^2}$$

**Impedance Parallel**

$$Z = \frac{RX}{\sqrt{R^2 + X^2}}$$

Name
Date Due
Score

## Lab Project 1: Component Identification

The ability to identify components by sight and to identify their use is a requirement in electronics.

### Objectives

1. Identify electrical components.

**Difficulty Level:** beginner

### Required Materials

1. Component parts kit (furnished by instructor).
2. Answer and Evaluation Chart 1 for recording measurements, answers and instructor scoring.

### Procedure 1: Identification Of Components



P-1. Using the components from the parts kit, record the following information on Chart 1: sketch a diagram of each component and record each components code or value.

### Lab Project Review

1. Electrolytic capacitors are distinguished from non-electrolytic capacitors by the markings on electrolytic capacitors indicating positive and negative polarity.
2. Low-power resistors and diodes are of similar size and shape. Diodes have one stripe and resistors have several.
3. Transistors have three leads.
4. SMD Ceramic capacitors are not marked.



Name
Date Due
Score

### Lab Project 4: Resistance in a Series Circuit

Series circuits are one of the most widely used circuits in electronics. This type of circuit has only one path for current (I) flow. In a series circuit, the total resistance ( $R_T$ ) is the sum of the individual resistance (R) values.

**Objectives**

1. Measure and calculate the total resistance of a combination of resistors wired in series.
2. Understand and explain the formula:  $R_T = R_1 + R_2 + R_3$ , etc.

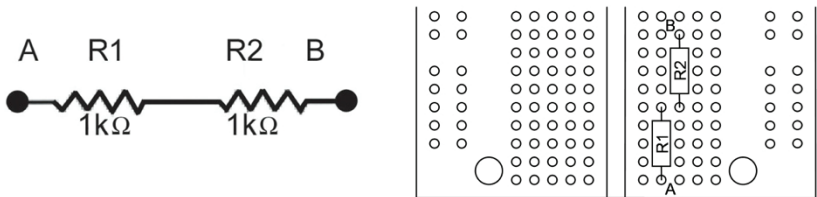
**Level of difficulty:** beginner

**Required Materials**

1. PB-503, PB-505 or PB-507 Electronic Trainer.
2. Multimeter.
3. Answer and Evaluation Chart 4 for recording measurements, answers and instructor scoring.
4. Parts List: Two 1 K $\Omega$  resistors.

**Circuit Construction**

- C-1. Construct the circuit illustrated in Figure 4-A.



**Figure 4-A:** Resistance in a Series Circuit

**Procedure 1: Calculation and Measurement of Resistance in a Series Circuit**

- P-1. Referring to Figure 4-A, calculate the total resistance between terminals A & B. Record the results.
- P-2. Referring to Figure 4-A, use an ohmmeter (set to 20 k $\Omega$ ) to measure the total resistance between terminals A & B. Record the results.

**Procedure 2: Measurement of Resistance in a Series Circuit**

- P-3. Referring to Figure 4-B, use an ohmmeter (set to 2 k $\Omega$ ) to measure the resistance of resistors R1 and R2. Record the results.

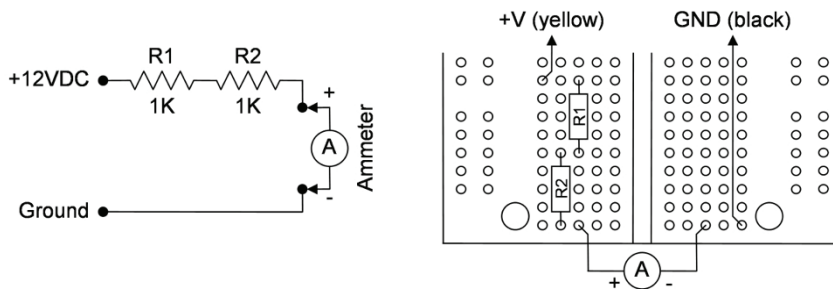
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### Procedure 1: Calculation of Current in a Circuit

- P-1A. Figure 6-A illustrates a two resistor series circuit. Calculate the total resistance ( $R_T$ ) of the circuit using the formula:  $R_T = R_1 + R_2 + R_3$ , etc. Record the answer.
- P-1B. Use Ohm's Law ( $I_T = V / R_T$ ) to calculate the total current ( $I_T$ ) of the circuit. Record the answer.
- P-2. Figure 6-B illustrates a one resistor series circuit. Use Ohm's Law ( $I = V / R$ ) to calculate the total current of the circuit. Record the answer.
- P-3. Is the resistance of circuit 6-B one-half or double that of circuit 6-A? Record the answer.
- P-4. Is the current of circuit 6-B one-half or double that of circuit 6-A? Record the answer.

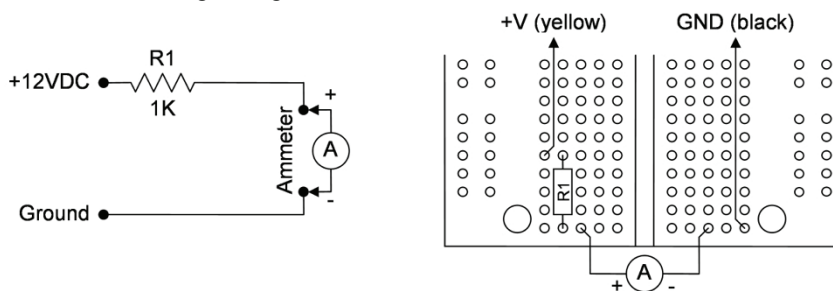
### Procedure 2: Control of Current by Resistance

- P-5A. Referring to Figure 6-C, measure the current of the two resistor series circuit. Record the results.



**Figure 6-C:** Control of Current by Resistance. Measurement Locations.

- P-5B. Does the calculated current equal the measured current? Record the answer.
- P-6A. Referring to Figure 6-D, measure the current of the one resistor series circuit. Record the results.



**Figure 6-D:** Control of Current by Resistance, Measurement Locations.

- P-6B. Does the calculated current equal the measured current? Record the answer.
- P-7. Examine the current measurements. When resistance is decreased, what is the effect on current? Record the answer.

### Lab Project Review

1. The relationship between current and resistance is inversely proportional.
2. Current can be calculated by using Ohm's Law ( $I = V / R$ ).

Name
Date Due
Score

## Lab Project 9: Voltage in a Series Circuit

The total voltage ( $V_T$ ) in a series circuit is divided between its resistors. The voltage drop is directly proportional to the value of each resistor.

### Objectives

1. Measure and calculate the voltage (V) drops across individual resistors in a series circuit.
2. Understand that voltage drops in a series circuit are proportional to the values of the series resistors.
3. Understand Ohm's Law:  $V = I * R$ .

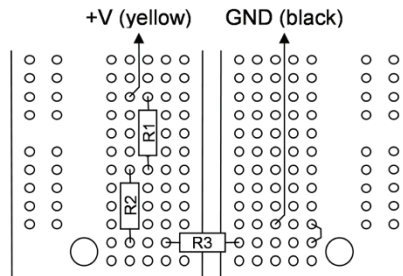
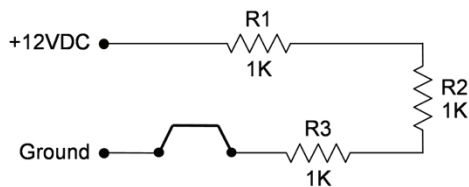
**Level of difficulty:** beginner

### Required Materials

1. PB-503, PB-505 or PB-507 Electronic Trainer.
2. Multimeter.
3. Answer and Evaluation Chart 9 for recording measurements, answers and instructor scoring.
4. Parts List:
  - A. Three 1 KΩ resistors.
  - B. One 2.2 KΩ resistor.

### Circuit Construction

- C-1. Construct the circuit illustrated in Figure 9-A.



**Figure 9-A:** Voltage in the Series Circuit.

### Procedure 1: Calculation of Voltage Drops in a Series Circuit

- P-1A. Figure 9-A illustrates three resistors in a series circuit. Calculate the total resistance ( $R_T$ ) using the formula  $R_T = R_1 + R_2 + R_3$ , etc. Record the answer.
- P-1B. Use Ohm's Law ( $I = V / R$ ) to calculate the total current ( $I_T$ ) of the series circuit. Record the answer.

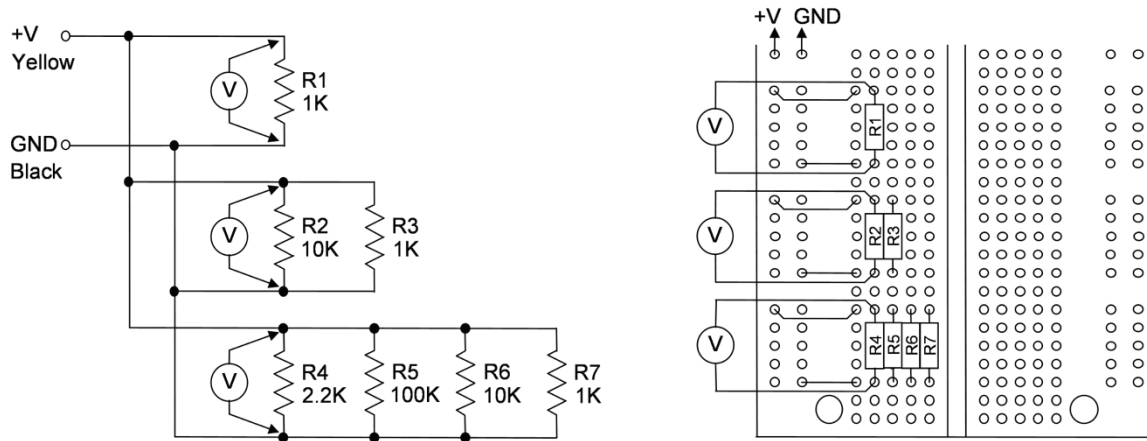
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### Procedure 1: Calculation of Voltages Across Parallel Components

- P-1 . Figure 11-A illustrates three parallel circuits: the first circuit has one resistor, the second circuit has two resistors and the third circuit has four resistors. All three circuits utilize variable power from the PB-503, PB-505 or PB-507.
- P-2. Calculate the voltage drop in the third circuit, as if the power supply was set at +5 VDC. Record the answer.
- P-3. Calculate the voltage drop in the third circuit, as if the power supply was set at +10 VDC. Record the answer.

### Procedure 2: Measurement of Voltages Across Parallel Components

- P-4. Insert the power supply wire. Adjust variable power supply to +5 VDC. Referring to Figure 11-B, use a voltmeter to measure the voltages of the first circuit, the second circuit and the third circuit. Record the results. Note: Even when additional resistors are added to the circuit in parallel, the voltage remains unchanged.



**Figure 11-B:** Voltage in the Parallel Circuit. Measurement Locations.

- P-5. Adjust variable power supply to +10 VDC. Using Figure 11-B, use a voltmeter to measure the voltages of the first circuit, the second circuit and the third circuit. Remember to move the power jumper. Record the results (Set the multimeter to 20VDC scale).
- P-6. Using the third circuit, measure the voltage across each of the four resistors. Measure the 1 k $\Omega$  resistor first, the 10 k $\Omega$  resistor second, the 100 k $\Omega$  resistor third and the 2.2 k $\Omega$  resistor last. Record the results. (Set the multimeter to 20VDC scale). Note: All the resistors in the circuit dropped the total voltage ( $V_T$ ).

### Lab Project Review

1. Components that are in parallel to each other drop identical voltages.
2. Voltage is equal across all resistors in a parallel resistive circuit.

Name
Date Due
Score

### Lab Project 14: Voltmeter Loading

Impedance (Z) is a form of resistance (R) and voltmeters have a very high degree of impedance. When measuring a circuit, there is little effect on the circuit's function by a voltmeter. A voltmeter should not change the operation of a circuit. When measuring across high impedance components, the voltmeter can change the way the circuit functions. The overall resistance of a circuit is reduced when components (i.e., voltmeter, resistor, etc.) are placed in parallel. Note: All voltmeters have a certain amount of internal resistance. This allows some current to flow through the meter (this causes the meter to operate). Some circuit current will pass through a meter altering the voltage drop of the component being measured. This can change the value of the circuit.

**Objectives**

1. Understand that loading effects can affect the accuracy of a voltmeter.
2. Understand Ohm's Law:  $V = I * R$ .

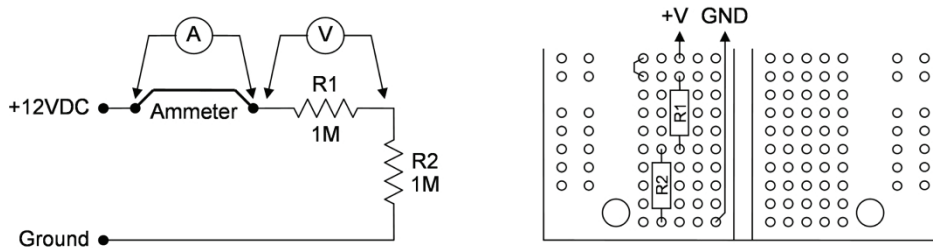
**Level of difficulty:** beginner

**Required Materials**

1. PB-503, PB-505 or PB-507 Electronic Trainer.
2. Two multimeters (ammeter and voltmeter).
3. Answer and Evaluation Chart 14 for recording measurements, answers and instructor scoring.
4. Parts List: Two 1 MΩ resistors.

**Circuit Construction**

C-1. Construct the circuit illustrated in Figure 14.



**Figure 14:** Voltmeter Loading.

Figure 16-B: Resistance in the Combination Circuit. Second Circuit.

**Procedure 3: Calculation and Measurement of Combination Circuit Values**

- P-14A. Referring to Figure 16-B, calculate the total current at A1. Record the answer.
- P-14B. Calculate the total current at A2 and A3. Record the answer.
- P-15A. Measure the total current at A1. Record the answer. Note: Remove jumper when measuring current. Replace jumper when done.
- P-15B. Measure the total current at A2 and A3. Record the answer. Note: Remove jumper when measuring current. Replace jumper when done.
- P-16. Compare the calculated current and measured current at A2 and A3. Are they within 5%? If not recheck. Record the answer.

**Circuit Construction**

- C-3. Construct the circuit illustrated in Figure 16-C.

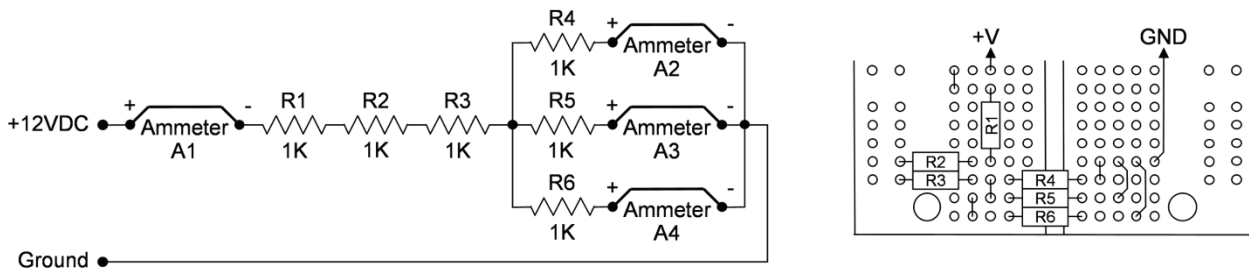


Figure 16-C: Resistance in the Combination Circuit. Third Circuit.

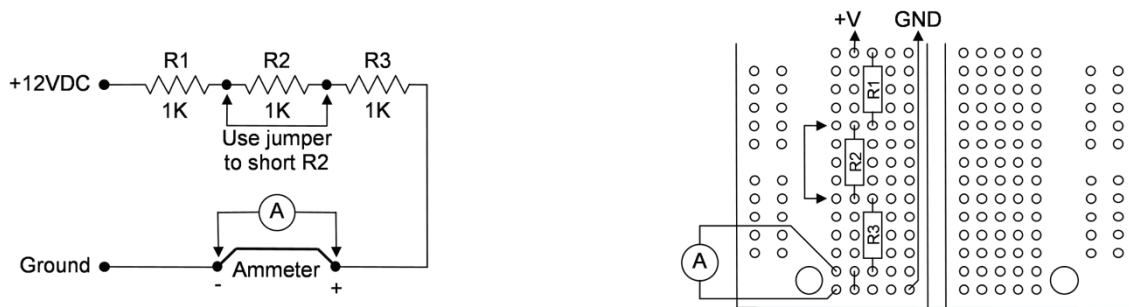
**Procedure 4: Measurement of Current in Multiple Branches of a Segment**

- P-17. Figure 16-C illustrates a combination circuit with three branches. Note: The current splits through the circuit segment and current can be measured at A2, A3 and A4. The sum of A2, A3 and A4 can be measured at A1, which is in series with the power supply.
- P-18. Measure the total current at A1. Record the results.
- P-19. Measure the branch currents at A2, A3 and A4. Record the results.
- P-20. Add the measurements of A2, A3 and A4 together. Does the sum equal the current measured at A1? Record the answer.

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- P-2B. As if the circuit was operating under normal conditions, use Ohm's Law ( $I = V / R$ ) to calculate the total current ( $I_T$ ) the circuit. Record the answer.
- P-2C. Use Ohm's Law ( $V = I * R$ ) to calculate the voltage drops across resistors: R1, R2 and R3. Record the answers.
- P-3A. Referring to Figure 18-A, measure the total current ( $I_T$ ) of the circuit. Record the results (Set the multimeter to 20mA scale).
- P-3B. Measure the voltage drops across each individual resistor: R1, R2 and R3. Record the results (Set the multimeter to 20VDC scale).
- P-3C. Compare the calculated current and measured current at R1, R2 and R3. Are they within 5%? If not - recheck. Record the answer.

### Procedure 2: Characteristics of a Shorted Circuit



**Figure 18-B:** The Short Circuit.

- P-4. Referring to Figure 18-B, insert a jumper wire on the board as indicated. This will simulate a short and remove R2 from the circuit.
- P-5. With R2 now out of the circuit, calculate the total resistance ( $R_T$ ) for the circuit. Record the answer.
- P-6. Use Ohm's Law to calculate the new total current ( $I_T$ ). Record the answer.
- P-7. Use Ohm's Law ( $V = I * R$ ) to calculate the voltage drops across each individual resistor: R1, R2 and R3. Record the answers. Note: R2, being out of the circuit, should not have any voltage drop ( $V = 0$ ).
- P-8A. Referring to Figure 18-B, measure total current. Record the result.
- P-8B. Measure the voltage drop across each individual resistor: R1, R2 and R3. Record the results.

### Lab Project Review

1. In a closed, or normally operating circuit, all series components will have the correct current through them and will drop the predicted voltages.
2. When a component is shorted, it is cut out of the circuit so there isn't any voltage drop.
3. In a partially shorted circuit, the non-shortened components will have more current and voltage through them than under normal operating conditions.

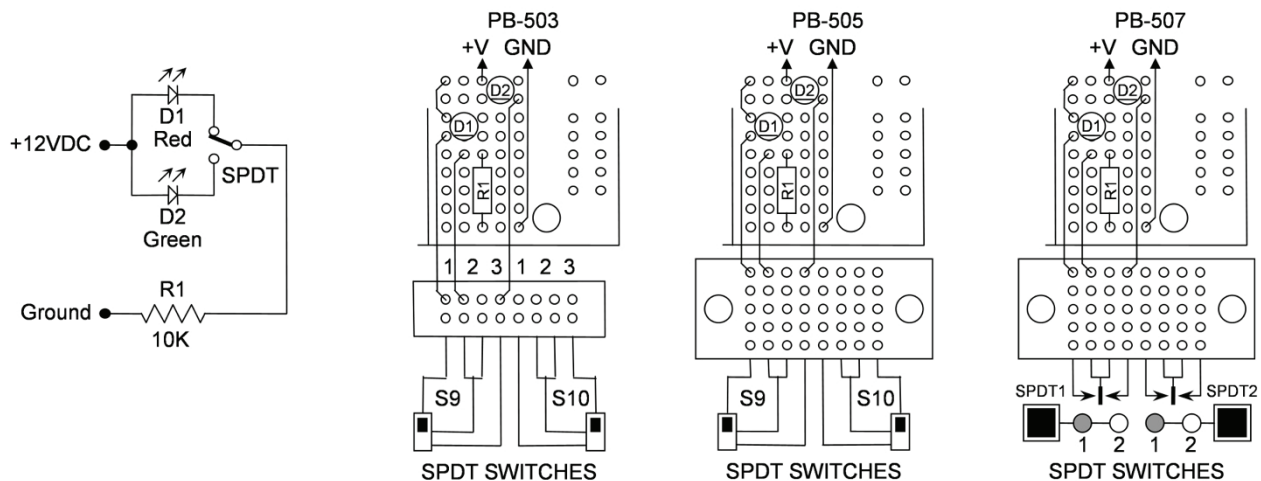
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### Procedure 1: The Single Pole Single Throw (SPST Switch)

- P-1A. Referring to Figure 20-A, the circuit illustrates a single pole, single throw (SPST) switch with a red LED to indicate on or off. Is the circuit opened or closed? Will the LED illuminate? Record the answers. Note: This procedure is using a part of the SPDT switch from the trainer. A SPST switch is obtained this way.
- P-1B. If a jumper wire were inserted between the switch terminals, would the circuit be opened or closed? Would the LED illuminate? Record the answers.
- P-2A. Turn power on and set to +12 VDC. Place the switch in the down position on PB-503 and PB-505 or in the right position on PB-507. Is the circuit opened or closed? Is the LED illuminated? Record the answers. Note: The switch position on the PB-507 trainer is indicated by the corresponding LED lighting up.
- P-2B. Place the switch in the up position on PB-503 and PB-505 or in the left position on PB-507. Is the circuit opened or closed? Is the LED illuminated? Record the answers.
- P-3. Do the predictions from P-1A and P-1B match the results of P-2A and P-2B? Record the answer. Turn power off.

### Circuit Construction

- C-2. Construct the circuit illustrated in Figure 20-B.



**Figure 20-B:** The Switch. SPDT Switch.

### Procedure 2: The Single Pole Double Throw (SPDT) Switch

- P-4A. Referring to Figure 20-B, the circuit illustrates a single pole, double throw (SPDT) switch which shifts between two LEDs. If the SPDT switch is in the up position on PB-503 and PB-505 or in the left position on PB-507, which LED will light? Record the answer.
- P-4B. If the SPDT switch is in the down position on PB-503 and PB-505 or in the right position on PB-507 which LED will light? Record the answer.



## Electronics Fundamentals Student Lab Manual

answer. Note: This circuit is considered unbalanced because the values of all the resistors are not the same on each side of the circuit.

- P-6B. Calculate the voltage between output terminal B & ground using the formula:  
 $V_{B-G} = V_T * R4 / (R3 + R4)$ . Record the answer.
- P-6C. Calculate the voltage drop across output terminals A & B using the formula:  
 $V_{A-B} = V_A - V_B$  or  $V_B - V_A$ . Record the answer.
- P-7A. Turn power on. Adjust power to +12 VDC. Measure the voltage from output terminal A to ground. Record the results.
- P-7B. Measure the voltage from output terminal B to ground. Record the results.
- P-7C. Measure the voltage between output terminals A & B. Record the results.
- P-8. Compare the calculated values to the measured values. Do they match? Record the answer.

### Lab Project Review

1. The Wheatstone Bridge is used for accurate measurements because it maintains a constant voltage ratio across its outputs.
2. The important concept about bridge circuits is not amount of resistance in their branches but their ratios.

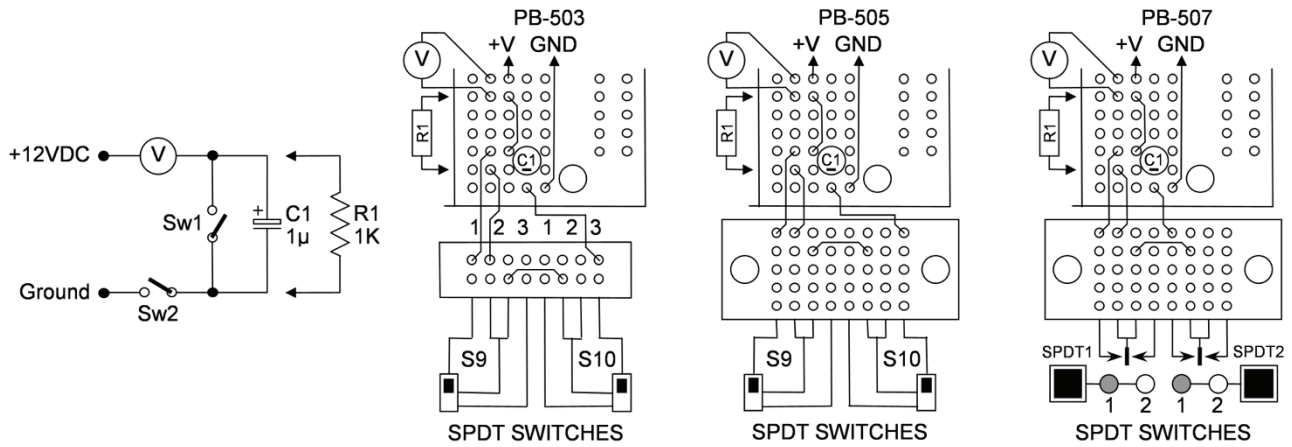


Figure 24: The RC Time Constant

- P-2. Calculate the time constant for the circuit to fully charge the capacitor (with the voltmeter in series) using the formula:  $T = R * C$ . Record the answer. Note: The voltmeter is going to provide the series resistance for the capacitor's time constant. The voltmeter will drop the difference between the applied voltage and the capacitor's charge.
- P-3A. Use the 63.2% principle, calculate the voltage that should be dropped by the capacitor after the first time constant. Record the answer.
- P-3B. Use the 63.2% principle, calculate the voltage that should be dropped by the capacitor after the second time constant. Record the answer.
- P-3C. Use the 63.2% principle, calculate the voltage that should be dropped by the capacitor after the third time constant. Record the answer.
- P-3D. Use the 63.2% principle, calculate the voltage that should be dropped by the capacitor after the fourth time constant. Record the answer.
- P-3E. Use the 63.2% principle, calculate the voltage that should be dropped by the capacitor after the fifth time constant. Record the answer.

**Procedure 2: Measurement of the Time Constant**

- P-4. Referring to Figure 24, place Sw1 and Sw2 (wired as on/off switches) in the circuit as indicated: Sw1 and Sw2 is closed. Set the voltmeter to 20 VDC range and place it in the circuit where indicated. Turn power on. Note: The voltmeter will drop all 12 VDC. When Sw1 is opened, there will be a charging path available for the capacitor. Remark: Sw1 is S9 on PB-503 and PB-505; SPDT1 on PB-507. Sw2 is S10 on PB-503 and PB-505; SPDT2 on PB-507.
- P-5A. Open Sw1. Use a timepiece to measure the voltage across the voltmeter after the first time constant. Record the result. Note: This will be difficult to accomplish and not completely accurate.
- P-5B. Measure the voltage across the voltmeter after the second time constant. Record the result.
- P-5C. Measure the voltage across the voltmeter after the third time constant. Record the result.

Name
Date Due
Score

**Lab Project 26: Answer and Evaluation Chart 26  
Inductors: Use and Identification**

Question	Answers	Points	Score
P-1			
P-4			
P-5			
	<b>Total</b>		
	<b>Percentage Score</b>		

Name
Date Due
Score

## Lab Project 29: RC Phase Shift

Phase shift circuits are essentially circuits that contain capacitance and inductance. Phase shift circuits are widely used in communications electronics. The series RC circuit causes the source current to lead the source voltage.

### Objectives

1. Calculate and measure the phase shift of a series RC circuit.
2. Measure the RC phase with a dual-trace oscilloscope.

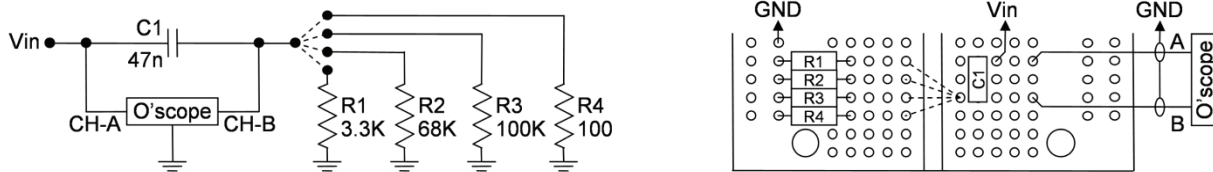
**Level of difficulty:** advanced

### Required Materials

1. PB-503, PB-505 or PB-507 Electronic Trainer.
2. Oscilloscope.
3. Answer and Evaluation Chart 29 for recording measurements, answers and instructor scoring.
4. Parts List:
  - A. One 100  $\Omega$  resistor.
  - B. One 3.3 K $\Omega$  resistor.
  - C. One 68 K $\Omega$  resistor.
  - D. One 100 K $\Omega$  resistor.
  - E. One 47 nF capacitor.

### Circuit Construction

- C-1. Construct the circuit illustrated in Figure 29.



**Figure 29:** RC Phase Shift

Name
Date Due
Score

**Lab Project 31: Answer and Evaluation Chart 31  
Impedance**

Question	Answers	Points	Score
P-1A			
P-1B			
P-1C			
P-1D			
P-1E			
P-2			
P-3A			
P-3B			
P-4A			
P-4B			
P-5			
		<b>Total</b>	
		<b>Percentage Score</b>	

## Electronics Fundamentals Student Lab Manual

- P-8. Referring to Graph 33, do the upper and lower cutoff frequencies approximately match the calculated cutoff frequencies? Record the answer.
- P-9. If the 10 k $\Omega$  resistor were replaced by a 470  $\Omega$  resistor, would the bandwidth increase or decrease? Record the answer.

### Lab Project Review

1. Parallel tuned circuits can be used to pass or block specific ranges of frequencies.
2. The middle range of frequencies that are either passed or blocked is called Bandwidth.
3. When a load is placed across the parallel LC portion of the circuit, a band-pass filter results. The midrange frequencies are passed to the load while the high and low frequencies are blocked.
4. When a load is placed across the resistor of the circuit, a band-notch filter results. The midrange frequencies are prevented from reaching the load.

## Electronics Fundamentals Student Lab Manual

- P-7A. Place the oscilloscope probe across output voltage ( $V_{R1}$ ). Set the oscilloscope to 2 VDC and measure the rectified signal. Record the results.
- P-7B. Measure the ripple frequency. Record the results.
- P-8. Use a voltmeter set to DC, measure the voltage across the 1 k $\Omega$  resistor. This is the average voltage. Record the results.
- P-9. Trace the input (AC1-AC2) and output signal (VR1) on Graph 35-C.

### Lab Project Review

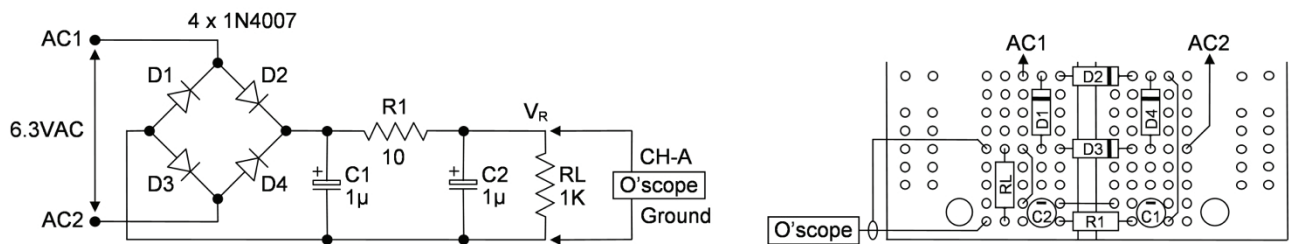
1. Rectifiers convert an AC signal input to a pulsating DC output.
2. Rectifiers can produce either a positive or negative DC signal.
3. A half-wave has a lower average output voltage than a full-wave rectifier.
4. Ripple frequency for a half-wave rectifier is the same as its input frequency.
5. Ripple frequency for a full-wave rectifier is double the input frequency.

**Procedure 1: Measurement of Full-Wave Filtering**

- P-1A. Figure 37-A illustrates a full-wave rectifier circuit with a capacitor filter. Apply a 6.3 VAC RMS voltage from AC power supplies to input (AC1 – AC2). Using an oscilloscope to view, trace the output across  $R_L$  on Graph 37-A.
- P-1B. Measure the AC ripple voltage at  $V_R$  using a voltmeter set to AC. Record the results.
- P-1C. Measure the DC output voltage at  $V_R$  using a voltmeter set to DC. Record the results.
- P-2A. Using an oscilloscope set to AC, measure the Peak-to-Peak ripple output at  $V_R$ . Record the results. Trace the output signal on Graph 37-B. Note: It may be necessary to adjust the Volts/cm to obtain a measurable signal.
- P-2B. Compare these measurements with the measurements of P-1B. Was the ripple Peak-to- Peak greater or smaller? Record the answer.
- P-2C. Was the ripple frequency the same or double than the input frequency? Record the answer.

**Circuit Construction**

- C-2. Construct the circuit illustrated in Figure 37-B.



**Figure 37-B:** The Capacitor As A Filter. Replacing The Filter Capacitors With Smaller Values.

**Procedure 2: The Effects of Reduced Capacitance**

- P-3. Figure 37-B illustrates the same circuit except that the capacitors have a smaller value. Apply a 6.3 VAC RMS voltage from AC power supplies to input (AC1 – AC2). Measure the output voltage at  $V_R$  using an oscilloscope set to DC. Trace the output signal on Graph 37-C.
- P-4A. Using the oscilloscope Measure the Peak-to-Peak ripple output signal. Record the results.
- P-4B. Using an AC voltmeter Measure the ripple voltage. Record the answers.
- P-4C. How much did the ripple voltage change from the first circuit (P-1B) the second circuit? Record the answer.

**Lab Project Review**

1. A full-wave bridge rectifier circuit produces less ripple than a half-wave rectifier with similar filtering.
2. The full-wave bridge rectifier’s ripple is twice the frequency as a similar half-wave circuit.



Name
Date Due
Score

**Lab Project 39: Answer and Evaluation Chart 39  
The Light Emitting Diode and Optocoupler**

Question	Answers	Points	Score
P-2	Chart 39-A		
P-3			
P-4			
P-6	Chart 39-B		
P-7			
P-8			
	<b>Total</b>		
	<b>Percentage Score</b>		

Name
Date Due
Score

### Lab Project 41: The TRIAC

The TRIAC acts like two SCRs operating in parallel. When this device is gated, current (I) can pass through either direction. It is an “on only” component.

**Objectives**

1. Measure TRIAC operation in “forward bias”.
2. Measure TRIAC operation in “reverse bias”.

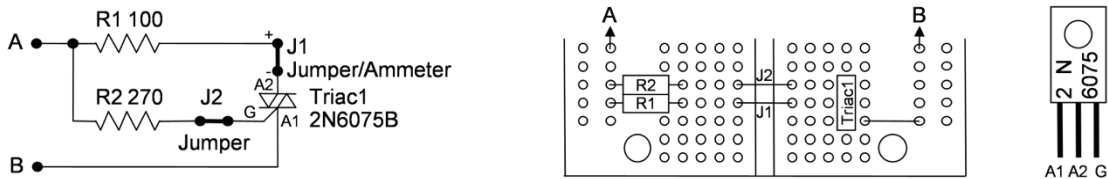
**Level of difficulty:** beginner

**Required Materials**

1. PB-503, PB-505 or PB-507 Electronic Trainer.
2. Multimeter.
3. Answer and Evaluation Chart 41 for recording measurements, answers and instructor scoring.
4. Parts List:
  - A. One 100 Ω resistor.
  - B. One 270 Ω resistor.
  - C. One TRIAC: 2N6075B.

**Circuit Construction**

C-1. Construct the circuit illustrated in Figure 41.



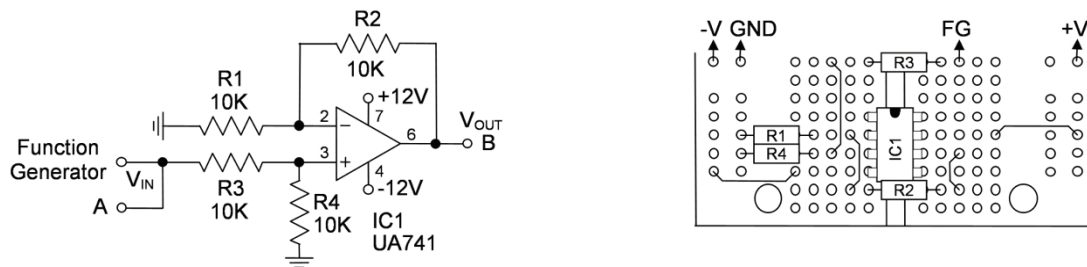
**Figure 41:** The TRIAC.

**Procedure 1: The Operational Amplifier as a Non-inverting Signal Amplifier**

- P-1A. Figure 43-A illustrates an Operational Amplifier in a non-inverting signal amplifier circuit. Gain ( $A_V$ ) can be calculated using the formulas:  $A_V = 1 + R_2 / R_1$ ,  $A_V = V_{OUT} / V_{IN}$ . Apply a 1 VACp-p signal at 1kHz from the function generator to the circuit as indicated.
- P-1B. Calculate the gain using the formula:  $A_V = 1 + R_2 / R_1$ . Record the answer.
- P-1C. Calculate the output voltage for this circuit  $V_{OUT} = V_{IN} * A_V$ . Record the answer.
- P-2. Apply the +12 VDC, -12 VDC and the ground to the circuit. Turn power on. Set both channels of the oscilloscope to 1 Volt/cm. Place the probes at terminals A & B. Place the Channel A trace in the upper half of the graticule and the Channel B trace in the lower half. Measure both traces. Trace the input and output signals on Graph 43-A.
- P-3. Measure the output Peak-to-Peak signal. Record the answer.
- P-4. Was there a 180° phase shift between the input and output signals? Record the answer.

**Circuit Construction**

- C-2. Construct the circuit illustrated in Figure 43-B.



*Figure 43-B: Operational Amplifier as a Non-inverting Unity Gain Amplifier.*

**Procedure 2: The Operational Amplifier as a Non-inverting Unity Gain Amplifier**

- P-5A. Figure 43-B illustrates an OP-AMP in a non-inverting unity gain amplifier circuit. Apply a 1 VACp-p signal at 1 kHz from the function generator to the circuit as indicated. Calculate the gain using the formula:  $A_V = 1 + R_2 / R_1$ . Record the answer.
- P-5B. Calculate the output voltage for this circuit  $V_{OUT} = V_{IN} * R_4 / (R_3 + R_4) * A_V$ . Record the answer.
- P-6. Set both channels of the oscilloscope to 0.5 Volts/cm. Place the probes at terminals A & B. Place the Channel A trace in the upper half of the graticule and the Channel B trace in the lower half. Measure both traces. Trace the input and output signals on Graph 43-B.
- P-7. Measure the output Peak-to-Peak signal. Record the answer.
- P-8. Was there a 180° phase shift between the input and output signals? Record the answer.

**Lab Project Review**

1. The operational amplifier's input and output signals are in phase if the non-inverting input is used.
2. The signal must be divided to obtain unity amplifier.

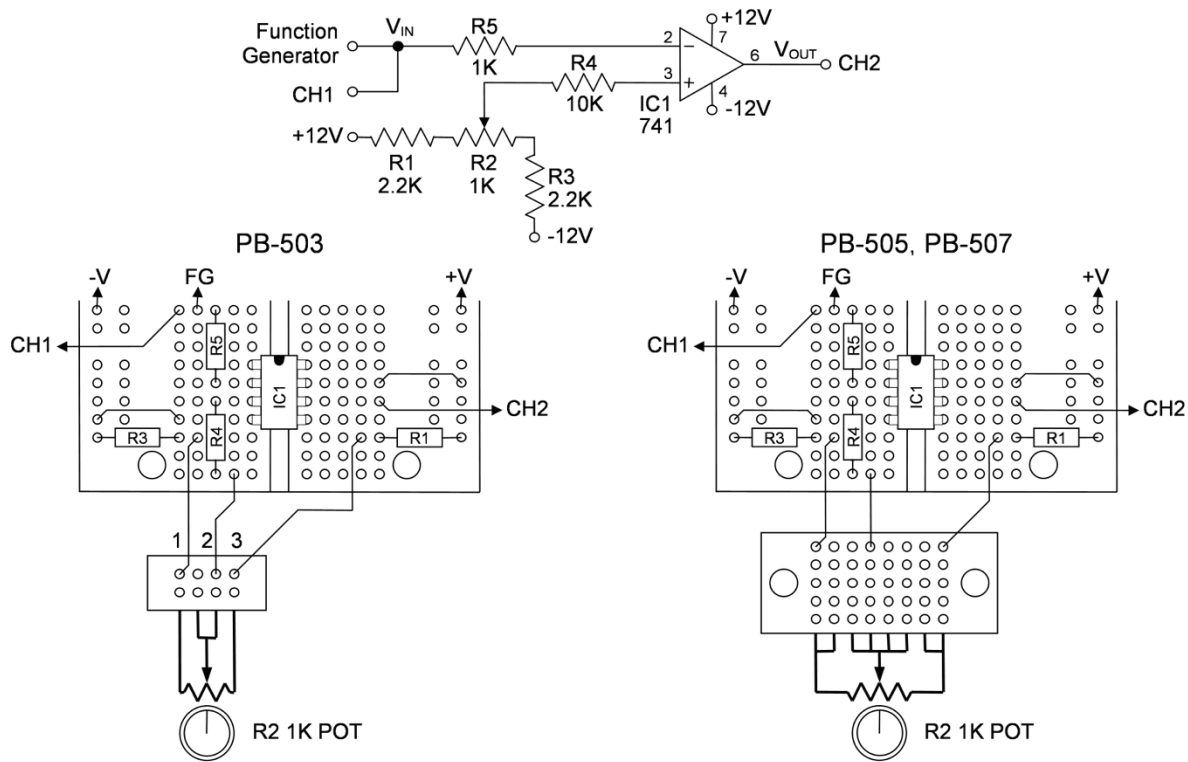


Figure 45: Triangle to square wave with variable duty cycle.

- P-3. Set the oscilloscope like so: CH1 on the top half of the screen, DC, x10, 2V/div; CH2 on the bottom half of the screen, DC, x10, 10V/div; Time base: 200μs/div; Trigger CH1. Turn power on. Adjust the +V power supply to 12VDC and -V power supply to -12VDC. Connect oscilloscope and power supplies +V and -V terminals to the circuit, as illustrated.
- P-4. Set the R2 potentiometer at the half of the course. What is the shape of the output signal? Record the answer.
- P-5. Rotate the R2 potentiometer between the two extremes. Observe the effect on the output signal. Record the answer.
- P-6A. Set the wiper voltage at -2VDC. Using the formula:
 
$$\text{Duty Cycle \%} = 100 \times (\text{Duration for which } V_{out} \text{ is High}) / (\text{Duration of a period}),$$
 calculate the duty cycle of the output signal. Record the answer.
- P-6B. Trace the input and output signals on Graph 45-A.
- P-7A. Set the wiper voltage at +2VDC. Calculate the duty cycle of the output signal. Record the answer.
- P-7B. Trace the input and output signals on Graph 45-B.

**Lab Project Review**

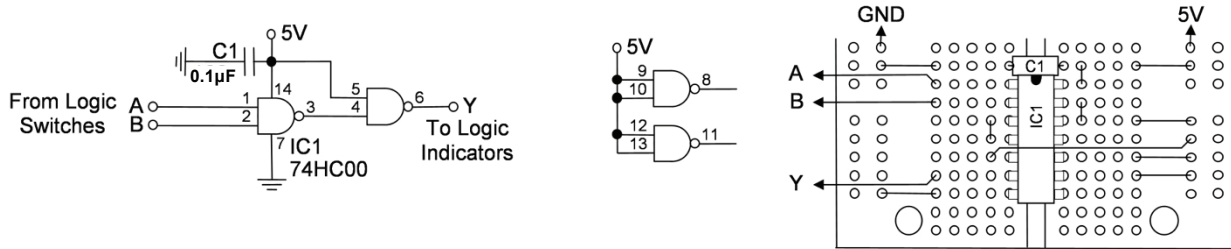
1. Using the comparator is the easiest method of obtaining a rectangular signal with variable duty cycle.

## Electronics Fundamentals Student Lab Manual

- P-6. Turn the power on. Go through all four possible combinations of the inputs. Complete the truth table 47-C with the results obtained. Turn the power off.
- P-7. Compare the truth tables 47-A and 47-C. What do you observe? Record the answer.

### Circuit Construction

- C-4. Construct the circuit illustrated in Figure 47-D.



**Figure 47-D:** The NAND gate with an inverter on output, version 2.

- P-8. Turn the power on. Go through all four possible combinations of the inputs. Complete the truth table 47-D with the results obtained. Turn the power off.
- P-9. Compare the truth tables 47-C and 47-D. What do you observe? Record the answer.

### Lab Project Review

1. The logic gate NAND performs the inverse function than the AND gate.
2. The NAND gate can be used as an inverter if one of the inputs is connected to 5V or if the inputs are connected to each other.
3. If a NAND output is connected to an inverter, the circuit will work as an AND gate.

Name
Date Due
Score

## Lab Project 49: The “XOR” and “XNOR” gates

Digital circuits are the basis of modern computer technology. Each integrated circuit is designed to perform a specific function. The XOR and NXOR gates are basic digital devices. They have two inputs and one output. XOR (eXclusive OR) gate output is high (1) if one, and only one, of the inputs are high (1). XNOR gate output is low (0) if one, and only one, of the inputs are high (1).

### Objectives

1. Measure the operation of an XOR gate.
2. Measure the operation of an XNOR gate.

**Level of difficulty:** beginner

### Required Materials

1. PB-503, PB-505 or PB-507 Electronic Trainer.
2. Answer and Evaluation Chart 49 for recording measurements, answers and instructor scoring.
3. Parts List:
  - A. One 100n capacitor.
  - B. Two 1 kΩ resistors.
  - C. One Integrated Circuit: 74HC86.
  - D. One Integrated Circuit: 74HC266.

### Circuit Construction



C-1. Construct the circuit illustrated in Figure 49-A.

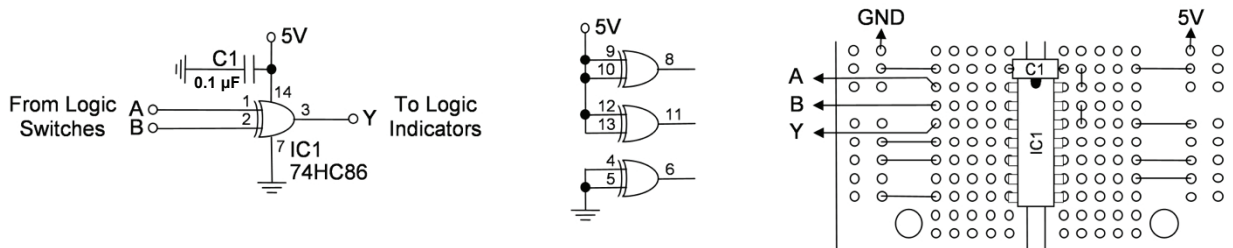


Figure 49-A: The XOR gate.

Name
Date Due
Score

**Lab Project 50: Answer and Evaluation Chart 50**  
**The Combinational logic circuits**

Question	Answers	Points	Score
P-2	Truth Table 50-A1		
P-3	Truth Table 50-A2		
P-4			
P-5			
P-7	Truth Table 50-B1		
P-8	Truth Table 50-B2		
P-9			
P-10			
	<b>Total</b>		
	<b>Percentage Score</b>		

Name
Date Due
Score

## Lab Project 52: The Common Collector Amplifier

The common collector amplifier, often called the emitter follower, is an extremely useful circuit. This is because the output voltage, taken at the emitter, is always a certain amount less than the input voltage. This amplifier is not used for voltage gain, but, instead used for current gain and to match impedance. Common collector amplifiers are typically the output stage of an amplifier circuit. This because the output level will not greatly decrease when a low impedance load is placed at the output. Common collector amplifiers have no phase shift between input and output signals.

### Objectives

1. Measure current gain for a common collector amplifier.
2. Measure the output voltage from a common collector amplifier.
3. Confirm that common collector amplifiers have no phase shift between input and output signals.

**Level of difficulty:** medium

### Required Materials

1. PB-503, PB-505 or PB-507 Electronic Trainer.
2. Oscilloscope.
3. Multimeter.
4. Answer and Evaluation Chart 52 for recording measurements, answers and instructor scoring.
5. Parts List:
  - A. One 220  $\Omega$  resistor.
  - B. One 1 K $\Omega$  resistor.
  - C. Two 22 K $\Omega$  resistors.
  - D. One 1  $\mu$ F electrolytic capacitor.
  - E. Two 470  $\mu$ F electrolytic capacitor.
  - F. One Transistor: 2N2222.

### Circuit Construction

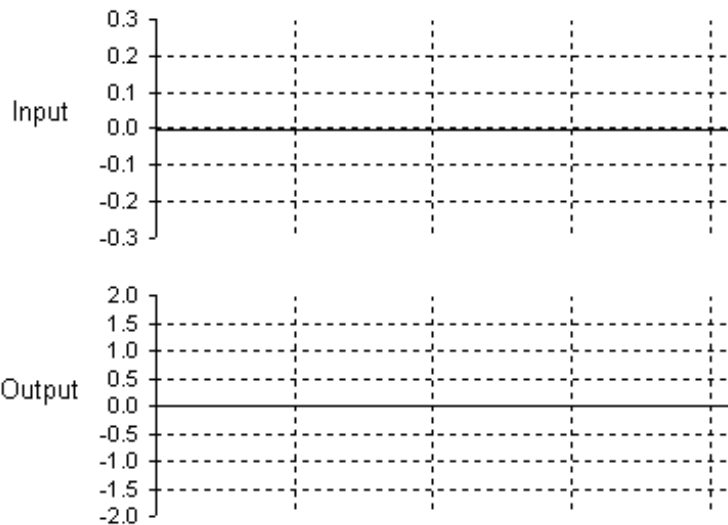
- C-1. Construct the circuit illustrated in Figure 52.



Name
Date Due
Score

### Lab Project 54: Answer and Evaluation Chart 54 The FET Amplifier

Question	Answers	Points	Score
P-1B			
P-2			
P-3			
P-4	Graph 54		
P-5			
P-6			
<b>Total</b>			
<b>Percentage Score</b>			



**Graph 54:** FET Amplifier Input and Output Waveforms.

Name
Date Due
Score

**Lab Project 56: Answer and Evaluation Chart 56  
Oscillators**

Question	Answers	Points	Score
P-2			
P-3			
P-4			
P-5			
P-6			
P-8			
P-9			
P-11A			
P-11B			
	<b>Total</b>		
	<b>Percentage Score</b>		

2. Oscillators with crystals are used to obtain accurate and stable frequencies.

Name
Date Due
Score

**Lab Project 58: Answer and Evaluation Chart 58  
Oscillators with logic gates**

Question	Answers	Points	Score
P-2			
P-3			
P-4			
P-5			
P-6			
P-8			
P-9			
P-10			
<b>Total</b>			
<b>Percentage Score</b>			

## **Appendix A**

### **Use of the Global Specialties' Electronic Trainer, Model PB-507**

The PB-507 Advanced Circuit Design Workstation is a versatile, time saving tool for circuit designers, engineering technicians, students, and hobbyists. A large breadboard area and a wide choice of built-in circuit accessories allow rapid and accurate construction of virtually any type of analog or digital circuit.

The circuit breadboard area includes over 4100 contact points. The PB-507 can be used to construct from basic series and parallel circuits to the most complicated multi-stage microcomputer circuits, incorporating the latest in industrial technology.

The trainer is equipped with USB interface which can be used to fully control the trainer settings from the computer or for firmware upgrade. A graphic display is used for the user interface. On this display you can read all of the trainer settings and the component modules working values. A number of LEDs show the input and output signals state.

Working parameters of the modules (waveforms, signal types, frequencies, levels, duty cycles, voltages and all other settings) can be saved. The PB-507 Trainer has ten storage locations in non-volatile memory to store states for recalling. When automatic save is turned on, the settings will be saved in the non-volatile memory after 3 seconds from the last modification of a parameter. The PB-507 can be configured so that these settings to be loaded when the trainer is turned on.

Display settings, counter mode, automatic save, power on settings and the trainer security level is configurable.

Fixed and variable, positive and negative output DC power supplies provide circuit power. In addition to the DC power supplies, the PB-507 also provides a 12.6 volt center-tapped AC supply.

A multiple-waveform function generator supplies sine, triangle, and square wave output for analog circuits. For digital circuits a pulse generator can be used which supplies rectangular wave with variable duty cycle, with TTL or CMOS level, user selectable.

A self scaling and autoranging frequency counter may be used for measuring frequency.

Outputs include two debounced pushbutton switches and a bank of eight selectable logic switches.

Two built-in potentiometers and two SPDT switches are provided for circuit control and adjustment. Connections to external test equipment or signal sources may be made using the BNC connector on the PB-507. A built-in speaker may be used for an analog output.

Eight bicolor LED's make up eight Logic Indicators that will display logic high and low conditions based on either TTL or CMOS thresholds, selectable by the user.

A built-in logic probe is useful in circuit troubleshooting and two hexadecimal to seven-segment LED's displays may be used in circuit designs.

The PB-507 eliminates the clutter and confusion that often results when constructing sophisticated electronic circuits. Alligator clips and similar connectors are seldom needed.

Sockets on the PB-505 allow insertion of components or wires of up to 20 gauge.

#### **Description of Individual Features**

In order to use the full capabilities of the PB-505 properly, it is highly recommended that the user become familiar with the panel layout and the features of the workstation components. (See figure below).

### Power

By combining the three DC power supplies on the PB-505, the user may work with virtually any type of integrated circuit or discrete component. The fixed 5 volt supply has become an industry standard for powering digital IC's. IC's which require +5 V, +12 V, and -5 V are easily accommodated by the PB-505. The variable supply output voltages may be changed by using the adjustment knobs on the front panel. The positive and negative outputs are continuously variable from +1.3 to +15 volts and -1.3 to -15 volts respectively. Both variable supply outputs are referenced to circuit common. This creates a split supply which is often used with differential and operational amplifiers (Op Amps). In addition to the DC power supplies, the PB-505 also provides a 12.6 volt center-tapped AC supply. This allows the user to construct any of a variety of half-wave and full-wave rectified power supplies on the breadboarding area and apply power by simply connecting jumper wires to the three AC supply output posts.

### Function Generator

The multi-waveform function generator provides continuously variable frequency signals from 0.1 Hz (for extra low frequency work) to radio frequency signals of 100 kHz. The frequency is selected in six decade ranges, with a vernier pot to adjust frequency within each range. The sine wave output is factory adjusted for minimum distortion. The triangle waveform is adjusted for best linearity. The standard square wave and TTL level outputs are both set at a 50% duty cycle. The TTL output, capable of driving up to 10 TTL loads, is continuously available and in phase with the square wave output. The low output impedance of the sine, square, and triangle waveforms (600 ohms) assures maximum coupling of the output signal to the device being driven. All outputs can withstand a continuous short circuit to ground.

### Logic Indicators

Sixteen LEDs, eight red and eight green, make up eight Logic Indicators that will display logic high and low conditions based on either TTL or CMOS thresholds, selectable by the user. Operating voltage can also be selected by the user to be either at +5 volts, or at the setting of the 1.3 to 15 volt +V supply. This selection should be the same as the operating circuitry that is to be monitored. The red LEDs will light when the voltages at the inputs are 2.2 volts or higher and in the TTL position, or 70% of the operating voltage or higher when in the CMOS position. The green LEDs will light when the voltages at the inputs are 0.8 volts or less when in the TTL position, or 30% of the operating voltage or less when in the CMOS position. An unconnected input, or an input not at a valid logic level, will cause both LEDs to be extinguished. Note that the thresholds determined by the TTL positions are only accurate when +5 volt range is selected. The 100 k $\Omega$  input impedance ensures minimal loading effects of the circuit under test.

### Debounced Pushbuttons (Pulsers)

The PB-505 uses clocked flip-flops to provide debounced pushbutton switch functions. The pushbutton circuitry has open-collector outputs that can sink up to 250 mA each. This type of debouncing gives the user a sharp, glitch-free trigger source that assures reliable operation in digital circuits. Each pushbutton has a normally-open and a normally-closed output. If necessary, a pull-up resistor can connect any pulser output to any of the positive voltage sources.

### Potentiometers

Two potentiometers are provided on the PB-505. The resistance values chosen (1 k and 10 kohms) may be used in common circuit applications such as volume controls, DC offset controls for op amps and timing circuit controls. All leads for both potentiometers are available and uncommitted.

# Electronics Fundamentals Courseware

## In this course the student will:

- **Study the theory and design of electronic circuits, such as: Series vs Parallel, Impedance, Resonant and Filters**
- **Understand the various components and hardware: Resistors, Capacitors, Switches, Inductors, Integrated Circuits, Transistors and Transformers**
- **Study Rectifiers and Amplification**
- **Own a complete schematic symbol guide plus an extensive technical glossary**
- **This popular course is designed to be used with Global Specialties Electronic Trainers**



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