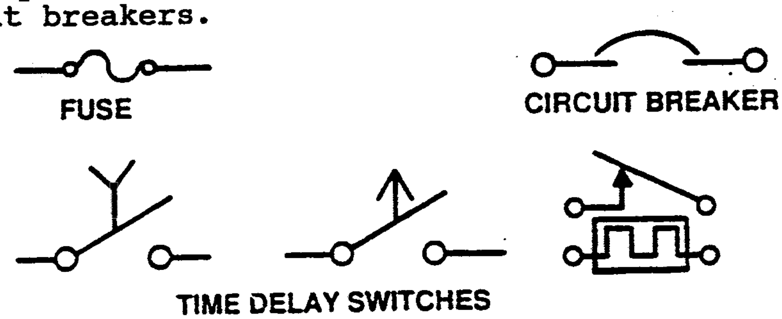
There are many different types of devices which are designed to protect the equipment. In FIGURE 7, we see some of the types of automatic circuit breakers.



Operation - The fuse contains a low melting point metal strip. High current causes the metal to melt, thus opening the circuit.

There are many types of fuses; we will be concerned here with two basic types:
Fast Blow or Rapid Action - spring loaded for fast break; the spring applies tension on the metal strip at all times.
Slow Blow or Time Delay - withstands high starting current, but blows if high current continues.

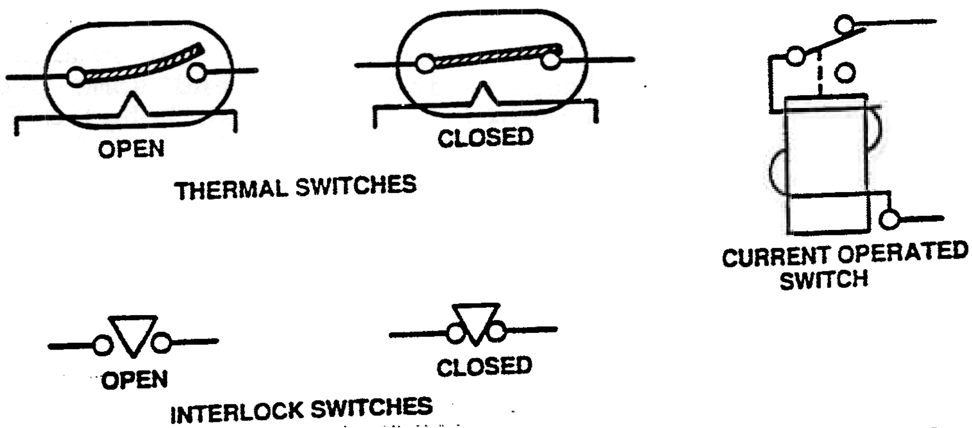
The Ampere rating is the maximum current the fuse will withstand before the wire burns open.

The Voltage rating would be determined as the maximum amount of voltage allowed across the fuse before arcing will occur.

Example:

250V, 2.5A; 125V, 5A; 125V, 6A.

Next we must look at circuit breaker types, in FIGURE 8.



Here again we have a group of protective switches. The thermal switch and the relay operated circuit breaker are automatic circuit protection devices. The interlock switch is a manual personnel protection device.

The thermal switches contain two metals with different expansion ratios. Too much current causes the strip to bend away from the contact, thus opening the circuit. It resets only when cool. This is an automatic circuit protection device.

The relay operated circuit breaker will carry high current and is fast acting. When the current exceeds the pre-determined current rating, the relay opens, thus cutting off current to the circuit. This is an automatic current protection device.

The interlock switches are used to break circuits when entry would be harmful to the operator. This is a personnel protection device.

In FIGURE 15 we see a simple two-card circuit, consisting of a power supply card and a relay card. Before we can even think about troubleshooting this circuit, we must first review the basic purpose and operation of the major components.

Transformer T1 -(Center-tapped secondary) - Steps down the applied voltage and produces two signals, 180 degrees out of phase with each other.

Diodes CR1 and CR2 are used as a full-wave positive rectifier, and will produce a pulsating DC signal which will have a frequency twice the frequency of the input signal. For example, with a 60 Hertz signal applied to the input of T1, there will be a pulsating DC of 120 Hertz at the output of the rectifier.

Resistor R6 is a rheostat, and is used to control the current of the AC voltage divider network comprised of R5, R6, and R7. As the wiper is moved upwards across R6, more resistance is shorted out, thus decreasing the total resistance, therefore increasing current flow. The opposite happens when the wiper is moved downward.

Capacitors C1, C2, and inductor L1 are configured as an LC pi filter. Capacitors store voltage in an electrostatic field and that property is very beneficial at this point. The capacitor C1 will charge up to the peak value of the voltage from the rectifier. As the signal (a pulsating DC) from the rectifier begins to go negative, C1 will begin to discharge. Before C1 can fully discharge, it will feel a positive-going voltage from the rectifier, and will begin to charge up again. The resultant charge, partial discharge, charge will be reflected as a sawtooth waveform at TP4, PC-130-82.

The positive potential at the top of plate of C1 is also felt at L1, and will cause current to flow through L1. Inductors store voltage in an electromagnetic field and oppose a change in current. In this case, L1 will oppose a change in the direction of current flow; that is, it will maintain current flow toward the output of the circuit. As current flows through L1, a electromagnetic field will expand around L1, resulting in a slight increase in voltage and the placing of a

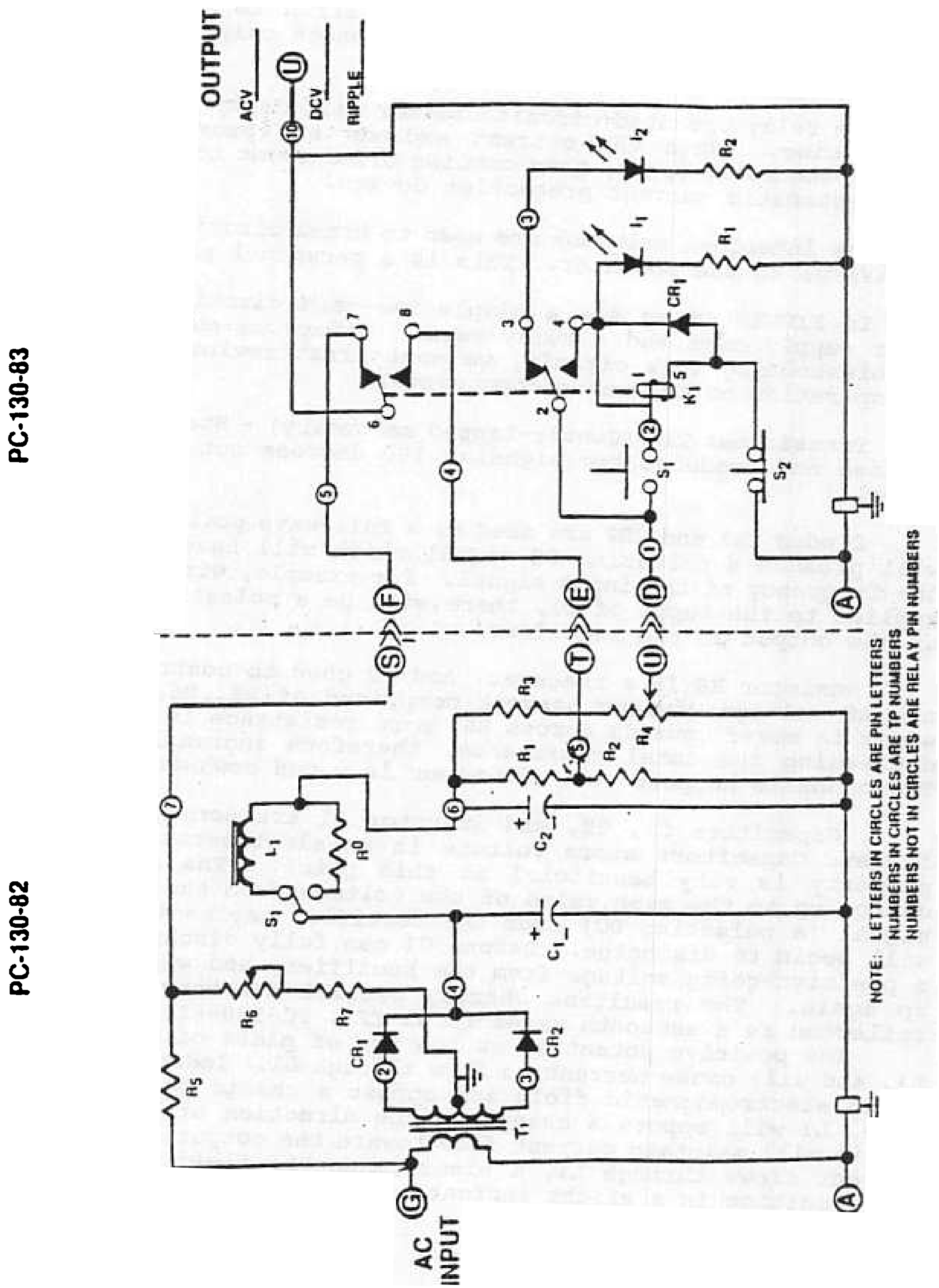

PC-130-83
PC-130-82
OUTPUT
ACV
DCV
RIPPLE
AC INPUT
NOTE: LETTERS IN CIRCLES ARE PIN LETTERS
NUMBERS IN CIRCLES ARE TP NUMBERS
NUMBERS NOT IN CIRCLES ARE RELAY PIN NUMBERS

FIGURE 15

positive potential at the top of C2. When C1 begins to discharge, the field will begin to collapse, but current will continue to flow in the same direction.

The positive potential at the top of C2 will cause C2 to charge up to the voltage of the electromagnetic field. As the field collapses, C2 will discharge. The combined action of C1, C2, and L1 will be such that the output voltage of the power supply card (PC-130-82) will be relatively high. C1 is often called the "boost" capacitor because it will be used to initially raise the output voltage. C2 will be used to limit the amount of ripple (AC fluctuations on a DC voltage) and is often called the "ripple" capacitor.

Of the many different types of filters we could use, an LC pi is the best choice because it will give us the best combination of highest voltage and lowest ripple at the output of our power supply.

Voltage divider R1/R2 is used to establish the output DC voltage applied to PC-130-83, through the closed contacts of relay K1 and to the output of PC-130-83.

Voltage divider R3/R4 is used to establish the operating voltage for relay K1. Resistor R4 is a potentiometer, (a voltage controlling device), and when adjusted will apply a voltage through S1 to relay K1 of PC-130-83.

Push-to-Make Switch S1, when closed, applies a DC voltage of approximately 12 volts to the coil of relay K1 to energize K1.

Push-to-Break Switch S2, when open, removes a ground potential from the coil of relay K1, de-energizing the relay.

Electromagnetic Relay K1 is used to apply either an AC or DC voltage to TP10 and Pin U, the output of PC-130-83. When de-energized, as shown on the schematic, an AC voltage is applied through closed contacts 6 and 7 to TP10. A DC voltage is applied through closed contacts 2 and 3 to LED I2.

When K1 is energized, contacts 6 and 7 open and 6 and 8 close. The DC voltage from PC-130-82 is then applied to TP10. At the same time, contacts 2 and 3 open and 2 and 4 close. I2 will extinguish, and I1 will illuminate.

Light Emitting Diodes (LEDs) I1 and I2 are used to indicate what type of voltage is applied to TP 10, PC-130-83. When illuminated, I1 will indicate that a DC voltage is at TP10. When I2 is illuminated, an AC voltage will be applied to TP10.

During this and previous lessons, we have discussed the theory of operation of individual components as well as a simple circuit. Unfortunately; electrical and electronic circuits never operate correctly all the time, and it is your job as a technician to determine why a circuit is not operating correctly. By applying the basic rules of troubleshooting and some particular methods you will learn in this lesson, locating malfunctions will become fairly easy.

Three basic principles must be recognized and learned in the approach to troubleshooting; namely, SECTIONALIZE, LOCALIZE, AND ISOLATE. There is, however, an element which must be incorporated continually during the troubleshooting process. That element is VISUALIZATION.

VISUALIZATION, looking, requires that we develop a keen sense of perception. Use all of your senses to find out where the problem is. Look for visual indications of trouble spots. Look, touch, smell, and listen.

EXAMPLES:

Lights that do not light.
Fuses that may be blown.
Interlock switches that may not be closed.
Power supply controls tampered with.
Broken circuit interconnecting wires.
Broken or cracked printed circuit (PC) boards.
Solder joints that are loose or appear to have cold joints.
Components that are discolored or distorted from normal appearance, (swollen, cracked, broken).

With power disconnected, components may be touched (if safety permits) to detect heat. Some bad components can be detected by the way they smell, such as a burned resistor. Vacuum tube problems can be spotted sometimes by the lack of a glowing filament, or improper seating in the tube socket.

To relate "VISUALIZE" to the circuit studied here, you will:

1. Listen for K1 to energize when S1 is pressed and for K1 to de-energize when S2 is pressed.
2. Look for I1 to illuminate when S1 is pressed and for I2 to illuminate when S2 is pressed. Only one LED will be lit at a time.
3. Look for the proper waveforms at Test Points on the circuit cards. A sawtooth with a frequency of 60 Hertz at TP4, PC-130-82, indicates that one of the diodes is not functioning, while a pulsating DC waveform at 120 Hertz indicates that capacitor C1 is malfunctioning.

One method of troubleshooting is called the "Half-Split" Method, and it works quite well. To follow the half-split method of troubleshooting; you begin by first making voltage and/or waveform measurements at the output of a circuit. Your second check should be at the input to the circuit in order to assure that you do, in fact, have a good input. If there is a good input, your third series of measurements should be at (or near) the mid-point of the circuit. You have now split the circuit in half. If you still get a faulty reading, continue splitting the remaining circuitry in half until you get a normal indication. By now, you should have localized the problem to a specific portion of the circuit and can use normal troubleshooting procedures (voltage/resistance measurements) to locate the malfunctioning component.

To relate "SECTIONALIZE" to the circuit studied here you will:

1. Check the circuit output at TP10, PC-130-83 to find the malfunctioning output. (Remember to check TP10 with relay K1 energized and de-energized, you <u>must</u> check both AC and DC outputs).
2. Check the outputs of PC-130-82 at TP7 (AC voltage) and TP5 (DC voltage).
3. If the outputs of PC-130-82 are good, you have SECTIONALIZED the malfunction to PC-130-83. If either output is bad, you have SECTIONALIZED the malfunction to PC-130-82.

To relate "LOCALIZE" to the circuit studied here you will:

1. Check voltages and/or waveforms starting at the output of the malfunctioning circuit card found in the "SECTIONALIZE" process.
2. Localize the malfunction to one of the following circuits:
   a. AC voltage divider - R5, R6, R7 (PC-130-82).
   b. Rectifier - CR1, CR2 (PC-130-82).
   c. Filter - C1, L1, C2 (PC-130-82.
   d. DC voltage dividers - R1/R2, R3/R4 (PC-130-82).
   e. Relay - K1 contacts (PC-130-83).
   f. Relay control - S1 and S2 (PC-130-83).

To relate "ISOLATE" to the circuit studied here you will:

1. Check voltages/waveforms within the localized circuit to isolate the malfunction to a component.
2. Shut off power and make resistance checks as needed to verify the component malfunction.

Let's incorporate what we have just learned by doing a little troubleshooting on the 2 card setup.

In order to tell if there is a malfunction in a circuit, we must first know what the normal outputs (voltages/waveforms) are. Let us assume that these are the normal outputs.

PC-130-83 (K1 de-energized)	(K1 energized)
TP10 - 11 VAC (RMS)	TP10 - 10.2 VDC
30 V Pk/Pk	70 mV Ripple

PC-130-82
TP7 - 11 VAC (RMS)
30 V Pk/Pk

13.2 VDC (K1 de-energized)
10.2 VDC (K1 energized)

20.9 VDC
Sawtooth Waveform, 120 Hz, 400 mVolts Ripple

Here's an example of using the "half-split" method of throubleshooting the circuits on the PC-130-82 and PC-130-83 cards.

FIRST CHECK: OUTPUT OF THE CIRCUIT - TP10, PC-130-83
AC output - normal.
DC output - Zero DC volts, zero ripple voltage.
K1 won't energize, I1 won't illuminate (Visual check)

SECOND CHECK: INPUT TO THE CIRCUIT - PIN G, PC-130-82
PIN G - 14 VAC (RMS) 40 V Pk/Pk

THIRD CHECK: OUTPUT OF CIRCUIT CARD PC-130-82 (mid-point)
TP5 - Zero DC voltage.
TP7 - Not checked since the AC voltage at the output of the 83 card was good.

FOURTH CHECK: MID-POINT OF 82 CARD
TP4 - DC voltage - Normal.
Ripple voltage - Normal.
Ripple frequency - Normal.

<u>WE HAVE SECTIONALIZED OUR MALFUNCTION TO PC-130-82.</u>

FIFTH CHECK: MID-WAY BETWEEN NORMAL AND FAULTY INDICATIONS
There are two circuits between our normal and faulty indications, the LC pi filter, and DC voltage divider R1/R2. We must now try to LOCALIZE our malfunction to one of these circuits. TP6 lies between the two circuits, so this is a good place to check.
TP6 - DC voltages slightly higher than normal.
Ripple voltage slightly higher.
These indications tell us that there is an output from the filter, so the malfunctioning circuit must be the DC voltage divider.

<u>WE HAVE LOCALIZED OUR MALFUNCTION TO THE DC VOLTAGE DIVIDER</u>.

SIXTH CHECK: ISOLATING TO A COMPONENT
Since we had a DC voltage at TP6, and zero voltage at TP5 we know the problem is in the voltage divider, but we don't know which resistor is faulty. We must now isolate our malfunction to a component.
Measure ER1 (TP6 - TP5) - The voltage reading is the same as at TP6, which tells us that either R1 is open or R2 is shorted.
Turn power off and measure the resistance of R1. A resistance reading of is observed. Measure resistance of R2, zero ohms is read R2 is shorted.

<u>WE HAVE ISOLATED OUR MALFUNCTION TO A SPECIFIC COMPONENT</u>.

Using the "Half-Split" method of troubleshooting, we have troubleshot our 2 card circuit to a specific component and we can say that the malfunction was an OPEN R1 on PC-130-82.
The "Half-Split" method of troubleshooting is not the only method that could be employed in trying to locate a malfunction; but it does incorporate a logical approach in determining what is the cause of our incorrect output.