In previous subjects you were taught some of the components which made up power supplies. These were transformers, capacitors, inductors and resistors.

You also were shown that the electronic trainer contained a power supply which converted the AC voltage of the power line to DC voltage. You used the DC voltage of the trainer power supply during the first two weeks.

In the field you will often have to troubleshoot and repair electronic power supplies. Because the power cupply circuits is simple, it will be used for your first introduction to a complete working electronic circuit.

FIGURE 3 is a typical power supply block diagram. Your AC line voltage first goes through a transformer. The AC output from the transformer goes through a rectifier which converts AC into pulsating DC. The DC goes through a filter which filters out the pulses to make a smooth DC. The filtered DC is applied to the top of a voltage divider, from which various levels of DC voltage can be applied to different parts of the following circuit.

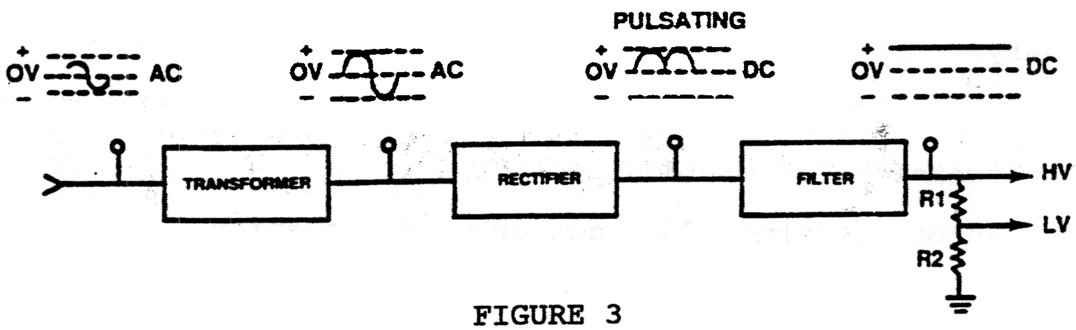


FIGURE 3

FIGURE 3 shows levels of two DC voltages from the voltage divider, a high voltage and a low voltage.

What is the purpose of a power supply in electronic equipment?

A power supply converts AC line voltage to the required DC operating voltages for electronic circuits. These DC voltages may be high or low voltage, and positive or negative DC.

Because you have already studied transformers, filters and voltage dividers, we will go straight to the rectifier block, which is the only item new to you. Notice that the rectifier is shown converting AC to pulsating DC.

In FIGURE 4 are three types of schematic representations for rectifiers, showing the direction in which current will flow.

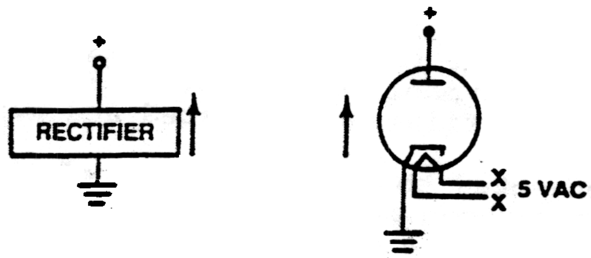


FIGURE 4

A rectifier will produce DC because it conducts current in only one direction.

View A of FIGURE 4 is a block diagram with a symbol representing a rectifier. Current will flow through the rectifier from negative to positive, of course, but ------ if you reversed the polarity of the applied voltage, so that a negative voltage was applied at the top, current would NOT flow.

A rectifier is like a one-way check valve in a water system; current can't flow backwards through it. It is strictly a one-way current device.

There are two types of electronic rectifiers. Both of them are called "Diodes". The word "diode" means that it has two connections. There are two type of diodes. One of them is a vacuum tube, the other is one of the solid state devices known as a semiconductor diode.

The vacuum tube gets its name from the fact that it is a tube which has the air pumped out, and, therefore, contains a partial vacuum.

A semiconductor gets its name from the fact that it is partially a conductor, and partially an insulator. The polarity of the voltage across it determines whether it will conduct or not conduct.

A vacuum tube diode shown in FIGURE 5 contains two main parts inside the vacuum chamber. One is called the cathode and the other is called the anode. Because the anode is made from a large metal plate, it is usually called the "plate".

Some cathodes have to be heated by a separate electrical wire called a filament. You have probably seen a filament before in a light bulb, and know that it is thin wire which glows and gives off heat and light when current flows through it, as shown in FIGURE 5, view B.

Some cathodes are combined with the filament to make just one common cathode-filament. The vacuum tube in FIGURE 5, is of this type. Note the schematic symbol is view B, of FIGURE 5, contains no cathode symbol because the filament is coated and acts as a cathode.

The filament is connected to the 5v winding of the transformer. The filament heats the cathode because it is on the insode of the cathode, which is shaped like a cylinder. The cathode is coated with a chemcial which gives off electrons when heated.

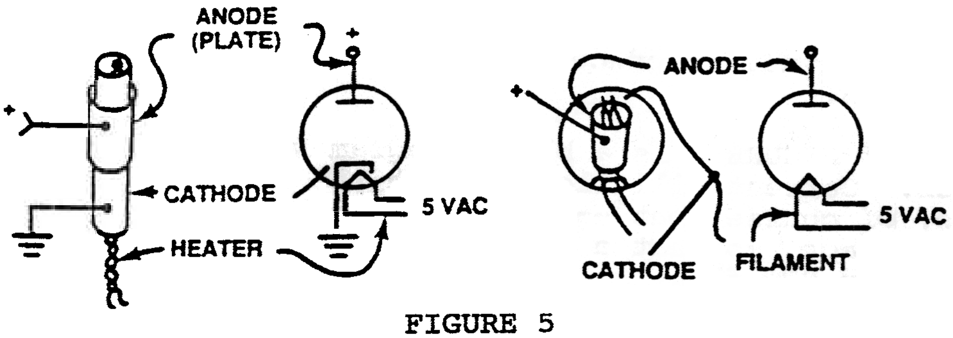


FIGURE 5

The metal plate of the vacuum diode consist of a large metal cylinder coaxial around the smaller cathode cylinder. The plate is connected to a high voltage. When this voltage is positive, the negative electrons from the cathode are attracted to it. The electrons enter the plate and cause current to flow in the plate wire.

Electrons leaving the cathode cause current to flow through the wire to the cathode and replace them, as shown in FIGURE 6.

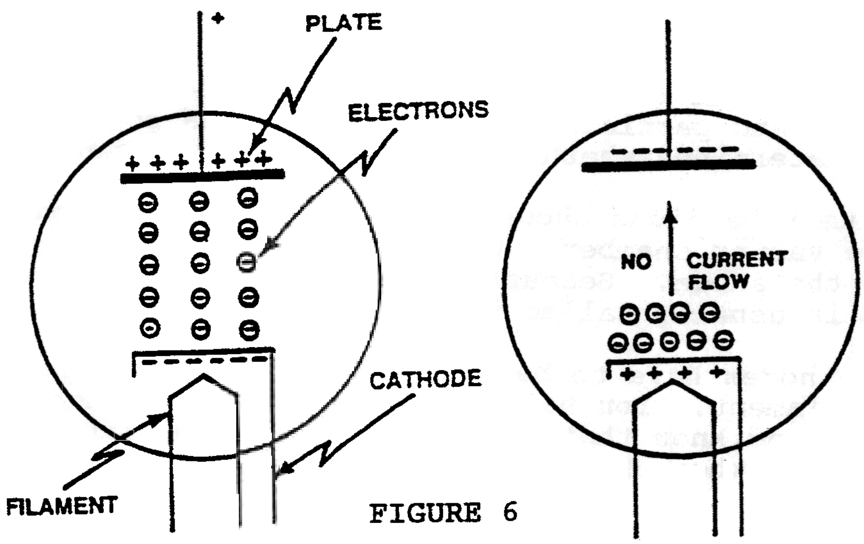
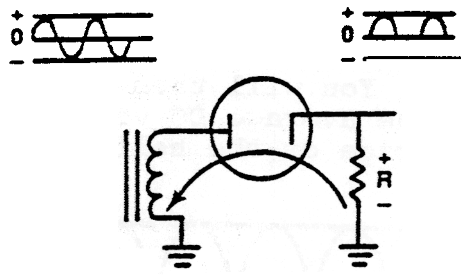


FIGURE 6

A rectifier passes current in only one direction. Therefore, although there is a complete sine wave applied to its input, it will conduct only on one half-cycle. The way this diode is connected, it is the positive half-cycle applied to the plate which causes it to conduct. Because a conducting tube has a very low resistance, the positive half-cycle is felt on the output. As shown in FIGURE 7, by the output waveform, which starts at zero volts and rises to a high positive voltage, the average DC voltage is positive.

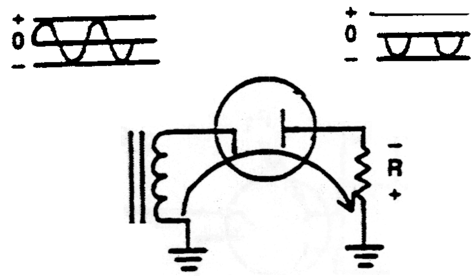
How could this circuit be connected in order to get a negative DC voltage out?



POSITIVE
RECTIFICATION

FIGURE 7

Reversing the connections to the diode would put the AC sine wave on the cathode, as shown in FIGURE 8. The tube conducts only when its plate is more positive than the cathode. Therefore, the negative half-cycle on the cathode would cause conduction. The output waveform would be a string of negative pulses, which would average out to a negative DC voltage. DC current would then flow down through the load resistor toward ground.



NEGATIVE
RECTIFICATION

FIGURE 8

Why are the DC voltages so much lower than the peak voltages at the same test point?

Notice in FIGURE 8 that the wave shape spends half of its time at zero volts. It climbs rapidly to peak and drops quickly back to zero again, after spending only a brief time at peak. The DC voltmeter averages out these swings and gives you a reading which is the average DC voltage.

If you are the mathematical type, you may have looked up the formula for converting peak voltage to average DC voltage and discovered that the formula gives you about two times that DC. The reason is that the formula is based on a full sine wave, which is all you have here.

You can oversome the power loss of a half-wave rectifier by adding another half to the circuit, with its output 180 degrees out of phase with the first. You will then get full wave rectification, as shown in FIGURE 9. The average DC voltage of this waveform is much higher than the average of the half-wave rectifier. Why?

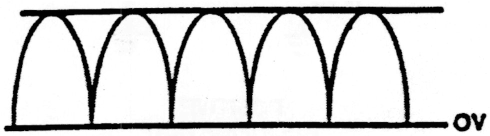


FIGURE 9

The waveform does not spend half its time at zero volts, as it did during half-wave rectification. Therefore, the average voltage of the waveform is higher.

If you will study the full-wave rectifier in FIGURE 10, you will be able to see how alternate positive alternations are applied to plate (P_1), causing I to flow through R_L. The next alternate positive halfwave causes P_2 to be positive and I_2 will flow.

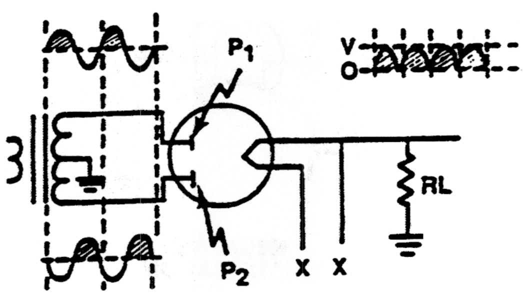


FIGURE 10

A semiconductor diode is less complex than a vacuum tube diode. It has no filament because it does not need to be heated. It is solid material throughout, shown in FIGURE 11, rather than two or more separate elements hanging inside a container.

Its two solid substances, which are joined together, are called "P" and "N" material. To conduct, the "P" material must be connected to the most positive voltage and the "N" material must be connected to the most negative voltage. Like the vacuum tube diode, it will conduct only in one direction, from cathode to anode.

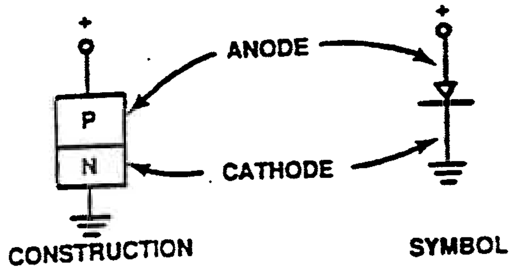


FIGURE 11

Some advantages of the solid state devices over the vacuum diode are as follows:

Much smaller - weighs much less

Less fragile

Operates at lower voltage

Does not require heater (filament), much more durable

The main disagvantage would be that it cannot operate at very high voltages.

Figure 12 shows some physical characteristics as related to the schematic symbol.

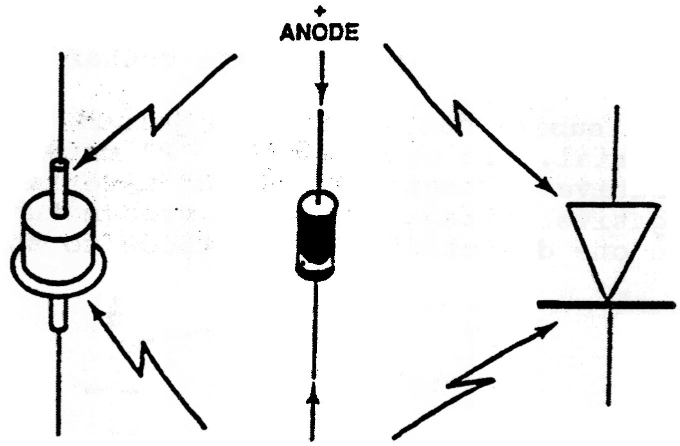


FIGURE 12

The following checks with an ohmmeter can help determine the condition of a solid state diode.

To check a diode, make 2 ohmmeter measurements.

Measure across the diode with the ohmmeter, and then reverse the leads and re-measure.

There should be a difference between the reading of 10:1 or higher. On the digital multimeter, use the Hi power ohm setting.

Now we must look at the semiconductor diode positive half-wave rectifier as shown in FIGURE 13.

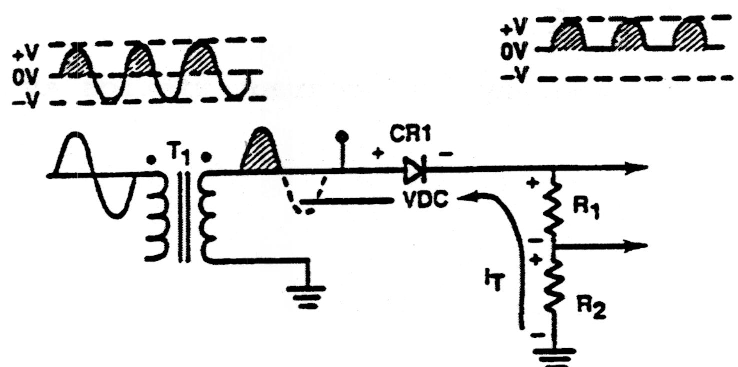


FIGURE 13

The anode is connected to the transformer secondary and the cathode is connected to ground through the voltage divider R_1 and R_2.

The output can be taken across R_1 or both R_1 and R_2.

The diode will conduct on the positive alternation, and will be turned off on the negative alternation.

There is one positive output pulse for each cycle, therefore the output frequency is the same as the input frequency.

Now to look at the negative half-wave rectifier as shown in FIGURE 14.

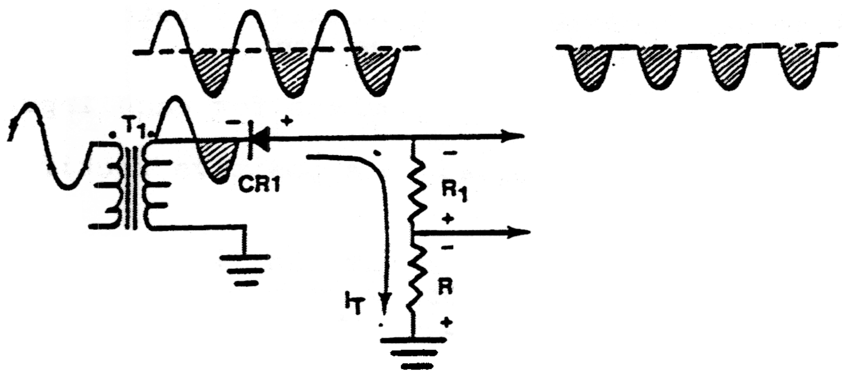


FIGURE 14

The two major differences in the negative rectifier and the positive rectifier is that, in the negative rectifier the diode CR1 has been reversed, and the output is negative. The two rectifiers can be conbined by using a transformer with a center tapped secondary and make the full-wave rectifier shown in FIGURE 15.

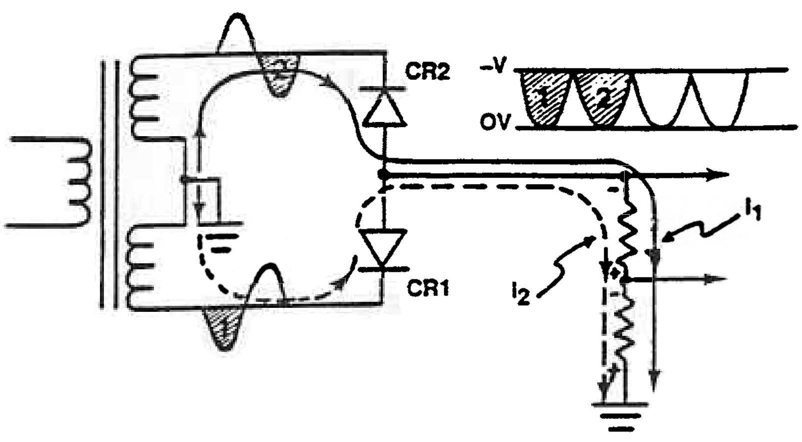


FIGURE 15

Full-wave means that both positive and negative alternations are used to produce a pulsating DC. This pulsating DC will have a frequency that is double the input frequency because there are two pulses per cycle.

The cathode of one diode is connected to one end of the transformer winding and the cathode of the other diode is connected to the other end of the transformer winding. The transformer center tap is grounded.

Be sure that the diodes are installed properly. IF one diode is installed backwards, the transformer will be shorted, which will cause some adverse effect such as a: blown fuse, tripped circuit breaker, or burned out transformer or diodes.

One diode will conduct on the positive alternation and the other on the other on the negative alternation.

There are two negative output pulses for each input cycle.

The circuit can be converted to a positive rectifier by reversing both diodes.

So far we have said nothing about the filter. You have seen that the rectified pulsating DC is not very smooth. A smooth DC voltage is needed for most electronic circuits. The circuit which smoothes out the pulsating waveshape from the rectifier, and turns it into DC, is called a filter.

There are four general types of filters shown in FIGURE 16, named for the components which they contain: Inductance, Capacitance and Resistance, RC, and LC filters. We will discuss them one at a time.

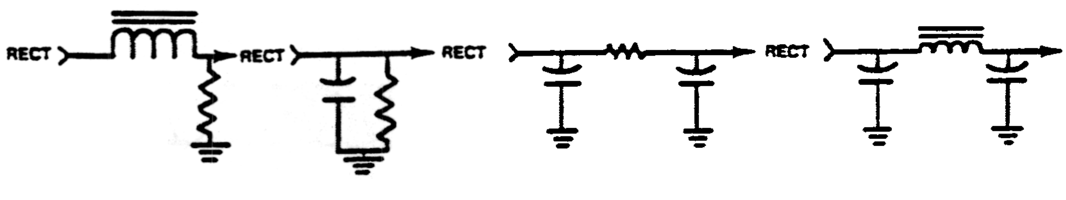
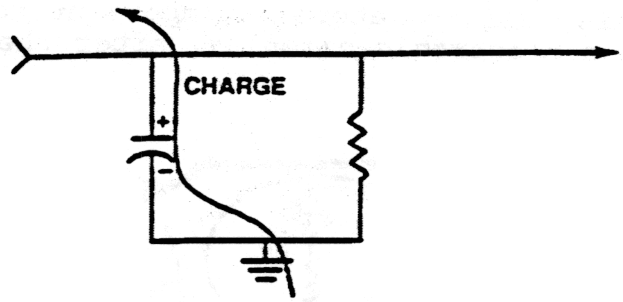


FIGURE 16

A coil <u>opposes a change in current</u>. In some circuits, an inductive filter is used to <u>limit current changes</u>. However, this type filter is rarely used. Most circuits are <u>sensitive to voltage changes</u>, not current changes.

If <u>opposing changes in voltage</u> is the principal purpose of a filter, what <u>component</u> would be used?

The capacitance filter shown in FIGURE 17, which is often used, will oppose changes in voltage. It stores energy in the form of a voltage charge in the capacitor. The capacitor will charge up to the peak value of the applied voltage from the rectifier. Because its discharge path between cycles is through the voltage divider, it will take some time to discharge. In the meantime, the next peak of the cycle would charge it to the full peak voltage again.



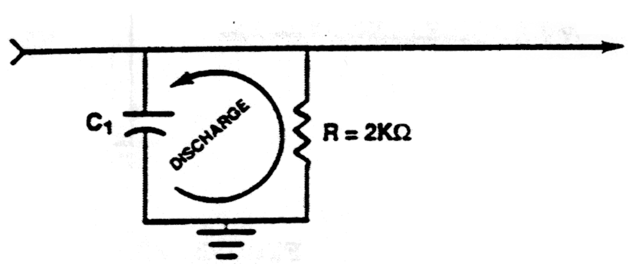
C_1 CHARGE PATH

FIGURE 17

Although the voltage ordinarily drops instantly when the power is turned off, in this case, it dropped very slowly. It would not drop at all if the scope and meter were not connected. The capacitor is discharging through them, instead of through the resistor.

When power is on, the high positive voltage from the rectifier at the top of C_1 causes it to charge instantly. Note that there is no resistance in the charge path to slow down the charging of the capacitor . Remember $TC = RC_1$.

When the power is turned off, the charged capacitor now discharges, as shown by the arrow in FIGURE 18. Note that the discharge path is through R_1. This slows down the discharge time of the capacitor.



C_1 DISCHARGE PATH

FIGURE 18

The length of time to discharge would depend upon the size of the capacitor and the amount of resistance. In circuits in the field, not only would the capacitors and resistors be larger then in this simple teaching circuit, but the voltage could be as high as 40,000 volts or more in some of the radars.

The resistors in the circuit are often called "bleeder" resistors, because one of their functions is to "bleed off" the voltage charge on the capacitors when power is turned off.

What does this tell you about an important safety step to take, before working on electronic circuits, after the power is turned off?

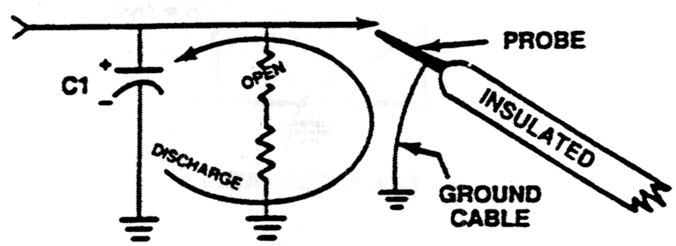


FIGURE 19

Before working on a circuit, always use a shorting stick on power supply capacitor after turning off the power. The reason is that bleeder resistors sometimes open, which would leave the high voltage on the filter capacitor.

Now we will look at four basic filters, the first of which is the inductive filter shown in FIGURE 20.

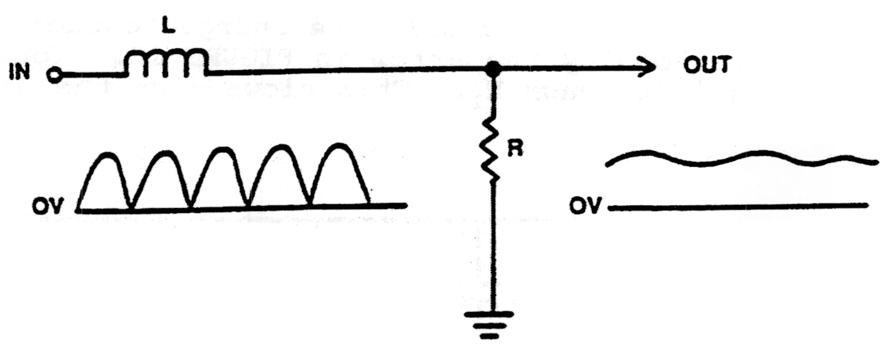


FIGURE 20

Listed are some things to know about the LR type filter.

Stores energy in elctro magnetic field.

Opposes a change in current.

High impedance to AC ripple.

Low resistance to current.

Used for heavy load or good current regulation.

The second type of filter is the capacitive type. This filter is shown in FIGURE 21.

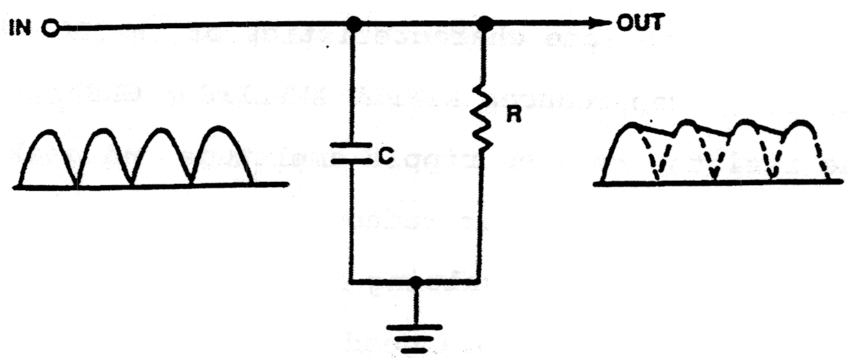


FIGURE 21

Listed below are some characteristics of the capacitive filter.

Stores energy in electrostatic field.

Opposes a change in voltage.

The capacitor discharges through load between peaks.

The smaller the capacitance of the capacitor, the greater the ripple.

The capacitor charges rapidly through the diode and transformer winding to the voltage of the peaks.

The capacitor has to discharge through resistor between peaks. Due to long time constant, the capacitor will only partially discharge.

The third type of filter is the RC Pi filter. This filter is shown in FIGURE 22.

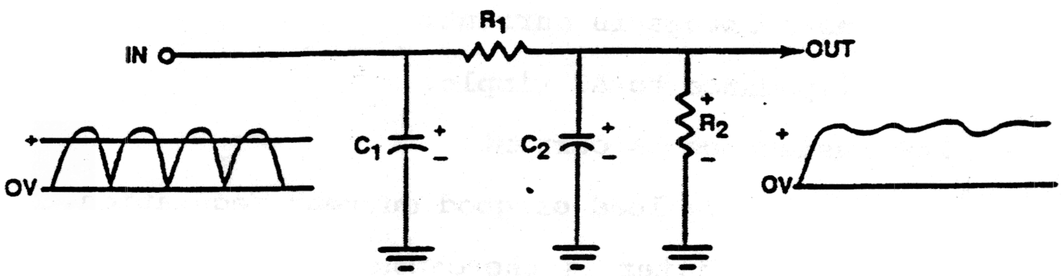


FIGURE 22

Listed below are some characteristics of the RC Pi filter.

The first cap reduces RIPPLE AMPLITUDE GREATLY.

The resistor reduces ripple amplitude and peak amplitude.

The second cap further reduces ripple amplitude.

R_1 drops voltage, resulting in lower DC output voltage.

The Pi filter will do a good job if there is little current flow.

Example of use: A cheap small portable radio.

From your knowledge of the effect of capacitors in parallel on total capacitance, what would be the effect on the output DC voltage, and ripple voltage, if another capacitor was added in parallel with C_1?

More capacitance would result from hooking two in parallel. The increased capacitance would cause a longer discharge time. The longer discharge time means that the voltage would not fall as far, before the next voltage peak. This would raise the average DC voltage, and lower the amplitude of the ripple voltage, as shown in FIGURE 23.

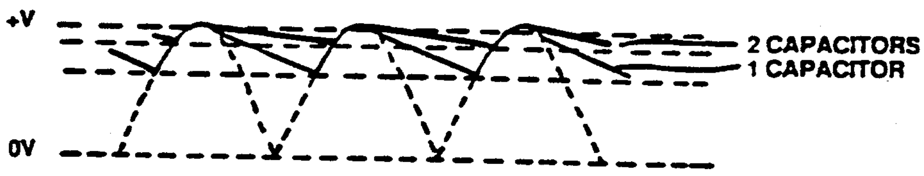


FIGURE 23

The fourth type of filter is the LC Pi filter. This filter is shown in FIGURE 24.

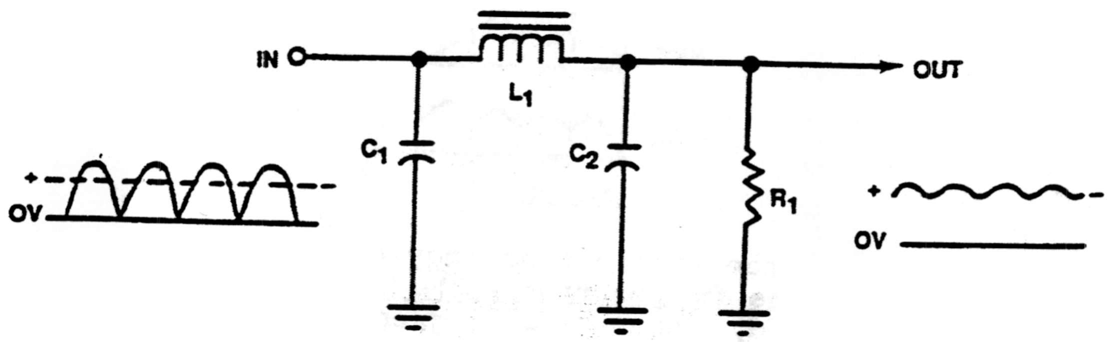


FIGURE 24

Listed below are some characteristics of the LC Pi filter.

The action of both caps is the same as for an RC Pi filter.

The inductor does not reduce the DC voltage as much as a resistor does, due to low DC resistance.

The LC Pi filter is best

The more LC sections that are added the greater the filtering.

Without troubleshooting the power supply, the technician would be missing the most important part of this lesson, thus let's do some troubleshooting.

To find out if both diodes in a full wave power supply are working, you check the ripple frequency. A <u>half</u>-<u>wave</u> rectifier produces a 60hz ripple, which is the same frequency as the line voltage. A <u>full</u>-<u>wave</u> rectifier uses both sides of the line voltage sine wave to produce double the line frequency in the ripple, 120 hz.

Your scope will not measure frequency directly, but, you can use it to compare a known frequency with one that is not known. In this case, you want to know if the output ripple is the same frequency as the input sine wave, or two times that frequency. If it is the same frequency, the period of the ripple waveform would be the same as the period of the input sine wave.

If the ripple frequency was two times the frequency of the input sine wave, would its period be two times the input sine wave, or half the input sine wave?

Two times the frequency is one half the period. As the frequency goes up, the peaks of the waveform come closer together.

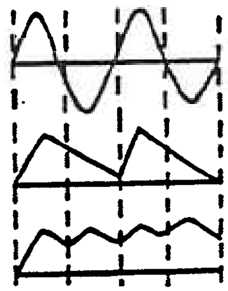


FIGURE 26

You would compare the ripple frequency of the rectifier with the line frequency. If the frequency was the same, one diode is open. If both diodes are good, the output frequency is two times that of the line voltage frequency.

Of course, you must find out WHICH diode was open. How would you do that?

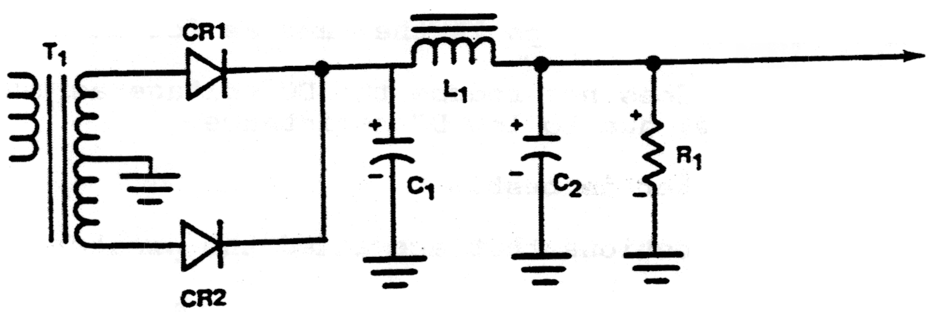


FIGURE 27

If there was no output from the power supply, no AC on any of the secondary windings, but AC the primary, what is the trouble?

The primary winding is open. The AC would be present because the winding connections are connected to the line voltage.

If your transformer has only one secondary winding, how would you tell the difference between an open primary and an open secondary?

You would use an ohmmeter and check the resistance of each winding. The open winding would show infinite resistance.

As far as any action by you is concerned, would it really make any difference which winding was open?

No. The transformer couldn't be repaired. You would install a new one, no matter what was wrong with it.

Probably the most difficult malfunction to find in a power supply is a leaking capactior. ALL electrolytics leak a little bit. As they age, they will leak more. The question is: How much is too much, and how to tell? What are the symptoms.

As long as the output of the power supply meets voltage and ripple specifications, all components are considered to be good. In fact, power supplies are usually "over-engineered." Meaning that, in some cases, if one capacitor opens, the effect on the output DC voltage and ripple voltage will not be great enough to affect the circuits using the power.

Therefore, your first step in tracking down a leaking capacitor is to check the output DC and ripple voltages to see if they are within tolerance.

The next step is to ELIMINATE from your thinking the components which COULDN'T be causing the trouble.

This is the hardest lesson for a beginning troubleshooter to learn. Symptoms do NOT tell you what is WRONG in a circuit. They tell you what is RIGHT. Then, by a process of ELIMINATING the obviously good components, as shown by your checks, you finally get down to the one which is BAD, becuase it is the ONLY ONE LEFT! You know that it is bad, because you have proved that all others are good!

Troubleshooting LC Pi,

Trouble - C_1 Open.
Symptoms - DC output lower than normal.
Output ripple voltage increases a little.

Trouble - C_2 open.
Symptoms - DC output voltage nearly the same.
Output ripple voltage greatly increased

Trouble - L_1 open.
Symptoms - No output.
Higher than normal DC input.

Trouble - R_1 open.
Symptoms - Higher than normal DC voltages.

Trouble - C_1 short
Symptoms - No voltage at input or output.

Trouble - C_2 short.
Symptoms - No output.
Much lower than normal input voltage.

Trouble - L_1 short.
Symptoms - Higher Dc output voltage.
Higher output ripple voltage.
Input Dc voltage equals output voltage.
Input ripple voltage equals output ripple voltage.

Trouble - R_1 short.
Symptoms - No output.
Input voltage much lower than normal.
Transformer overheats.
Same symptoms as C_2 short.

To summarize:

Rectifiers.

Vacuum Tube diode.

Half wave positive.
Half wave negative.
Full wave.

Semi conductor diode.

Half wave positive.
Half wave negative.
Full wave positive.
Full wave positive.

Filters.

Inductive.
Capacitive.
RC Pi filter.
LC Pi filter.