OBJECTIVE PAGE

1. Given schematic diagrams of power supply circuit cards, answer questions on solid state half-wave rectifiers, full-wave rectifiers, bridge rectifiers, filters, and voltage doublers. Seven of ten answers must be correct.

2. Given a solid-state trainer, oscilloscope, digital multimeter, schematic diagrams of a voltage doubler, halfwave, fullwave, bridge rectifiers, and filters, the student will perform circuit measurements and troubleshooting procedures. Seventy percent of all measurements must be correct.

Power Supplies

1. Introduction: During this instructional period, you will be introduced to a number of different power supplies. Many of the electrical products used in our everyday life uses voltages from a power supply other than a battery. The power supply is used to convert an AC voltage, furnished by the utilities company, into a DC voltage which is required to operate such things as radios, televisions and stereo equipment.

   Without a power supply to convert an AC voltage to the DC voltages used to operate these electrical components, it would be virtually impossible to have the conveniences we enjoy today. A television without a power supply and voltage dividers would require many different sizes of batteries. These batteries would have to be extremely large due to the current that would be drawn and the number of batteries would be quite large. In other words, the television we use today would probably be so large it would fill an entire room.

2. Refer to figure 1. A power supply can be divided into five different blocks, each having to perform a completely separate function.

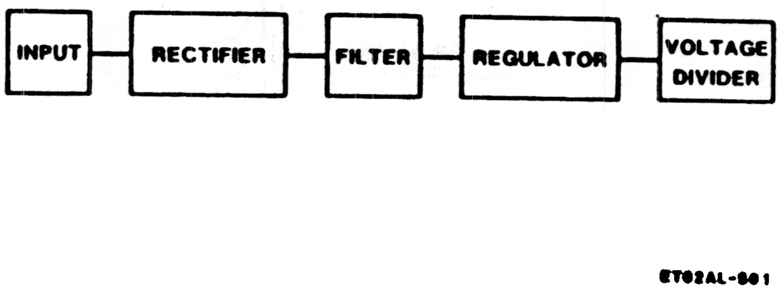


Figure #1

   a. Input Block - The input block consists of a transformer that will receive an input AC signal from some power source. The purpose of a transformer is to transfer electrical energy from one circuit to another circuit by electromagnetic induction (mutual inductance). The transformer will perform the transfer of energy without any change in frequency, but can change the voltage and current from the input source to some desired voltage and current required by the load.

      (1) The transformer is composed of two or more coils, called windings, wrapped around some type of core material. The core material will be either air, soft iron or steel. If the transformer is to be used at low frequency, normally between

60 hertz and 400 hertz, it will require a core of low reluctant magnetic materials, usually iron. At frequencies higher than 400 hertz an air core is used to prevent losses that would occur due to the magnetic properties of iron.

The primary winding is connected to the AC power source and receives the input signal.

(b) The secondary winding receives the signal from the primary winding through mutual inductance and supplies the energy to the circuit load.

The core provides a path for the magnetic field of force, to insure the flux lines will cross the secondary windings.

(2) Step-up transformer:

Refer to figure 2

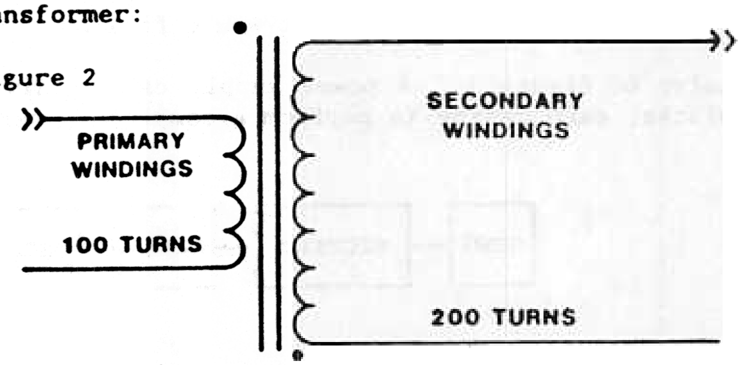


Figure 2

A step-up transformer is used to increase the voltage value of the input A.C. signal to some higher voltage value. This is accomplished by the number of turns of wire on the coil of the primary winding versus the number of turns of wire of the secondary windings. This is called the transformer ratio. If the primary windings consist of 100 turns of wire and the secondary windings has 200 turns of wire, the ratio would be 1:2. To determine this ratio of a step up trip, simple divide the number of turns of wire on the primary windings into itself, which will always be one, then divide the number of turns on the primary into the number of turns on the secondary. In the example above, the solution is 100 + 100 = 1 (primary), 100 + 200 = 2 (secondary) = 1:2. The amount of voltage transferred from the primary to the secondary is determined from the turns ratio. With the example above, if the amplitude of the input signal was 5VAC, then using the ratio, the voltage induced into the secondary would be 10VAC. The ratio states that for every one volt in the primary there will be 2 volts induced into the secondary. (1:2 ratio = one volt primary = 2 volts secondary). Another principle of a step-up transformer is, if the voltage is increased, then the current will be decreased by the same ratio. In the example, if the primary windings had 2 amperes of current, the secondary would have 1 ampere of current. The ratio is used again to determine the current flow. This can be done by division using the two numbers of the ratio. To determine the current flow in the secondary of a step-up transformer in the example above (1:2 ratio) simply take the amount of current in the primary and divide it by the ratio number of the secondary. If there is 2 amperes of current in the primary and the ratio number for the secondary is 2 then divide 2A by 2 which equal 1 ampere.

The power input and power output of a transformer can be determined after the voltage and current has been established. By multiplying the primary voltage times the primary current the results would be the power input. Power is measured in watts and the letter symbol for watts is W. In the example that has been used, the input voltage is 5VAC and the current is 2 amperes, this means the input power is 10 watts. The same function is performed to determine the output power. Multiply the secondary voltage times the secondary current to determine the secondary power. The voltage in the secondary of the example is 10VAC and the current is 1 ampere, 10 VAC times 1 ampere equals 10 watts.

The desired efficiency of a transformer is 100%, this means the input power is equal to the output power. To determine the efficiency of a transformer, divide the output power by the input power and multiply the results by 100. In the example, the output power is 10 watts and the input power is 10 watts. 10 watts (output) divided by 10 watts (input) equal 1. Multiply 1 by 100 to get 100% efficiency. This means there is no loss in power from the primary to the secondary.

(3) Step-Down transformer.

Refer to figure 3

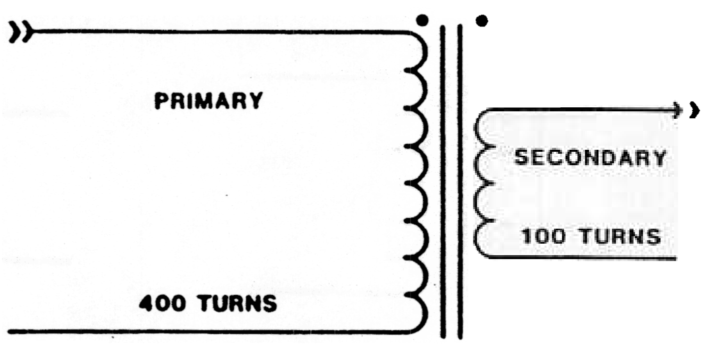


Figure 3

A step down transformer is used to decrease the input voltage to some lower voltage value in the secondary. As with a step up transformer, this function is determined by the number of turns of wire in the primary and secondary windings. The difference is the primary winding in a step down has more turns than the secondary. To determine the ratio for a step down transformer divide the number of turns in the secondary into itself, this will always be 1, then divide the number of turns in the primary. In the example of figure 3, the ratio for this transformer is 4:1. To determine how much voltage will be induced into the secondary, simply divide the amplitude of the input signal by the ratio number of the primary. If 20VAC were applied to the transformer of figure 3, then divide 20VAC by 4 and the results 5 VAC is the amount of voltage induced into the secondary. To determine the amount of current induced into the secondary, multiply the current in the primary by the ratio number of the primary. If 2 amperes of current is present in the primary and the ratio number of the primary is 4, the results (8 amperes) is the current that was induced into the secondary.

Power determination and efficiency is made using the same process as was used in step-up transformers.

(4) Phase relationship - The phase of the current in the secondary of a transformer is dependent upon the phase of the voltage into the primary winding and the direction of the winding in the secondary. If the secondary windings are wound in the same direction as the primary windings, then the phase between the input signal and the output signal will be the same. If the secondary windings are wound in the opposite direction of the primary windings, then the phase between the input signal and the output signal is 180° out of phase. The schematic drawing of a transformer will show the phase relationship between the primary and secondary of a transformer with the use of dots. The dots on a schematic indicate which windings are in phase. Refer to figure 4.

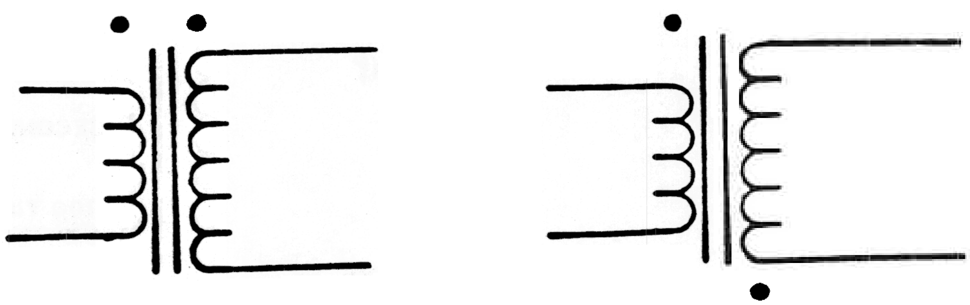


Figure 4

b. Rectifier Block: The rectifier circuit is the most important point in the power supply. The rectifier circuit is responsible for converting the AC waveform from the input block into a pulsating DC waveform. One of the several different rectifier circuits may be used to accomplish this task. These circuits are the half-wave rectifier, the full-wave rectifier, the full-wave bridge rectifier, and the voltage doubler.

(1) HALF-WAVE RECTIFIER: Figure 5 shows the schematic diagram for a half-wave rectifier. The half-wave rectifier is the simplest type of Rectifier used. It consist of only one diode, but for explanation purposes, a load resistance must be placed in the circuit to complete the path for current flow and to develop the output signal.

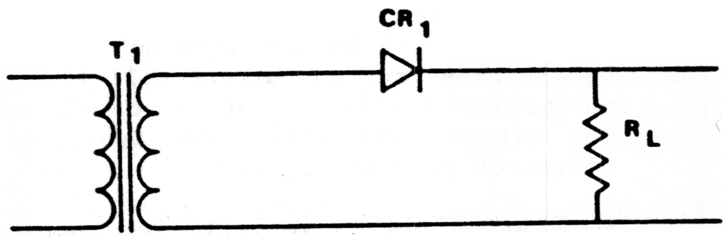


Figure 5

The half-wave rectifier in figure 5 is a positive half-wave rectifier. It is called a positive half-wave rectifier because it only uses the positive portion of the input sine wave and produces a positive pulsating DC signal.

(a) During the positive alternation of the input voltage, the positive alternation of the sine wave causes the anode of the diode to become positive with respect to the cathode. The diode is now forward biased and will conduct. Current will now flow from the negative side of the transformer secondary, through the load resistor, through the diode to the positive side of the transformer secondary. This path for current flow will exist during the complete positive alternation of the input waveform because the diode will remain forward biased as long as the positive signal is applied to the anode. The resulting output of the rectifier will be developed across the load resistor and will be a positive pulse very similar to the positive alternation of the input waveform. (See figure 6)

Output waveform of a positive half-wave rectifier

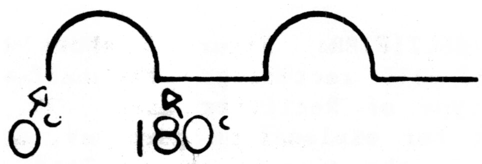


Figure 6

During the negative alternation of the input sinewave, the anode is negative with respect to the cathode and the diode will become reverse biased. As long as this condition exist, no current will flow in the circuit and an output signal cannot be developed across the load. The circuit now gives the appearance of producing a series of positive pulses.

A negative half wave rectifier operates very similar to a positive half wave rectifier except the output will be a series of negative pulses. (refer to figure 7).

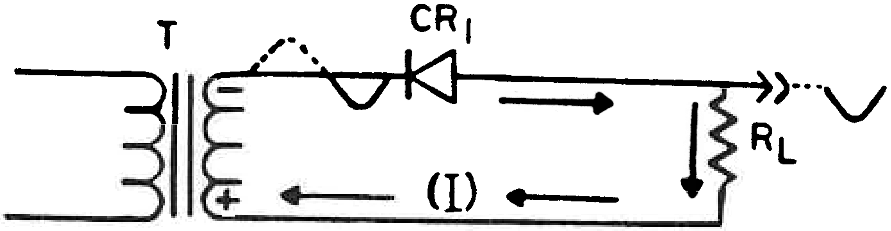


Figure 7

During the positive alternation, the diode is reversed biased, no current will flow through the circuit and no signal will be developed across the load. This condition will exist anytime a positive alternation is present on the cathode. When the negative alternation is present on the cathode, the diode will be forward biased and current will flow from the negative side of the secondary through the diode, through the load resistance to the positive side of the secondary. This condition will allow a negative pulse to be developed across the load resistance and will continue until the negative is removed from the cathode. The output of a negative half-wave rectifier will be a series of negative pulses.

The amplitude of the output will be approximately the same as the peak voltage of the input signal if measured with the oscilloscope. If the digital multimeter is used to measure the pulsating D.C. voltage, it will indicate the average voltage. The average voltage of a sinewave is zero volts, however, if the negative portion of a sinewave is clipped off the average value changes to some positive value. Since the waveform swings positive but never goes negative, the average voltage will be positive. To determine the average value of a pulsating DC signal using a half wave rectifier, multiply the peak voltage by .318.

$$E_{Ave} = E_{peak} \times .318$$

(The average value of a signal is the average of all the instantaneous values during one alternation. For one positive alternation, the voltage value increases from 0 volts to some maximum peak value and decreases back to 0 volts, the average value would be some value between the two limits.)

(The instantaneous value of an alternating voltage or current is the value of voltage or current at one particular instant. The value may be zero if the particular instant is the time in the cycle at which the polarity is changing. It may also be the same as the peak value, if the selected instant is the time in the cycle at which the voltage or current stops increasing and starts decreasing. There are actually an infinite number of instantaneous values between zero and peak value.)

Ripple Frequency. The half-wave rectifier gets its name from the fact it conducts during only half the input cycle. Its output is a series of pulses with a frequency that is the same as the input frequency. Thus when operating from a 60 hertz line source, the frequency of the pulses is 60 hertz. The frequency at which the pulses appear is called ripple frequency.

(2) Conventional Full-Wave Rectifier: A full-wave rectifier uses two diodes and a center-tap transformer. Before discussing a full-wave rectifier, consider these points about a center-tapped transformer.

Refer to figure 8. A center-tapped transformer is composed of 2 windings, the primary winding and 1 secondary winding which is divided by a ground connected to the center of the secondary winding.

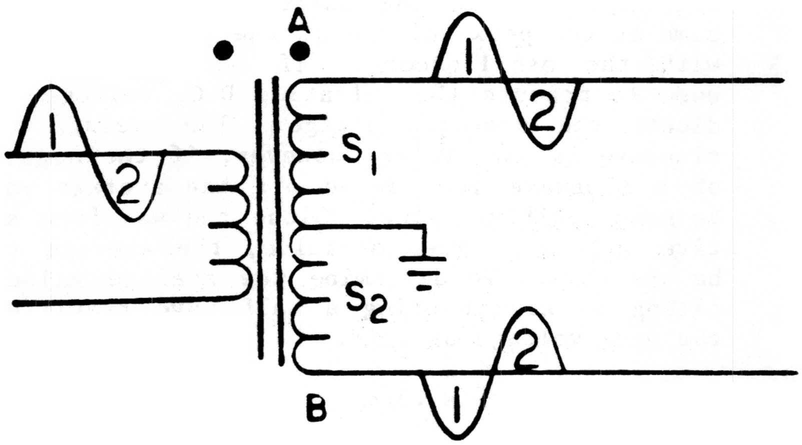


Figure 8

When a center-tap of a transformer is grounded, the voltage at the opposite sides of the secondary windings are 180 degrees out of phase. The amplitude of these two signals will be the same because there is the same number of windings above the ground as there is below the ground. When the voltage at point A is positive with respect to the ground, the voltage at Point B is negative with respect to ground.

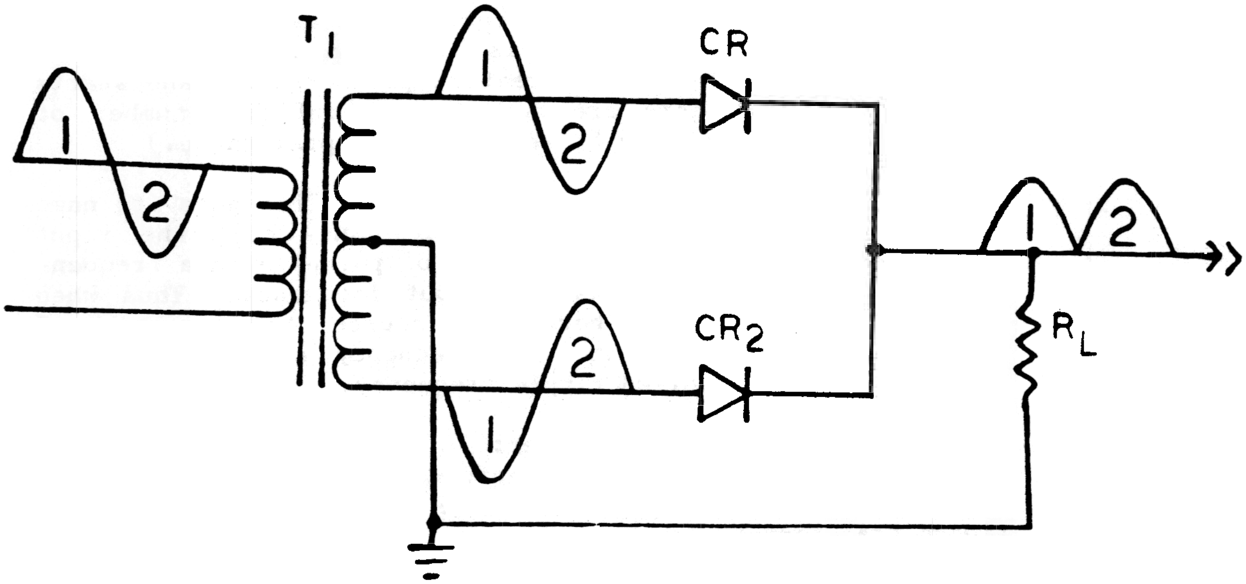


Figure 9

Theory of operation of a full-wave rectifier: (Refer to figure 9). During the first half cycle the anode of CR1 is positive with respect to the cathode and the anode of CR2 is negative with respect to the cathode, thus CR1 is forward biased while CR2 is reversed biased. During the second half cycle, the anode of CR1 is negative with respect to the cathode while the anode of CR2 is positive with respect to the cathode, causing CR1 to be reserved biased and CR2 to be forward biased.

Refer to figure 10.

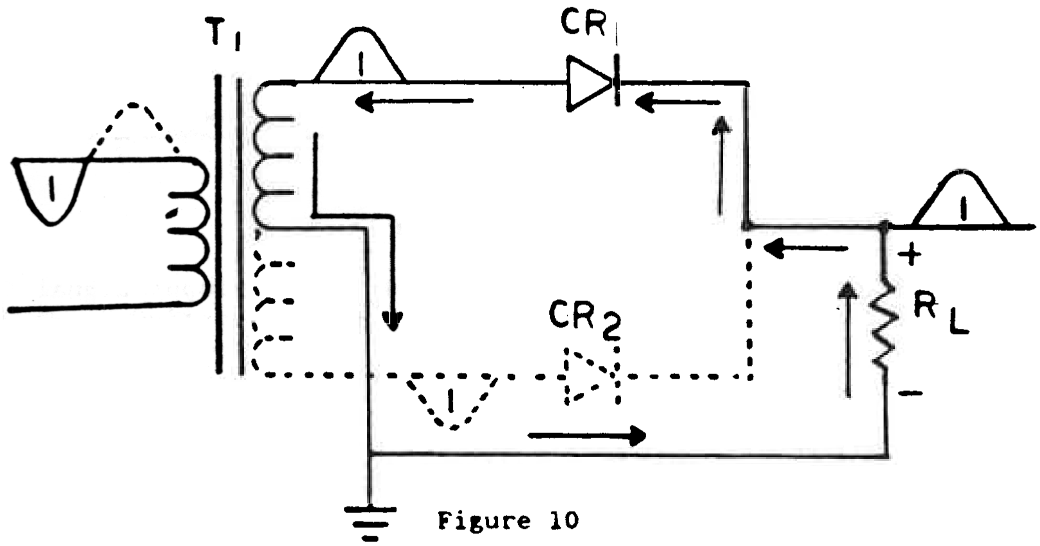


Figure 10

When CR1 is forward biased current will flow from ground through the load resistor, through the diode CR1 to the upper half of T_1, through T1 to the center tap and back to the ground. As current flows through the load resistor, a positive signal is developed at the junction of R_L and CR1. This signal is a positive DC pulse with an amplitude approximately the same as the input signal. This signal is developed during the first half of the input cycle only.

Refer to figure 11

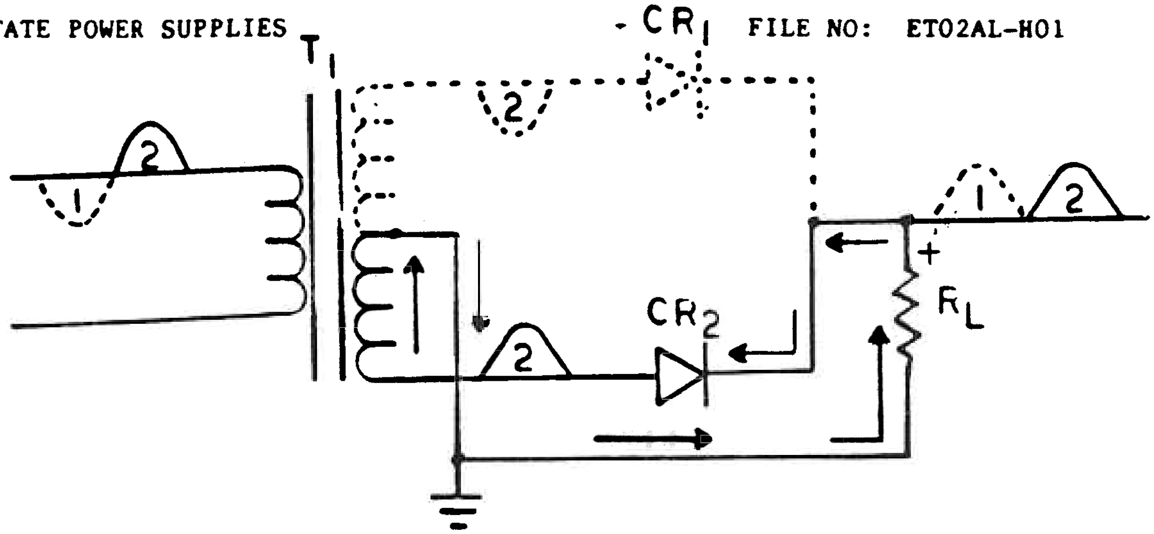


Figure 11

During the second half cycle of the input signal CR2 is forward biased and will allow current to flow. CR1 is reversed biased during this half cycle. Current will now flow from ground through the load resistor, through CR2, up through the lower half of the transformer to the center-tap and back to ground. Current is still flowing in the same direction across the load resistor so that a positive signal will be developed at the junction of CR2 and R_L. During this one cycle of the input sinewave, two positive DC pulses have been developed. With this condition the output frequency has doubled. If the input frequency is 60 Hertz, the positive alternation will be present 60 times. After the full-wave rectification there will be 120 positive pulses at the output. The amplitude, if measured by an oscilloscope, will be approximately the same as the peak input signal. If the DC output signal is measured with a digital, the indication will be the average value of the peak signal. To determine the average value of a full-wave rectified signal, multiply the peak value by .636.

Example: input peak value 10 VAC

10 VAC x .636 = 6.36VDC

(3) Bridge Rectifier:

Refer to figure 12.

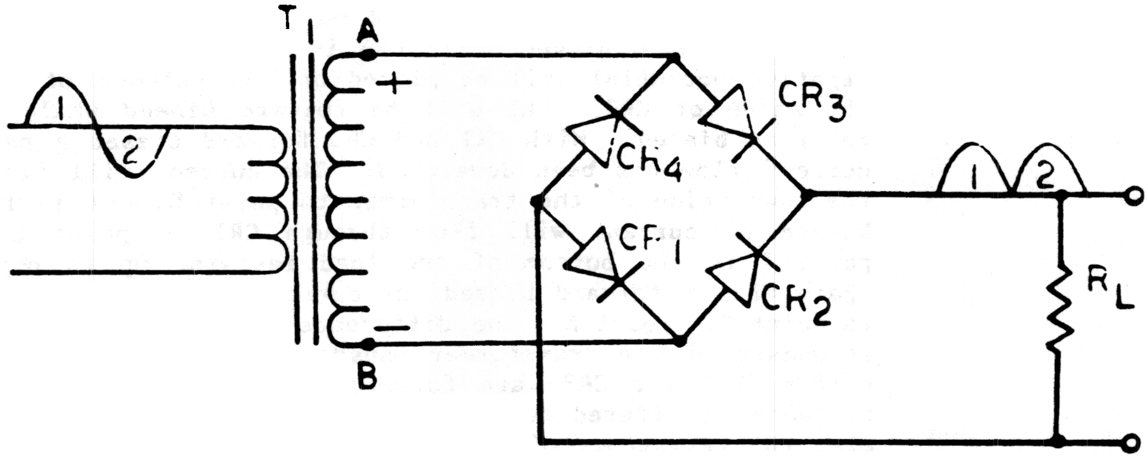


Figure 12

A full-wave bridge rectifier has one advantage over the conventional full-wave rectifier which is the amplitude of the output signal. The frequency of the positive pulses will be the same in either rectifier. When the output signal is taken from a bridge rectifier, it is taken across the entire potential of the transformer, thus the output signal will be twice the amplitude of a conventional full wave rectifier. For the first half cycle of a bridge rectifier refer to figure 13.

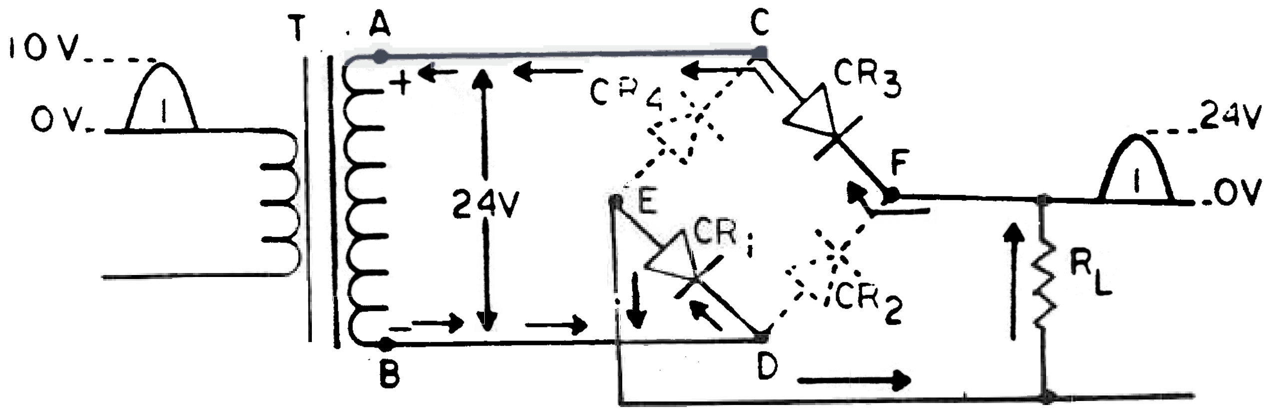


Figure 13

During the first half cycle of the input signal a positive potential will be felt at point A and a negative potential is felt at point B. Under this condition, a positive potential is felt on the anode of CR3 and on the cathode of CR4. CR3 will be forward biased while CR4 is reversed biased. Also a negative potential will be placed on the cathode of CR1 and the anode of CR2. CR1 will be forward biased while CR2 is reversed biased. With CR1 and CR3 forward biased a path for current flow has been developed. The current will flow from the lower side of the transformer to point D, CR1 is forward biased so current will flow through CR1 to point E, from point E to the bottom of the load resistor up to point F. Again CR3 is forward biased, so current will flow through CR3 to point C. Point A - The difference of potential across the secondary of the transformer causes the current to flow, the diodes (CR1 and CR3) are forward biased so very little resistance is offered to the current flow by these components, also the resistance of the transformer is very small, so approximately all of the applied potential will be developed across the load resistor. If the potential from point A to point B of the transformer is 24 volts, the output developed across the load resistor will be a positive pulse approximately 24V in amplitude.

Refer to figure 14.

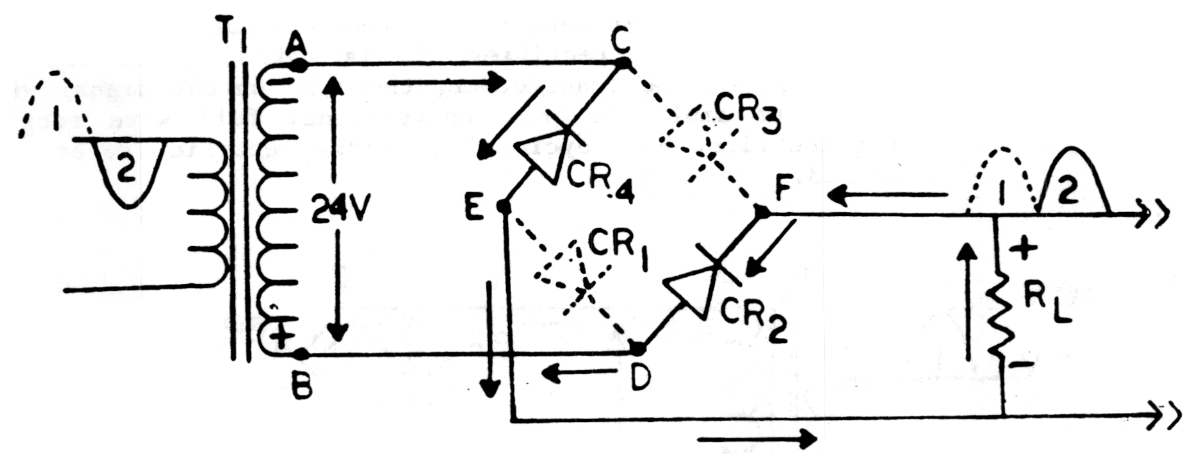


Figure 14

When the next alternation of the input is felt, the potential across the transformer reverses polarity. Now a negative potential is felt at point A and a positive potential is felt at point B. With a negative felt at point C, CR4 will have a negative on the cathode and CR3 will have a negative on the anode. A positive at point D will be felt on the anode of CR2 and the cathode of CR1. CR4 and CR2 will be forward biased and create a path for current flow. CR1 and CR3 will be reversed biased so no current will flow. The path for current is from Point A to Point C through CR4 to point E to the bottom side of the load resistor, through the load resistor to point F through CR2 to point D to the lower side of T1. Current flows because of the full potential across the entire transformer, the current through the load resistor will develop the complete voltage potential.

The frequency of the output pulses will be twice that of the input pulses because both cycles of the input are being used to produce an output.

Figure 16 shows the Bridge Rectifier that is used on the Nida Trainer. This rectifier has a ground at the junction of CR1 and CR3, so the input signal is limited. The rectifier will limit the input signal to positive pulses by forward biasing CR1 or CR3. Under this condition, this rectifier will only produce an output signal with an amplitude equal to one of the input peaks or to the same output as a conventional full wave rectifier.

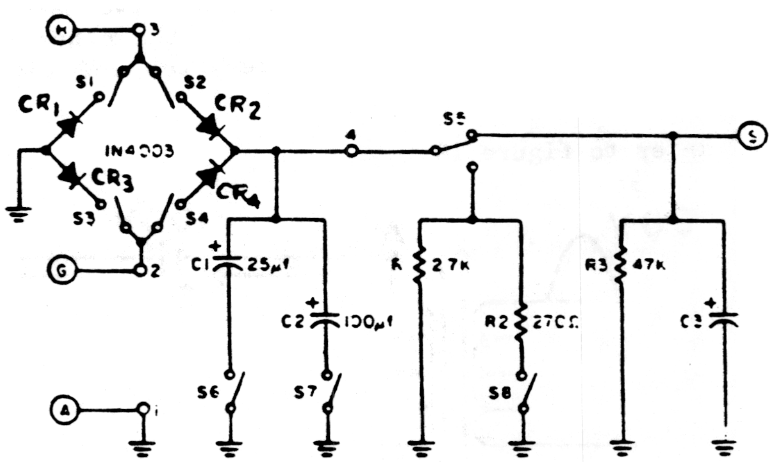


Figure 16

(4) Voltage Doublers: The circuit produces higher DC voltage than the normal half-wave and full-wave rectifier circuit. The double can be used as a power source when low load currents are needed and where poor regulated power sources are used. A voltage doubler does exactly as its name implies, the output DC level is approximately twice that of the input

AC peak value. The most common application of high voltage output of voltage doublers is the anodes of cathode ray tubes, which are used for radar scope presentations, oscilloscope presentations, or TV picture tubes. Voltage Doublers may also be used as primary power supplies when low current is required.

Half-Wave Voltage Doubler: (Refer to figure 17)

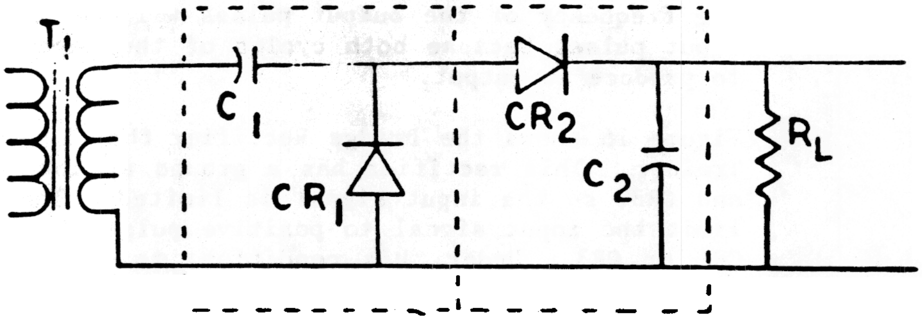
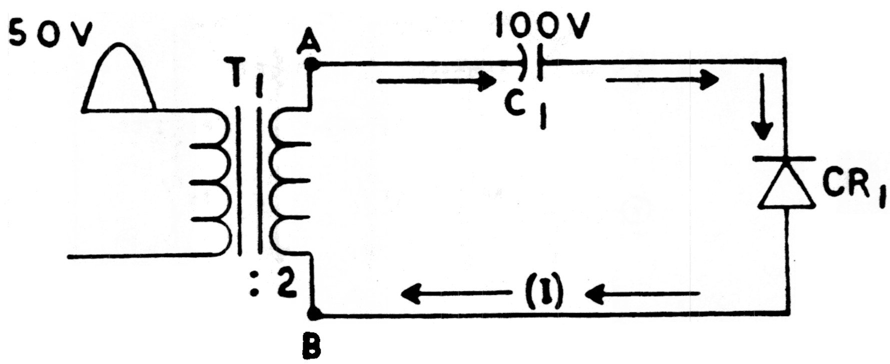


Figure 17

Figure 16 shows the schematic diagram for a half-wave voltage doubler. If this schematic is broken down into separate parts, you can see that there are two half wave rectifiers. One consisting of C1 and CR1 and the other consisting of C2 and CR2. R_L is the load resistor and simply develops the output signal.

Refer to figure 18.



First half cycle of the input signal.

Figure 18

When the input signal goes positive, Point A of the secondary will have a negative potential and point B will have a positive potential. Under these conditions, a positive potential will be felt on the anode of CR1. CR1 is now forward biased

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and current will flow from point A to the negative side of C1, from the positive side of C1 through the forward biased diode CR1 and Point B of the transformer. When this occurs, C1 will charge to the full value of the potential induced across the transformer. C1 cannot discharge back through the diode when the input signal is removed because of the polarity of the charge on C1. The plate of C1 that is tied to CR1 is positive so the cathode of CR1 feels this potential and is reversed biased. Assuming the input peak value was 50V peak and the transformer is a 1:2 ratio, C1 will charge to 100V.

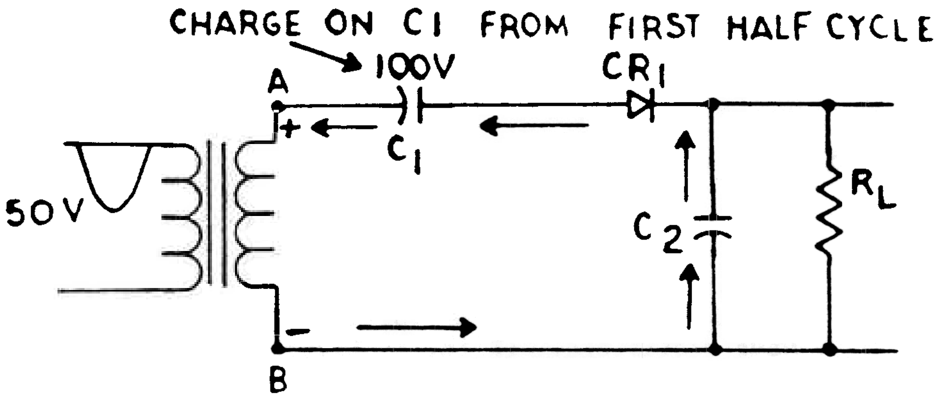


Figure 19

Second half cycle of input signal

When the input signal goes negative, a positive potential is felt at Point A and negative at point B. Now it could be said that a new circuit has been formed consisting of C1, T1 secondary, CR2, and C2 in series. This circuit will have two power sources, C1 and T1 secondary. (Due to the charge that was placed on C1 during the first half cycle, C1 acts as a power source). This circuit can be redrawn as in figure 20.

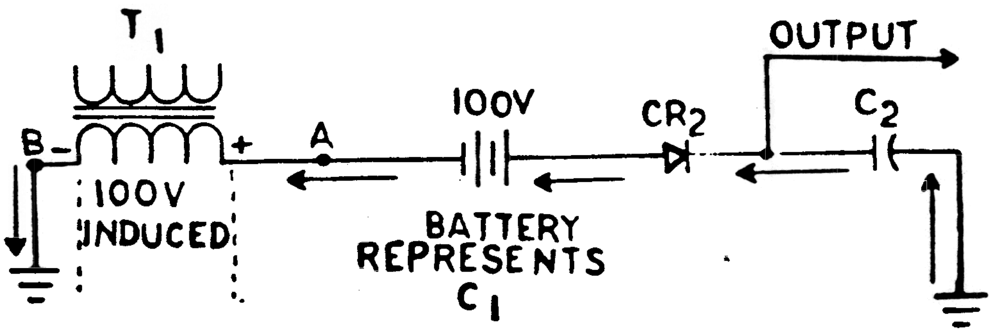


Figure 20

When power sources are placed in series they add, if a volt meter could be placed from point B of the transformer, to the anode of CR2, it would measure the potential of both power sources. The path for current flow will be from point B to the negative side of C2, from the positive side of C2 to the cathode of CR2. The anode of CR2 feels the positive 100V of the charge on C1 and is forward biased. Current flows through CR2 to the positive side of C1 and from the negative side of C1 to Point A. This current flow causes C2 to charge to the full potential of both power sources. (C1 and T2 secondary). Since these voltages add, the charge on C2 is 200V. If the load resistor is large, C2 will not be able to discharge before the next cycle is induced across the transformer and begins this entire process again. With a 100V peak to peak signal as an input, this circuit has produced an output of 200V.

(5) Fullwave Voltage Doubler:

The main advantage of a full wave voltage doubler over the half wave voltage doubler is better voltage regulation, less output ripple amplitude, and an increase in output ripple frequency. A fullwave voltage doubler consist of two halfwave rectifiers. (Refer to figure 21).

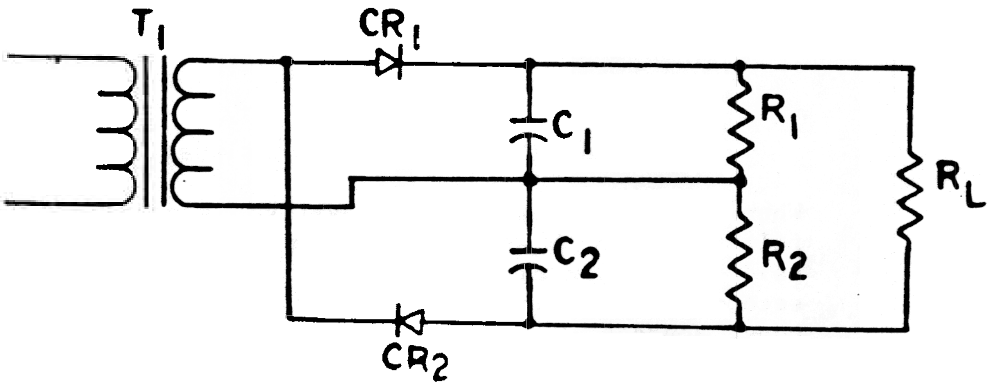


Figure 21

First half cycle of the input signal

Refer to figure 22.

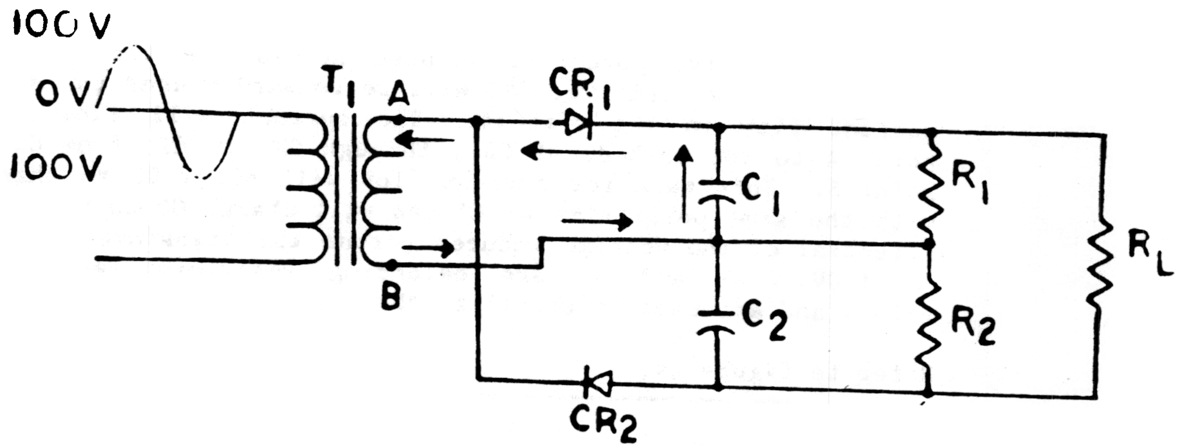


Figure 22

During the half cycle of the input signal that is negative, a polarity of positive at point A and negative at point B is established. With this condition, CR1 is forward biased and will allow current to flow. The path for current flow will be from point B of the secondary to the bottom of C1, from the top of C1 through CR1 to point A. With this path for current flow C1 will charge to the full peak voltage induced across the transformer, which is 100V. C1 cannot discharge completely because CR1 will be reversed biased after C1 is charged and the load resistor is large enough to cause C1 to discharge very slowly.

Second half cycle of the input signal.

Refer to Figure 23.

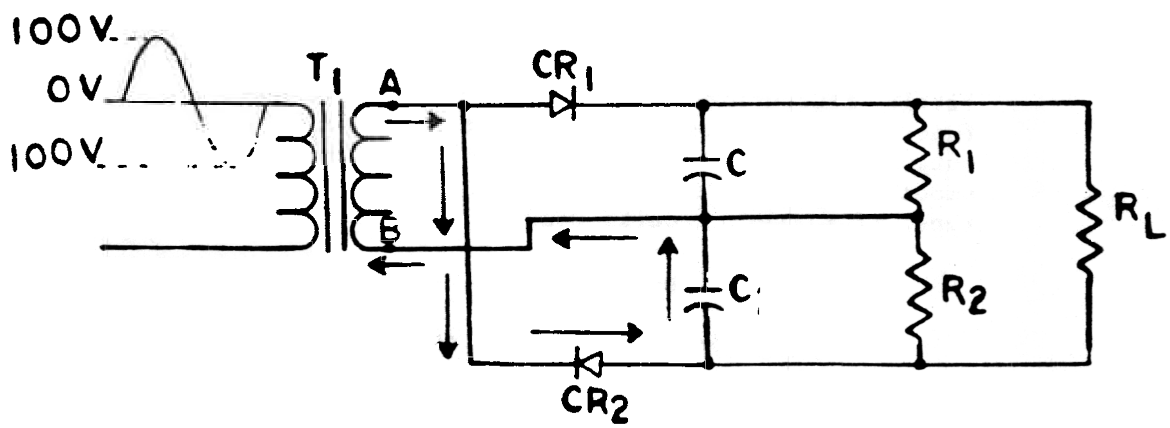


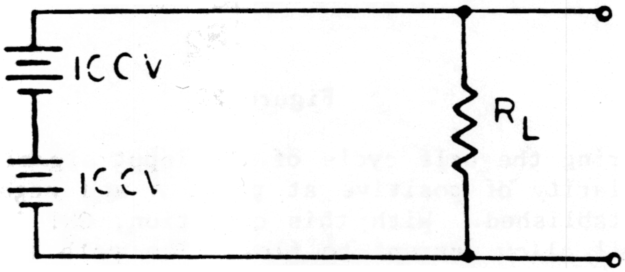
Figure 23

During the second half cycle of the input signal, Point A now feels a negative potential induced across the transformer. Point B is now positive, CR2 will be forward biased and allow current flow in the circuit. The current will flow from point A to the cathode of CR2, through CR2 to C2, from C2 to Point B. This path for current flow will allow C2 to change with the same polarities as C1 and will charge C2 to the full potential of the voltage induced across the transformer which is 100V. R_1 and R_2 are balancing resistors (equal in value) and are used to stabilize the charges on C1 and C2.

Refer to figure 24.

Represents Charge on C1

Represents Charge on C2



Output 200V

Figure 24

Once C1 and C2 are charged to equal values, they are in series. Remember power sources in series add, so the full potential across the circuit will be the two charges added together. Once these two capacitors have charged to the full potential they will hold these values due to the large value of the load resistor and the extreme amount of time it would take to discharge these components.

c. Filter Block: The output from a rectifier circuit is a pulsating D.C. This pulsating DC cannot be used in most electronic circuits due to the fluctuation of the voltage output. To make this output voltage usable, it must be smooth to a steady output with very little fluctuation. A filter circuit is used to perform this function. The filter circuit is placed between the rectifier and output load and uses capacitors, resistors, and inductions to smooth, (or decrease the ripple voltage). There are four basic types of filter circuits used in Basic Electronics. They are

1. Simple Capacitor filter

2. LC (choke - input) filter

3. LC (capacitor input) filter (Pi type)

4. RC (capacitor input) filter (Pi type)

(1) Capacitor filter - The capacitor filter is the most basic type of filter and its use is very limited. It can be used in circuits that require extremely high voltage and low

current, such as, power supplies for cathode ray tubes or electrons tube circuits which require very little load current from the supply. This filter is also used where the power supply ripple frequency is not critical.

Refer to Figure 25.

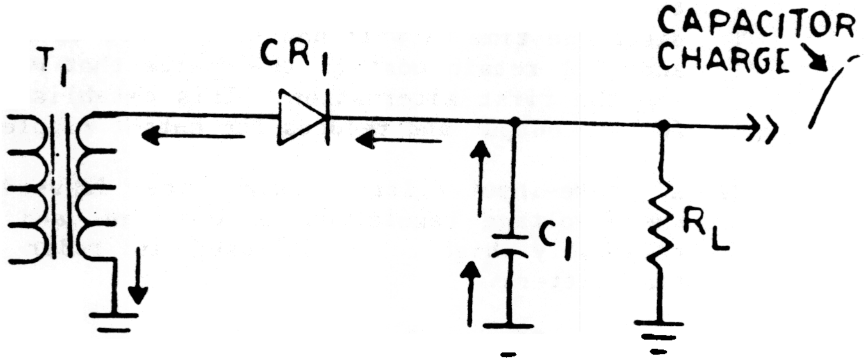


Figure 25

When a positive potential is felt at the top of T1, CR1 will be forward biased and allow current to flow from the bottom of T1 to the bottom of C1 and from the top of C1 through CR1 to the top of T1. With this path for current flow, C1 will charge to some positive potential. This positive potential will be less than the peak value induced across the transformer because of the voltage drop of CR1. The charge time of C1 will be extremely short due to the RC time constant of CR1 (which is forward biased and resistance is low) and C1.

Refer to figure 26

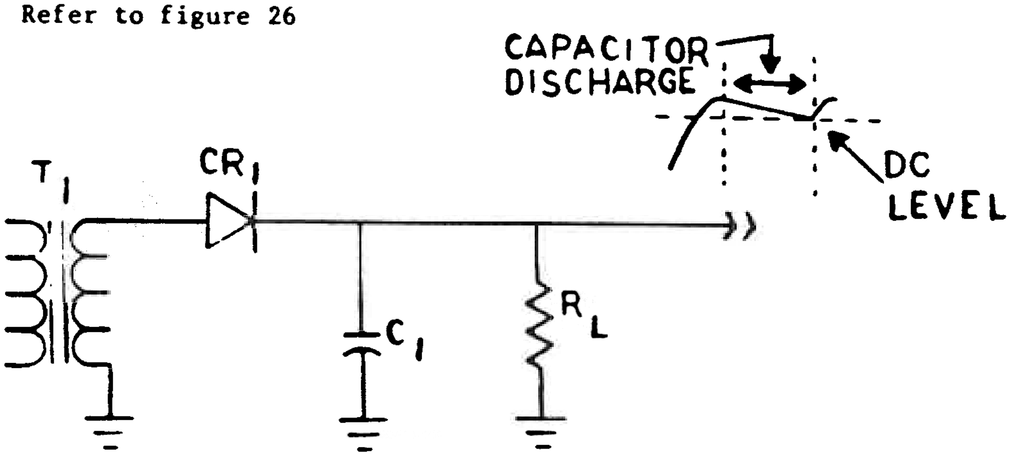


Figure 26

When the next alternation of the input is felt on the secondary of T1, the top of T1 will be negative. With the negative on the anode of CR1, it will become reverse biased and will not allow current to flow through it. Now C1 has a chance to discharge, it will discharge through the load resistor. The RC time constant of R_L and C1 should be very long and with this long TC, C1 will discharge very slow. Due to this slow discharge time C1 will not be allowed to discharge completely and will retain most of the charge that was placed there during the first alternation. This establishes a high DC level for the output and reduces the output ripple.

(2) LC choke-input Filter: This filter is used in power supplies where voltage regulation is important and current output is relatively high. It is used in radar and communication transmitters.

Refer to Figure 27

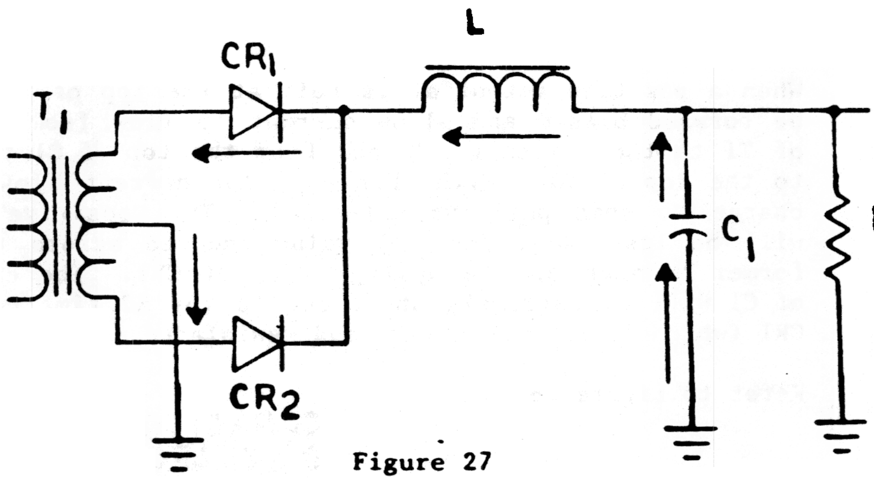


Figure 27

By placing L1 in series with the output of the rectifier, it attempts to keep the current through the load flowing at a constant rate. Figure 27 shows the charge path for C1. Any time the current starts to decrease in this circuit the magnetic field of L1 will begin to collapse and attempt to keep current moving at a constant rate.

Refer to figure 28.

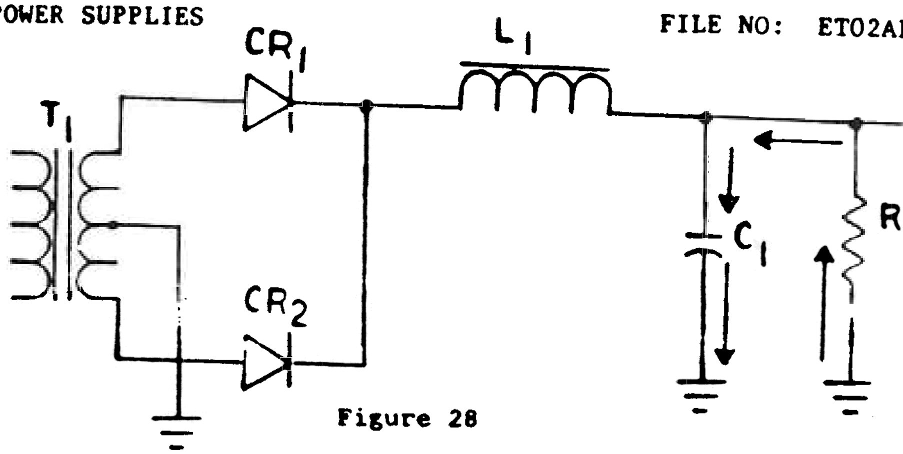


Figure 28

Figure 28 show the discharge path for C1. Again the charge time is short, so that the C1 can charge rapidly and the discharge time is extremely long to prevent the capacitor from discharging completely.

(3) LC Capacitor Input Filter: This is one of the most commonly used filters. It is used in circuits that require a low current output and a load current that must be relatively constant, such as, radio receivers and small audio power supplies.

Refer to figure 29.

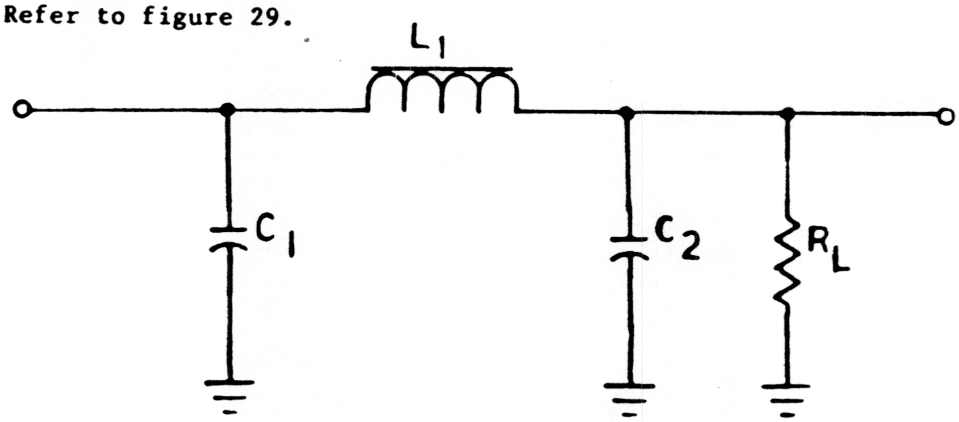


Figure 29

The purpose of C1 is to reduce the ripple to a relatively low level and at the same time establish the DC level for the output C1 will charge to the maximum peak value of the input signal. C1 will charge very rapidly but will discharge extremely slow. With this slow discharge time, the voltage on C1 will not discharge back to zero before the next pulse is felt on C1 and recharges it.

L1 and C2 form the LC filter and reduces the ripple even further. L1 has a high value of inductance and a high value of inductive Reactance which offers a high reactance to the ripple frequency. C2 offers a low reactance to the ripple. L1 and C2 form a voltage divider and because of the reactance offered by each component, most of the ripple is dropped across L1 and very little ripple is felt across C2 and the load. L1 and C2 has very little effect on the DC voltage because the only opposition to current flow is the internal resistance of the wire of L1.

The LC filter provides good filtering action over a wide range of currents. C1 filters best when the load is drawing very little current. L1 filters best when the current is highest. The complementary nature of these two components ensure that good filtering will occur over a wide range of frequencies.

The LC filter has two disadvantages, it is more expensive to build and the inductor is heavy and bulky.

Regulator and voltage divider blocks. These blocks will be covered in another lesson.