MINISTRY OF HIGHER EDUCATION & SCIENTIFIC RESEARCH
DIYALA UNIVERSITY
COLLEGE OF ENGINEERING
ELECTRICAL POWER & MACHINE DEPARTMENT

INDUSTRIAL POWER ELECTRONIC LABROTORY

PRACTICAL EXPERIMENTS IN POWER ELECTRONIC

FOR STUDENTS OF THIRD STAGE

EXPERIMENT NO.1

EXPERIMENT NA. POWER SUPPLY CIRCUITES .

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EXPERIMENT 1
POWER SUPPLY CIRCUITES .

this Curriculum supported by the Chief of electrical power & machine department

PH.D

NASRALLA SALMAAN KHALAF

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OBJECTIVE

1. Understanding the operation of power supply circuits.
2. Measuring AC voltages.
3. Measuring DC voltages.

DISCUSSION

All of electronic circuits require certain constant dc supply voltages to supply the required operating voltages. If only a small amount of power is needed, batteries can be used to deliver a dc supply, as is the case with portable equipment such as calculators, watches, transceivers, radios, multimeters, and so on. With larger electronic systems such as computer systems, and television sets, the dc supply voltages will be obtained from a dc power supply. The dc power supply converts an ac line input to the required dc voltages.

An ideal dc power supply should have: (1) the output voltage is desired and constant, (2) no undesired noise or ripple exists in output voltage, and (3) the ac output impedance is extremely low. In practice, it is difficult to design a power supply to meet these conditions completely.

All of dc power supply circuits include the following section:

(1) Voltage and current level conversion
(2) Rectifier
(3) Filter
(4) Regulator

The transformer is used to provide a step-up or step-down ac voltage and current from the line voltage and current. Most electronic circuits require a step-down transformer to step down the ac voltages and to step up the ac currents from the outlet.

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Power supplies used for the operation of transistor circuits usually provide only low dc voltages of about 2 to 28V. The operation of most operational amplifiers generally requires symmetrical dc voltages of ±12 to ±15V. The V_{CC} labeled on op-amp schematics represents the positive with respect to ground, while V_{EE} represents the negative with respect to ground. The power supply for TTL circuits requires a fixed voltage of +5V.

The rectifier circuit converts the ac voltage to a pulsating dc voltage, also called pseudo-dc voltage. The filter circuit is used to smooth out the pulsating dc and provides a useful and smoother dc voltage for the electronic circuit. In most cases, the filter output will change in the variation of the load. Therefore a regulator circuit is required. The regulator will tend to keep the output voltage constant by sensing any changes in output voltage and trying to return it to its original value. Therefore the ideal voltage regulator could be considered as a voltage source with a constant output voltage.

Half-wave Rectifiers

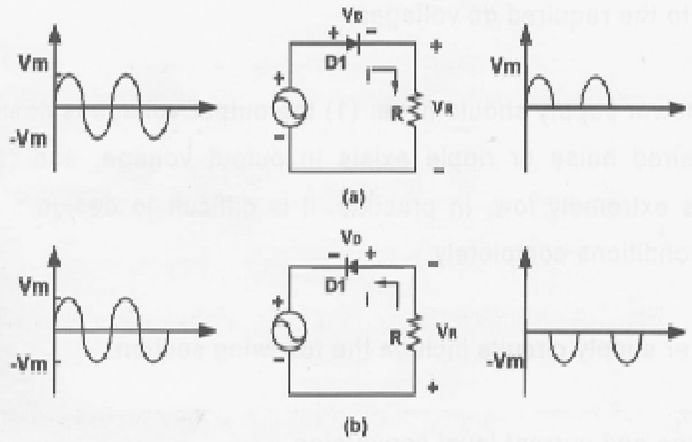

Fig.1-1 Half-wave rectifier circuits

There are three types of rectifiers frequently used to convert AC voltage into DC voltage. These are half-wave, full-wave, and bridge full-wave rectifiers. The simplest rectifier circuit shown in Fig. 1-1(a) is a positive half-wave rectifier. Before analyzing the operation of this rectifier circuit, keep the concept in mind that a rectifier diode conducts only when a forward bias is applied. On the positive half-cycle of the ac voltage, the diode D1 is forward-biased and conducts, allowing current to pass

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through the road resistor R. Since the resistance of the forward-biased diode is very low and negligible, the voltage across R equals the input voltage. On the negative half-cycle, the diode is reverse-biased and, therefore, nonconducting. No voltage wave presents in the load circuit. The voltage waveforms in the rectifier circuit are shown in Fig. 1-2.

Fig. 1-1(b) shows a negative half-wave rectifier circuit. The operation of this circuit is opposite to that of positive half-wave rectifier. On the negative half-cycle of the ac voltage, the diode is forward-biased and conducts a current through R. On the positive half-cycle, the diode is reverse-biased and is not conducting. Therefore only the negative half of the ac voltage is present in the load circuit.

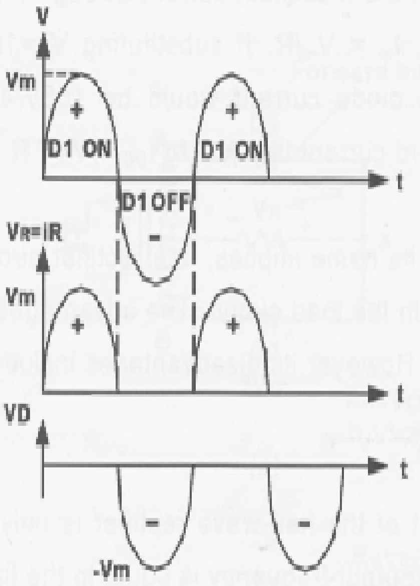

Fig.1-2 Voltage waveforms in a half-wave rectifier

In considering rectifier circuits, it is important to consider the ratings of the rectifier diodes, which include (1) the peak inverse voltage, and (2) the maximum average forward current. For a half-wave rectifier circuit, the diode conducts in the maximum forward current of V_m/R, where V_m is the input peak voltage. The relationship between the effective value and peak value is expressed by the equation:

Peak value = Effective value (RMS) × 1.414-----------------------------------(1-1)

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If a 110-V input voltage is applied, the diode will withstand a reverse voltage of V_m = 110V × 1.414=155V. In such cases the diode with a peak inverse voltage (PIV) rating over this voltage value must be used. Fortunately the PIV ratings of most rectifier diodes typically vary from about 400 to 600V.

The output average voltage of half-wave rectifier is calculated by

$$V_{DC}=(1/\pi)\,V_{peak} \quad \text{--(1-2)}$$

For the case above, the average voltage would be about 49V.

For the Fig.2-1 example, the maximum current through the diode occurs at ac peak voltage applied, that is, $I_m = V_m/R$. If substituting V_m=155V and R=49Ω into this equation, the maximum diode current would be 155V/49Ω=3.16A. Therefore the maximum average forward current is equal to $I_{DC} = V_{DC}/ R$ =1A.

A half-wave rectifier, as its name implies, is a rectifier circuit that only half of the ac voltage wave is present in the load circuit. The advantages of this rectifier circuit are simple and inexpensive. However its disadvantages include larger ripple voltage and smaller average current.

Since the voltage output of the half-wave rectifier is only the positive half-cycle of the ac input voltage, the output frequency is equal to the line frequency.

Center-tapped Transformer Full-Wave Rectifier

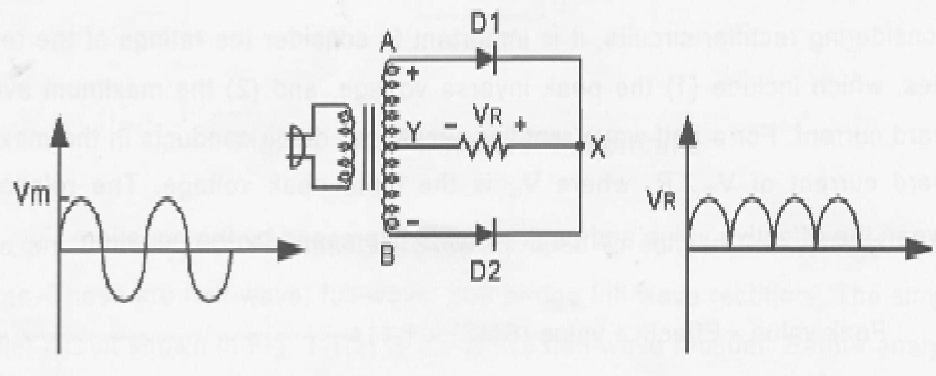

Fig.1-3 Full-wave rectifier with center-tapped transformer

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For many applications it is desirable to have a rectifier circuit which supplies current during both half-cycles of the ac power and, thus provides a more continuous current to the load. A full-wave rectifier circuit with center-tapped transformer is shown in Fig. 1-3. This circuit can be considered as two half-wave rectifiers in parallel with inputs that have a phase difference of 180 degrees. The voltage output of the full-wave rectifier is equal to the voltage developed by each half of the transformer secondary. On the positive half-cycle, D1 conducts and D2 is not conducting. The current path is shown in Fig. 1-4(a). On the negative half-cycle, D2 conducts and the current path is shown in Fig. 1-4(b). In each case, the direction of current flow through the load resistor is the same.

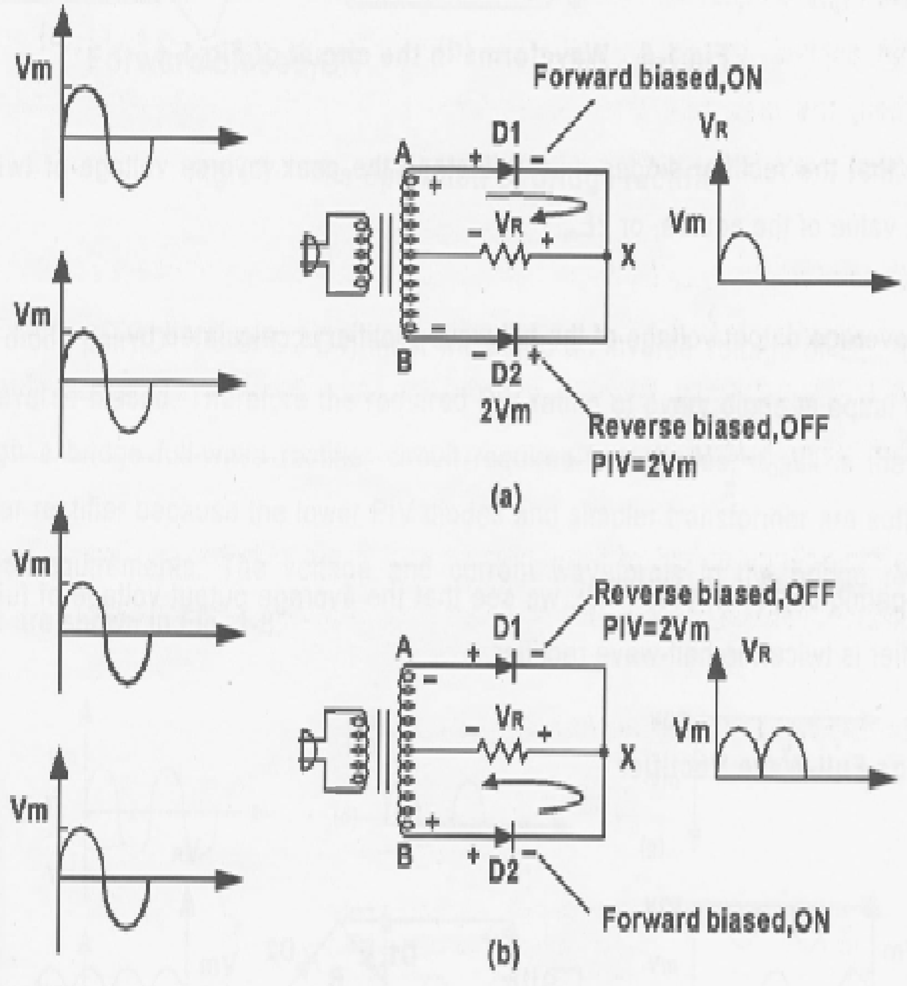

Fig.1-4 Center-tapped transformer full-wave rectifiers

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The voltage and current waveforms in the full-wave rectifier circuit are shown in Fig. 1-5.

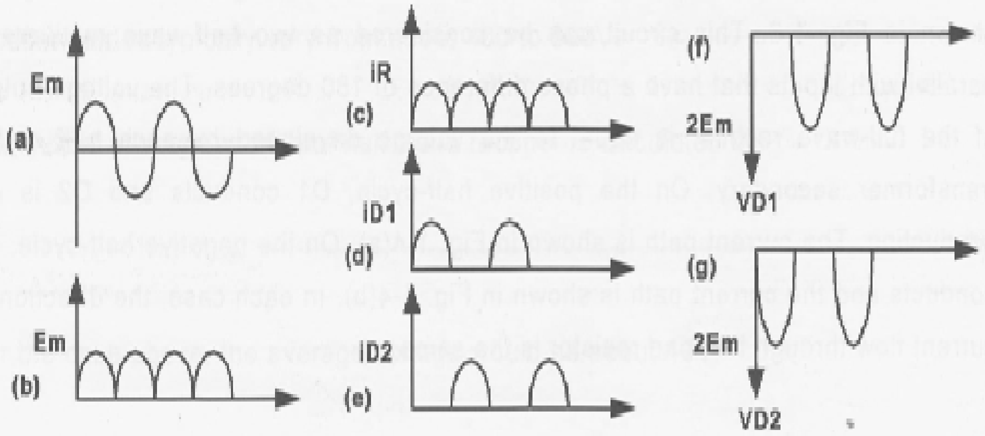

Fig.1-5 Waveforms in the circuit of Fig.1-4

Note that the rectifier diodes must withstand the peak inverse voltage of twice the peak value of the source, or $2E_m$.

The average output voltage of the full-wave rectifier is calculated by

$$V_{DC} = \frac{2}{\pi} V_{Peak} \quad \text{(1-3)}$$

Comparing Eqs.(1-2) with (1-3), we see that the average output voltage of full-wave rectifier is twice the half-wave rectifier.

Bridge Full-Wave Rectifier

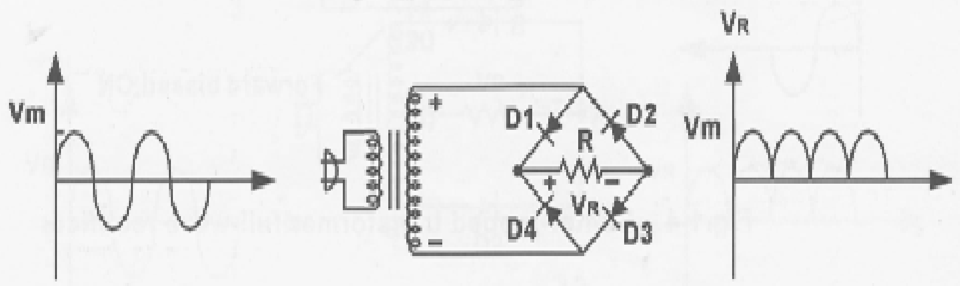

Fig.1-6 Bridge full-wave rectifier

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A way to obtain full-wave rectification, which does not require a center-tapped transformer, is shown in Fig. 1-6. This circuit is called the bridge rectifier because the connection of these four rectifier diodes and the load is similar to the bridge configuration. On the positive half-cycle, D1 and D3 conduct. On the negative half-cycle, D2 and D4 conduct. As shown in Fig. 1-7, the diode pairs D1-D3 and D2-D4 conduct alternatively. In each case, the direction of current flow through the load R is the same.

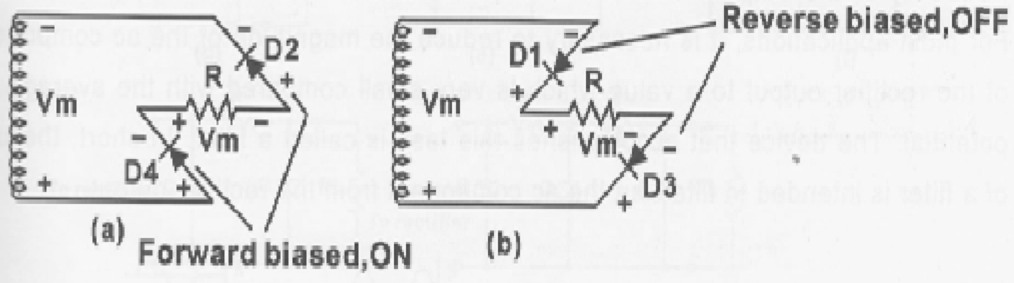

Fig.1-7 The operation of bridge rectifier

Each diode pair (D1-D3 or D2-D4) must withstand an inverse voltage of $2E_m$, during it is reverse-biased. Therefore the required PIV rating of every diode is equal to E_m. Though a bridge full-wave rectifier circuit requires four diodes, it still is the most popular rectifier because the lower PIV diodes and simpler transformer are sufficient for the requirements. The voltage and current waveforms in the bridge rectifier circuit are shown in Fig. 1-8.

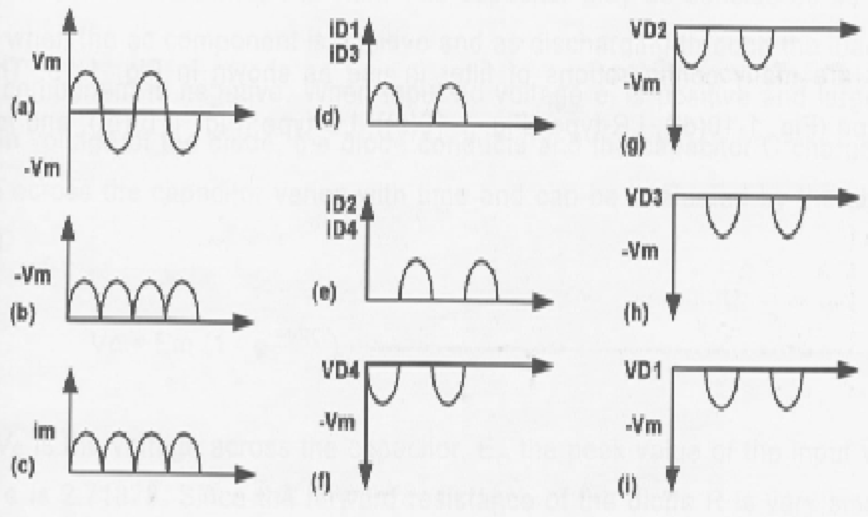

Fig.1-8 Waveforms in the bridge rectifier circuit

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Filters

The output voltages of rectifier circuits vary with time as shown in Fig. 1-9. The output can be considered as a voltage that varies about the average dc potential. Often the average dc potential is called the dc component of the output. For the half-wave rectifier output, the lowest and most predominant frequency of the ac component is the frequency of the ac line. The lowest and most predominant frequency of the output from a full-wave rectifier is twice the ac supply frequency. For most applications, it is necessary to reduce the magnitude of the ac component of the rectifier output to a value which is very small compared with the average dc potential. The device that accomplishes this task is called a filter. In short, the use of a filter is intended to filter out the ac component from the rectifier output.

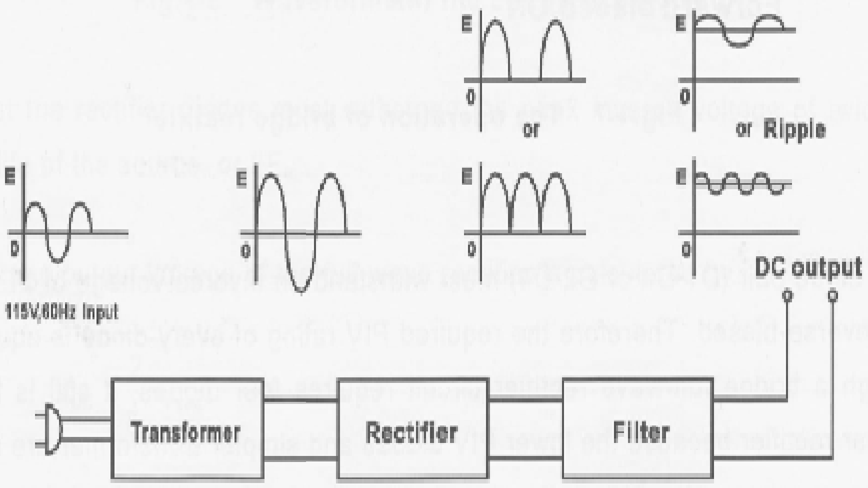

Fig.1-9 Basic block diagram of a dc power supply

There are many configurations of filter in use as shown in Fig. 1-10. These are RC-type (Fig. 1-10(d)), LR-type (Fig. 1-10(a)), LC-type (Fig. 1-10(b)), and multiple π type.

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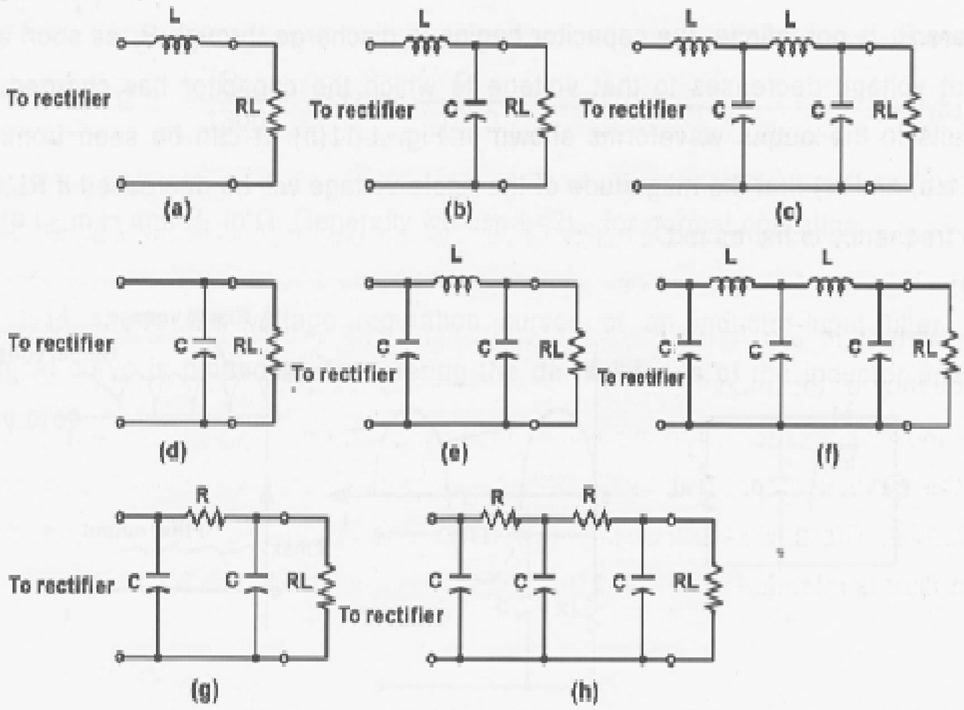

Fig.1-10 Power supply filter configurations

The most popular filters used in power supply circuits are (1) capacitor filter; (2) inductor-input filter; (3) capacitor-input filter; and (4) resistor-capacitor filter.

(1) Capacitor Filter

Using a large capacitor in parallel with the load R_L as shown in Fig. 1-11(a), the simplest capacitor filter circuit is built. The capacitor may be considered as storing charge when the ac component is positive and as discharging through the load when the ac component is negative. When input ac voltage e_i is positive and larger than the cutin voltage of the diode, the diode conducts and the capacitor C charges. The voltage across the capacitor varies with time and can be evaluated by the charging formula.

$$V_C = E_m (1 - e^{-t/RC}) \text{ --(1-4)}$$

where V_C is the voltage across the capacitor, E_m the peak value of the input voltage e_i, and e is 2.71828. Since the forward resistance of the diode R is very small, the voltage across the capacitor would quickly reach a constant value equal to the peak value of the alternating current supplying the rectifier if R_L were infinite. In practice

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where R_L is not infinite, the capacitor begins to discharge through R_L as soon as the input voltage decreases to that voltage to which the capacitor has charged. This results in the output waveforms shown in Fig. 1-11(b). It can be seen from Figs. 1-11(b) and (c) that the magnitude of the ripple voltage will be decreased if RL, C, or the frequency is increased.

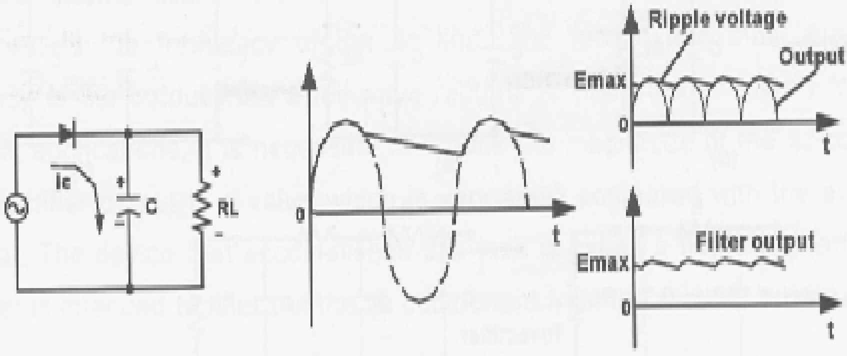

Fig.1-11 Half-wave rectifier with Capacitor filter.(a) Circuit, (b) Action of the capacitor, (c) Load voltage

(2) Inductor-input Filter

Fig. 1-12 shows the inductor-input filter circuit. This circuit is also called the choke filter or L filter. The use of the inductor is to store up energy in the form of magnetic field and to release it to the load evenly. Thus the inductor increases its energy storage during the peaks of the ac component of rectifier output and releases it when the rectifier output falls below the load voltage.

When the inductance is too small or when the load current is very small, the inductor does not deliver current over the full cycle. In this case, the filter acts as a capacitor filter discussed above. Either sufficient inductance is in the filter or the load current has increased, so that the critical value for the inductance is reached. At this critical value, the current is flowing at all times in the inductor. This flow of current in the inductor prevents the capacitor from discharging, and the load voltage is maintained at a constant value.

The inductance-output voltage relation is shown in Fig. 1-13. The inductance at the critical point on the ideal load curve is called the critical inductance L_C. The L_C value is the minimum value of inductance required for keeping the output voltage at a constant value. It can be calculated by the equations:

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$$LC \geq \frac{R_L}{1300} \text{ or } LC \geq \frac{R_L}{1000} \quad \text{------(1-5)}$$

where L_C in H and R_L in Ω. Generally we use $L=2L_C$ for normal operation.

Fig. 1-14 shows the voltage regulation curves of an inductor-input filter. The practical curve is plotted by considering the dc resistance of the inductor and the diode drop.

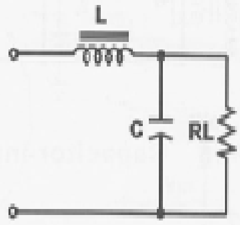
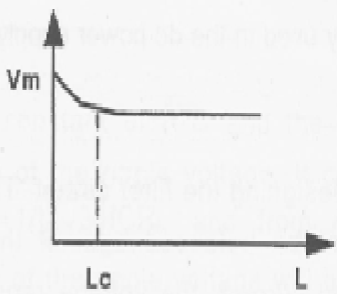


Fig.1-12 Inductor-input filter



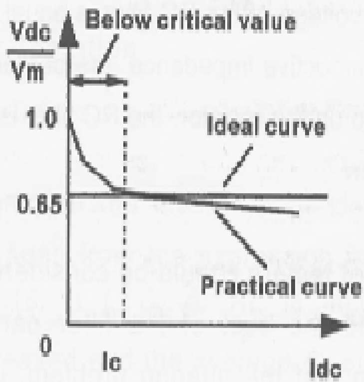


Fig.1-13 L vs output voltage **Fig.1-14 Load curves**

(3) Capacitor-input Filter

A capacitor-input filter is a modified inductor-input filter with a capacitor connected across the input terminals of the filter as shown in Fig. 1-15. This filter is also called the π filter. The capacitor-input filter has an output characteristic that is higher than the inductor-input filter. On the other hand, the regulation of the capacitor-input filter is poorer than that of the inductor-input filter. Because of the additional filtering

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effect of the input capacitor, the percent of ripple is lower than the ripple content of the inductor-input filter. The output voltage and the percent of voltage regulation depend on the values of load resistance, diode resistance, and the secondary resistance of transformer, regardless of the input capacitor. The magnitude of ripple voltage is determined by the load and the input capacitance.

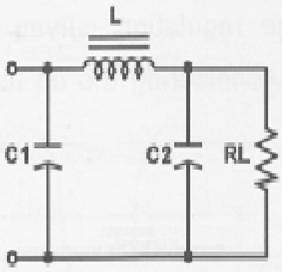

Fig.1-15 Capacitor-input filter

(4) RC Filter

The RC filter shown in Fig. 1-16 is a modified π filter by replacing the inductor with a resistor. The output voltage of the RC filter is equal to that of the π filter minus the resistor drop. If R equals the inductive impedance, the percent of ripple are the same. Since the factor of the voltage drop on the resistor, the RC filter is usually used in the dc power supply whose load current is low.

A number of factors should be considered in designing the filter circuit. The size, the weight, and the cost of the filter parts must be balanced against the electrical requirements of the filtering problem, the load current, the voltage regulation, and the percent of ripple. The final filter design is a compromise between these factors.

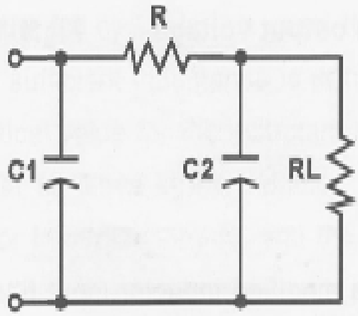

Fig.1-16 RC filter

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Fig. 1-17 shown the dc power supply with a capacitor filter connected to the center-tapped full-wave rectifier output. The output voltage of the rectifier discussed before varies with time as shown in Fig. 1-17(a). The output voltage varies from 0 to V_m at the frequency of 120Hz. When a large capacitor is connected in parallel with the load R_L as shown in Fig. 1-17(b), the capacitor charges to the peak value of the input voltage. As soon as the input voltage decreases to that voltage to which the capacitor has charged, the capacitor starts to discharge through R_L.

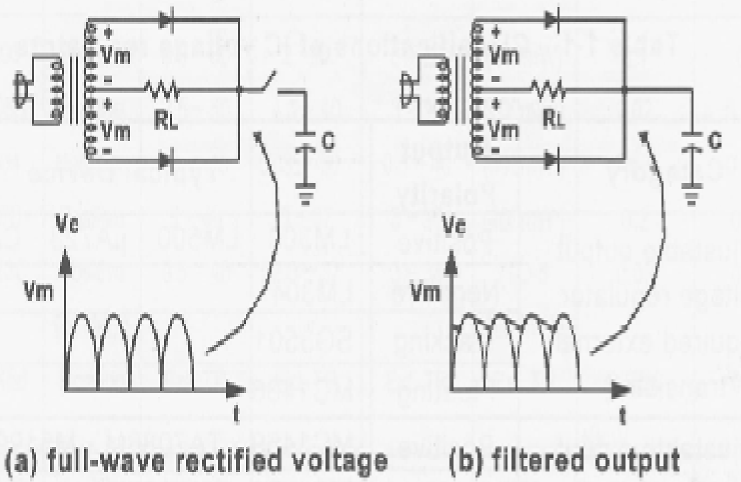

Fig.1-17 Capacitor filter operation

The time constant of R_LC and the frequency of the input voltage determine the magnitude of the ripple voltage. It can be seen from the expression for the ripple factor, $r = 1/\left(2\sqrt{3}\right)fCR_L$ and from Fig. 1-18. If f, C, or RL is increased, the magnitude of the ripple voltage will be decreased and the average dc output will be increased.

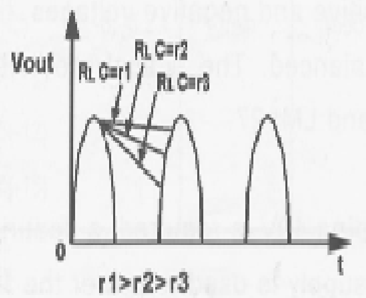

Fig.1-18 Ripple voltage

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IC Voltage Regulators

Today IC voltage regulators are widely used in dc power supply circuits. These regulators provide the designer a simple, inexpensive way to obtain a source of regulated dc voltage. There are a number of linear voltage regulator types as listed in Table 1-1. Each has its own particular characteristics and best uses, and selection depends on the designer's need and trade-offs in performance and cost.

Table 1-1 Classifications of IC voltage regulators

Category	Output Polarity	Typical Device
Adjustable output voltage regulator (required external transistor)	Positive	LM300 、LM500 、µA723 、CA3085
	Negative	LM304
	Tracking	SG3501
	Floating	MC1466
Adjustable output voltage regulator	Positive	MC1469 、TA7086M 、M5199AY
	Negative	MC1463 、TA7085M
	Tracking	RC4094 、MC1468 (± 15 V)
Fixed output voltage	Positive	LM340 、µA7800
	Negative	LM320

It can be seen from Table 1-1 that the regulator categories include (1) adjustable output voltage with low output current of a few decade in mA; (2) adjustable output voltage with high output current of a few hundred in mA; and (3) fixed output voltage. A tracking regulator provides a regulated source of symmetrical positive and negative voltage that is required for supplying operational amplifiers, etc. In addition to supplying regulated positive and negative voltages, the tracking regulator assures that these voltages are balanced. The typical products include SG3501, RC4194, MC1468, LM125, LM126, and LM127.

If an output voltage exceeding 40V is required, a floating regulator such as MC 1466 can be used. An auxiliary supply is used to power the MC1466. This supply must be isolated from the main supply voltage since the MC1466 floats on the output voltage. A standard regulator such as µA723, and LM304 can be used to regulate output voltages above 40V by the use of level shifting techniques.

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The specifications of IC voltage regulators are listed in Table 1-2.

Table 1-2

Category	Device	Polarity	Input voltage range (V)	Output voltage range (V)	Input-output differential (V)	Peak output current (mA)	Load regulation (%)	Line regulation (%/V)	Tempera stability (%) (0-75°C)
Variable low power	LM300	Positive	8.5 ~ 30	2 ~ 20	3 ~ 20	(500mW)	0.1	0.1	0.3
	LM305A	Positive	8.5 ~ 50	4.5 ~ 40	3 ~ 30	(800mW)	0.02	0.025	0.3
	LM304	Negative	-8 ~ -40	-0.035 ~ -30	0.5 ~ 40	(500mW)	1mA	0.056	—
	LM376	Positive	9 ~ 40	5 ~ 37	3 ~ 30	(400mW)	0.2	0.03	0.23
	µA723C	Positive (or Neg.)	9.5 ~ 40	2.0 ~ 37	3 ~ 38	(TO-5 800 mW)	0.03	0.01	0.75
	MC1466	Floating	Ext. TR	Ext. TR	Ext. TR	Ext. TR	0.03% +3mV	0.03	
Variable medium power	MC1469R	Positive	9 ~ 35	2.5 ~ 32	2.1 ~ 33	600	0.005	0.003	0.15
	MC1463R	Negative	-9 ~ -35	-3.8 ~ -32	-3 ~ -35	500	0.05	0.03	0.15
	M5199AY	Positive	9.5 ~ -35	2.5 ~ 32	2.5 ~ 33	1000	0.04	—	0.75
	MC1468	Tracking	±17.5~±25	±14.5~±20	2 ~ 11	100	0.07	0.006	0.15
	SG3501	Tracking	±16.5~±25	±10 ~ ±23	2 ~ 15	100	(30mV)	(20mV)	1
	RC4194TK	Tracking	±9.5~±35	0.05~±23	3 ~ 35	250	0.001	0.02	0.23
	RC4195TK	Tracking	±18~ ± 30	±(15±0.5)	3 ~ 15	150	(5mV)	(2mV)	0.38
Three-terminal	LM309	Positive	7 ~ 35	5	2 - 30	1500	(50mV)	(4mV)	Long-term stability 20m V
	LM340- XX	Positive	35(5~18V) 40(24V)	5, 6, 8, 12 15, 18, 24	2min	1500			
	LM320- XX	Negative	-25 (-5,-5.2) -35(-12) -40(-15)	-5, -5.2 -12, -15	2min	1500			

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For further understanding the operation of IC voltage regulators, a typical type of CA3085 is introduced as follows.

The CA3085 series monolithic ICs are positive-voltage regulators capable of providing output currents up to 100mA with wide input ranges from 1.7V to 40V.

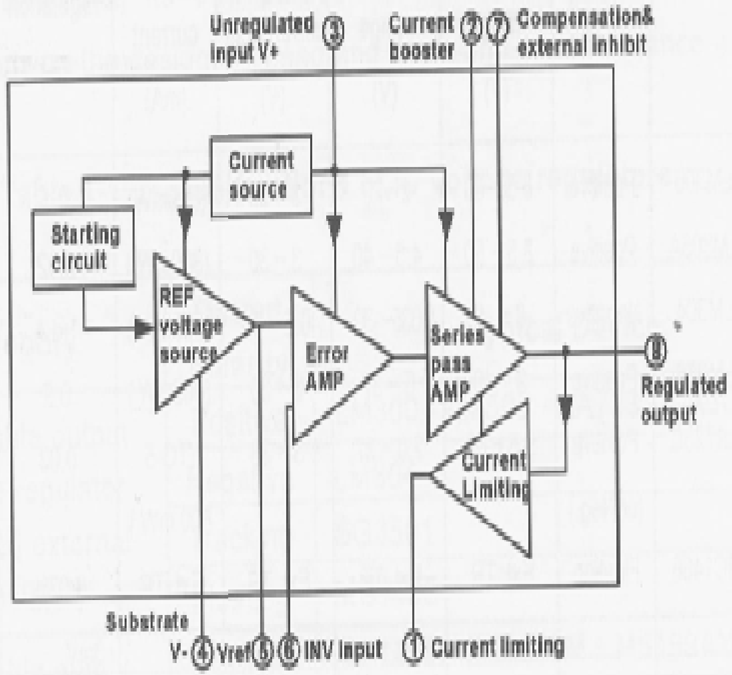

Fig.1-19 Block diagram of CA3085

The block diagram of CA3085 is shown in Fig. 1-19. Fundamentally, the circuit includes:

1. Starting circuit
2. Reference voltage source
3. Current source
4. Error amplifier
5. Series pass amplifier
6. Current limiting

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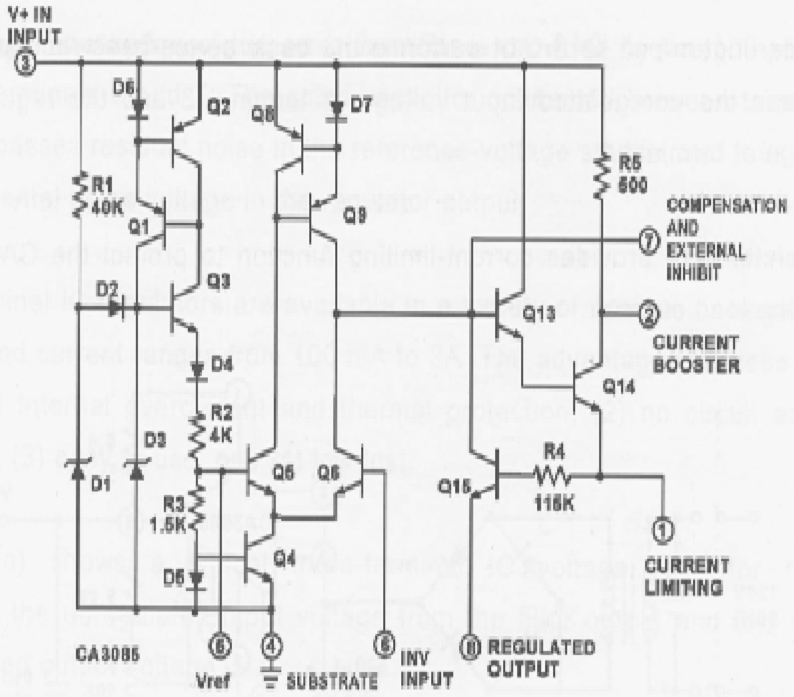

Fig.1-20 Schematic diagram of CA3085

Fig. 1-20 provides the schematic diagram of CA3085. The circuit description is made by referring to Figs. 1-19 and 1-20.

(1) When the unregulated input voltage is applied to terminal 3, the reference diode D3 receives a current of approximately 620 mA from the constant-current circuit consisting of Q3 and the current-mirror D6, Q1, and Q2, and then a nominal reference voltage of 5.5V is developed. Current to startup the constant-current source initially is provided by auxiliary zener diode D1 and R1. Diode D2 blocks current from R1-D1 source after latch-in of the constant-current source establishes a stable reference potential.

(2) The voltage developed across D3 drives the series divider network consisting of the B-E junction of Q3, diode D4, resistors R2 and R3, and diode D5, and a voltage of approximately 4V is developed between the cathode of D4 and the terminal 4.

(3) Transistors Q5 and Q6 comprise the differential amplifier that is used as a voltage-error amplifier to compare the stable reference voltage applied at the base of Q5 with a sample of the regulator output voltage applied at terminal 6. The error voltage output of the differential amplifier is then fed to the base of Q13.

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(4) The darlington pair Q13-Q14 performs the basic series-pass regulating function between the unregulated input voltage at terminal 3 and the regulated output voltage at terminal 1.

(5) Transistor Q15 provides current-limiting function to protect the CA3085 and/or limit the load current.

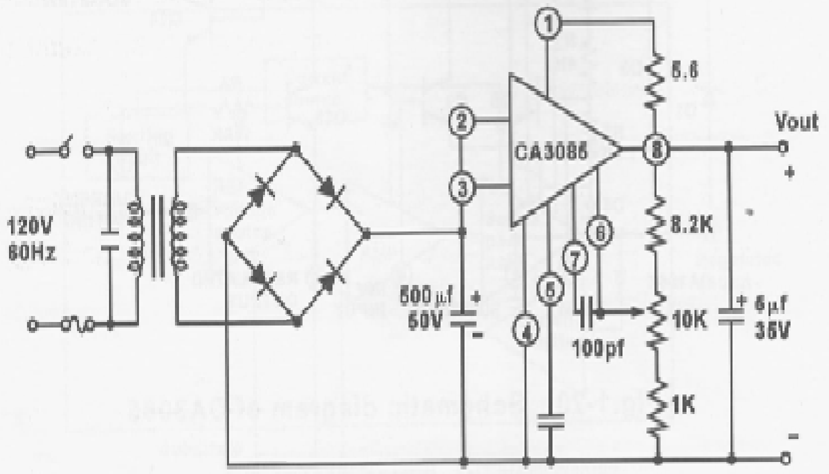

Fig.1-21 Basic power supply using CA3085

Fig.1-21 shows a basic regulated power supply using the CA3085. The AC 120-V line voltage is stepped down by the power transformer, full-wave rectified by the diode bridge circuit, and smoothed by 500-µF capacitor to provide unregulated dc to the CA3085 regulator input. Terminals 2 and 3 are tied together to eliminate the voltage drop which would otherwise be developed across resistor R5, thus the regulator can operate at the highest current levels.

The 5.6-Ω resistor is used to determine the maximum output current. As the voltage drop across the resistor increases, base drive is supplied to transistor Q15 so that it becomes increasingly conductive and diverts base drive from Q13-Q14 pass transistor to reduce output current accordingly.

The output voltage is divided by the series divider network consisting of resistors 8.2K, 10KΩ, and 1KΩ to obtain a portion of output voltage. This voltage varies with the variation of the output voltage and is fed back to the inverting input (terminal 6) of the error amplifier. The output voltage can be adjusted to the minimum value of 1.7V by varying the potentiometer 10KΩ.

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Frequency compensation of the error-amplifier is provided by the 100-pF capacitor between terminals 6 and 7. The small capacitor connected between terminal 5 and ground bypasses residual noise in the reference-voltage source, and thus decreases the incremental noise voltage in the regulator output.

Three-terminal IC regulators are available in a variety of positive or negative output voltages and current ranges from 100 mA to 3A. The advantages of these regulators include (1) internal overcurrent and thermal protection, (2) no circuit adjustments necessary, (3) easy to use, and (4) low lost.

Fig. 1-22(a) shows a typical three-terminal IC voltage regulator circuit. E_{in} represents the unregulated input voltage from the filter output and E_{out} represents the regulated output voltage.

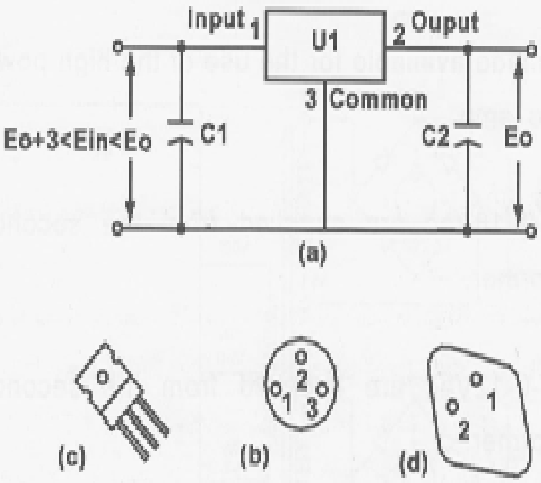

Fig.1-22 Connections and packages of three-terminal IC voltage regulators

The input capacitor C1 is required if regulator is located an appreciable distance from power supply filter. The output capacitor C2 is necessary for to improve stability and transient response.

Two typical three-terminal devices are LM340 and LM320 developed by National. The LM340 is a positive output regulator while the LM320 is a negative output regulator. The equivalent devices are 78xx and 79xx series by Motorola. The output voltages are listed in Table 1-3.

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Table 1-3

Device	Output Voltage
7805	+5 V
7812	+12 V
7815	+15 V
7818	+18 V
7905	-5 V
7912	-12 V
7915	-15 V
7918	-18 V

Description of Experiment Circuit

Fig. 1-23 shows the circuits of the power supply unit KL-51001. The unit furnishes the following outputs:

1. Fixed 110Vac is made available for the use of the high power devices such as ac motor and electric lamp.

2. Dual fixed 18V-0-18Vac are supplied from the secondary windings of the step-down transformer.

3. Dual fixed 12V-0-12Vac are supplied from the secondary windings of the step-down transformer.

4. Fixed 12Vdc is supplied from the three-terminal regulator output of 7812.

5. Fixed 5Vdc is supplied from the three-terminal regulator output of 7805.

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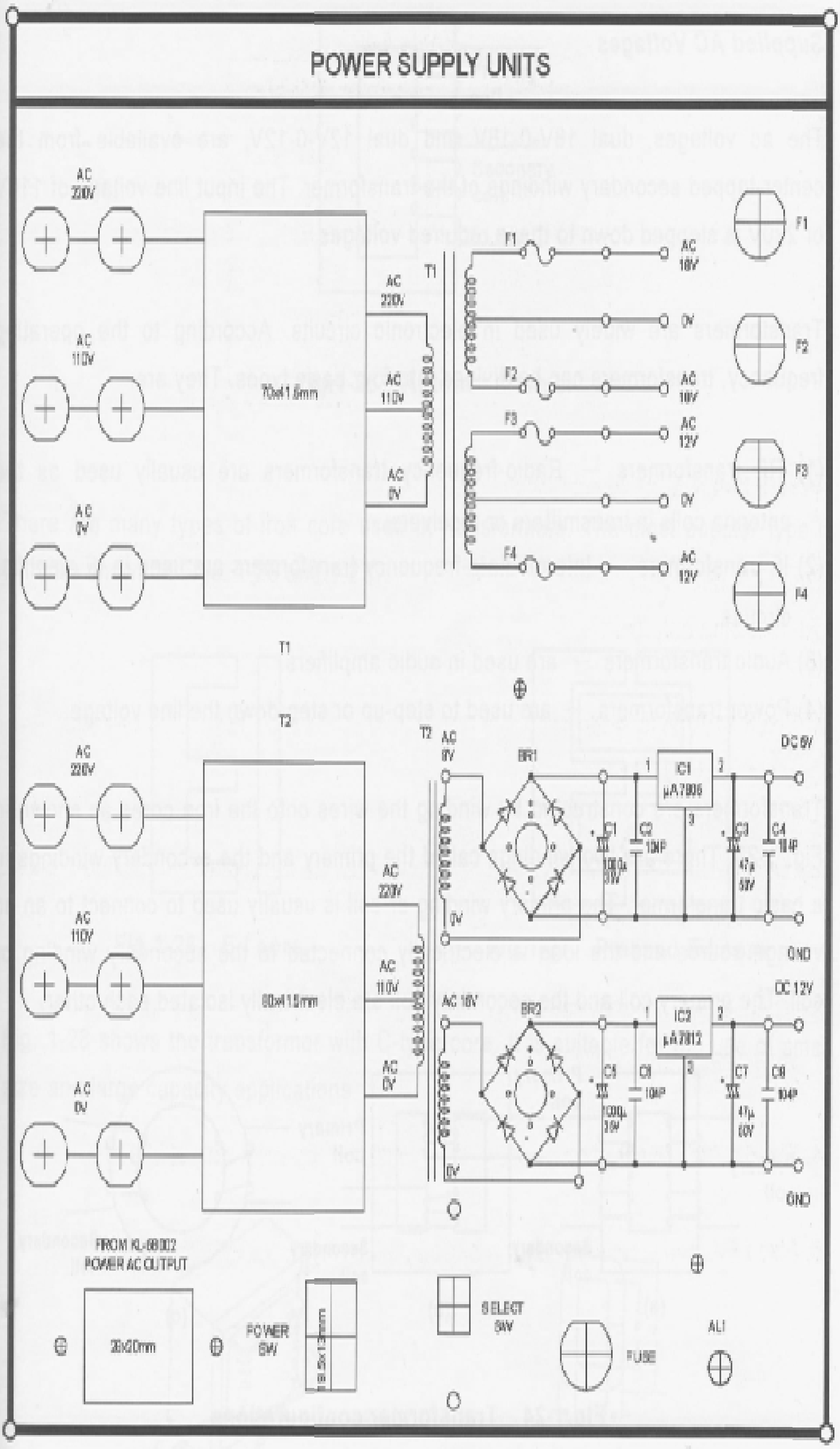

Fig.1-23 Power supply unit

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Supplied AC Voltages

The ac voltages, dual 18V-0-18V and dual 12V-0-12V, are available from the center-tapped secondary windings of the transformer. The input line voltage of 110V or 220V is stepped down to these required voltages.

Transformers are widely used in electronic circuits. According to the operating frequency, transformers can be divided into four basic types. They are:

(1) RF transformers — Radio-frequency transformers are usually used as the antenna coils in transmitters or receivers.
(2) IF transformers — Intermediate-frequency transformers are used in IF amplifier circuits.
(3) Audio transformers — are used in audio amplifiers.
(4) Power transformers — are used to step-up or step-down the line voltage.

Transformers are constructed by winding the wires onto the iron cores as shown in Fig. 1-23. There are two windings called the primary and the secondary windings in a basic transformer. The primary winding or coil is usually used to connect to an ac voltage source and the load is electrically connected to the secondary winding or coil. The primary coil and the secondary coil are electrically isolated each other.

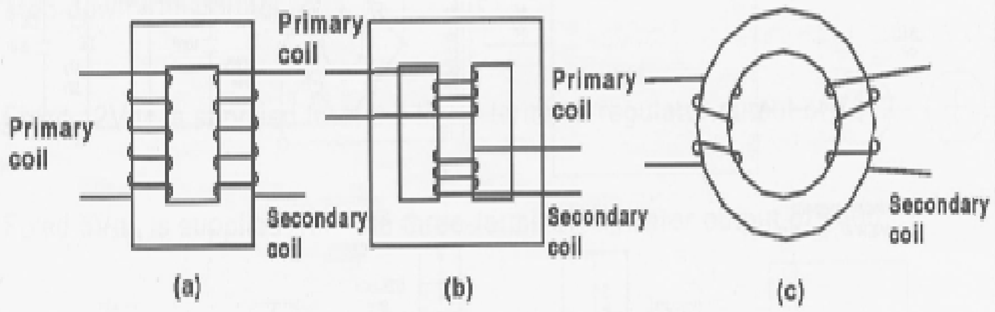

Fig.1-24 Transformer configurations

A special transformer called the autotransformer is constructed by winding a continuous coil onto a core, which acts as both the primary and secondary. It is shown in Fig. 1-24.

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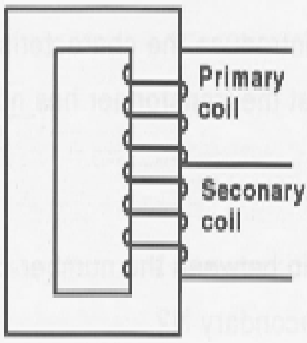


Fig.1-25 Autotransformer

There are many types of iron core used in transformers. The most popular type is E-I core shown in Figs. 1-26 and 1-27.

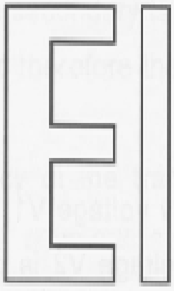


Fig.1-26 E-I core

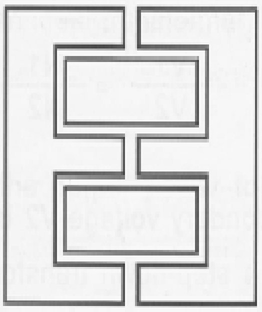
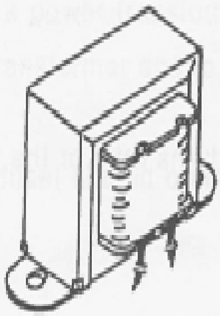
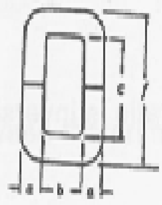


Fig.1-27 Pressed E-I core

Fig. 1-28 shows the transformer with C-type core. It is suitable for the use of small size and large capacity applications.



(a)



(b)

Fig.1-28 C-core transformer

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For convenience sake, we introduce the characteristics of the ideal transformer. The ideal transformer means that the transformer has no losses.

1. Turns Ratio:

The turns ratio is the ratio between the number of turns in the primary N1 and the number of turns in the secondary N2.

$$\text{Turns ratio} = \frac{N1}{N2} = k$$

2. Voltage Ratio:

The voltage ratio is the ratio between the primary voltage V1 and the secondary voltage V2.

$$\frac{V1}{V2} = \frac{N1}{N2} = K$$

If the secondary voltage V2 is smaller than the primary voltage V1, the transformer is called a step-down transformer. If the secondary voltage V2 is greater than the primary voltage V1, the transformer is called a step-up transformer.

3. Current Ratio:

The current ratio is the ratio between the primary current I1 and the secondary current I2.

$$\frac{I2}{I1} = \frac{N1}{N2} = K$$

The current ratio is inversely proportional to the turns ratio or the voltage ratio.

$$\frac{I2}{I1} = \frac{V1}{V2} = \frac{N1}{N2} = K$$

4. Impedance Ratio:

From Z = V / I, the primary impedance Z_1 equals V_1 / I_1 or $I_1 = V_1 / Z_1$. The secondary impedance Z_2 is V_2 / I_2 or $I_2 = V_2 / Z_2$.

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$$V_1 \left(\frac{V1}{Z1}\right) = V2 \left(\frac{V2}{Z2}\right)$$

$$\frac{Z1}{Z2} = \left(\frac{V1}{V2}\right)^2$$

$$\frac{V1}{V2} = \frac{N1}{N2} = K$$

$$\frac{Z1}{Z2} = \left(\frac{N1}{N2}\right)^2 = K^2 \quad \text{or} \quad Z1 = Z2\,K^2$$

. Power Ratio:

The power in the secondary of the transformer is equal to the power in the primary. The input power in the primary is equal to $P1=V1xI1$ and the output power in the secondary is equal to $P2=V2xI2$. For an ideal transformer, the power ratio is 1 and therefore the efficiency is 100%.

The efficiency of the transformer is the ratio of the output power to the input power.

$$\text{Efficiency} = \frac{\text{Output power or energy}}{\text{Input power or energy}} = \frac{\text{Output power}}{\text{Output power+Dissipated power}}$$

From the above equation, the efficiency of a practical transformer is always less than 1 because the transformer exists a number of losses.

When using a power transformer, the following rules must be strictly followed to protect the transformer and to avoid electric shock:

1. A proper fuse(should be inserted in the line between the primary coil and line input.

2. Ambient temperature should be below 90°C.

3. Place the transformer apart from any audio or radio amplifiers as possible to prevent these devices from electromagnetic interference.

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4. Make sure that proper voltages and currents before using a power transformer.

5. Do not connect the coils to a dc power supply.

6. Do not pull the coil terminals.

7. Do not touch the transformer to avoid electric shock.

Supplied DC Voltages

The power supply unit provides two dc voltages: +5V and +12V. These two fixed voltages are provided by three-terminal IC regulators µA7805 and µA7812, respectively. Fig. 1-29 shows the schematic diagram of µA78Mxx series and µA78xx series devices.

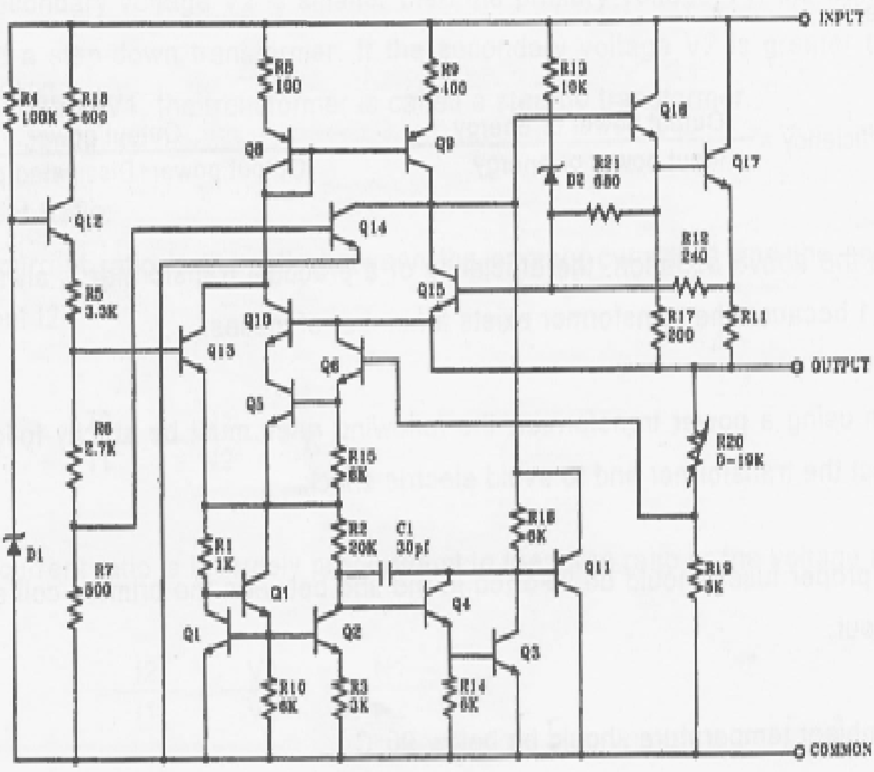

Fig.1-29 Schematic of µA78xx series

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The maximum output current of µA78xx series positive voltage regulators is approximately 1A, while µA78Cxx series and µA78Mxx series provide the maximum output current of about 0.5A. The maximum output current is determined by the resistors R9, R11, and R16.

The temperature-compensation circuit for 5-V reference is formed by transistors Q1~Q7 and resistors R1~R3, R10, and R14~R16, and capacitor C1. Darlington pair Q3-Q4 forms the voltage-error amplifier. Transistor Q11 acts as a dynamic load of the voltage-error amplifier and determines the gain of this amplifier. Transistors Q8 and Q9 form the current source circuit to supply the collector current of Q11. The base of Q13 is biased at the reference voltage of 5V. The reference voltage is developed by diode D1 and the series divider network consisting of the base-emitter junction of Q12, resistors R5, R6, and R7.

Transistor Q14 performs thermal overload protection. When the operating temperature increases over 175°C, Q14 conducts and diverts base drive from Q16-Q17 pass transistor to reduce output current.

Transistor Q15 is used for short-circuit current limiting. In normal operation, the Darlington pair Q16-Q17 performs the basic series-pass regulating function between the unregulated input voltage and the regulated output voltage. If the output is short-circuited, the large amount of output current flows through R11 and the voltage drop across this resistor increases, base drive is supplied to transistor Q15 so that it becomes increasingly conductive and diverts base drive from Q16-Q17 pass transistor to reduce output current. The components R11, R12, R13, D2, and Q15 perform the function of output transistor safe-area compensation to limit the ranges of output current and input-output voltage difference.

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EQUIPMENT REQUIRED

1 - Power Supply Unit KL-51001

1 - Isolation Transformer KL-58002

1 - Meter Unit KL-58001

PROCEDURE

☐1. Connect AC LINE INPUT of Power Supply Unit KL-51001 · KL-58002 to an AC outlet using the supplied power cord.

A. AC Voltage Measurements

☐2. Connect the ac voltmeter (0-110V scale) across the ac output terminals labeled AC18V and 0 with test leads.

☐3. Turn on the power. Measure and record the ac output voltage as indicated by the ac voltmeter.

Vac = ____________ V

☐4. Turn off the power. Exchange test leads and repeat step 3.

Vac = ____________ V

Is there good agreement between steps 3 and 4?

____

Turn off the power.

☐5. Connect the ac voltmeter (0-110V scale) across the ac output terminals labeled AC18V and AC18V with test leads.

☐6. Turn on the power. Measure and record the ac output voltage as indicated by the ac voltmeter.

Vac = ____________ V

☐7. Turn off the power. Exchange test leads and repeat step 6.

Vac = ____________ V

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Is there good agreement between steps 6 and 7?

____

State the relation between steps 7 and 4.

____

Turn off the power.

☐8. Connect the ac voltmeter (0-110V scale) across the ac output terminals labeled AC12V and 0 with test leads.

☐9. Turn on the power. Measure and record the ac output voltage as indicated by the ac voltmeter.

Vac = ____________ V

☐10. Turn off the power. Exchange test leads and repeat step 9.

Vac = ____________ V

Is there good agreement between steps 9 and 10?

____

Turn off the power.

☐11. Connect the ac voltmeter (0-110V scale) across the ac output terminals labeled AC12V and AC12V with test leads.

☐12. Turn on the power. Measure and record the ac output voltage as indicated by the ac voltmeter.

Vac = ____________ V

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☐13. Turn off the power. Exchange test leads and repeat step 12.

Vac = ____________ V

Is there good agreement between steps 12 and 13?

____

State the relation between steps 10 and 13.

____

Turn off the power.

B. DC Voltage Measurement

☐14. Connect the dc voltmeter (0-20V scale) across the dc output terminals labeled DC12V and GND with test leads. For the proper polarity connections, the terminal DC12V (the positive) should be connected to the terminal 20V (the positive) and the terminal GND (the negative) to terminal 0 (the negative).

☐15. Turn on the power. Measure and record the dc output voltage as indicated by the dc voltmeter.

Vdc = ____________ V

☐16. Turn off the power. Connect the dc voltmeter (0-20V scale) across the dc output terminals labeled DC5V and GND with test leads. The terminal DC5V should be connected to the terminal 20V and the terminal GND to terminal 0.

☐17. Turn on the power. Measure and record the dc output voltage as indicated by the dc voltmeter.

Vdc = ____________ V

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☐18. Turn off the power. Connect the dc voltmeter (0-10V scale) across the dc output terminals labeled DC5V and GND with test leads. The terminal DC5V should be connected to the terminal 10V and the terminal GND to terminal 0.

☐19. Turn on the power. Measure and record the dc output voltage as indicated by the dc voltmeter.

Vdc = ____________ V

Is there good agreement between steps 17 and 19?

CONCLUSION

The DC voltmeter is the measuring instrument used to measure dc voltages. It is always connected in parallel with the terminals of the circuit component whose voltage we wish to measure. Verify the polarity and measurement range before applying power to the circuit. Choosing a range too small or reversing the polarity will cause the pointer to hit the mechanical stop at the end of the scale. It will be impossible to obtain a valid reading in this case, and the voltmeter may be damaged.

The AC voltmeter is the measuring instrument used to measure ac voltages. The same rules about the DC voltmeter apply to the AC voltmeter except that the polarity is regardless.

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