3

Experiments for Rectifying Circuit

Chapter 3 Experiments for Rectifying Circuit

3.1 Study Objective:

(1) Understanding the principles and features of half-wave, full-wave and bridge rectifier.
(2) Understanding the principles of dual power supply and voltage doubler rectifier.
(3) Understanding the meaning of ripple factor and voltage regulation factor.

3.2 Basic Description:

3.2.1 New Terminology:

(1) Maximum Value (Emax or Em, Vmax or Vm)
Maximum value is also called peak value. For a waveform of AC signal that is usually in the form of sine wave, the largest instantaneous value in one cycle of this waveform is called the maximum value, as shown in Fig 3.1(a).

(2) Peak-to-peak Value (Vp-p or Ep-p)
Peak-to-peak value is the voltage difference between the maximum positive value and maximum negative value in one cycle. Vp-p of a sine wave is equal to 2 Vm, as shown in Fig 3.1(b).

(3) Effective Value (Vrms or Erms)
Effective value is also called root means square value, which can be expressed as the following equation.

$$Vrms = \sqrt{\frac{\int V^2 dt}{T}}$$

Its equivalent circuit is shown in Fig 3.2 (a) (b). When the heat generated by R1 is equal to that by R2, the effective value (Erms) of Eac is equal to E. The relation between effective value and maximum value is:

$$Vrms = 0.707Vm = Vm / \sqrt{2}$$

(4) Average Value (Vave or Eave)

Average value can be calculated from dividing the area of half cycle of the sine wave by the width of this half cycle. The relation between verage value and maximum value is:

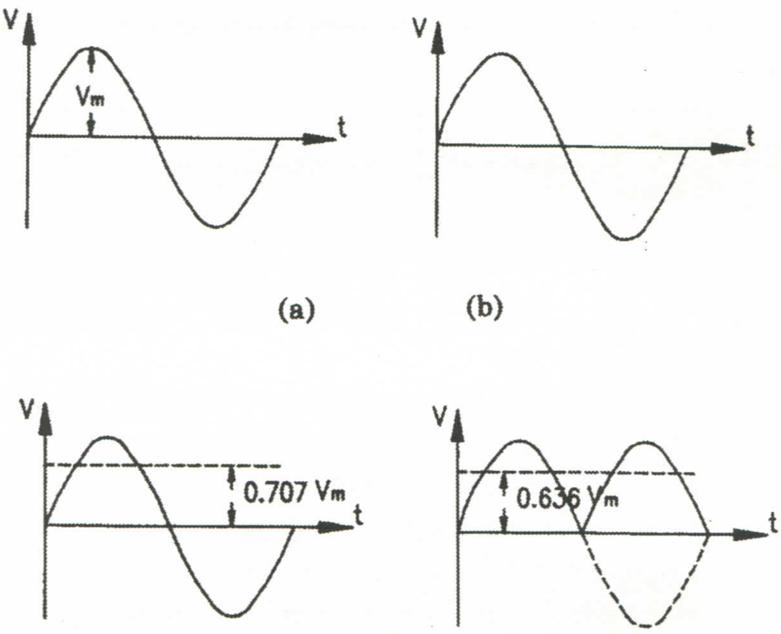
Vave = 0.636 Vm

∵ Vrms = 0.707 Vm

∴ Vrms / Vave = 0.707 / 0.636 = 1.11 -- waveform factor

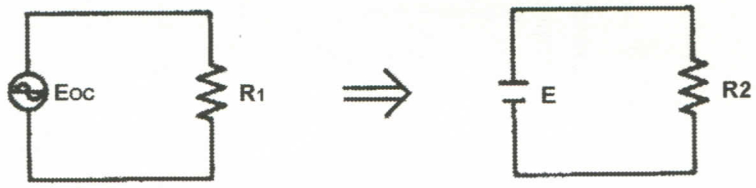
Vave / Vrms = 0.636 / 0.707 = 0.9

$$\text{Vm / Vave} = \text{Vm} / \frac{2}{\pi}\text{Vm} = \frac{\pi}{2} \quad \text{-- peak factor}$$



(a) (b) (c) (d)

Fig 3.1 (a) (b) (c) (d)



$$P = \frac{E^2 rms}{R} = \frac{E^2 ac}{R} = \frac{E^2}{R}$$

E=Erms

Fig 3.2 (a) (b)

3.2.2 Basic Principle:

(1) DC Power Supply

Electronic equipment requires DC power as the power supply. Besides the secondary battery and dry battery, the transformation from ACV to DCV is most frequently used for DC power supply. The complete DC power supply shall consist of all building blocks as shown in Fig 3. The AC electricity will be transformed into the required voltage through the transformer, then will be rectified as the pulsating DC by the rectifier. The pulsating DC will be turned into DC with minimum ripple by the filter. If the DC signal will be applied to a load with considerable verification of resistance, a voltage regulator shall be added. The most frequently used rectifiers are:
(1) half-wave rectifier, (2) full-wave rectifier, and (3) bridge rectifier.

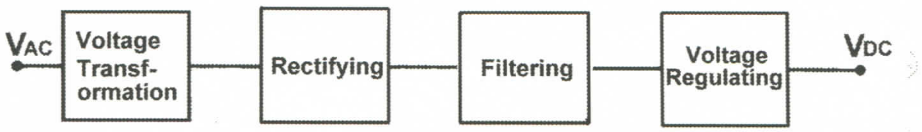


Fig 3.3

(2) Half-wave Rectifier

1) The half-wave rectifier is shown in Fig 3.4 (a). During the positive half cycle of input waveform Vi as shown in Fig 3.4 (b), the diode will be turned on, and the equivalent circuit is illustrated in Fig 3.4 (c) which has Vo = Vi. During the negative half cycle, the diode will be cut off, and the equivalent circuit is illustrated in Fig 3.4 (d). As shown in Fig 3.4 (b), Vo only appears in positive half cycle. We can get: Vdc = Vav = 0.9 Vrms / 2 = 0.45 Vrms.

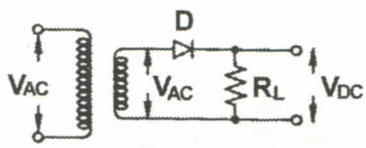


Fig 3.4 (a)

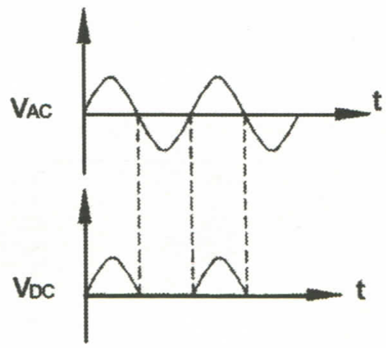


Fig 3.4 (b)

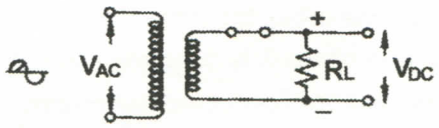


Fig 3.4 (c)

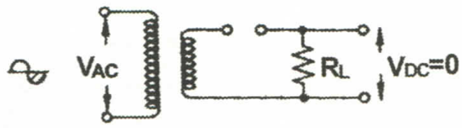


Fig 3.4 (d)

2) Half-wave Rectifier with a Filter Capacitor

The output waveform of the half-wave rectifier without a filter capacitor is shown in Fig 3.4 (b) Vo. The circuit of half-wave rectifier with a filter capacitor is shown in Fig 3.5 (a) and (b) which represent the situations of charge and discharge respectively. The output waveforms are shown in Fig 3.5 (c) and (d) which represent the situations of RL = 1KΩ and RL = ∞ respectively. The larger RL will result in the longer discharge interval, which will make the output voltage smoother.

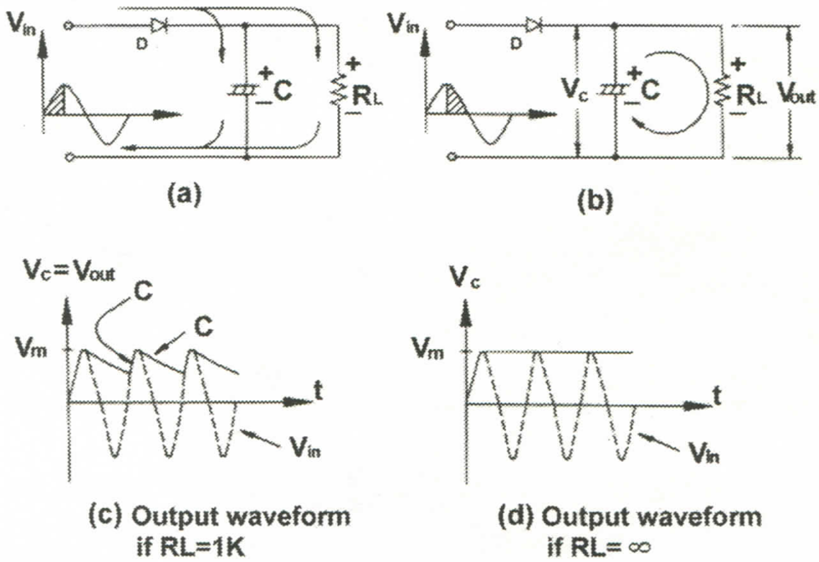


Fig 3.5 Half-wave Rectifier with a Filter Capacitor

(3) Full-wave Rectifier

The full-wave rectifier circuit is shown in Fig 3.6 (a). It shill be noted that a center-tapped transformer, with Vac1 = Vac2, must be used in this circuit.

1) During the positive half cycle, the input voltage Vac1 is shown in Fig 3.6 (b). As the upper end of Vac1 is positive and the lower end of Vac1 is negative, D1 will be forward conducted, whereas D2 will be reversely cut off. The equivalent circuit is shown in Fig 3.6 (c), and Vo is shown in Fig 3.6 (d).

2) During the negative half cycle, the input voltage Vac2 is shown in Fig 3.6 (e). As the upper end of Vac2 is negative and the lower end of Vac2 is positive, D2 will be forward conducted, whereas D1 will be reversely cut off. The equivalent circuit is shown in Fig 3.6 (f) in which the direction of current flowing through RL is same as positive half cycle, and Vo is shown in Fig 3.6 (g).

AC line voltage

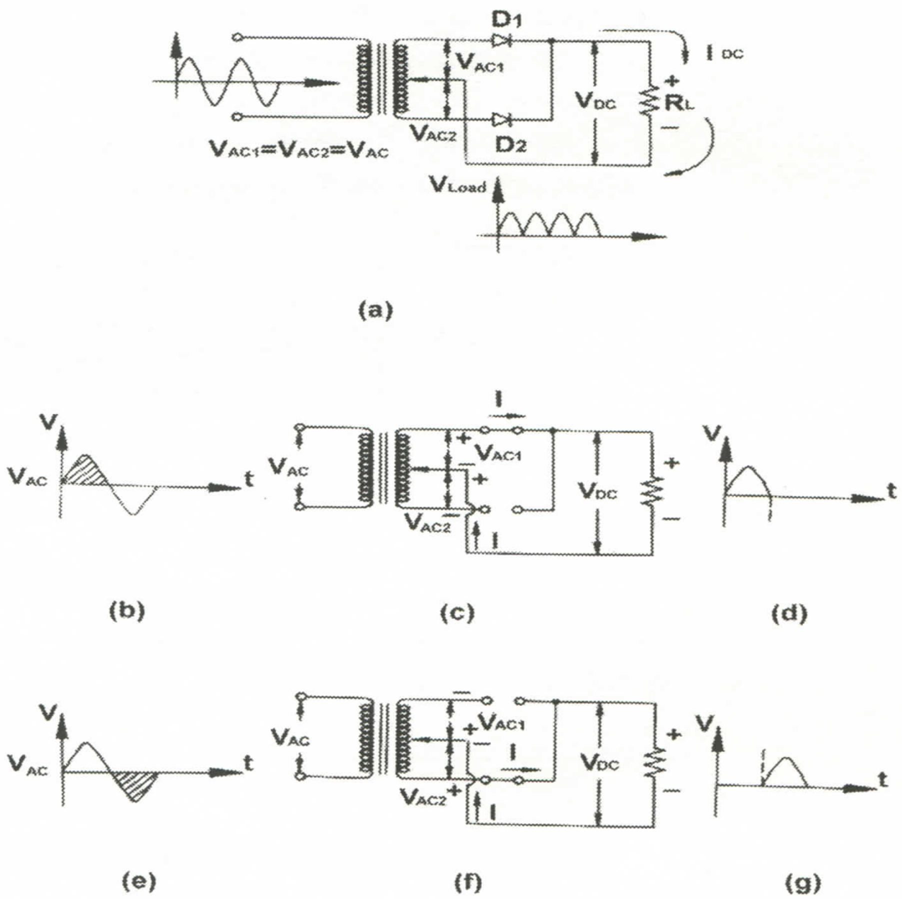


Fig 3.6 Full-wave Rectifier Circuit

(4) Bridge Rectifier

The bridge rectifier circuit is shown in Fig 3.7 (a), where in four diodes are utilized.

1) During the positive half cycle, the input voltage Vac is shown in Fig 3.7 (b). D1, D2 are forward conducted, and D3, D4 are reversely cut off. The equivalent circuit is shown in Fig 3.7 (c), and Vo is shown in Fig 3.7 (d).
2) During the negative half cycle, the input voltage Vac is shown in Fig 3.7 (e). D1, D2 are reversely cut off, and D3, D4 are forward conducted. The equivalent circuit is shown in Fig 3.7 (f), and Vo is shown in Fig 3.7 (g).

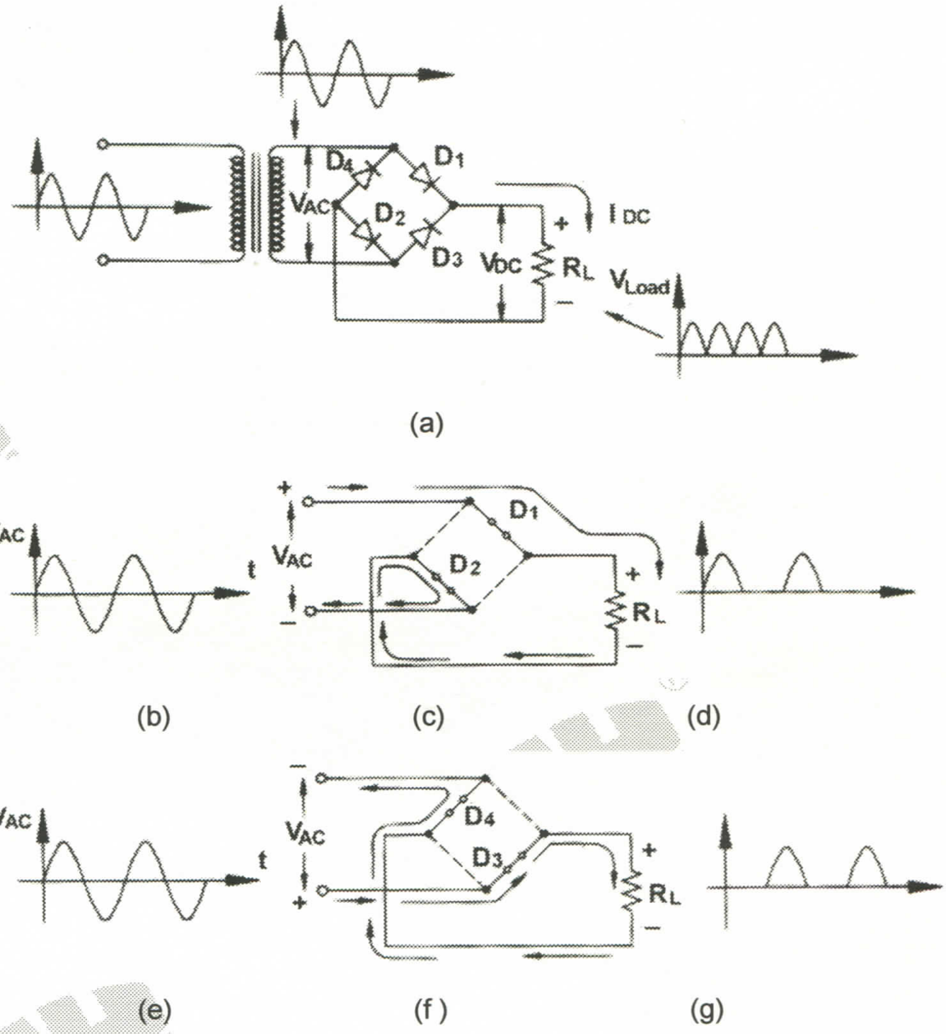


Fig 3.7 Bridge Rectifier Circuit

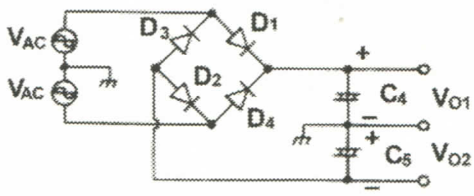
(5) Dual AC Line Voltage Rectifier

Dual power supply rectifier circuit is shown in Fig 3.8 (a), wherein one center-tapped transformer and four diodes will be utilized.

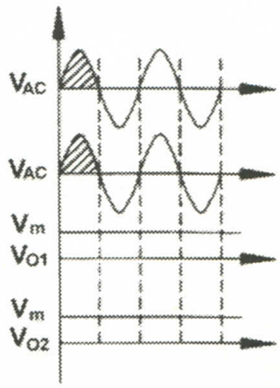
1) During the positive half cycle, the input voltages Vac1 and Vac2 are shown in Fig 3.8 (b). D1, D2 are forward conducted, and D3, D4 are reversely cut off. The equivalent circuit and current loop are shown in Fig 3.8 (c). C1 and C2 will be respectively charged by i1, i2, which will result in positive-voltage output Vo1 and negative-voltage output Vo2 (b is the ground point). During the negative half cycle, D3, D4 are forward conducted, and D1, D2 are reversely cut off. The equivalent circuit and current loop are shown in Fig 3.8 (d). C1 and C2 will be respectively charged by i3, i4 through the same charge loop as i1, i2, which will result in the same output polarity as positive half cycle.

2) Output voltage Vo1 = Vab

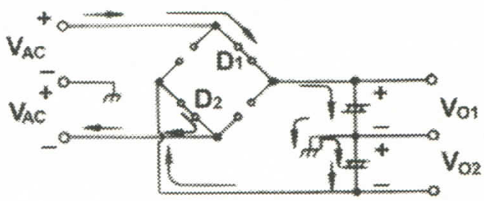
Vo2 = Vbc = -Vcb



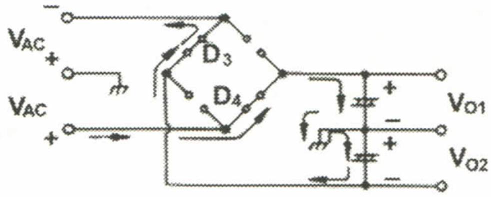
(a)



(b)



(c)



(d)

Fig 3.8

(6) Voltage Doubler Rectifier

The voltage doubler rectifiers can be classified into full-wave voltage doubler rectifier and half-wave voltage doubler rectifier. The half-wave voltage doubler rectifier can be further expanded to multiplying voltage doubler

1) Full-wave voltage doubler rectifier is shown in Fig 3.9

a. During the positive half cycle, the input voltage Vac is shown in Fig 3.10 (a). D1 is forward conducted, and D2 is reversely cut off. The equivalent circuit is shown in 3-10 (b). C1 will be charged to the peak value Vm of Vac, and the polarity is indicated by C1. The output voltage Voc1 is shown in Fig 3.10 (c).

b. During the negative half cycle, the input voltage Vac is shown in Fig 3.10 (d). D2 is forward conducted, and D1 is reversely cut off. The equivalent circuit is shown in 3-10 (e). C2 will be charged to the peak value Vm of Vac, and the polarity is indicated by C2. The output voltage Voc2 is shown in Fig 3.10 (f).

c. Vout = Vo1 + Vo2 = 2 Vm = 2($\sqrt{2}$ Vrms), and the waveform is shown in Fig 3.10 (g).

2) Half-wave voltage doubler rectifier is shown in Fig 3.11
   a. During the negative half cycle, the input voltage Vac is shown in Fig 3.12 (a). D1 is forward conducted, and D2 is reversely cut off. The equivalent circuit is shown in 3-12 (b). C1 will be charged to the peak value Vm of Vac, and the polarity is indicated by C1.
   b. During the positive half cycle, the input voltage Vac is shown in Fig 3.12 (a). D2 is forward conducted, and D1 is reversely cut off. The equivalent circuit is shown in 3-12 (d). C2 will be charged to the voltage equal to 2Vm.
   c. Vout = Vc2 = 2Vm (when R2 is maximum), and the waveform is shown in Fig 3.12 (e).

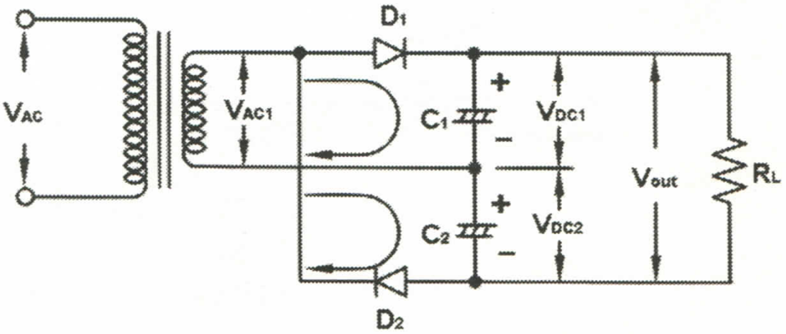
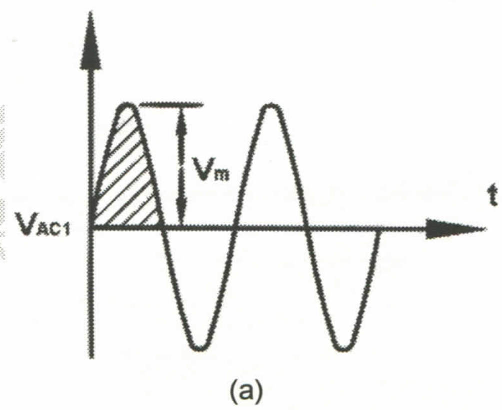
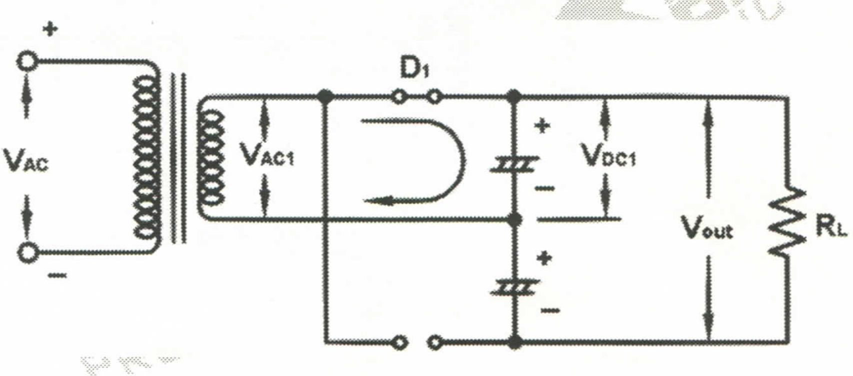


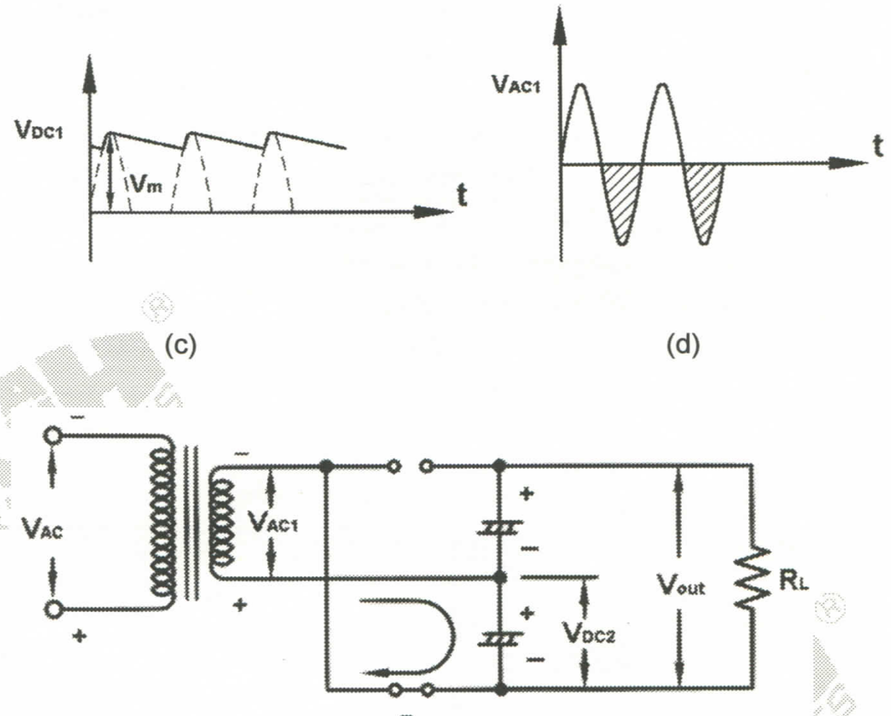
Fig 3.9



(a)



(b) Equivalent Circuit



(e) Equivalent Circuit

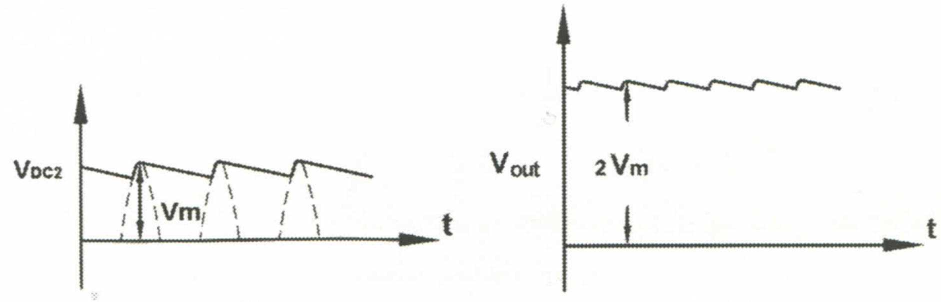


Fig 3.10

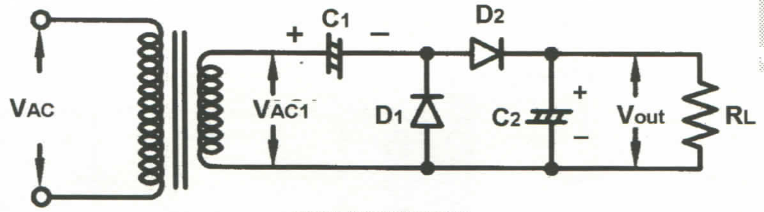
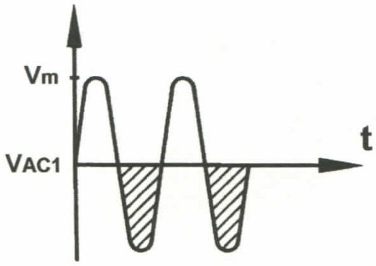
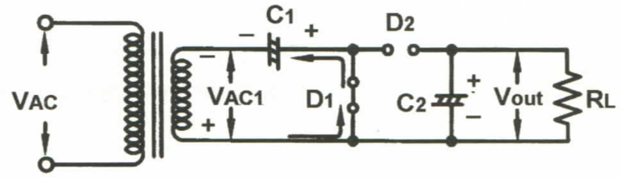


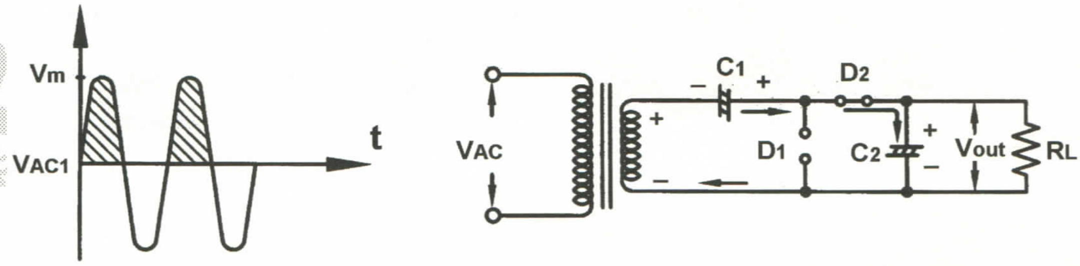
Fig 3.11 Half-wave Voltage Doubler Rectifier



(a)

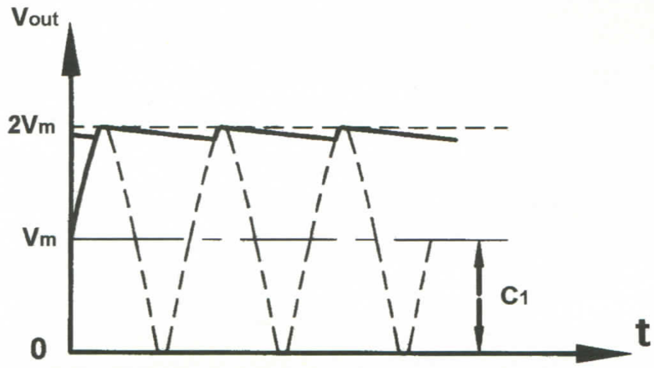


(b) Equivalent Circuit(negative half cycle)



(c)

(d) Equivalent Circuit (positive half cycle)



(e) voltage across two terminals

Fig 3.12

3) Multiplying Voltage Doubler Rectifier

The multiplying voltage doubler rectifier is shown in Fig 3.13. This circuit is expanded from the half-wave voltage doubler rectifier, also having the same principle as the half-wave voltage doubler rectifier. The output voltage and polarity are shown in Fig 3.13.

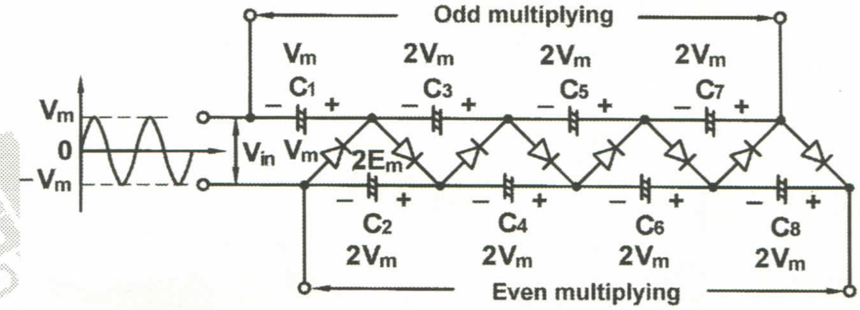


Fig 3.13 Multiplying Voltage Doubler Rectifier

(7) Filter Circuit

The output DC voltage of the rectifier circuit without a filter is in the nature of pulsating DC that makes it unsuitable as a DC source for electronic circuit. The filter circuit must be added to result in a stabilized DC. Filters can be classified into:

1) Capacitor Filter:

This is the most commonly used filter. Before the load is connected, Vo is equal to Vm, whereas Vdc will be less then Vm after the load is connected as shown in Fig 3.14. Disadvantageously, when the load is large (R is small), this filter circuit will result in large ripple and poor voltage regulation factor.

2) RC Filter:

This filter has better effect comparing with the filter with single capacitor. However, its disadvantages are lower DC output voltage and higher cost. When the value of R is increased, ripple will be reduced, but Vdc will also reduce.

3) π-Type Filter:

This filter uses an inductor to replace the R in the RC filter so that the ripple can be reduced (XL= 2 π fL, where the ripple frequency f is larger than DC frequency), while Vdc will not be reduced.

4) L-type Filter:

The filter function is implemented by using the characteristics of inductor, wherein the inductor will react against the variation of current. This filter is applicable in large load.

The circuit diagrams of various filters are shown in Fig 3.15.

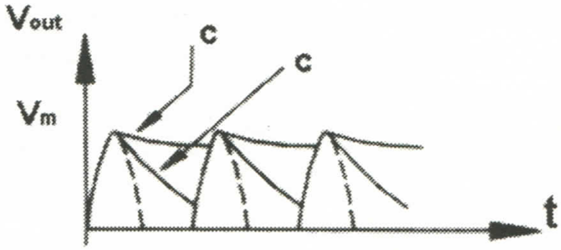
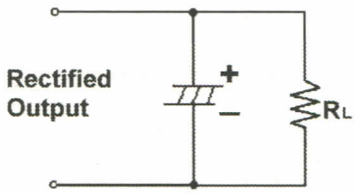
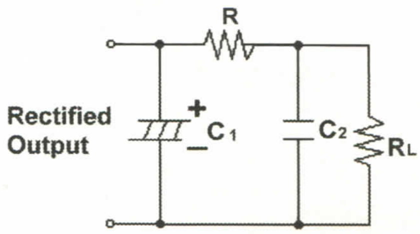


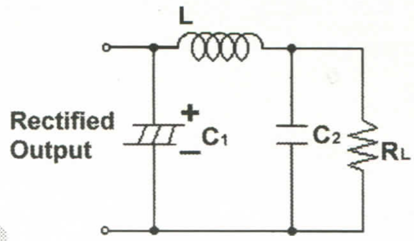
Fig 3.14 Output Waveform of Capacitor Filter



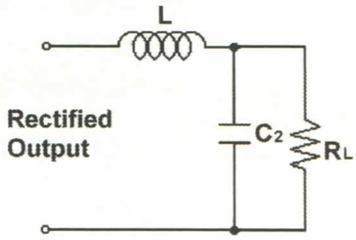
(a) C Filter



(b) RC Filter



(c) π-Type Filter



(d) L-type Filter

Fig 3.15 The Circuit Diagrams of Various Filters

Ripple:

The pulsating component of the output voltage in the DC power supply is referred to as ripple, as shown in Fig 3.16. The quality of the DC power supply can be identified by comparing with the ripple factor.

$$\text{Ripplefactor} \quad r = \frac{\text{effective value of ripple voltage}}{\text{DC voltage (averag evalue)}}$$

$$= \frac{Vr(rms)}{Vdc}$$

The waveform of ripple is not the sine wave, but is very similar to the sine wave. Typically, the Vr (rms) shall be calculated in terms of sine wave. However, to get the approximation,

$$Vr\,(rms) = \frac{Vin}{\sqrt{2}} = \frac{V}{2\sqrt{2}}$$

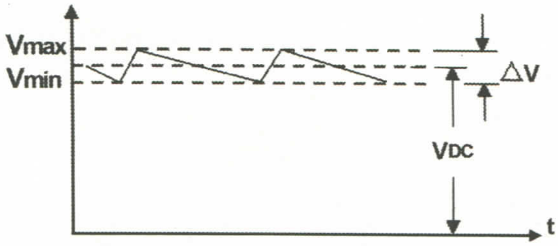


Fig 3.16 Peak-to-peak Value of Ripple Voltage

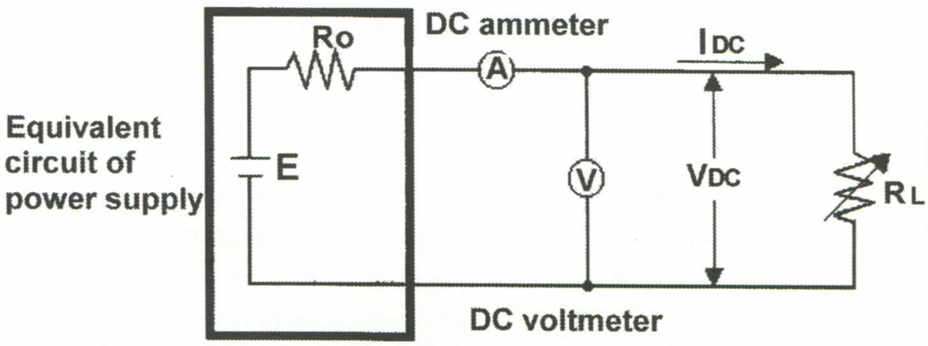
(8) Voltage Regulation Factor

The equivalent circuit of a power supply is shown in Fig 3.17. While the load is connected, Vo, responsive to the resistance variation of the load, will also be varied. The variation status can be expressed by voltage regulation factor (VR %), wherein the smaller VR % indicates the better performance of this power supply.

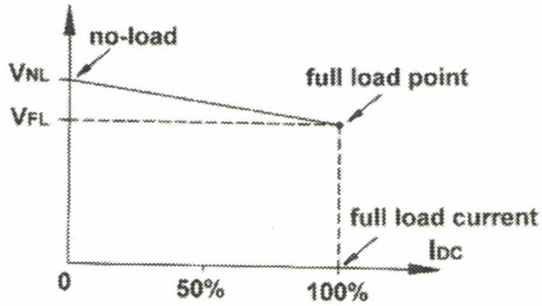
$$\text{Voltage regulation factor} = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$$

V_{NL}: Vo during no-load.

V_{FL}: Vo during full load.



(a) Test Circuit for Voltage Regulation Factor



Percentage of load current versus full load current

(b) Voltage Regulation Factor Curve

Fig 3.17

3.3 Experiment Equipments:

(1) KL-200 Linear Circuit Lab.
(2) Experiment Module : KL-23002.
(3) Experiment Instrument : 1. Multimeter.
2. Oscilloscope.
(4) Tools : Basic hand tools.
(5) Materials : As indicated in the KL-23002.

3.4 Experiment Items:

Item one (3-1): Experiment for half-wave rectifier circuit

3-1-1 Half-wave rectifier circuit without a filter capacitor

3-1-1-1 Experiment Procedures:

(1) Firsts fix the module KL-23002 in the KL-200 Linear Circuit Lab, then locates the block marked 23001-block c.

(2) a. Insert the short-circuit clip by referring to Fig 3-1(a) and the short-circuit clip arrangement diagram 23002-block c.1.
b. Apply AC source 9V to Vac.
c. Measure V by using ACV scale of multimeter and oscilloscope respectively, then record in Table 3-1 (a).

d. Measure the output terminal (OUT) by using DCV scale of multimeter and oscilloscope, wherein the DC scale of oscilloscope will be used to test Vdc and the AC scale of oscilloscope will be used to test the ripple. Then record in Table 3-1 (a).

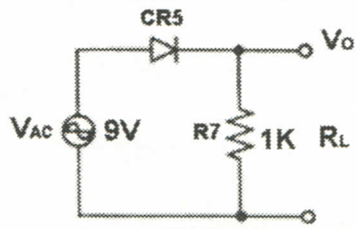


Fig 3-1 (a)

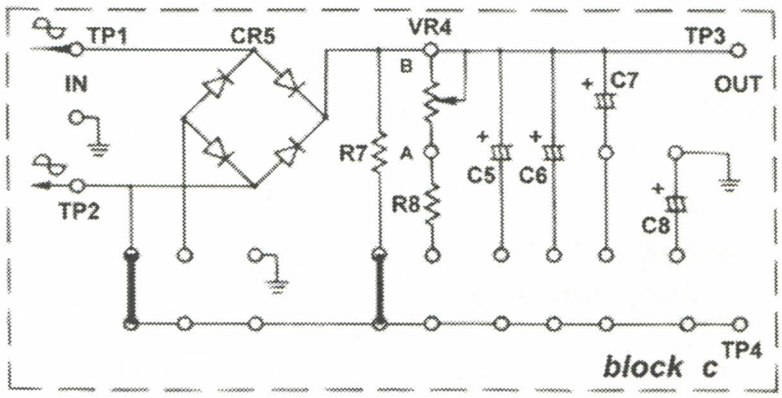


Fig 23002-block c.1

3-1-1-2 Experiment Result: Indicated in Table 3-1 (a).

3-1-2 Half-wave rectifier circuit with a filter capacitor

3-1-2-1 Experiment Procedures:

(1) a. Insert the short-circuit clip by referring to Fig 3-1(b) and the short-circuit clip arrangement diagram 23002-block c.2. (C6: 220 μ)

b. Apply AC source 9V to Vac.

c. Measure input terminal (Vac) by using ACV scale of multimeter and oscilloscope respectively, then record in Table 3-1 (a).

d. Adjust VR4 (VR1M Ω)to minimum, then measure the output terminal (OUT) by using DCV scale of multimeter and oscilloscope, wherein the DC scale of oscilloscope will be used to test Vdc and the AC scale of oscilloscope will be used to test Vr (ripple). Then record in Table 3-1 (a).

e. Adjust VR4 (VR1M Ω)to maximum, then repeat step (1)-d.

(2) a. Insert the short-circuit clip by referring to the short-circuit clip arrangement diagram 23002-block c.3.(Change C6 to C5, change R_L to 1KΩ).

b. Measure output-terminal (OUT) by using DCV scale of multimeter and oscilloscope respectively, wherein the DC scale of oscilloscope will be used to test Vdc and the AC scale of oscilloscope will be used to test Vr(ripple). Then record in Table 3-1 (a).

3-1-2-2 Experiment Result: Record in Table 3-1 (a).

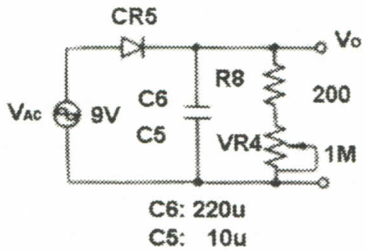


Fig 3-1 (b)

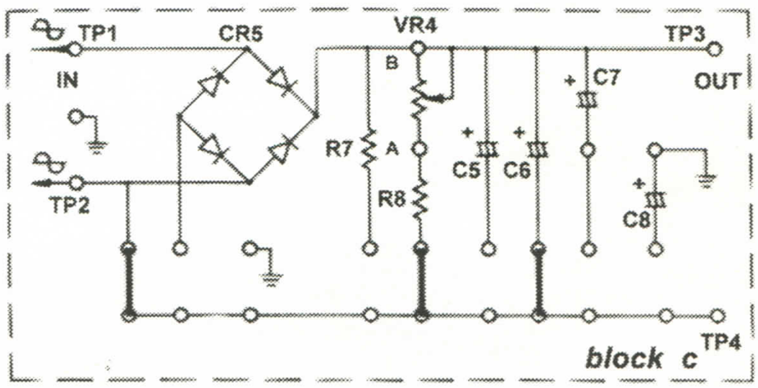


Fig 23002-block c.2

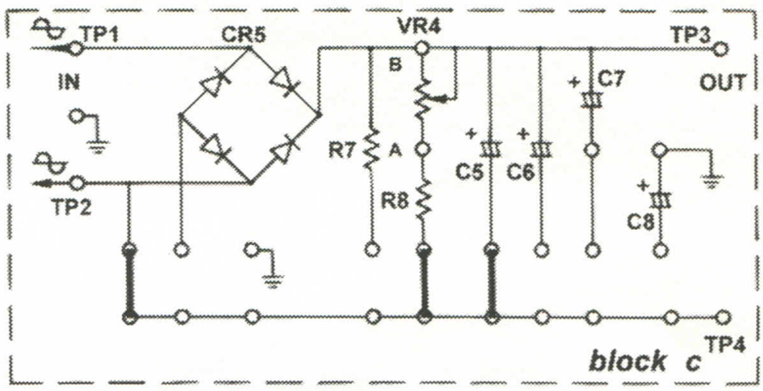


Fig 23002-block c.3

Item two (3-2): Experiment for full-wave rectifier circuit

3-2-1 Full-wave rectifier circuit without a filter capacitor

3-2-1-1 Experiment Procedures:

(1) Firsts fix the module KL-23002 in the KL-200 Linear Circuit Lab, then locates the block marked 23001-block c.

(2) a. Insert the short-circuit clip by referring to Fig 3-2(a) and the short-circuit clip arrangement diagram 23002-block c.4.

b. Apply AC source 9V-0V. 0V-9V to Vac1 and Vac2 respectively.

c. Measure Vac1, Vac2 by using ACV scale of multimeter and oscilloscope respectively, then record in Table 3-1 (b).

d. Measure the output terminal (OUT) by using DCV scale of multimeter and oscilloscope, wherein the DC scale of oscilloscope will be used to test Vdc and the AC scale of oscilloscope will be used to test the ripple. Then record in Table 3-1 (b).

3-2-1-2 Experiment Result: Record in Table 3-1 (b).

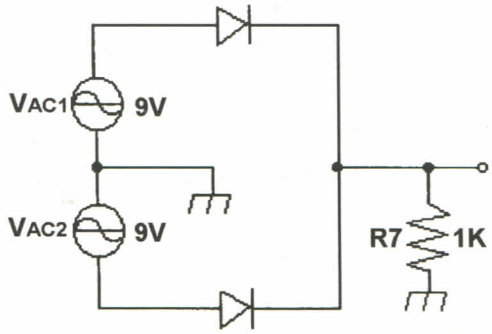


Fig 3-2 (a)

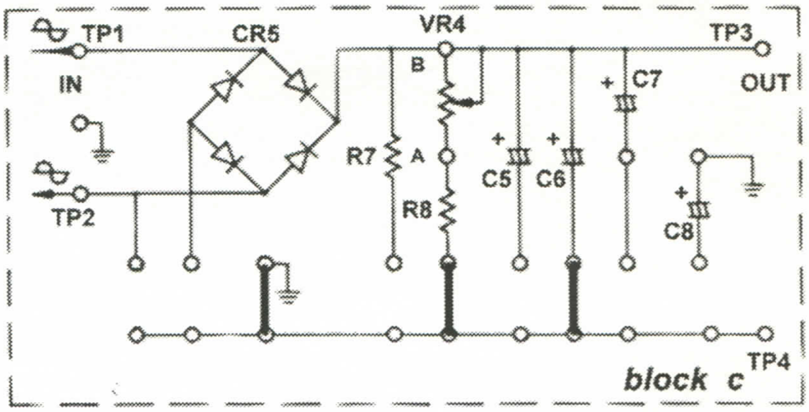


Fig 23002-block c.4

3-2-2 Full-wave rectifier circuit with a filter capacitor

3-2-2-1 Experiment Procedures:

(1) a. Insert the short-circuit clip by referring to Fig 3-2(b) and the short-circuit clip arrangement diagram 23002-block c.5. (C6: 220 μ)

b. Apply AC source 9V-0V,0V-9V to Vac1,Vac2 respectively.

c. Measure Vac1, Vac2 by using ACV scale of multimeter and oscilloscope respectively, then record in Table 3-1 (b).

d. Adjust VR4 (VR1M Ω) to minimum, then measure the output terminal (OUT) by using DCV scale of multimeter and oscilloscope, wherein the DC scale of oscilloscope will be used to test Vdc and the AC scale of oscilloscope will be used to test Vr (ripple). Then record in Table 3-1 (b).

e. Adjust VR4 (VR1M Ω) to maximum, then repeat step d.

(2) a. Insert the short-circuit clip by referring to the short-circuit clip arrangement diagram 23002-blockc.6. (Change C6 to C5, change R_L to 1KΩ).

b. Measure output-terminal (OUT) by using DCV scale of multimeter and oscilloscope respectively, wherein the DC scale of oscilloscope will be used to test Vdc and the AC scale of oscilloscope will be used to test Vr(ripple). Then record in Table 3-1 (b).

3-2-2-2 Experiment Result: Record in Table 3-1 (b).

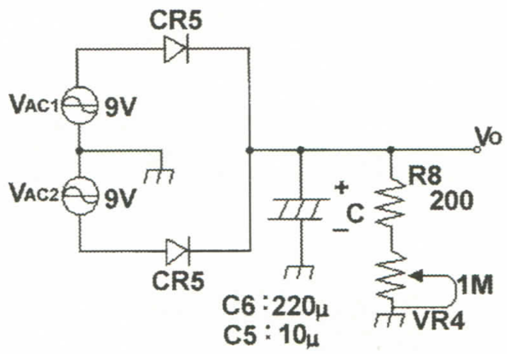


Fig 3-2 (b)

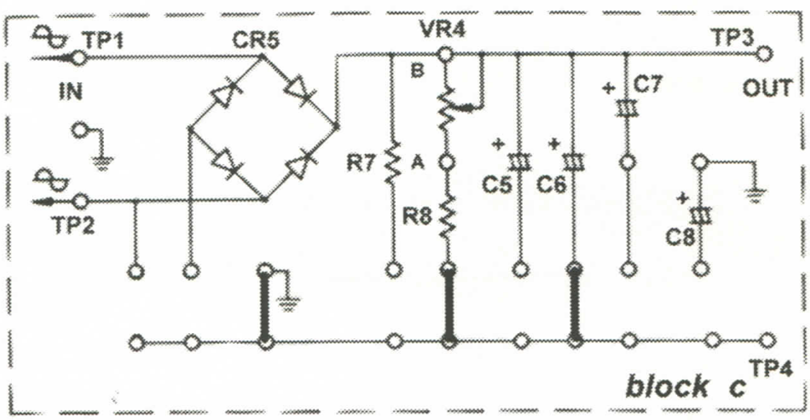


Fig 23002-block c.5

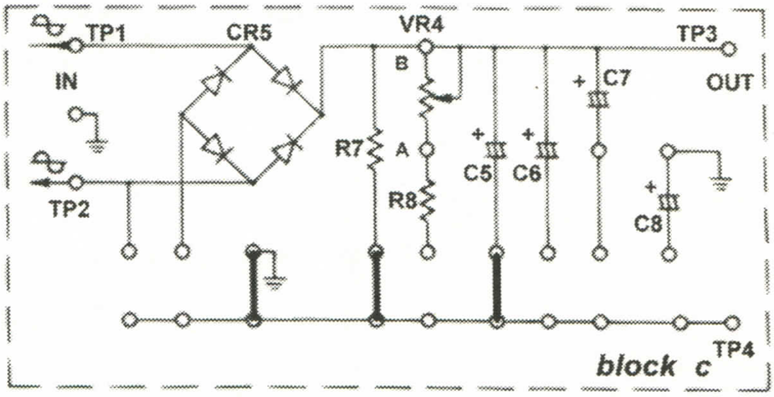


Fig 23002-block c.6

Item three (3-3): Experiment for bridge rectifier circuit

3-3-1 Bridge rectifier circuit without a filter capacitor

3-3-1-1 Experiment Procedures:

(1) Firsts fix the module KL-23002 in the KL-200 Linear Circuit Lab, then locates the block marked 23001-block c.

(2) a. Insert the short-circuit clip by referring to Fig 3-3(a) and the short-circuit clip arrangement diagram 23002-block c.7.

b. Apply AC source 18V to Vac.

c. Measure Vac by using ACV scale of multimeter and oscilloscope respectively, then record in Table 3-1 (c).

d. Measure the output terminal (OUT) by using DCV scale of multimeter and oscilloscope, wherein the DC scale of oscilloscope will be used to test Vdc and the AC scale of oscilloscope will be used to test Vr(ripple).Then record in Table 3-1 (c).

3-3-1-2 Experiment Result: Record in 3-1 (c).

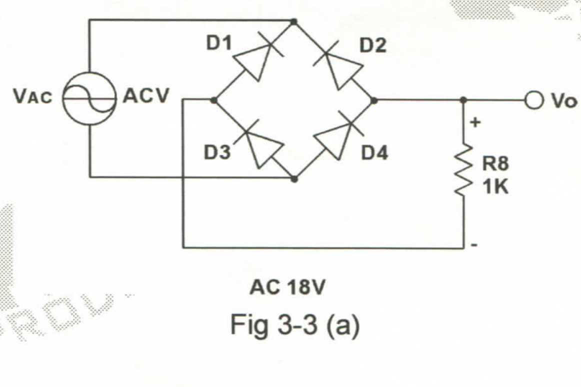


Fig 3-3 (a)

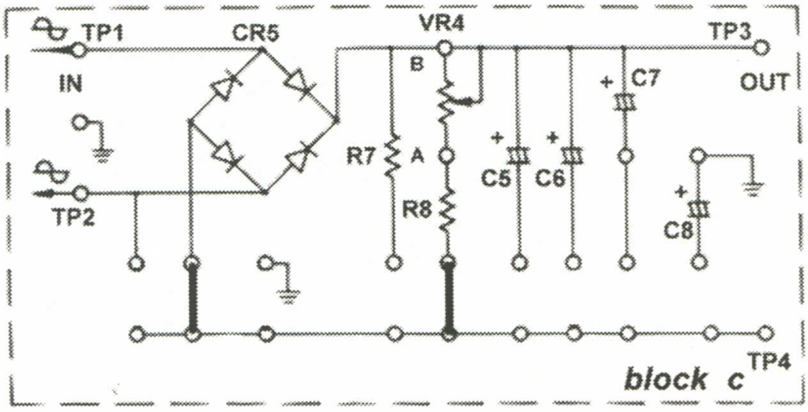


Fig 23002-block c.7

3-3-2 Bridge rectifier circuit with a filter capacitor

3-3-2-1 Experiment Procedures:

(1) a. Insert the short-circuit clip by referring to Fig 3-3(b) and the short-circuit clip arrangement diagram 23002-block c.8. (C7: 100μF)

b. Apply AC source 18V to Vac.

c. Measure Vac by using ACV scale of multimeter and oscilloscope respectively, then record in Table 3-1 (c).

d. Adjust VR4 (VR1MΩ) to minimum, then measure the output terminal (OUT) by using DCV scale of multimeter and oscilloscope, wherein the DC scale of oscilloscope will be used to test Vdc and the AC scale of oscilloscope will be used to test Vr (ripple). Then record in Table 3-1 (c).

e. Adjust VR4 (VR1MΩ) to maximum, then repeat step d.

(2) a. Insert the short-circuit clip by referring to the short-circuit clip arrangement diagram 23002-block c.9.(Change C7 to C5, change R_L to 1KΩ).

b. Measure output terminal (OUT) by using DCV scale of multimeter and oscilloscope respectively, wherein the DC scale of oscilloscope will be used to test Vdc and the AC scale of oscilloscope will be used to test Vr(ripple). Then record in Table 3-1 (c).

3-1-2-2 Experiment Result: Record in Table 3-1 (a).

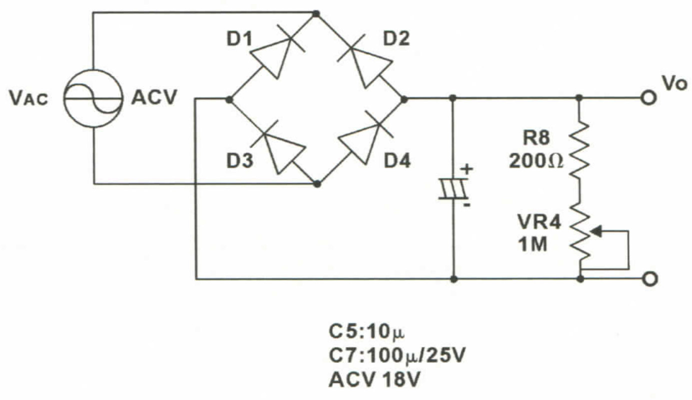


Fig 3-3 (b)

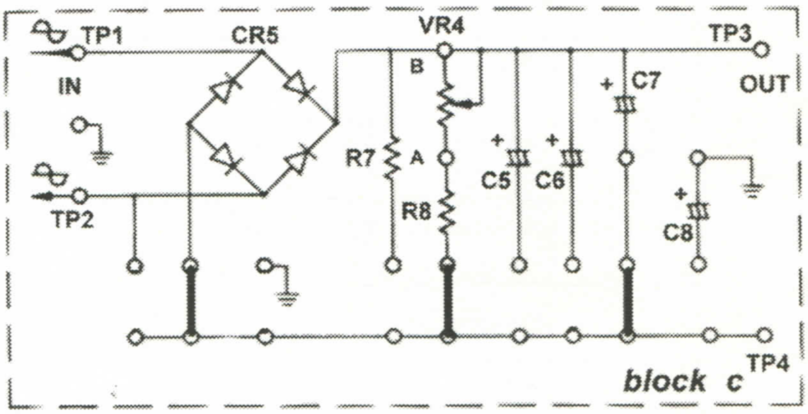


Fig 23002-block c.8

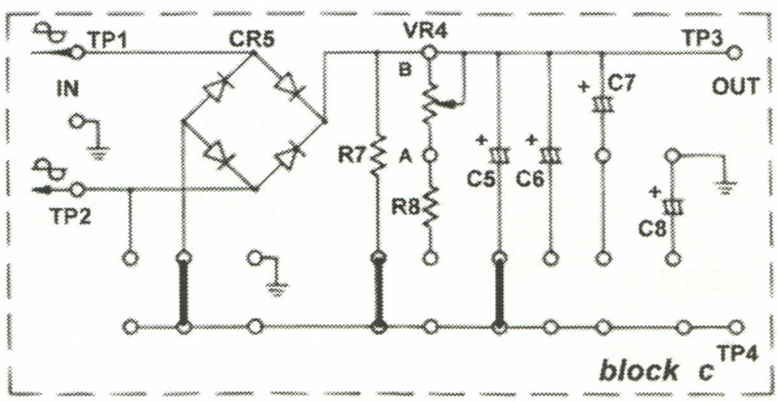


Fig 23002-block c.9

Circuit \ Test point \ Vrms/Vp-p		Multimeter		Oscilloscope		
		DC	AC	IN	OUT	
					Vdc	Vr
a	Without C					
Half-wave	C6:220u VR4:MAX.					
	C6:220u VR4:MIN.					
	C5:10u R : 1K					
b	Without C					
Full-wave	C6:220u VR4:MAX.					
	C6:220u VR4:MIN.					
	C5:10u R : 1K					
c	Without C					
Bridge-wave	C6:220u VR4:MAX.					
	C6:220u VR4:MIN.					
	C5:10u R : 1K					

Table 3-1

Item four (3-4): Experiment for dual power supply rectifier circuit

3-4-1

3-4-1-1 Experiment Procedures:

(1) Firsts fix the module KL-23002 in the KL-200 Linear Circuit Lab, then locates the block marked 23001-block c.

(2) a. Insert the short-circuit clip by referring to Fig 3-4(a) and the short-circuit clip arrangement diagram 23002-block c.10.

b. Apply AC source 9V-0V. 0V-9V to Vac1 and Vac2 respectively.

c. Measure Vac1, Vac2 by using ACV scale of multimeter and oscilloscope respectively, then record in Table 3-2 (a).

d. Measure Vdc1, Vdc2 and Vdc3 by using DCV scale of multimeter and oscilloscope respectively, then record in Table 3-2 (a).

3-4-1-2 Experiment Result: Record in Table 3-2 (a).

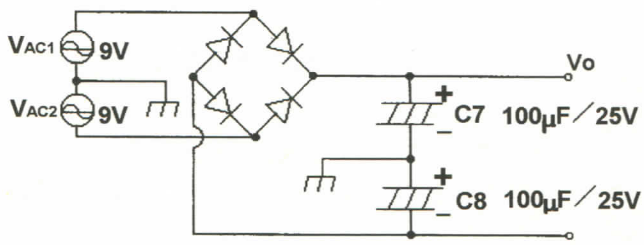


Fig 3-4 (a)

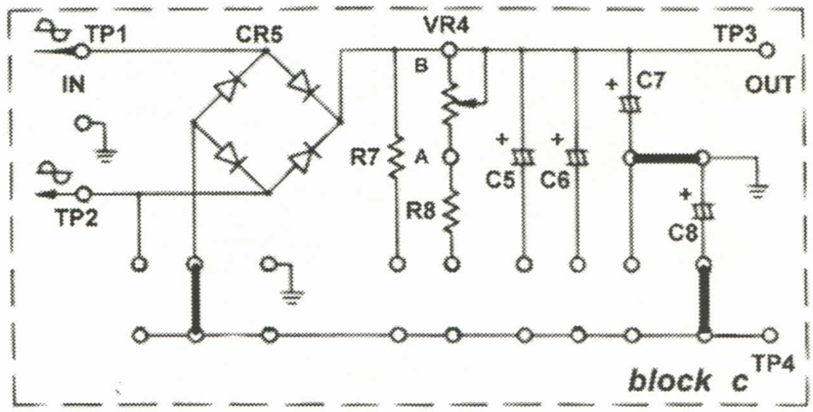


Fig 23002-block c.10

Item five (3-5): Experiment for voltage doubler rectifier circuit

3-5-1

3-5-1-1 Experiment Procedures:

(1) Firsts fix the module KL-23002 in the KL-200 Linear Circuit Lab, then locates the block marked 23001-block b.

(2) a. Insert the short-circuit clip by referring to Fig 3-5(a) and the short-circuit clip arrangement diagram 23002-block b.

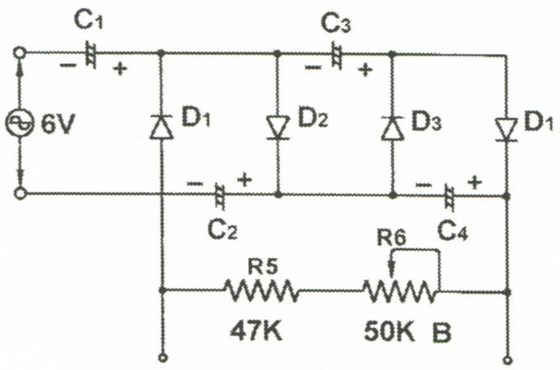
b. Apply AC source 9V to Vac, then adjust R6 (SVR50K) to minimum.

c. Measure Vac by using ACV scale of multimeter and oscilloscope respectively, then record in Table 3-2 (b).

d. Measure VC1, VC2, VC3 and VC4 by using DCV scale of multimeter and oscilloscope respectively, then record in Table 3-2 (b).

e. Adjust R6(SVR50K) to maximum, then measure the voltage across the two terminals of R_L by using DCV scale of multimeter and oscilloscope respectively, wherein the DC scale of oscilloscope will be used to test Vdc and the AC scale of oscilloscope will be used to test Vr(ripple). Then record in Table 3-2 (b).

3-5-1-2 Experiment Result: Record in Table 3-2 (b).



C1=C2=C3=C4=100 μ/50V

Fig 3-5 (a)

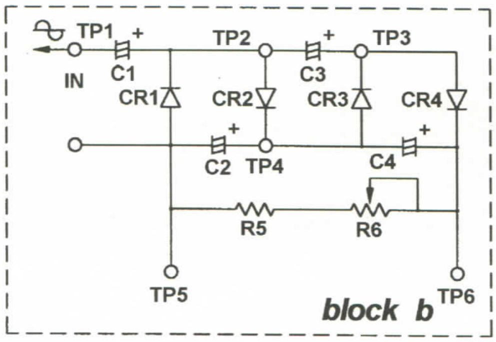


Fig 23002-block b

Instrument / Test point / Circuit		Multieter				Oscilloscope			
		Vac1	Vac2	Vdc1	Vdc2	Vac1	Vac2	Vdc1	Vdc2
a	Dual power supply					V, t Vpp	V, t Vpp	V, t Vdc	V, t Vdc

Instrument / Test point / Circuit			Multimeter					
			Vac(ACV)	Vc1	Vc2	Vc3	Vc4	V_{RL}
b	voltage doubler	R6 MAX.						
b	voltage doubler	R6 MIN.						
			Oscilloscope					
b	voltage doubler	R6 MAX.	V, t	V, t	V, t	V, t	V, t	V, t
b	voltage doubler	R6 MIN.	V, t	V, t	V, t	V, t	V, t	V, t

Table 3-2 (a) (b)

3.5 Experiment Discussion:

The rectifier circuits introduced in this unit include:

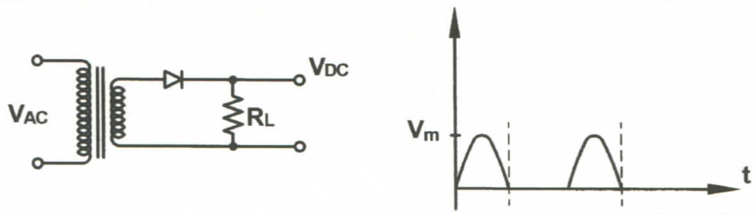
(1) half-wave rectifier circuit;

(2) full-wave rectifier circuit;

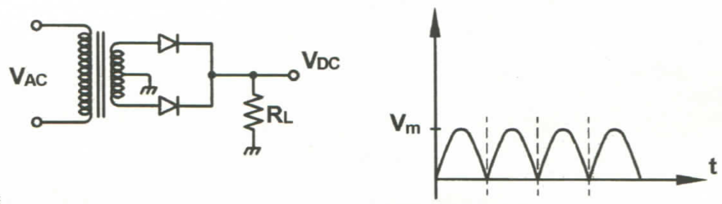
(3) bridge rectifier circuit.

Dual power supply rectifier and voltage doubler rectifiers are respectively the applications of full-wave rectifier and half-wave rectifier. We will summarize the results of various rectifier circuits under different loads as follows.

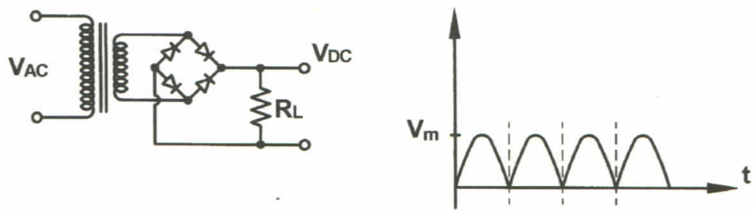
(1) Output waveforms comparison among the rectifier circuits without a filter capacitor.



(a) Half-wave rectifier



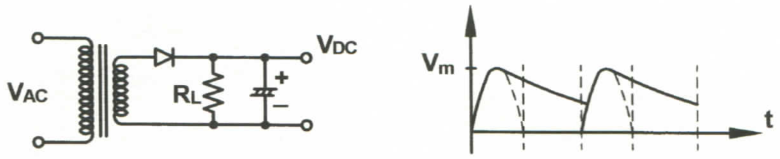
(b) Full-wave rectifier



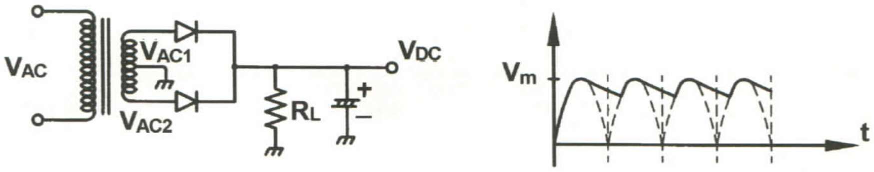
(c) Bridge rectifier

Fig (1)

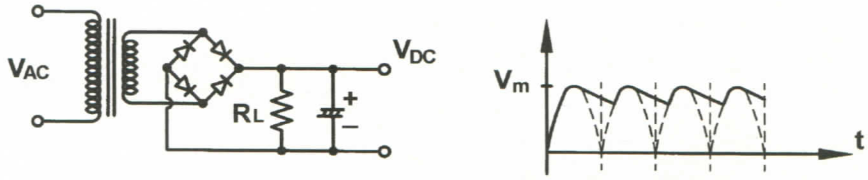
(2) Output waveforms comparison among the rectifier circuits with a filter capacitor.



(a) Half-wave rectifier



(b) Full-wave rectifier



(c) Bridge rectifier

Fig (2)

(3) Comparison among various

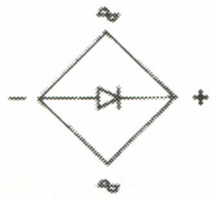
Classification \ Item / Load		Transformer	Diode	Withstand Voltage of Diode (PIV)	Withstand Voltage of Capacitor	Vdc	Ripple Freq.
Half-wave	R	single	one	Vm	———	0.318Vm 0.45Vac	60Hz
	R//C	single	one	2Vm	Vm	≒Vm	
	C	single	one	2Vm	Vm	=Vm	
Full-wave	R	Center-tapped	two	2Vm	———	0.636Vm 0.9Vac	120Hz
	R//C	Center-tapped	two	2Vm	Vm	≒Vm	
	C	Center-tapped	two	2Vm	Vm	=Vm	
Bridge	R	single	four	Vm	———	0.636Vm 0.9Vac	120Hz
	R//C	single	four	Vm	Vm	≒Vm	
	C	single	four	Vm	Vm	=Vm	

Table (1)

Vac → Vrms

Four diodes are equal to one bridge rectifier.

The withstand voltages indicated in Table (1) are theoretical values. The realistic values shall be 1.2 times of the theoretical values. The symbol of the rectifier is shown as follows:



The output voltage that hasn't gone through filter is called pulsating DC.

(4) The magnitude of the maximum output current of the rectifier circuit will be affected by the following factors:

1) Output current (power) of the transformer, and
2) Withstand current of the diodes (rectifier).

(5) If the load resistance is small, the output DC voltage will be varied as follows:

1) The ripple will become larger.
2) The effective voltage will become lower

$$\text{Voltage regulation factor} = \frac{\text{no\_load Vdc} - \text{full\_load Vdc}}{\text{full} - \text{load Vdc}} \times 100\%$$

$$= \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$$

The outputs of dual power supply rectifier, which is the application of full-wave rectifier, are +Vdc and –Vdc respectively. If the loads are identical, ｜+Vdc｜=｜-Vdc｜. Voltage doubler rectifier circuits can be classified into full-wave voltage doubler and half-wave voltage doubler. Three multiplying voltages doubler and universal voltage doublers were developed from the concept of half-wave voltage doubler. Voltage doublers typically have high voltage and low current output. The high voltage used in television set is two multiplying voltages doubler or three multiplying voltages doubler. Various voltage doubler circuits are shown in the following figures.

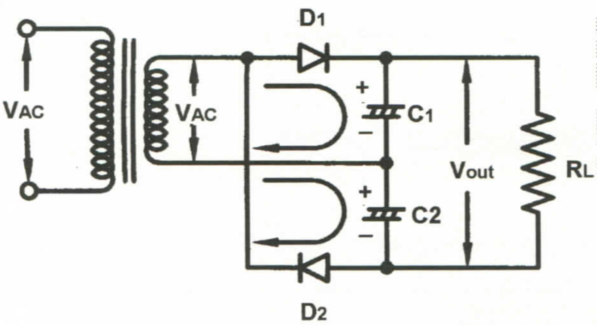


Fig 3 Full-wave Voltage Doubler

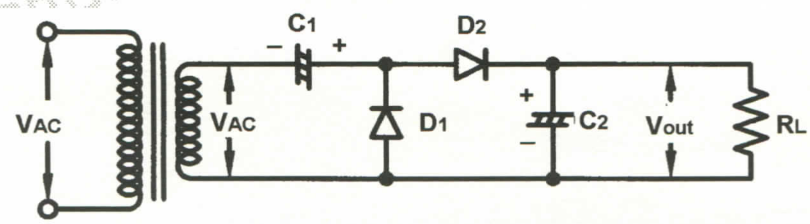


Fig 4 Half-wave Voltage Doubler

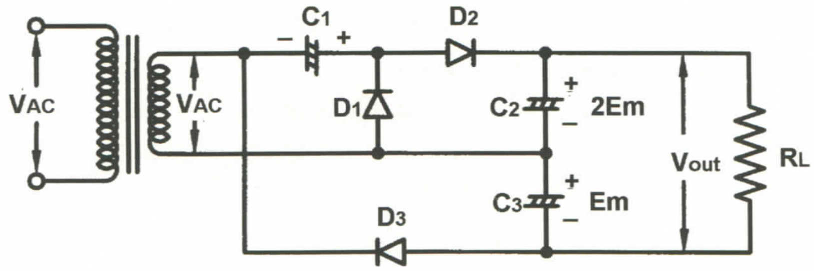


Fig 5 Half-wave Three Multiplying Voltage Doubler

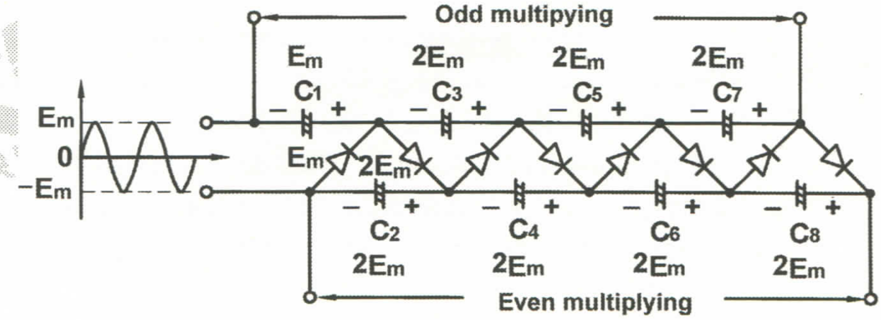


Fig 6 Universal Voltage Doubler

3.6 Repairs for Simulated Faults

Carry out the following repairs by referring to the test results of instruments along with the operating principle, but the electric iron is not allowed to be used. Briefly describe your steps for repairs.

3-1: Half-wave rectifier as shown in Fig 3-1 (a)

1. Fault phenomenon: There is no voltage output.
2. Fault parts:
3. Steps for repairs:

3-2: Full-wave rectifier as shown in Fig 3-2 (a)

1. Fault phenomenon: There is only half-wave output.
2. Fault parts:
3. Steps for repairs:

3-3: Bridge rectifier as shown in Fig 3-3 (a)

1. Fault phenomenon:
   ① There is only output in positive half cycle.
   ② Vo = 0.
2. Fault parts:
3. Steps for repairs:

3.7 Problems:

(1) Selection:

( ) 1. For half-wave rectifier, which is correct among the following descriptions:

1. Vdc = 0.636Vm.
2. Vdc = 0.9Vac, Vac = Vrms
3. Vdc = 0.318Vm

( ) 2. For full-wave rectifier, which is correct among the following descriptions:

1. Use center-tapped transformer.
2. Use one diode.
3. Vdc = 0.318Vm.

( ) 3. The maximum withstands voltage for the diode in the full-wave rectifier shall be:

1. 2Vm.
2. Vm.
3. 4Vm.

( ) 4. If the load resistance is not connected to the rectifier (only the filter capacitor is connected),

1. Vdc = 0.318Vm.
2. Vdc = 0.45Vac.
3. Vdc = Vm.

( ) 5. The smaller the load resistance of the rectifier, for Vdc:

1. the larger the ripple.
2. the smaller the ripple.
3. the ripple remains unchanged.

( ) 6. For rectifier circuits, which is wrong among the following descriptions:

1. Rectifier circuits only deliver positive voltage.
2. Rectifier circuits only have clamping function.
3. Rectifier circuits convert ACV to DCV.

( ) 7. The withstand voltage of the diodes in the bridge rectifier shall be:

1. PIV = 2Vm.
2. PIV = Vm.
3. PIV = Vdc.

( ) 8. For bridge rectifier, which is wrong among the following descriptions:

1. Use four diodes.
2. Use center-tapped transformer.
3. Its output waveform is it as the full-wave rectifier.

( ) 9. The ripple frequency of the bridge rectifier is:

1. 60Hz.
2. 240Hz.
3. 120Hz.

( ) 10. The rectified output voltage that has not gone through filter is called:

1. pulsating DC.
2. stabilized DC.
3. voltage with positive polarity.

( ) 11. For voltage doubler circuits, which is correct among the following descriptions:

1. Half-wave voltage doubler uses one diode.
2. Vo of the half-wave voltage doubler is 2Vm.
3. The maximum multiplying voltage for voltage doubler circuit is two times.

(2) Practice:

1. Use the following materials to complete a bridge rectifier circuit that can convert AC110V to DC12V.

Materials:

①	AC power cord:	110V / 5A	x 1
②	R:	68Ω / 2W	x 2
		1MΩ / 1/4W	x 1
③	C:	0.22μ / 250V	x 1
		470μ / 25V	x 1
④	D:	1N4001	x 4
⑤	Zd:	12V / 100mA	x 1

2. Referring the Fig (3) of 3-5 Experiment Discussion, complete a voltage doubler rectifier circuit that can convert AC110V to DC34V.

Materials:

①	Transformer:	AC110V / 12V	x 1
②	D:	1N4002	x 2
③	C:	100μ / 25V	x 2
④	R:	4.7K / 1/2W	x 1

3. Utilize the following materials to complete a rectifier circuit that delivers DC voltages DC7V and DC16V respectively. (Consider the voltage drop across D.)

Materials:

①	Transformer:	AC110V/0V, 6V, 12V	x 1
②	Power cord:	AC100V / 5A	x 1
③	D:	1N4002	x 1
④	Rectifier:	50V / 1A	x 1
⑤	C:	470μ / 25V	x 2