

# Chapter 7: Mains Power Supply Systems

## 1. Diodes

### Learning Objectives:

At the end of this topic you should be able to:

- draw and understand the use of diodes in half-wave and full-wave bridge rectifiers;
- draw and understand the use of capacitors used to smooth the output in half-wave and full-wave bridge rectifiers;
- calculate the peak value of the output voltage of half-wave and full-wave rectifiers given the rms input voltage.

### Rectification

The diode is at the heart of most rectification systems because current flows through it in one direction only.

The circuit diagram shows an AC power supply connected to a silicon diode and a resistor:

The first graph shows the effect on the current. When forward biased, a current flows through the diode and the resistor. As the AC supply voltage increases, current increases and the voltage  $V_{OUT}$  across the resistor increases.

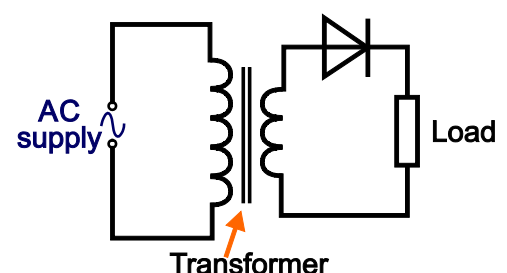
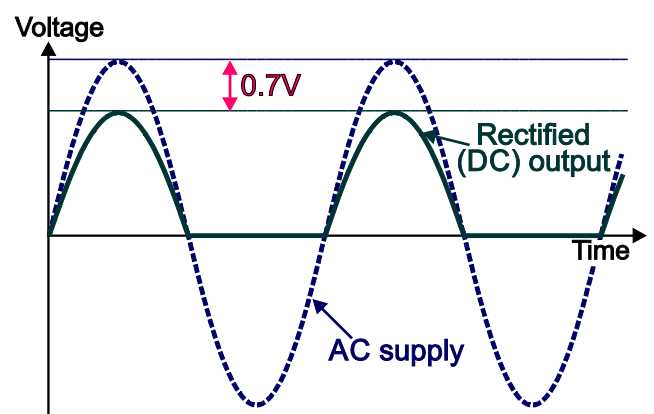
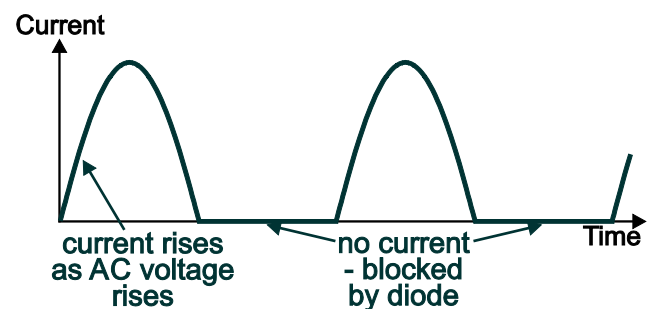
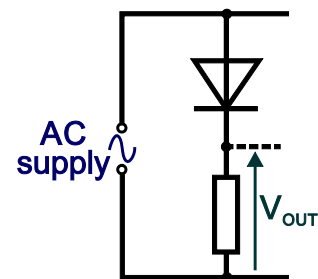
When the diode is reverse biased, it blocks the current and so the voltage across the resistor is zero.

The second graph shows the output voltage,  $V_{OUT}$ , compared to the AC supply voltage. It is DC as the voltage never drops below zero. However, it is not smooth DC, but consists of pulses of DC.

The peak value of  $V_{OUT}$  is 0.7 V below the peak value of the AC supply. This 0.7 V is dropped across the conducting diode.

This method, known as **half-wave rectification**, wastes 50% of the energy from the AC supply because the negative half cycle is completely removed by the diode.

The AC power supply is taken from the AC mains supply. A typical arrangement is shown opposite. The transformer reduces the 240 V mains supply to a lower value.



### Rms vs Peak Voltage

$$V_0 = V_{\text{rms}} \times \sqrt{2}$$

For example, suppose that the transformer secondary outputs a voltage of 12 V rms.

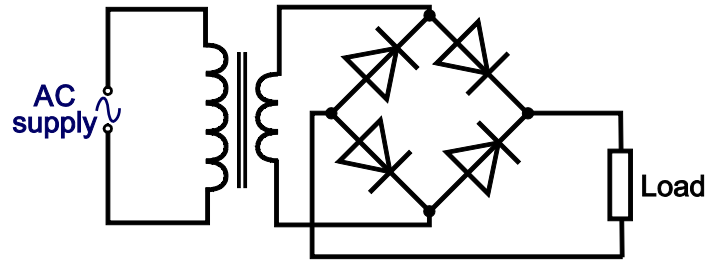
The peak secondary voltage is:

$$\begin{aligned} V_0 &= V_{\text{rms}} \times \sqrt{2} \\ &= 12 \times 1.414 \\ &= 16.97 \text{ V } (= \sim 17 \text{ V}) \end{aligned}$$

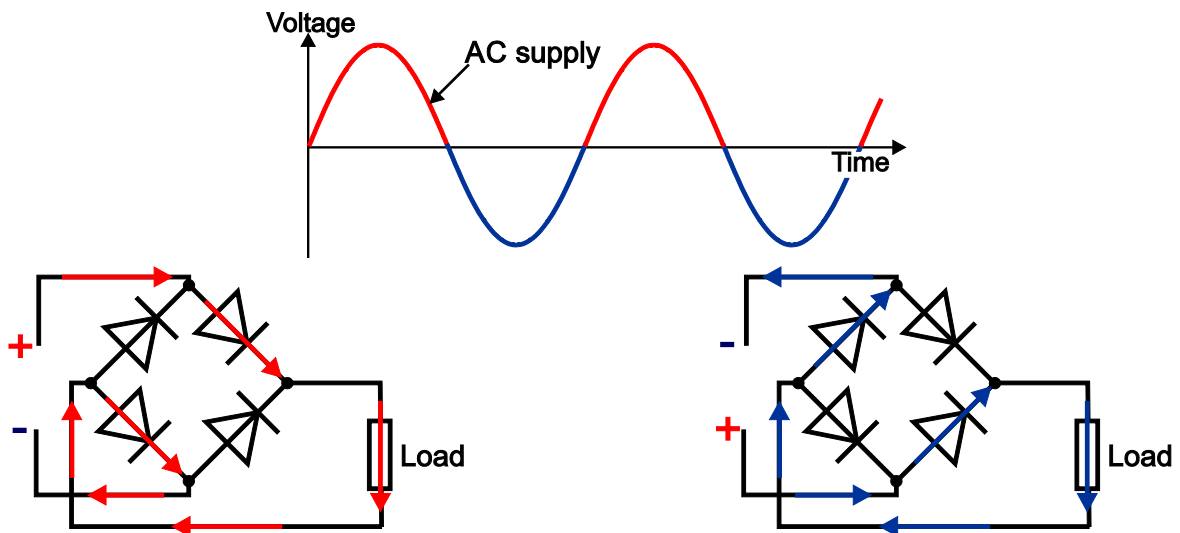
Taking into account the 0.7 V dropped across the diode when forward biased, the rectified output has a peak value of  $17 \text{ V} - 0.7 \text{ V} = 16.3 \text{ V}$

An improvement on the half-wave rectifier uses three extra diodes arranged as shown opposite.

This is called a **full-wave bridge rectifier**.

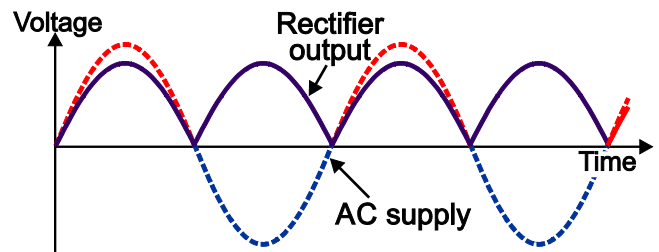


The diagrams show the current flow through circuit during each half cycle of the AC supply.



The current flows in the same direction through the load resistor during both half cycles of the AC supply – it is DC!

The graph shows the bridge rectifier output voltage compared to the AC supply.



**Note:**

- The negative part of the AC graph has been flipped to provide a second positive pulse within the same cycle.
- The peak voltage across the resistor is 1.4 V less than peak of the input signal due to the voltage drop across the **two** conducting diodes.

**Capacitive Smoothing**

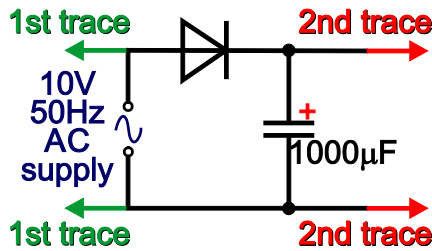
The process of rectification is the first stage of converting an AC supply into smooth DC. The outputs of both the half-wave and full-wave rectifiers are unsuitable for powering electronic circuits because of their ‘pulsing’ nature.

As a power source for electronic circuits, these pulses must be smoothed into steady DC. This is achieved by means of a **capacitor**, a device that can store electrical charge, usually a large value electrolytic capacitor of at least 1000  $\mu\text{F}$ .

(‘Circuit Wizard’ or a similar simulation program can be used to simulate the circuits that follow.)

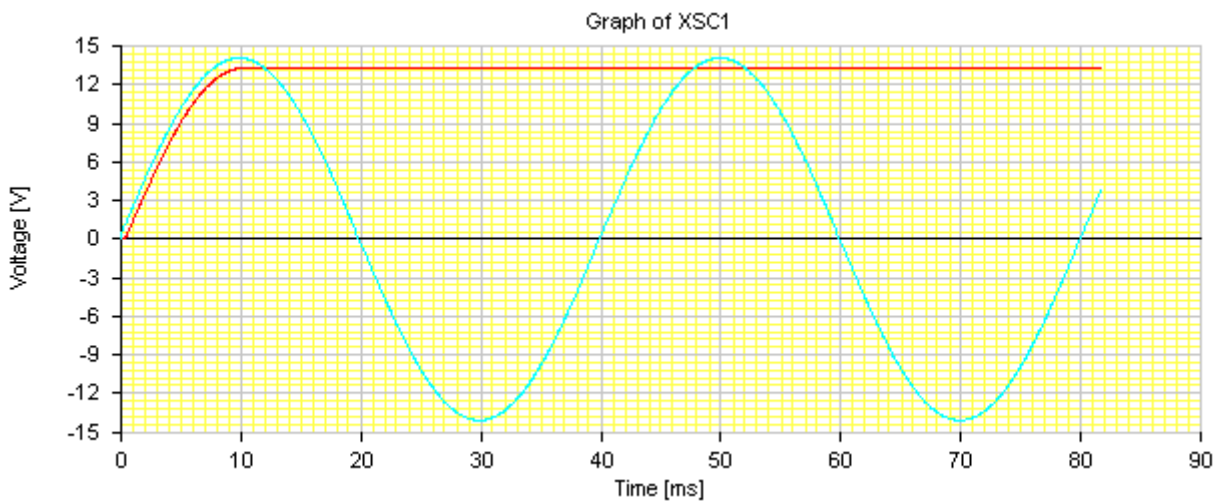
**1. Half-wave rectifier – no load**

For simplicity, the transformer has been replaced with a low voltage AC supply.



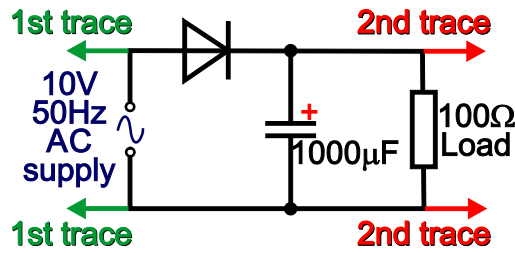
When using a dual-trace oscilloscope, both signals can be examined at the same time. In this case, there is a common ‘ground’ connection.

The resulting oscilloscope trace for this circuit is shown below. The output voltage,  $V_{\text{LOAD}}$ , shown in red, is steady once charge has built up on the capacitor.

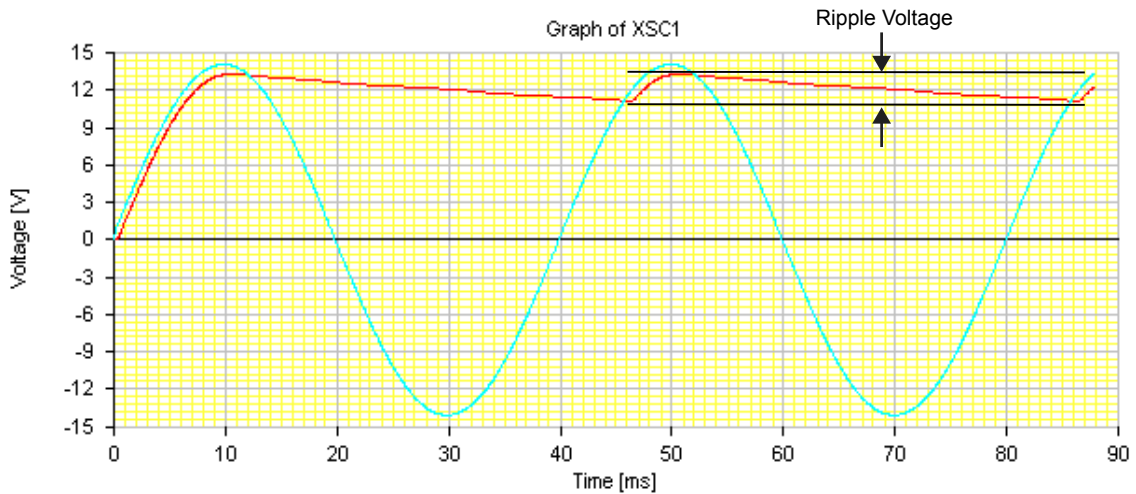


## 2. Half-wave rectifier – with load

A load is added to the output of the previous circuit. To begin with, this is a 100 Ω resistor.

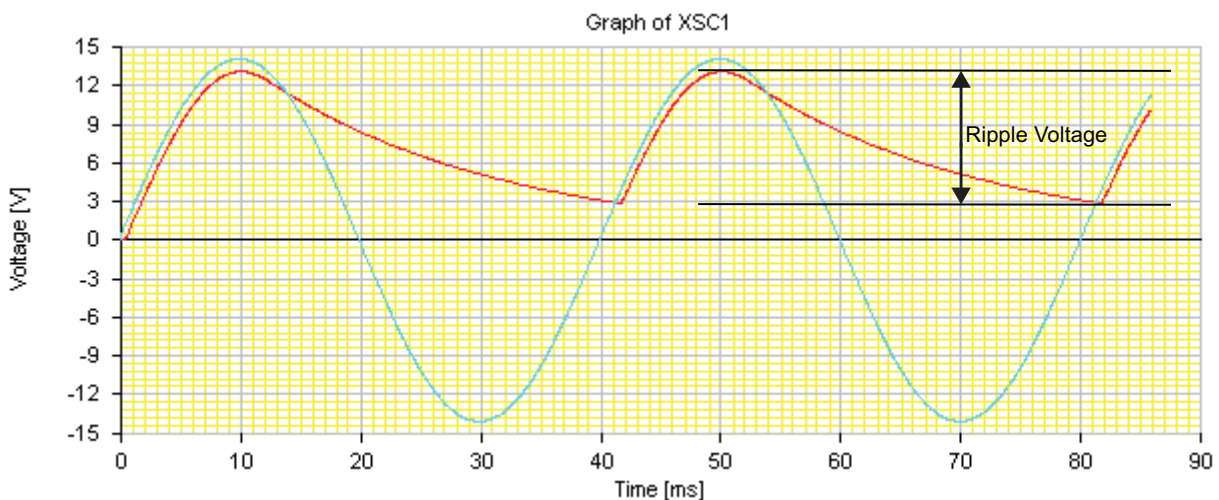


As before, when using a dual-trace oscilloscope, both signals can be examined at the same time. The resulting output voltage graph now becomes:



Now, the output voltage falls slightly, as current is drawn by the load resistor until the AC supply increases again to top up the capacitor. This process then repeats. The difference between the highest and lowest output voltage is called the **ripple voltage**.

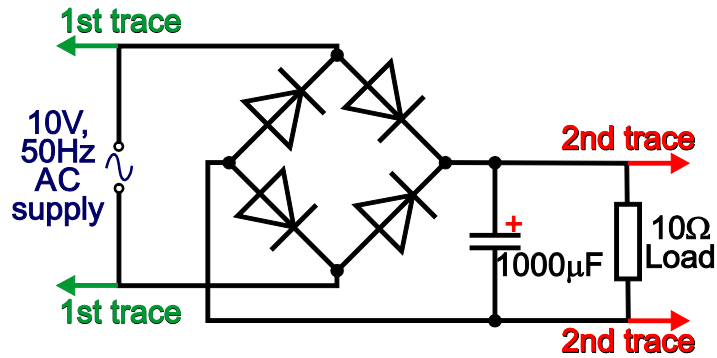
Next, the load resistor is decreased to 10 Ω, giving the following result:



The ripple voltage has increased significantly, highlighting a major drawback of this simple system, for low-value load resistance. Some improvements come from using a full-wave rectified supply.

### 3. Full-wave rectifier – with load

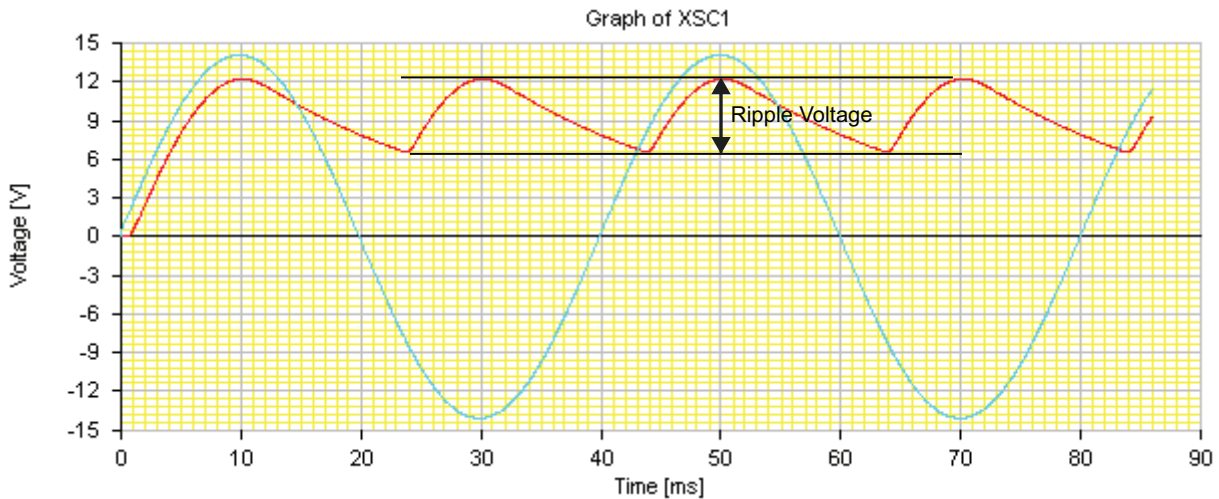
Next, compare the effect of using the same smoothing capacitor and load connected to a full-wave rectifier.



#### Warning!

When using a dual-trace oscilloscope, do not connect up both traces to the circuit at the same time. This can damage the diodes in the bridge. Connect to each signal separately, one at a time.

The output voltage graph looks like this:

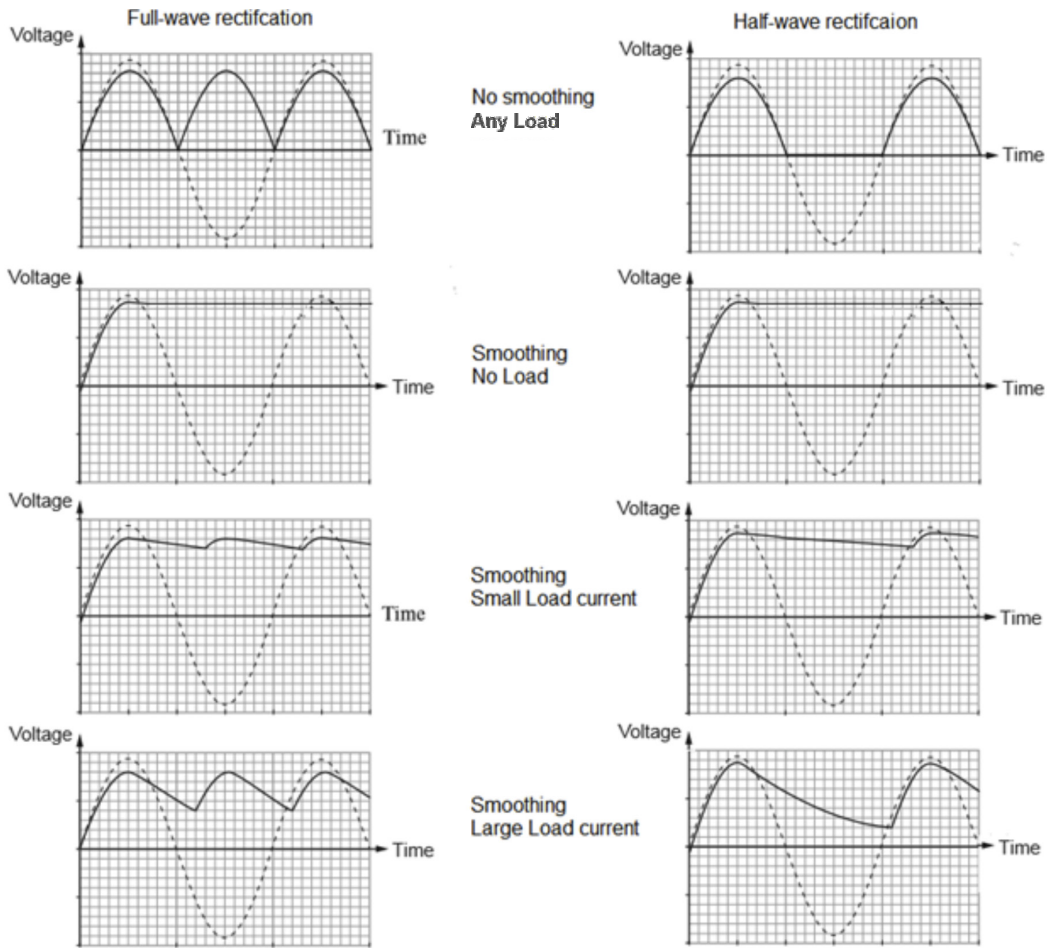


#### Note:

- the peak output voltage – lower due to an extra diode voltage drop in the bridge circuit;
- a smaller ripple voltage – actually halved, due to use of the negative half cycle;
- the higher ripple frequency – doubled.

## Summary

The four possible output graphs for full- and half-wave rectification are shown below:



## Calculation of ripple voltage

The value of the ripple voltage will depend on a number of factors:

- whether half-wave or full-wave rectification is involved;
- the value of the smoothing capacitor – the higher the value of the capacitor the smaller the ripple voltage for a given load;
- the size of the load – the smaller the load resistance the larger the load current and so the larger the ripple voltage.

The formula for calculating ripple voltage is:  $V_r = \frac{I_L}{f_r C}$

where:

$V_r$  is the peak-to-peak ripple voltage

$I_L$  is the load current

$f_r$  is the frequency of the ripple

$C$  is the capacitance of the smoothing capacitor

### Note:

- The ripple frequency,  $f_r$ , is 50 Hz for half-wave rectification and 100 Hz for full-wave rectification.
- In some textbooks the ripple voltage formula is quoted in terms of the supply frequency rather than the ripple frequency.

**Example 1:**

A simple power supply consists of a step-down transformer and a half-wave rectifier. It provides a load current,  $I_L$ , of 150 mA.

- a) Calculate the ripple voltage at the output of the power supply when a 1000  $\mu\text{F}$  smoothing capacitor is used.

Using

$$V_r = \frac{I_L}{f_r C}$$

$$V_r = \frac{150 \times 10^{-3}}{50 \times 1000 \times 10^{-6}}$$

$$= 3 \text{ V}$$

- b) The transformer secondary has an output of 15 V rms. Calculate the maximum and minimum voltages at the output of the power supply.

$$\text{Peak secondary voltage} = 15 \times \sqrt{2} = 21.2 \text{ V}$$

$$\text{Maximum output voltage} = 21.2 \text{ V} - 0.7 \text{ V} = 20.5 \text{ V}$$

$$\begin{aligned} \text{Minimum output voltage} &= 20.5 \text{ V} - V_r \\ &= 20.5 \text{ V} - 3 \text{ V} \\ &= 17.5 \text{ V} \end{aligned}$$

**Example 2:**

A power supply consists of a step-down transformer and a full-wave rectifier.

- a) The transformer secondary has an output of 10 V rms. Calculate the maximum voltage at the output of the power supply.

$$\text{Peak secondary voltage} = 10 \times \sqrt{2} = 14.1 \text{ V}$$

$$\text{Maximum output voltage} = 14.1 \text{ V} - 1.4 \text{ V} = 12.7 \text{ V}$$

- b) Calculate the ripple voltage at the output of the power supply when a 2200  $\mu\text{F}$  smoothing capacitor and a 50  $\Omega$  load are used.

$$\begin{aligned} \text{Load current } I_L &= \frac{12.7}{50} \\ &= 0.25 \text{ A} \end{aligned}$$

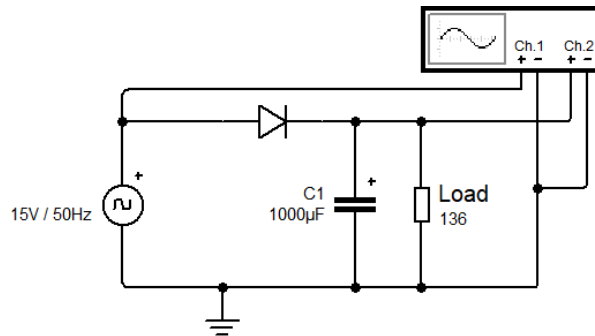
$$V_r = \frac{I_L}{f_r C}$$

$$V_r = \frac{0.25}{100 \times 2200 \times 10^{-6}}$$

$$= 1.1 \text{ V}$$

### Investigation 7.1

1. Set up the following circuit and compare the result with example 1 on previous page.



#### Comparison

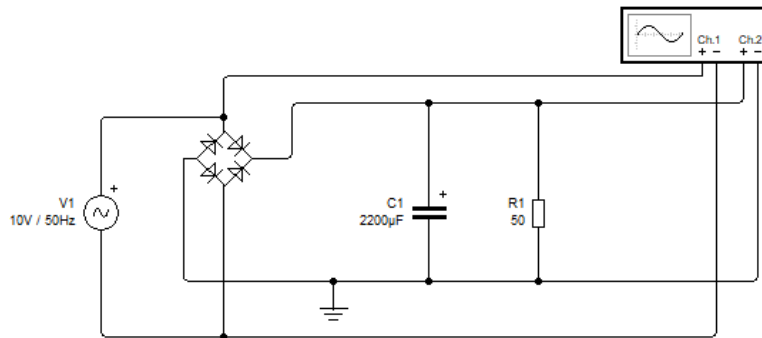
.....

.....

.....

.....

2. Set up the following circuit and compare the result with the example 2. Remember that if you are setting this circuit up on breadboard, **do not** use a dual-trace oscilloscope to observe input and output waveforms **simultaneously**.



#### Comparison

.....

.....

.....

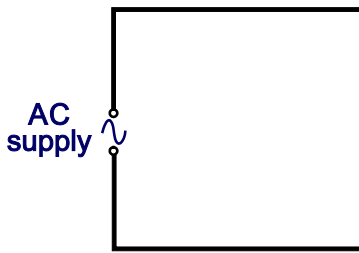
.....



**Exercise 7.1**

1. A 50 Hz 22 V peak AC supply is half-wave rectified and connected to a load.

a) Complete the circuit diagram of this arrangement.



b) Calculate:

i) the rms value of the supply voltage;

.....

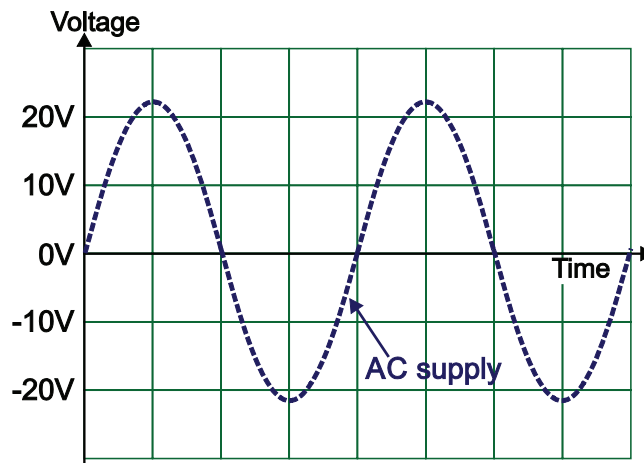
ii) the peak value of the output voltage  $V_{OUT}$ .

.....

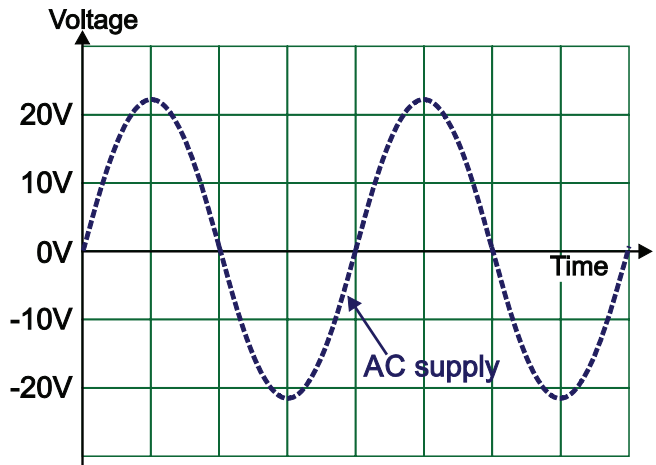
(iii) Calculate the ripple voltage when a 1800  $\mu\text{F}$  smoothing capacitor and a 120  $\Omega$  load are used.

.....

(iv) Sketch a graph to show the output voltage,  $V_{OUT}$ , of the half-wave rectifier when connected to the 120  $\Omega$  load.



2. The half-wave rectifier described in question 1 is replaced with a full-wave rectifier.
- (a) What is the new peak value of output voltage  $V_{OUT}$ ? .....
  - (b) What is the new frequency of the ripple voltage? .....
  - (c) Calculate the ripple voltage when a  $1500 \mu\text{F}$  smoothing capacitor and a  $50 \Omega$  load are used.  
.....  
.....
  - (d) What is the minimum value of  $V_{OUT}$ ? .....
  - (e) Sketch a graph to show the output voltage,  $V_{OUT}$ , of the full-wave rectifier when connected to the  $50 \Omega$  load.



## 2. Voltage Regulation

### Learning Objectives:

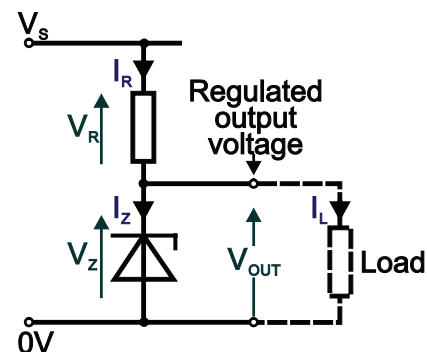
At the end of this topic you should be able to:

- draw the circuit diagram for a voltage regulator based on a zener diode;
- design a voltage regulator, based on a zener diode, to meet a given specification;
- calculate the maximum output current available from a given voltage regulator;
- calculate the power rating needed by the zener diode and series resistor in a given voltage regulator.

For many circuits, it is desirable to have a power supply which gives out a constant voltage regardless of the current it is delivering.

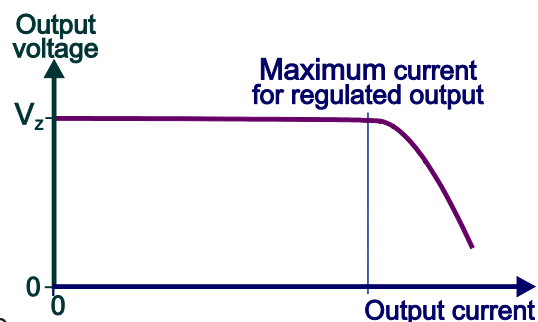
The circuit diagram shows a simple voltage regulator based on a zener diode. (The behaviour of the zener diode was discussed in Chapter 5.)

The appropriate zener voltage is selected, knowing the requirements of the power supply.



### Note:

- voltages  $V_R$  and  $V_z$  add up to the supply voltage  $V_s$ ;
- current  $I_R$  is the sum of zener current  $I_z$  and the load current,  $I_L$ .
- the zener diode requires a small current through it, known as the 'holding current' (~ 5 to 10 mA) to maintain zener breakdown;
- if the load is disconnected, the full current,  $I_R$ , flows through the zener diode;
- this regulator maintains a constant output voltage up to the point where zener current,  $I_z$ , falls below the holding current.



After that, the output voltage falls, as the graph shows. Eventually, the zener diode stops conducting and the circuit reverts to a simple voltage divider, with the supply voltage split between the two resistors.

### Example 1:

A portable CD player needs a power supply delivering a maximum current of 250 mA at a voltage of 7.5 V.

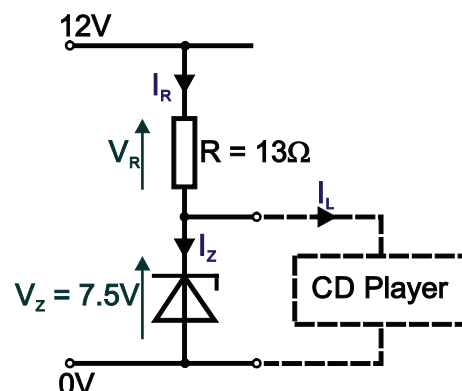
It will be used in a car, where the power source is the 12 V car battery.

The circuit for the CD player power supply is shown opposite:

a) Calculate:

i) the voltage,  $V_R$ , across the  $13\ \Omega$  resistor:

$$\begin{aligned} V_R &= V_S - V_Z \\ &= 12 - 7.5 \\ &= 4.5\ \text{V} \end{aligned}$$



- ii) the current,  $I_R$ , through the  $13\ \Omega$  resistor

$$\begin{aligned} I_R &= \frac{V_R}{R} \\ &= \frac{4.5}{13} \\ &= 0.346\ \text{A} = 346\ \text{mA} \end{aligned}$$

- iii) the zener current,  $I_Z$ , when the load current  $I_L = 250\ \text{mA}$

$$\begin{aligned} I_Z &= I_R - I_L \\ &= 346 - 250 \\ &= 96\ \text{mA} \end{aligned}$$

- b) Calculate the minimum power rating for the  $13\ \Omega$  resistor from the values:

1 W 2 W 3 W

$$\begin{aligned} P_R &= I_R \times V_R \\ &= 346 \times 4.5 \\ &= 1557\ \text{mW} = 1.557\ \text{W} \end{aligned}$$

Therefore, we choose a 2 W resistor.

- c) The car battery charges up to 13.8 V after a long journey.  
What is the new output voltage?

Output voltage = 7.5 V (but  $V_R$  increases by 1.8 V to 6.3 V).

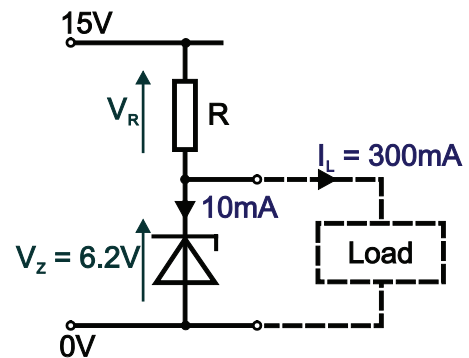
### Example 2:

The 6.2 V stabilised power supply shown opposite must provide a maximum load current,  $I_L$ , of 300 mA.

The zener diode requires a holding current of 10 mA.

- a) Calculate the preferred value of resistor R:

$$\begin{aligned} V_R &= V_S - V_Z & I_R &= I_Z + I_L & R &= \frac{V_R}{I_R} \\ &= 15 - 6.2 & &= 10 + 300 & &= \frac{8.8}{310} \\ &= 8.8\ \text{V} & &= 310\ \text{mA} & &= 0.0284\ \text{k}\Omega = 28.4\ \Omega \end{aligned}$$



The E24 resistor series does not have a  $28.4\ \Omega$  resistor. The nearest values are  $27\ \Omega$  and  $33\ \Omega$ .

Choosing the  $33\ \Omega$  resistor would **reduce** the current to below 310 mA. This would not allow a current of 300 mA for the CD player whilst maintaining the zener in reverse breakdown by passing a current of 10 mA through it.

The  $27\ \Omega$  resistor therefore must be used. This allows more current than required through the resistor. The excess flows through the zener diode.

In fact, the current through the  $27\ \Omega$  resistor would be:

$$\begin{aligned} I_R &= \frac{V_R}{R} \\ &= \frac{8.8}{27} \\ &= 0.326\ \text{A} = 326\ \text{mA} \end{aligned}$$

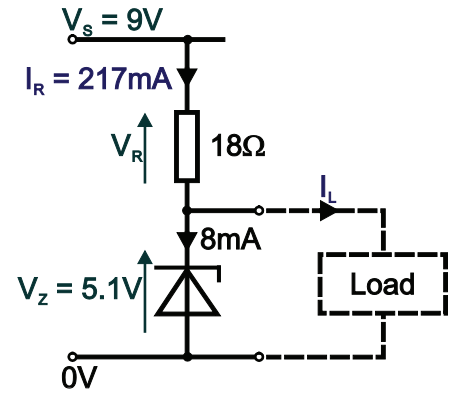
This increases power dissipation in both the resistor R and the zener diode.

**Example 3:**

The diagram shows the circuit for a regulated power supply.

The zener diode requires a holding current of 8 mA.

The current through the 18 Ω resistor is 217 mA.



- a) Calculate the maximum current available for the load.

$$\begin{aligned} I_L &= I_R - I_Z \\ &= 217 - 8 \\ &= 209 \text{ mA} \end{aligned}$$

- b) The load is now disconnected.

- i) Calculate the new value of  $I_Z$ .

$$\begin{aligned} I_Z &= I_R - I_L \\ &= 217 - 0 \\ &= 217 \text{ mA} \end{aligned}$$

- ii) Calculate the power now dissipated in the zener diode.

$$\begin{aligned} P_Z &= I_Z \times V_Z \\ &= 217 \times 5.1 \\ &= 1107 \text{ mW} = 1.1 \text{ W} \end{aligned}$$

- c) The load resistance is changed and the load current increases to 300 mA as a result.

Calculate the new value of the voltage across the load,  $V_L$ .

The maximum current available for the load has been exceeded, so the zener diode is no longer conducting.

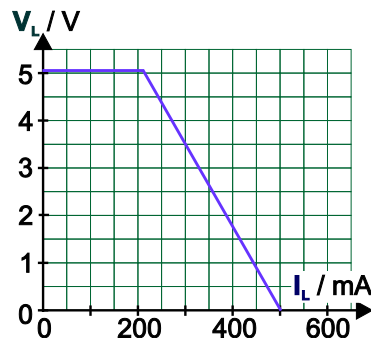
The voltage across the 18 Ω resistor is:

$$\begin{aligned} V_R &= I_R \times R \\ &= 300 \text{ mA} \times 18 \Omega \\ &= 5.4 \text{ V} \end{aligned}$$

Hence:  $V_L$

$$\begin{aligned} &= V_S - V_R \\ &= 9 \text{ V} - 5.4 \text{ V} \\ &= 3.6 \text{ V} \end{aligned}$$

- d) Sketch a graph to show how the voltage across the load,  $V_L$ , changes as  $I_L$  is increased gradually from 0 to its maximum value.

**Note:**

The graph passes through the points (209, 5.1) and (500, 0).

The point ( 500, 0) corresponds to a zero ohm load (short circuit) and represents the maximum current that can flow through the 18 Ω resistor. This can be confirmed by dividing the supply voltage of 9 V by 18 Ω to give 500 mA.

- (e)  $V_s = 9\text{ V}$  represents the peak output voltage from a half-wave rectifier with a  $3300\text{ }\mu\text{F}$  smoothing capacitor.  
Calculate the value of the ripple voltage and the minimum value of  $V_s$ , from the half-wave rectifier.

Warning: When using the  $V_r = \frac{I_L}{f_r C}$  formula in a regulated power supply calculation,

formula in a regulated power supply calculation,

the  $I_L$  in the formula now represents the total current flowing which is  $I_R$  (217 mA in this case).

$$\begin{aligned} \text{So} \quad V_r &= \frac{217 \times 10^{-3}}{50 \times 3300 \times 10^{-6}} \\ &= 1.3\text{ V} \end{aligned}$$

$$\begin{aligned} \text{Minimum value of } V_s &= 9\text{ V} - V_r \\ &= 9\text{ V} - 1.3\text{ V} \\ &= 7.7\text{ V} \end{aligned}$$

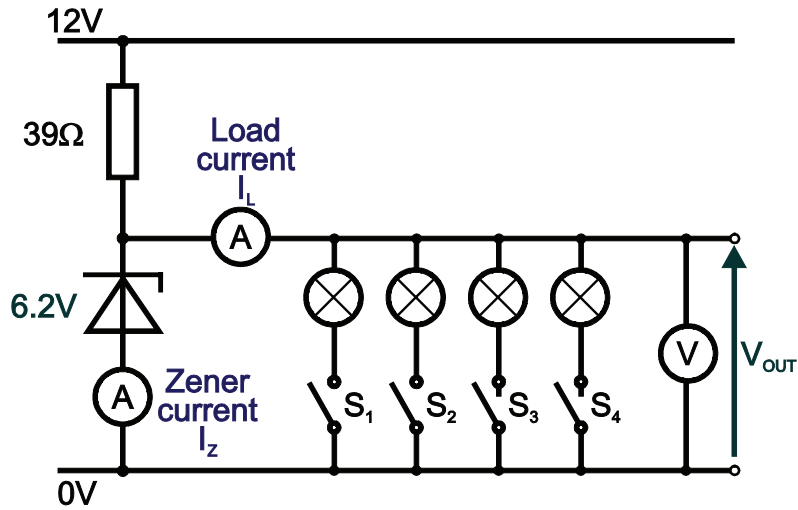
**Note:**

This minimum value of  $V_s$  from the rectifier reduces the current in the regulator and could make the zener current drop below its holding value.

For this reason it is important to keep the ripple voltage to a minimum.

**Investigation 7.2**

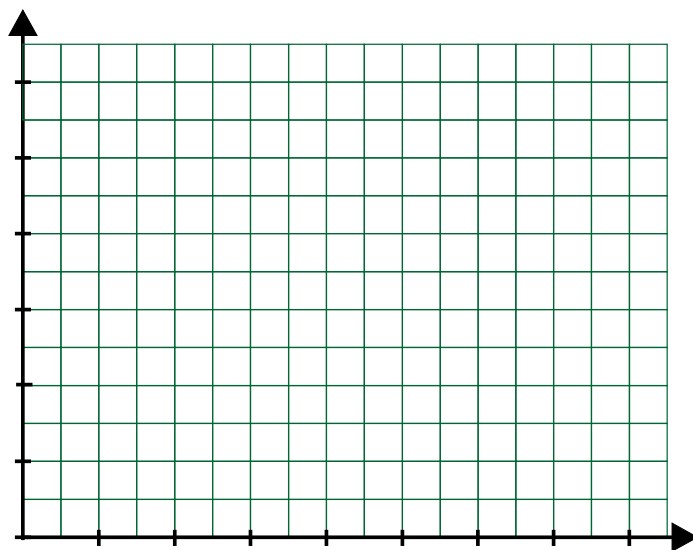
1. Set up the circuit shown below.



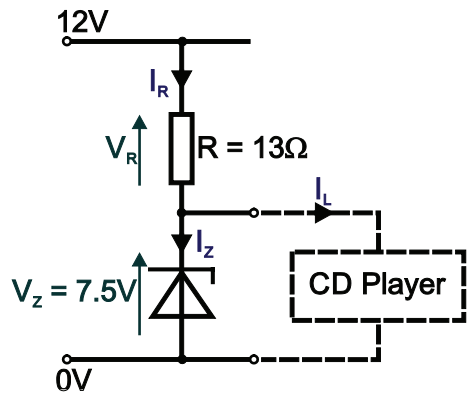
a) Complete the table below by recording the meter readings as each of the four switches,  $S_1$  to  $S_4$  are closed. The total current is the sum of the zener current,  $I_Z$ , and the load current,  $I_L$ .

Switch closed	Load current $I_L$ (mA)	Zener current $I_Z$ (mA)	Total current (mA)	Load voltage $V_{OUT}$ (V)
None	0			
$S_1$				
$S_1, S_2$				
$S_1, S_2, S_3$				
$S_1, S_2, S_3, S_4$				
$S_1, S_2, S_3, S_4$		<b>Zener removed</b>		

b) Draw a graph to show how load voltage,  $V_{OUT}$ , changes as load current,  $I_L$ , increases. Label the axes with suitable scales.



2. a) Set up the circuit shown below, using a simulation program. Use a 30 Ω resistor to represent the CD player.



- b) Measure and record the values of voltage and current to complete the table below. [The theoretical values have already been calculated in Example 1 on pages 266-267.]

	Zener voltage(V)	Zener current(mA)	Load current(mA)	Total current(mA)
<b>Theoretical value</b>	7.5	96	250	346
<b>Measured value</b>				

- c) Give reasons for any differences between the theoretical and measured results.

.....

.....

.....

.....

.....

.....

.....

.....

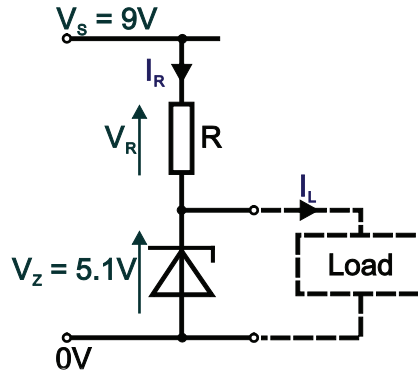
.....

.....



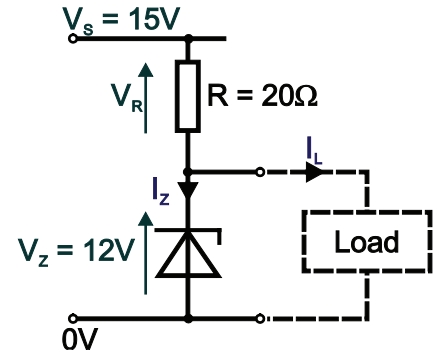
**Exercise 7.2**

1. The diagram shows the circuit for a simple voltage regulator, designed to deliver load currents up to 240 mA.  
The zener diode requires a current of 10 mA to maintain the zener voltage.



- a) i) What current,  $I_R$ , flows through resistor **R** when the load current is 240 mA?  
.....  
.....
- ii) What is the voltage,  $V_R$ , across resistor **R**?  
.....  
.....
- iii) Calculate the value of resistor **R**.  
.....  
.....
- b) When the load current,  $I_L$ , is 50 mA, calculate the power dissipated in:
- i) the zener diode;  
.....  
.....  
.....  
.....
- ii) resistor **R**.  
.....  
.....  
.....
- c) The power supply voltage drops to 8.5 V. What happens to the voltage across the load?  
.....  
.....
- d) Choose a suitable preferred value for resistor **R**?  
.....  
.....

2. The diagram shows a simple regulated power supply. The zener diode requires a current of at least 5 mA to maintain the zener voltage.



a) Calculate:

i) the voltage,  $V_R$ , across the  $20\ \Omega$  resistor;

.....

ii) the current through the  $20\ \Omega$  resistor.

.....

b) The load is suddenly disconnected.

i) What current,  $I_z$ , now flows through the zener diode?

.....

ii) Calculate the power now dissipated in the zener diode.

.....

.....

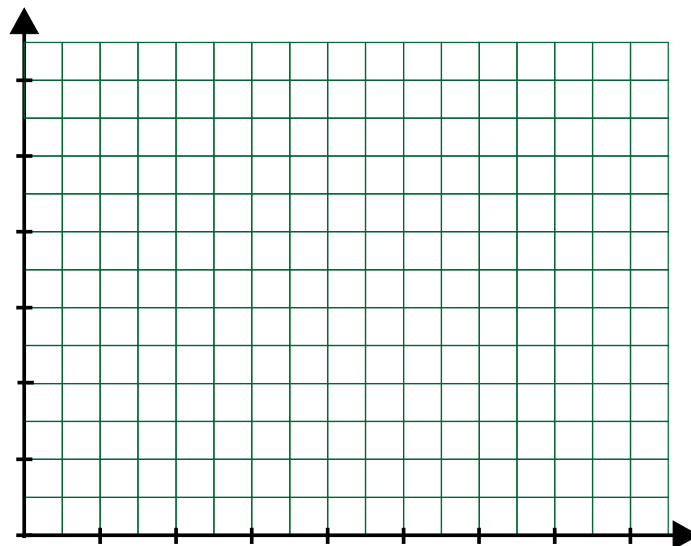
c) A load resistance is reconnected and load current,  $I_L$ , increases to 400 mA. Calculate the new value of output voltage,  $V_L$ .

.....

.....

.....

d) Sketch a graph to show how the voltage across the load,  $V_L$ , changes as the load current,  $I_L$ , is increased gradually from 0 to its maximum value.



- (e)  $V_s = 15\text{ V}$  represents the peak output voltage from a full-wave rectifier with a  $3900\text{ }\mu\text{F}$  smoothing capacitor.  
Calculate the value of the ripple voltage produced when the zener current is  $20\text{ mA}$

.....

.....

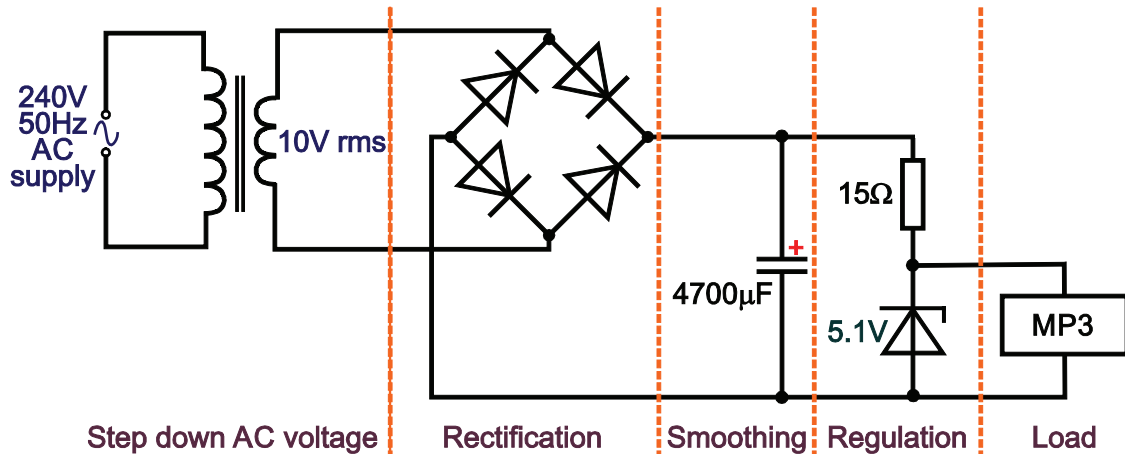
.....

### 3. Power Supply Design

The previous sections have examined in detail the sub-systems that make up a regulated power supply. The final example gives an overview of a complete power supply design.

#### Example 1:

The following circuit diagram shows the circuit diagram for a regulated power supply to operate an MP3 player from the mains supply. The MP3 player requires a maximum current of 400 mA. The holding current for the zener diode is 12 mA.



- a) What is the peak value of the voltage at the output of the transformer secondary?

$$\begin{aligned} V_0 &= V_{\text{rms}} \times \sqrt{2} \\ &= 10 \times 1.41 \\ &= 14.1 \text{ V} \end{aligned}$$

- b) What is the peak value of the voltage after rectification?

$$\begin{aligned} V_s &= 14.1 - 1.4 \\ &= 12.7 \text{ V} \end{aligned}$$

- c) What is the peak voltage across the 15 Ω resistor?

$$\begin{aligned} V_R &= V_s - V_z \\ &= 12.7 - 5.1 \\ &= 7.6 \text{ V} \end{aligned}$$

- d) Calculate the current through the 15 Ω resistor.

$$\begin{aligned} I_R &= \frac{V_R}{R} \\ &= \frac{7.6}{15} \\ &= 0.507 \text{ A} = 507 \text{ mA} \end{aligned}$$

- e) What is the maximum power dissipated in the 15 Ω resistor?

$$\begin{aligned} P_R &= I_R \times V_R \\ &= 507 \times 7.6 \\ &= 3.85 \text{ W} \end{aligned}$$

- f) What is the current flowing through the zener diode when the MP3 player is drawing the full 400 mA from the supply?

$$\begin{aligned} I_z &= I_R - I_L \\ &= 507 - 400 \\ &= 107 \text{ mA} \end{aligned}$$

- g) What is the power dissipated in the zener diode when the current through the MP3 player is 400 mA.

$$\begin{aligned} P_z &= I_z - V_z \\ &= 107 - 5.1 \\ &= 546 \text{ mW} \end{aligned}$$

- h) The MP3 Player is now disconnected. What is the power dissipation in the zener diode?

$$\begin{aligned} P_z &= I_z - V_z \\ &= 507 - 5.1 \\ &= 2586 \text{ mW} = 2.6 \text{ W} \end{aligned}$$

- i) Calculate the ripple voltage across the smoothing circuit.  
(Remember that  $I_R = 507 \text{ mA}$  must be used in the equation)

$$V_r = \frac{I_L}{f_r C}$$

$$\begin{aligned} V_r &= \frac{507 \times 10^{-3}}{100 \times 4700 \times 10^{-6}} \\ &= 1.1 \text{ V} \end{aligned}$$

- j) Calculate the minimum values of  $V_R$  and  $I_R$  when the value of the voltage after rectification is at its minimum.

$$\begin{aligned} V_s &= 14.1 - 1.1 \\ &= 11.6 \text{ V} \end{aligned}$$

$$\begin{aligned} \text{Minimum } V_R &= V_s - V_z \\ &= 11.6 - 5.1 \\ &= 6.5 \text{ V} \end{aligned}$$

$$\begin{aligned} I_R &= \frac{V_R}{R} \\ &= \frac{6.5}{15} \end{aligned}$$

$$= 0.433 \text{ A} = 433 \text{ mA}$$

- k) Describe how the ripple voltage affects the voltage and current in the regulation/load section of the power supply when the load current is 400 mA.

The 1.1 V fluctuation in  $V_s$  would be absorbed across a 15  $\Omega$  resistor. This would cause the current through the 15  $\Omega$  resistor to pulse between 433 - 507 mA, and the zener current to pulse between 33 and 107 mA at a frequency of 100 Hz.

The 33 mA minimum current through the zener is far in excess of the 12 mA holding current so the 5.1 V zener voltage is maintained.

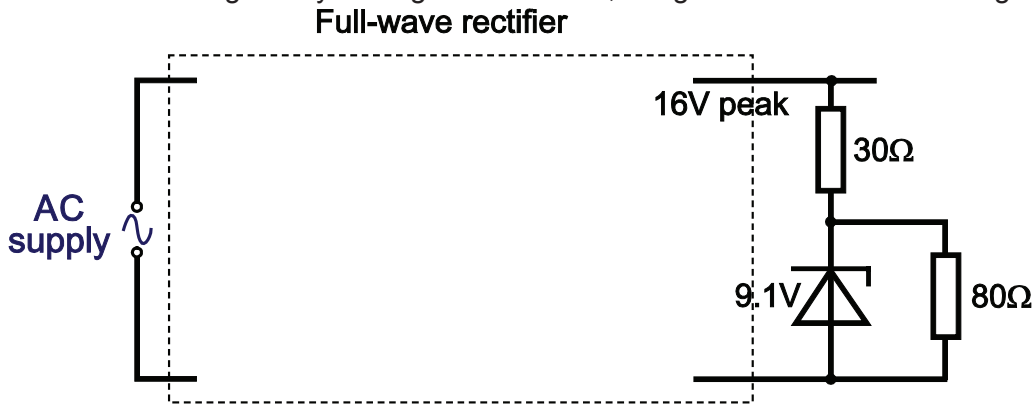
The load current will remain constant at 400 mA.

**Note:** The answers to parts e) and h) above illustrate the limitations of the zener diode regulated power supply in terms of the power dissipated in the components.

**Exercise 7.3**

The diagram below shows part of a regulated power supply delivering current to an  $80\ \Omega$  load.

a) Complete the circuit diagram by adding a transformer, bridge rectifier and smoothing capacitor.



b) The peak input voltage to the zener voltage regulator is 16 V.  
Calculate:

i) the rms voltage at the output of the transformer secondary;

.....

.....

ii) the voltage across the  $30\ \Omega$  resistor;

.....

.....

iii) the current through the  $30\ \Omega$  resistor.

.....

.....

c) The regulator is working correctly.  
Calculate:

i) the current through the  $80\ \Omega$  load;

.....

.....

ii) the current through the zener diode.

.....

.....

d) The circuit uses a  $2200\ \mu\text{F}$  smoothing capacitor. Calculate the value of the ripple voltage.

.....

.....

.....

- e) Calculate the voltage,  $V_R$ , across the  $30\ \Omega$  resistor, and the current,  $I_R$ , flowing through it when the peak input voltage to the regulator is at its minimum.

.....

.....

.....

.....

.....

.....

- f) Describe how the ripple voltage affects the voltage and current in the regulation/load section of the power supply when the load current is equal to the value calculated in part c) above.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....