Unit 28 Diode rectifiers

- A single diode, used as a rectifier, gives half wave rectification.
- Four diodes, in a bridge rectifier, give full wave rectification.
- Ripple voltage from a smoothed full wave rectifier $= \frac{I_{out}}{2 \times f \times C}$

When the mains 220 V_{AC} supply is used to power electronic circuits which require low voltage DC, a transformer is used to step down the AC voltage and then a single diode or a diode bridge is used to convert from AC to DC. The transformer also provides some isolation between the user and the dangerous mains voltages.

28.1 Examples

28.1 Calculate the output voltage waveform from the half wave rectifier circuit shown in Figure 28.1 (a).

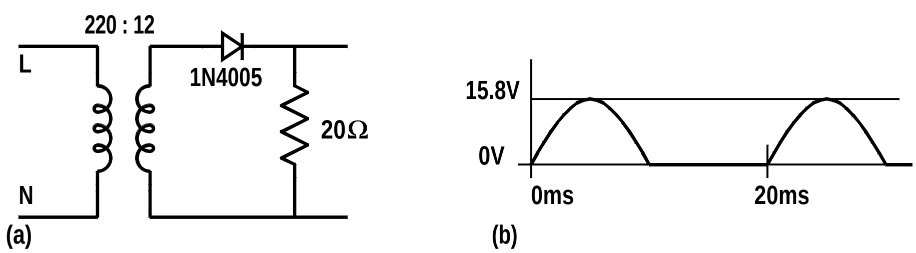

Figure 28.1: Example 28.1.

The output of this half wave rectifier circuit is across a load resistor $R_L = 20\,\Omega$ and consists of the positive half cycles of the voltage waveform out of the transformer secondary minus the voltage drop across the diode. The specification for the transformer is 220 V primary, 12 V secondary. The voltage amplitude or peak voltage (see Unit 9) at the secondary of the transformer is:

$$V_{peak} = 1.4 \times V_{RMS} = 1.4 \times 12\,\text{V} = 16.8\,\text{V}$$

The bulk resistance of the 1N4005 diode is $0.4\,\Omega$ so the total voltage drop across the diode is $0.7 + 0.4 \times I$. We then have the basic equation at the peak of the waveform:

$$16.8\,\text{V} = 0.7\,\text{V} + 0.4\,\Omega \times I + 20\,\Omega \times I$$

$$\text{which gives} \quad I = \frac{16.8 - 0.7}{20.4} = 0.79\,\text{A}$$

Therefore the maximum voltage across the load resistor is $20 \times 0.79 = 15.8\,\text{V}$ as shown in Figure 28.1 (b).

28.2 Give a scaled sketch of output voltage from the bridge rectifier circuit shown in Figure 28.2 (a).

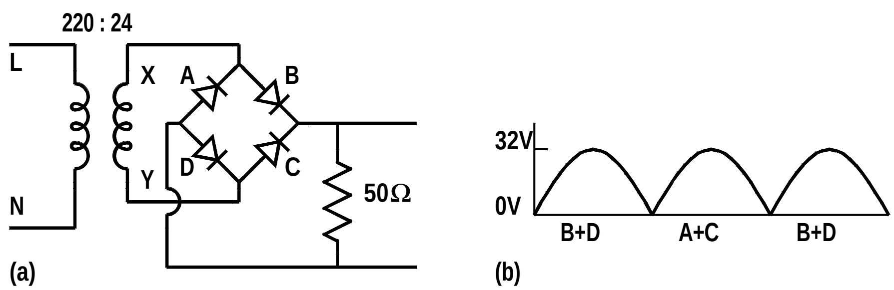

Figure 28.2: Example 28.2. Full wave rectifier circuit.

In this bridge circuit we first consider the positive half cycle of the output voltage from the transformer when X is positive with respect to Y. The diodes B and D are forward biased and the output voltage across the load resistor is positive. The effective circuit for current flow is shown in Figure 28.3 (a).

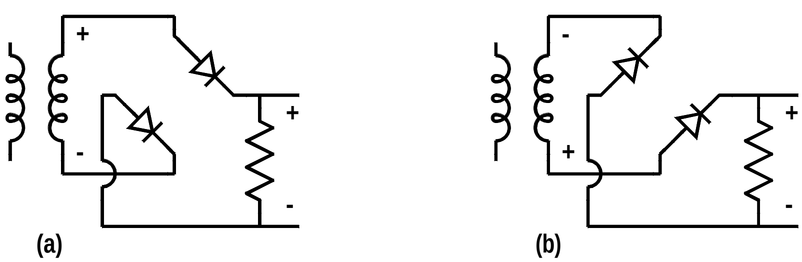

Figure 28.3: The two effective circuits for the two half cycles.

During the negative half cycle, X is negative relative to Y and diodes A and C are forward biased. This again gives a positive voltage at the top of the load resistor. The effective circuit in this case is shown in Figure 28.3 (b).

There are two diodes conducting at any one time so the basic equation for the peak voltage is:

$$24 \times 1.4 = 2 \times 0.7 + 2 \times I \times R_B + I \times 50\,\Omega$$

Taking an $R_B = 0.4\,\Omega$, this gives a peak current of 0.63 A and a peak voltage across the 50 Ω of 31.7 V.

28.3 Calculate the output voltage from the circuit of Figure 28.4 (a).

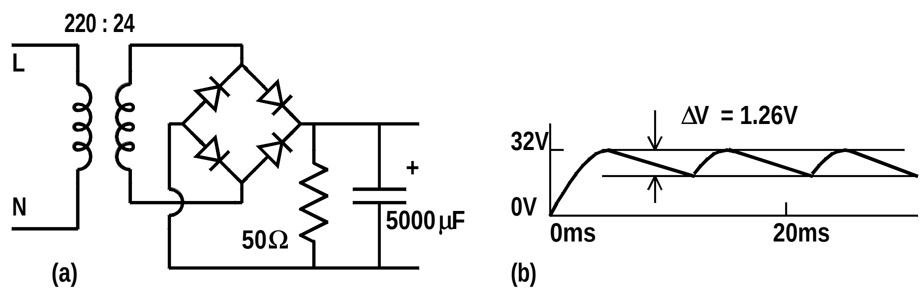

Figure 28.4: Example 28.3. Full wave rectifier with smoothing.

This is the same circuit as that in Example 28.2 but with the addition of a large smoothing capacitor of 5000 μF.

This type of large valued smoothing capacitor is manufactured using an electrolytic technology where the dielectric of aluminium oxide is formed in the wet electrolyte gel as the result of an applied voltage. The capacitor has a specific polarization and must be connected correctly into the circuit. If it is connected the wrong way around the electrolytic process goes into reverse, gas is evolved and the capacitor can explode. Always check the polarity of electrolytic capacitors before inserting them into circuits!

The output voltage waveform from this circuit is characterized by a peak which occurs at the peak of the AC waveform when the capacitor is charged up. During the dip in the rectified waveform, the capacitor acts as a reservoir and the stored charge in the capacitor maintains the current in the load for the 0.01 seconds (half the period of the 50 Hz mains) until the next peak occurs. During this time the voltage across the capacitor drops by an amount called the ripple voltage, ΔV, which is calculated as follows:

The current from the capacitor in the interval between the peaks is:

$$I_{out} = \frac{V_{out}}{R_L}$$

The charge which flows out of the capacitor is:

$$\Delta Q = \text{time} \times I_{out} = \frac{T}{2} \times I_{out} = \frac{I_{out}}{2 \times f}$$

This results in a drop, ΔV, in the output voltage which gives a ripple voltage:

$$\Delta V = \frac{\Delta Q}{C} = \frac{I_{out}}{2 \times f \times C}$$

When the component values corresponding to the circuit in Figure 28.4 (a) are inserted into this equation we get:

$$I_{out} = \frac{31.7\,\text{V}}{50\,\Omega} = 0.63\,\text{A}$$

and ripple voltage $\Delta V = \dfrac{I_{out}}{2 \times f \times C} = \dfrac{0.63}{2 \times 50 \times 5 \times 10^{-3}} = 1.26\,\text{V}$

as shown in Figure 28.4 (b).

The advantages of the full wave rectifier (which is available as a single component) are that:

- There is a more efficient use of the transformer which reduces the transformer size and weight.
- The output voltage is present for a greater fraction of the time than is the output from a half wave rectifier and therefore less smoothing is required to convert the output to a smoothed DC.
- The size of necessary smoothing capacitors is smaller and again this leads to a reduced size and weight.

28.2 Problems

28.1 Why are transformer sizes specified in V A rather than in watts?

28.2 Calculate the average output voltage and the ripple voltage for the half wave rectifier circuit shown in Figure 28.5. What will be the value of the new ripple voltage if the 470 Ω load resistor is replaced by a 10 kΩ load resistor?

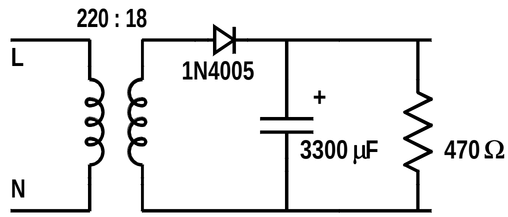

Figure 28.5: Problem 28.2.

28.3 Calculate the average output voltage and the ripple voltage for the full wave rectifier circuit shown in Figure 28.6.
Calculate the power dissipated in the load resistor.
Calculate the minimum power rating for the transformer.
What is the minimum required working voltage for the electrolytic capacitor?

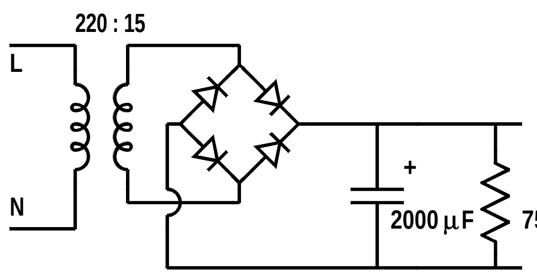

Figure 28.6: Problem 28.3.

28.4 Analyze the operation of the voltage multiplier circuit shown in Figure 28.7 by examining the flow of charge into the plates of the C_1 capacitor.

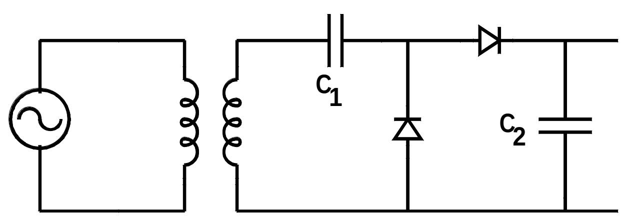

Figure 28.7: Problem 28.4.