

Module 4 Application of Definite Integral in Electronics

When discussing power supply circuit, the following formula is used to calculate the average DC load voltage $V_{L(avg)}$ in a full-wave bridge rectifier circuit.

$$V_{L(avg)} = 0.637 V_{L(peak)} \quad (1)$$

Where $V_{L(peak)}$ is the peak voltage across the load.

With the knowledge of definite integration, we can derive equation (1).

Figure 1 illustrates the full-wave bridge rectifier circuit. The 3N246 is the bridge rectifier IC and R_L is the load resistor. In the circuit, a virtual oscilloscope XSC1 is used to measure secondary voltage (channel A) and the load voltage (channel B). The digital multimeter XMM2 is used to measure the average DC voltage across the load resistor.

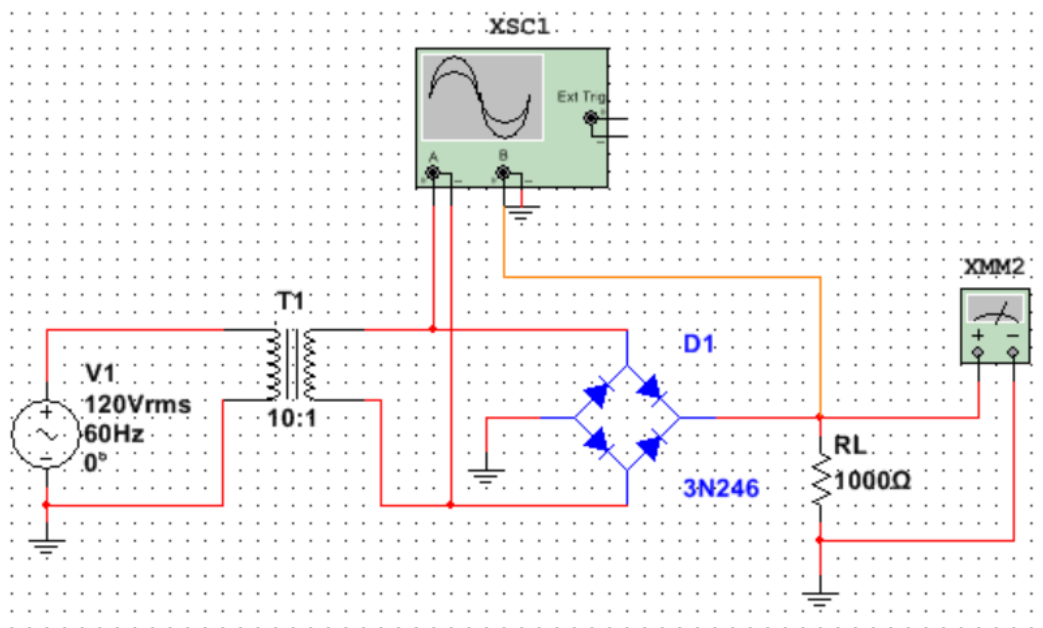


Figure 1. A full-wave bridge rectifier circuit

Figures 2 and 3 show the simulation results of the bridge rectifier circuit.

Figure 2. Average load voltage of the rectifier circuit

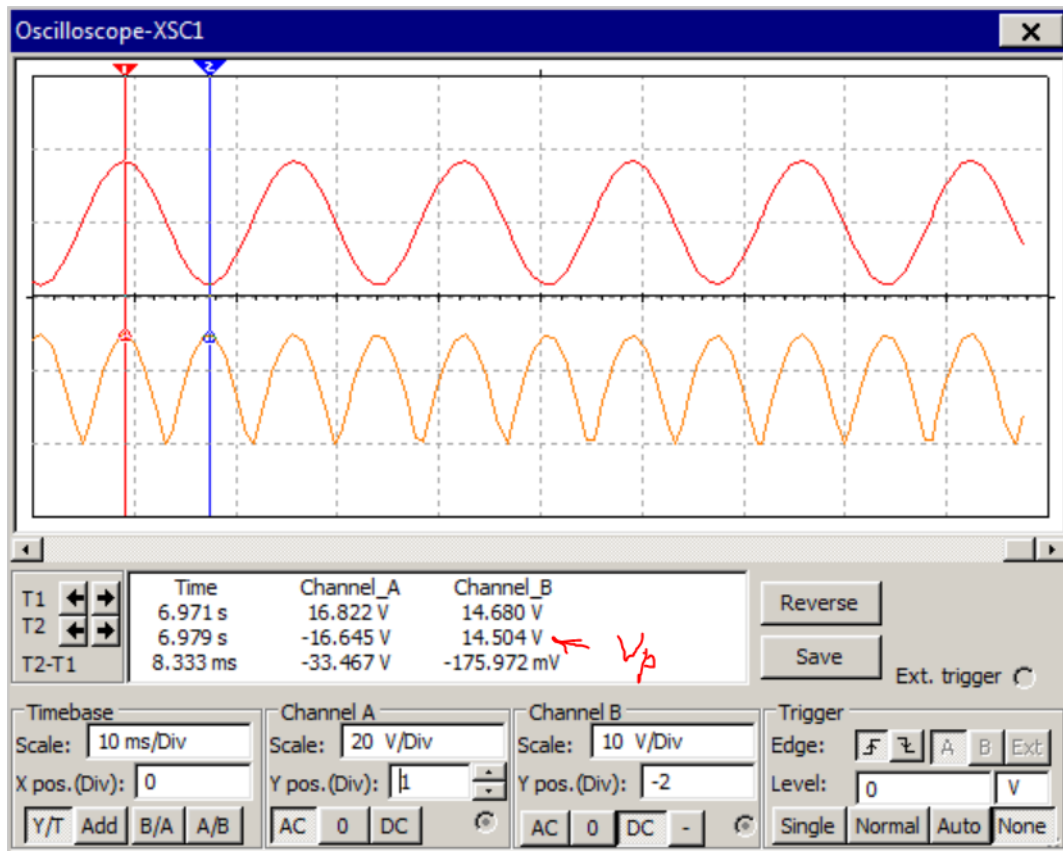
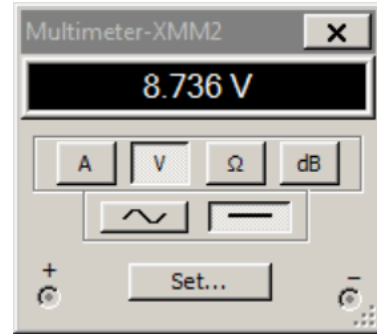


Figure 3. Peak load voltage of the rectifier circuit

It is seen on the oscilloscope that the rectified voltage (bottom waveform) is positive and the period is one half of the period of the secondary sinusoidal AC voltage (top). The sinusoidal AC voltage cycles 0 through 2π and the rectified voltage waveform cycles 0 to π .

The voltage on the load can be expressed by:

$$v(t) = V_p \sin(2\pi ft) \quad (2)$$

Where V_p is the peak voltage. Notice that $2\pi ft$ is an angle and can be substituted with the variable θ . So, $v(t)$ can also be written as:

$$v(\theta) = V_p \sin \theta \quad (3)$$

To determine the average DC voltage over a cycle, integrate the $v(\theta)$ over one cycle and divide by the interval π

$$\begin{aligned} V_{L(avg)} &= \frac{1}{\pi} \int_0^{\pi} v(\theta) d\theta = \frac{1}{\pi} \int_0^{\pi} V_p \sin \theta d\theta = \frac{V_p}{\pi} \int_0^{\pi} \sin \theta d\theta \\ &= -\frac{V_p}{\pi} (\cos \pi - \cos 0) = -\frac{V_p}{\pi} (-1 - 1) = \frac{2V_p}{\pi} = 0.637 V_p \end{aligned}$$

Thus, we proved that $V_{L(avg)} = 0.637 V_p$ for a full-wave rectifier circuit.

Based on the simulated voltage readings shown on Figures 2 and 3, $V_p = 14.504 V$ and $V_{L(avg)} = 8.736 V$, the ratio $V_{L(avg)} / V_p = 0.602$. This is close to the theoretical ratio 0.637 . The error is about 5% which can be contributed by the loading effect and other measurement issues.