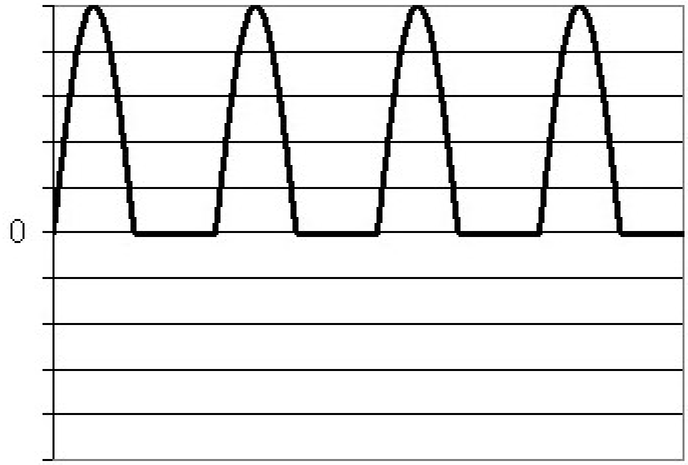
Half-Wave Rectification

That's where the diode comes into play. If we have a circuit that only conducts on the positive half wave of the sine wave, the average voltage would be positive, not zero, as shown in the following half-wave rectified signal.



In this case, the average (again, this corresponds to the DC component) is clearly positive, not zero. In fact, if you integrate the signal over one complete cycle, you arrive at

$$Vave = \frac{Vp}{\pi}$$

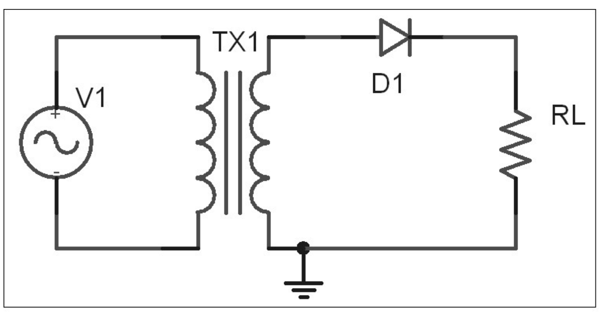
Also, if you perform an RMS analysis of this waveform, you discover that

$$V_{RMS} = \left|\frac{Vp}{2}\right|$$

Notice that this is smaller than the V_{RMS} for a sine wave by a factor of $\frac{1}{\sqrt{2}}$, which makes some sense, since part of the wave is missing.

The frequency of the half-wave rectified signal is the same as the frequency of the input signal -- it's just flat-lined for part of the cycle.

As indicated, we can use a diode to "cut off" half of the waveform. Typically, in our power supplies, we also use a transformer to reduce the amplitude of the original sine wave as well, as most of our working voltages are quite a bit smaller than the 120 V_{RMS} signal from our building wiring systems. Here's a typical Half-Wave Rectifier circuit:



The transformer steps down the voltage, then the diode allows current only when the incoming signal is positive with respect to ground. That current produces a voltage across the load resistor that's one diode drop below the input peak voltage.

Question: For the above circuit, V1 = 120 V_{AC} (that's shop talk for V_{RMS}) at 60 Hz, the transformer has a turns ratio of 8:1, the diode has a forward barrier potential of 0.7 V, and R_L = 220 Ω.

1. What is the peak voltage of the AC supply? 169.7 V_p
2. What is the peak voltage of the AC as seen at the secondary of the transformer? 21.2 V_p
3. Which peak will appear across the load resistor?

- [x] positive
- [ ] negative

4. Using the practical model of the diode, what will the peak voltage of the signal across the load resistor be?

   20.5 V_p

5. What is the frequency of the signal across the load? 60 Hz

6. What is the period, in milliseconds, of the signal across the load? 16.7 ms

7. What is the average voltage across the load? 6.53 V_{DC} (Notice the unit? Average voltage always corresponds to DC)

8. What is the RMS voltage across the load? 10.3 V_{RMS}

9. What power will the load resistor dissipate as heat? 478 mW

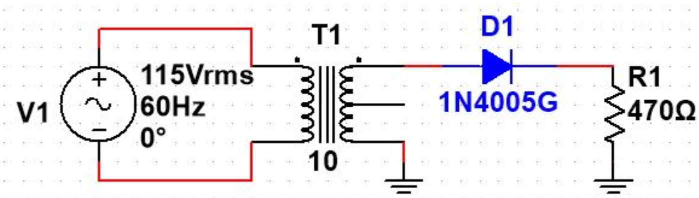
Notice one very important thing about units: all the voltages represent the same signal, but the numbers are very different. You MUST always include the appropriate subscript to indicate which measurement unit you mean -- V isn't going to cut it when working with AC signals! To help, though, the only subscripts you will use will be

- V_p
- $V_{p\text{-}p}$
- V_{DC}
- V_{RMS}

"V" by itself will refer to an instantaneous voltage, or, in some cases, to V_{RMS}.

Notice another thing: The numbers for V_{ave} and V_{RMS} are quite different. That means that our signal is not "pure DC", which is pretty obvious from the graph.

Here's a worked example for you to review on your own time.

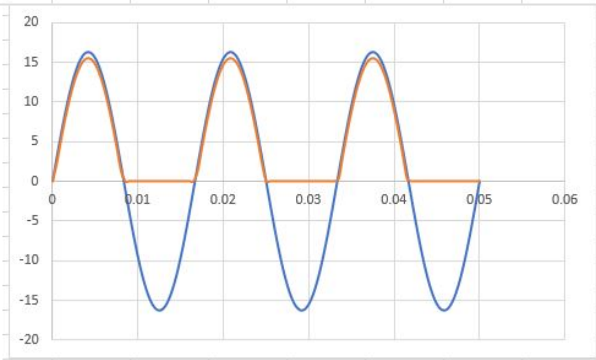


- Always start by converting the input signal to a peak voltage: $V_1 = 115 \cdot \sqrt{2}$ = 162.6 V_p

Take a look at the transformer: its turns ratio is 10:1; its secondary is centre-tapped, but we're using the entire secondary (if we were only using half of the secondary, the voltage would be half what the turns ratio predicts, but that's not an issue here -- just watch out for it!).

- So, the signal presented to the diode will be V1/10 = 16.2 V_p.
- From the diode's orientation, we see that it will conduct when the transformer signal is positive. So, for the positive half-cycle, we can replace the diode with a small voltage source, therefore the voltage presented to the load resistor will be the transformer voltage minus a diode drop. We'll assume 0.7 V, since we're not given any other information, so the positive peak voltage will be +15.6 V_p.

When the transformer signal is negative, the diode will be reverse biased, so we can replace it with an open switch. With no current possible through the load resistor, the voltage across it will be zero. This means we have a half-wave rectifier. The following plot compares the transformer output signal to the diode output signal:



- The frequency of the rectified signal is the same as the input at 60 Hz, so the period of this signal is 1/(60 Hz) = 16.7 ms.
- The average voltage, since this is a halfwave signal, can be predicted using $V=V_p/\pi$ = +15.6 V_p/π = +4.95 V_{DC}
- The power-related voltage, again for a halfwave signal, can be predicted using $V=|V_p/2|$ = 15.6 $V_p/2$ = 7.78 V_{RMS}
- The power dissipated by the resistor can be determined from the RMS voltage: $P=V_{RMS}^2/R$ = (7.78 $V_{RMS})^2$/470 Ω = 129 mW