Lecture 14, Oct 25, 2023

Regulator Design

- Diode selection is made more complex in a rectifier with a capacitor:
  - Input current only flows for a short period of time each cycle, which charges the capacitor and supplies the load – this leads to a significant current spike, so we need to ensure the peak repetitive surge current of the diode is high enough
  - Peak reverse voltage across the diode also increases significantly, since the output voltage stays high while the input voltage drops negative – the voltage drop is now close to twice the peak voltage minus the diode drop
    * Smaller ripple makes the peak reverse voltage closer to this
    * $PIV = 2V_p - V_{D_0}$
- The high peak current draw is a problem for power distribution grids, so we usually use some form of *power factor correction* to account for this
  - We can put an inductor in series with the input current; since the inductor resists change in current, this smoothes out the peaks (in theory, while in practice this doesn't work too well)

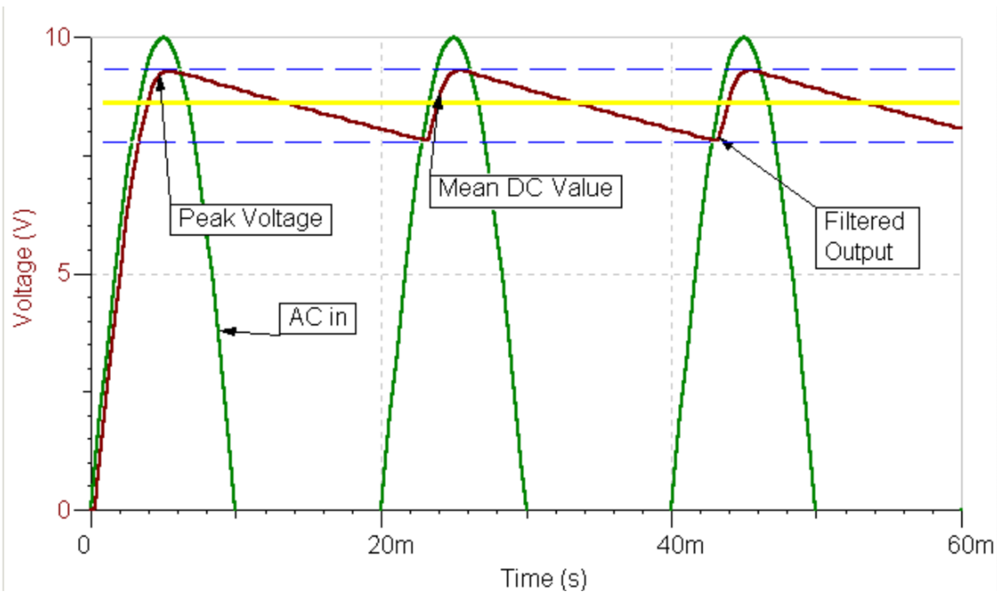

Figure 1: Plot of the output from a rectifier.

- The ripple voltage V_{RIPPLE} is typically defined as the peak-to-peak voltage difference of the output (distance between the two blue lines)
- For a capacitor, $V_{RIPPLE} = \frac{I_{LOAD}}{fC}$
  - Here we assume that the load current is roughly constant, which makes a straight-line approximation of the capacitor discharge valid
  - A larger capacitor and higher frequency (so peaks are closer) reduce the amount of ripple
- Note that in rectifier circuits, we typically use a *transformer*, which is a pair of coupled inductors wrapped around the same core; this steps down the line voltage and adds isolation between our circuit and the input
  - If the input (*primary*) winding is N_P and the output (*secondary*) winding is N_S, then the output voltage is $V_S = V_P \frac{N_S}{N_P}$
- Sometimes we will use the RMS voltage of the input AC signal, which can be converted into peak voltage by multiplying by $\sqrt{2}$

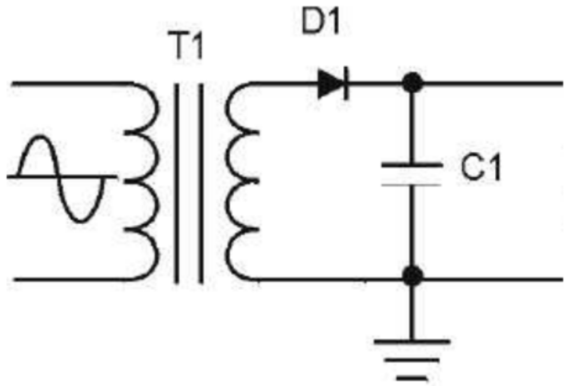

Figure 2: Example problem.

- Example: design the above half-wave rectifier by selecting C_1 and the RMS secondary voltage required for T_1, and specify the minimum PIV for D_1; the power supply will be regulated by a circuit that outputs 5 V DC and requires an input of at least 7 V; we want 20 mV peak-to-peak ripple, given a maximum load current of 1 A and $f = 60\,\text{Hz}$; assume $V_{D_0} = 1.0\,\text{V}, I_D = 1\,\text{A}$
  - Note that typically instead of targeting a small ripple input to the regulator, we typically leave the ripple rejection to the regulator
  - We can use the formula to solve for C_1 from the amount of ripple; we get $C \geq 0.833\,\text{F}$ (which is quite unrealistic)
  - Adding the ripple to the minimum output voltage and adding the capacitor voltage drop gets us a secondary voltage of about 8 V (where we have ignored the ripple voltage since it is comparatively small), or 5.66 V RMS
  - Therefore the PIV can be calculated by taking twice the peak secondary voltage and subtracting the diode drop, which is 15 V

Full-Wave Rectifiers

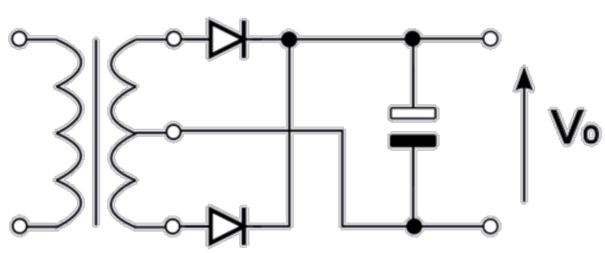

Figure 3: Full-wave rectifier circuit.

- By using a full-wave rectifier, we can effectively double the number of charging cycles (the input frequency), allowing us to select a smaller capacitor and get less ripple
- One way of implementing this is using a *center-tapped winding* on the transformer; this behaves like two separate secondary windings connected in series, so if we connect the center to ground, we get essentially a positive and a negative version of the AC signal
- These two signals are then fed through diodes and into the same capacitor circuit to rectify