Electronic Circuits Laboratory
EE462G
Lab #4

DC Power Supply Circuits Using Diodes

Instrumentation

This lab requires the use of:

➢ **Various features of the oscilloscope and function generator, most of which you should be familiar with by now from previous labs!**

➢ **Don't forget grounding issues! Both the function generator and oscilloscope grounds are the same node -- earth grounded!**

Power Supplies

Most information processing circuits require DC power for their embedded amplifiers and gates. Therefore, AC power from the local power company must be converted to DC for these circuits to function properly. There are 3 main operations to most power supplies:

➢ **Rectification (convert AC to pulsating DC)**

➢ **Filtering (Smooth pulsating DC to reduce peaks and raise valleys)**

➢ **Regulation (Control output voltage level to make it robust against input voltage fluctuations and load changes)**
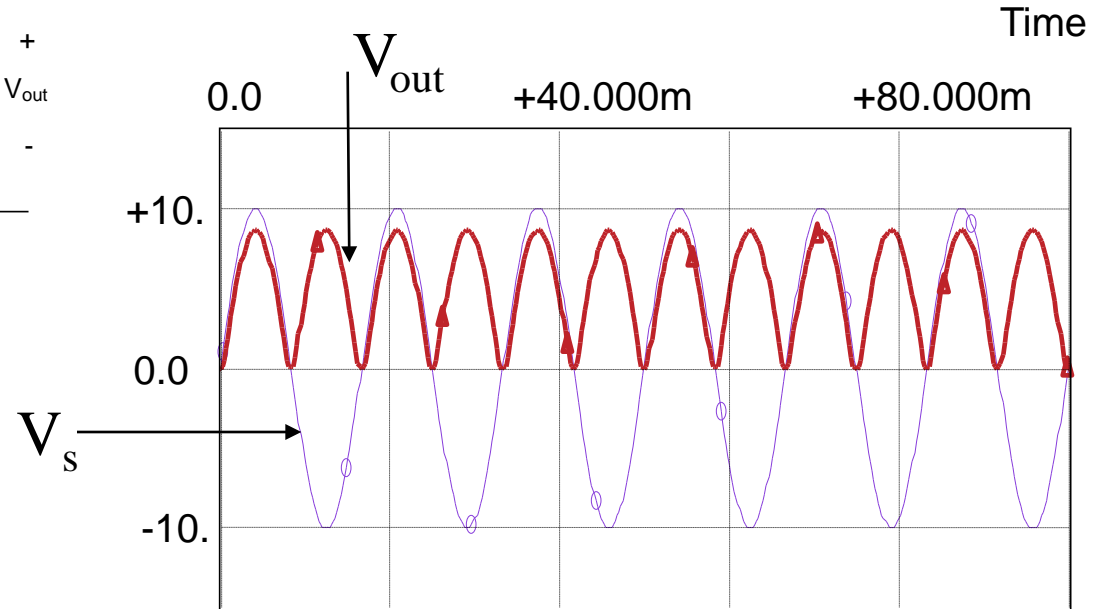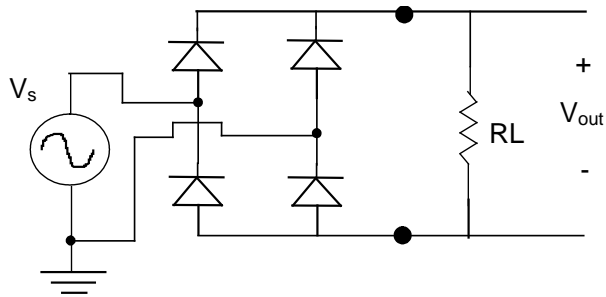
Rectification

A pulsating DC waveform can be created with the half-wave rectifier shown below:
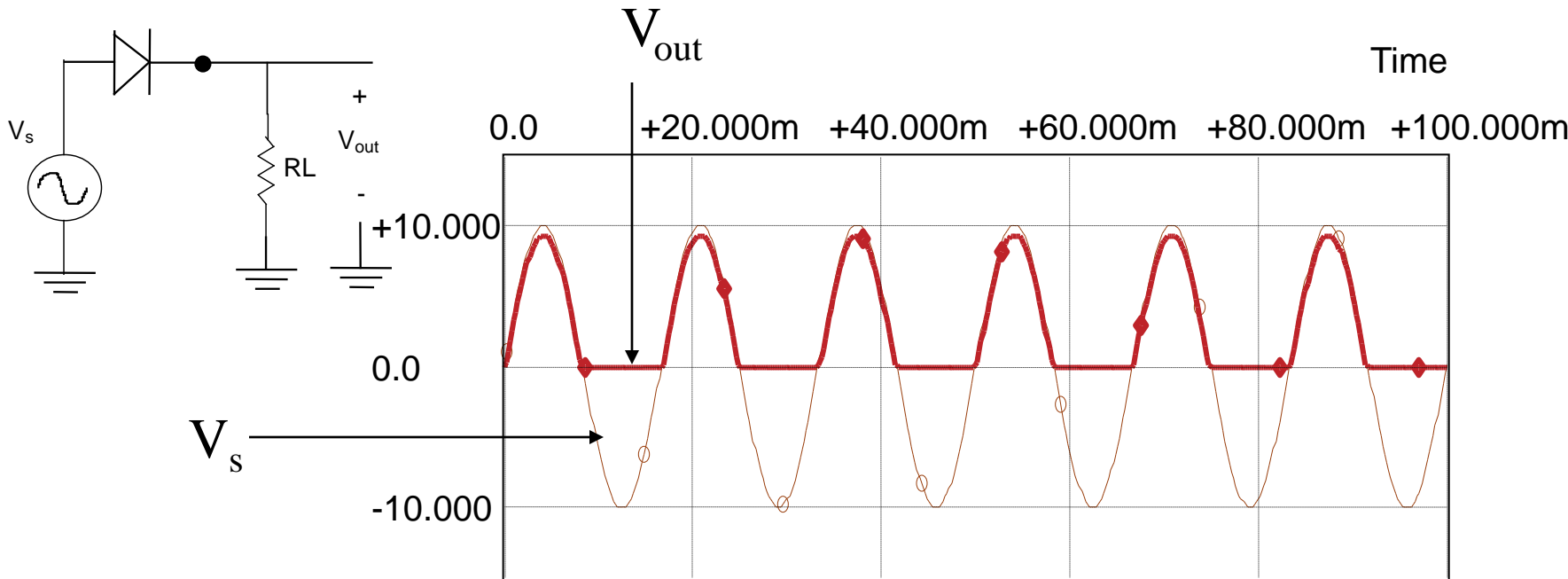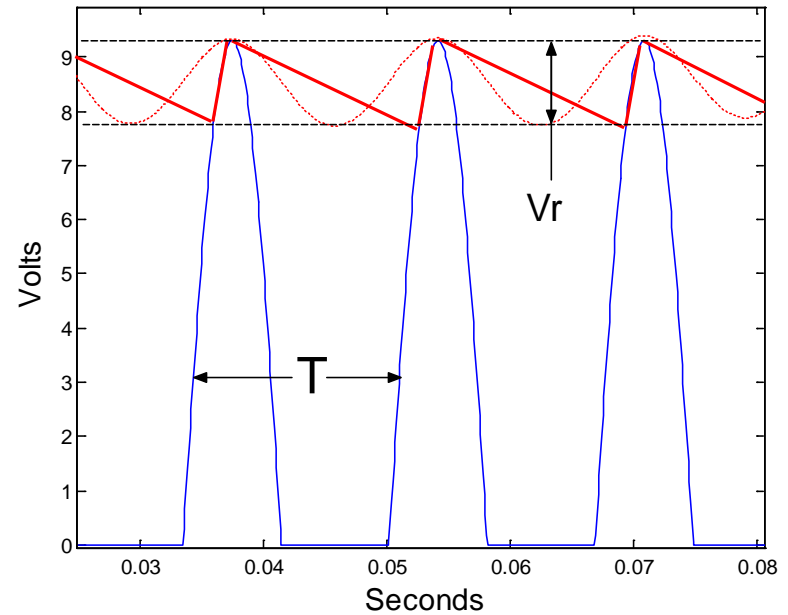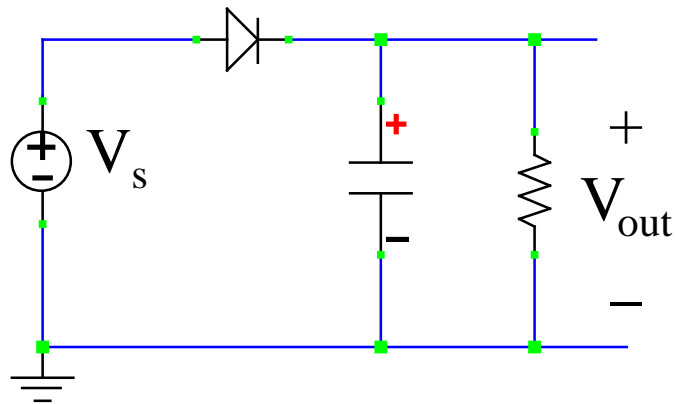
Rectification

A pulsating DC waveform can be created with the full-wave rectifier shown below.

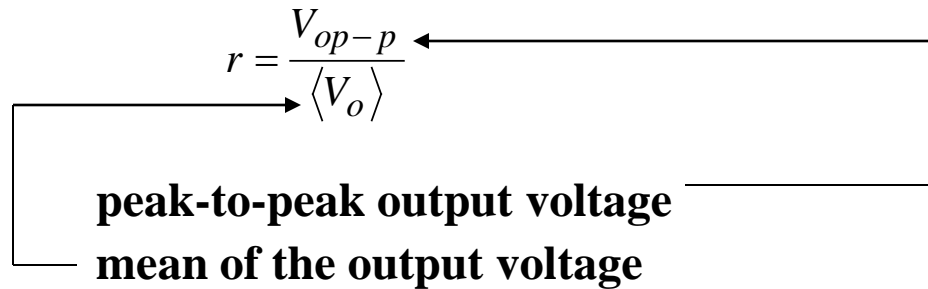**What are the advantages for full-wave over half wave rectification?**

Smoothing

A capacitor can be used to raise the valleys of the pulsating DC.

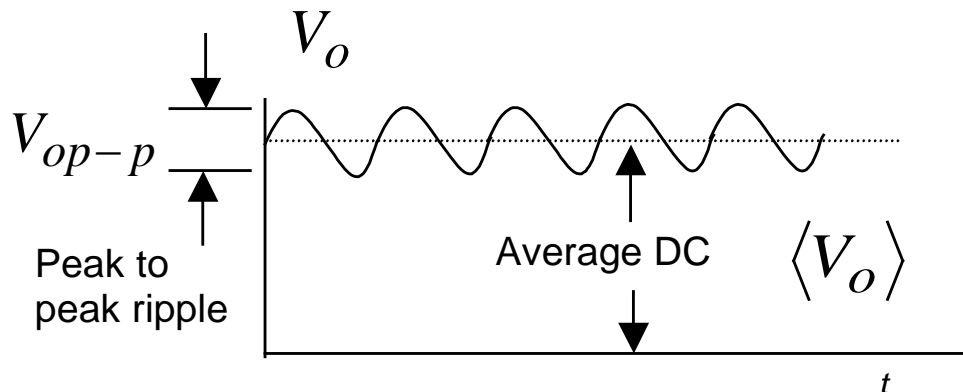Why doesn't the capacitor discharge as fast as it charges up?

Smoothing

A performance measure of a DC power supply is the *percent output ripple* expressed as *r* in the equation below:

$$r = \frac{V_{op-p}}{\langle V_o \rangle}$$

peak-to-peak output voltage

mean of the output voltage

Multiply *r* by 100 for *percent output ripple*.

V_o

V_{op-p}

Peak to
peak ripple

Average DC

$\langle V_o \rangle$

t

What scope *measure* functions can be used to obtain an estimate of *r*? What would the average or mean of this signal be, if AC coupling was used?

# Smoothing

Derive an approximate relationship between the capacitor value and ripple voltage V_r
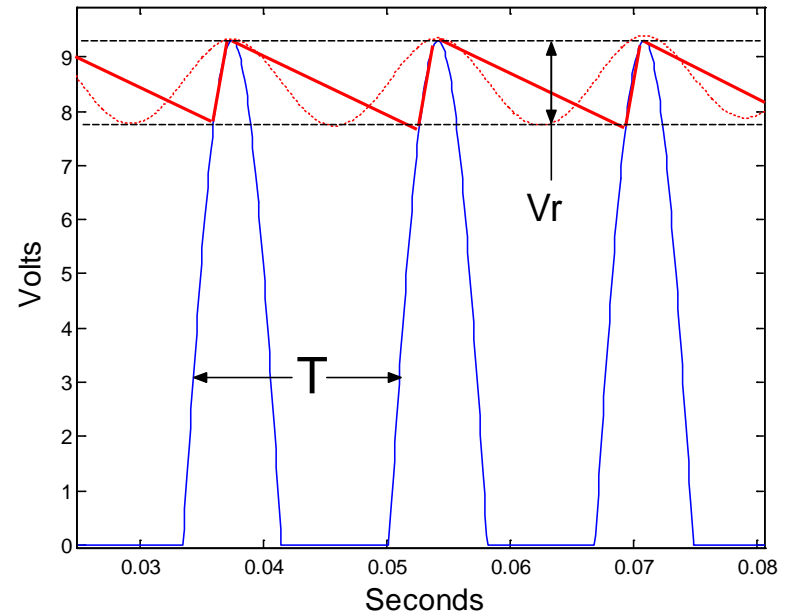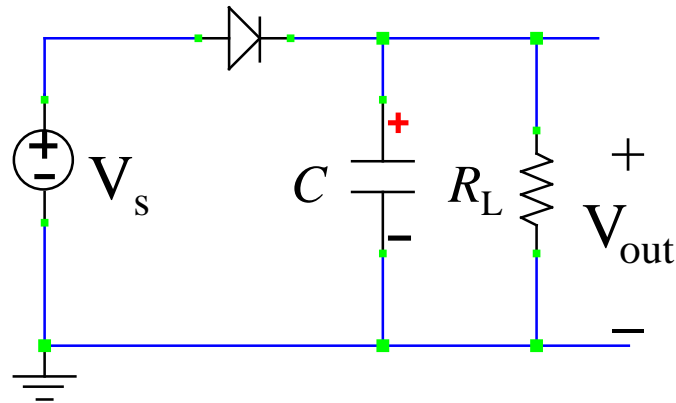
For diode-on state assume the time constant is much smaller than period T, so capacitor fully charges on pulse peaks (small cap-resistance product) and for diode-off state assume assume time constant is larger than period (large cap-resistance product) so capacitor discharges more slowly.

Smoothing
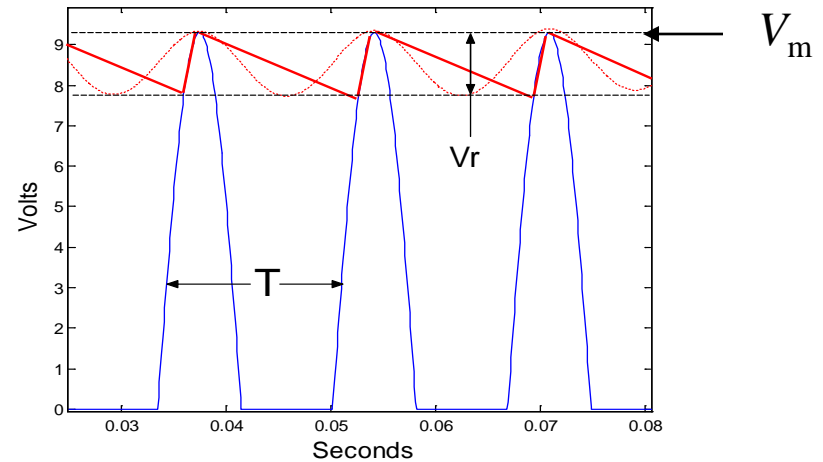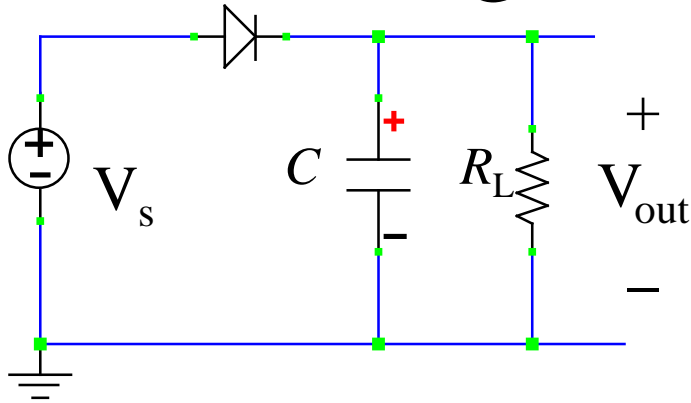
For discharge cycle (diode off), the charge removed from the capacitor is:

$$Q \approx \langle I_L \rangle T \quad \text{where } T \text{ is the period of wave form and } I_L \text{ is load current}$$

Charge is also related to the voltage change and capacitor value:

$$Q \approx V_r C$$

From the above, the following relationships can be derivedfor half-wave:

$$C \approx \frac{\langle I_L \rangle T}{V_r} \qquad C \approx \frac{\left(V_m - \frac{V_r}{2}\right)T}{V_r R_L} \qquad V_r \approx \frac{TV_m}{\frac{T}{2} + CR_L} \qquad V_m = V_{sp} - V_f \qquad V_{sp} \text{ is peak value of } V_s$$

Show for full-wave rectification:

$$V_r \approx \frac{TV_m}{\frac{T}{2} + 2CR_L} \qquad V_m = V_{sp} - 2V_f$$

Example

R_L=2.5k Ohms and C=100µF, and assume near-ideal diodes with v_f=0.5 Volts and v_s(t)=8sin(200πt). Find Vm, ripple voltage Vr, and Sketch $v_{out}(t)$ vs. t for 0<t<0.04 s.
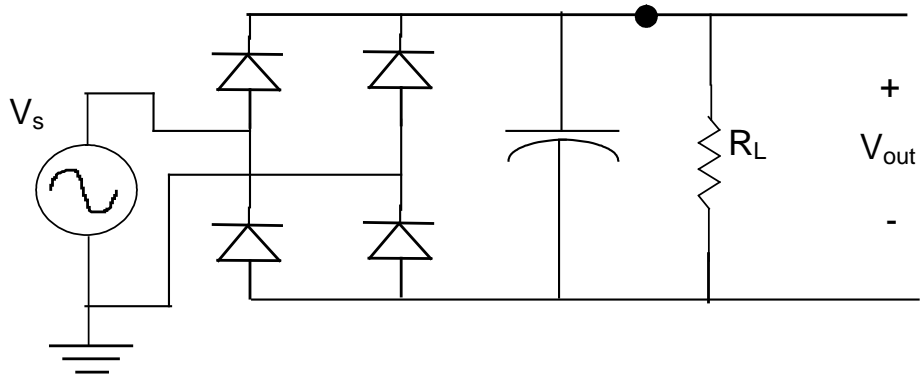
Regulation:

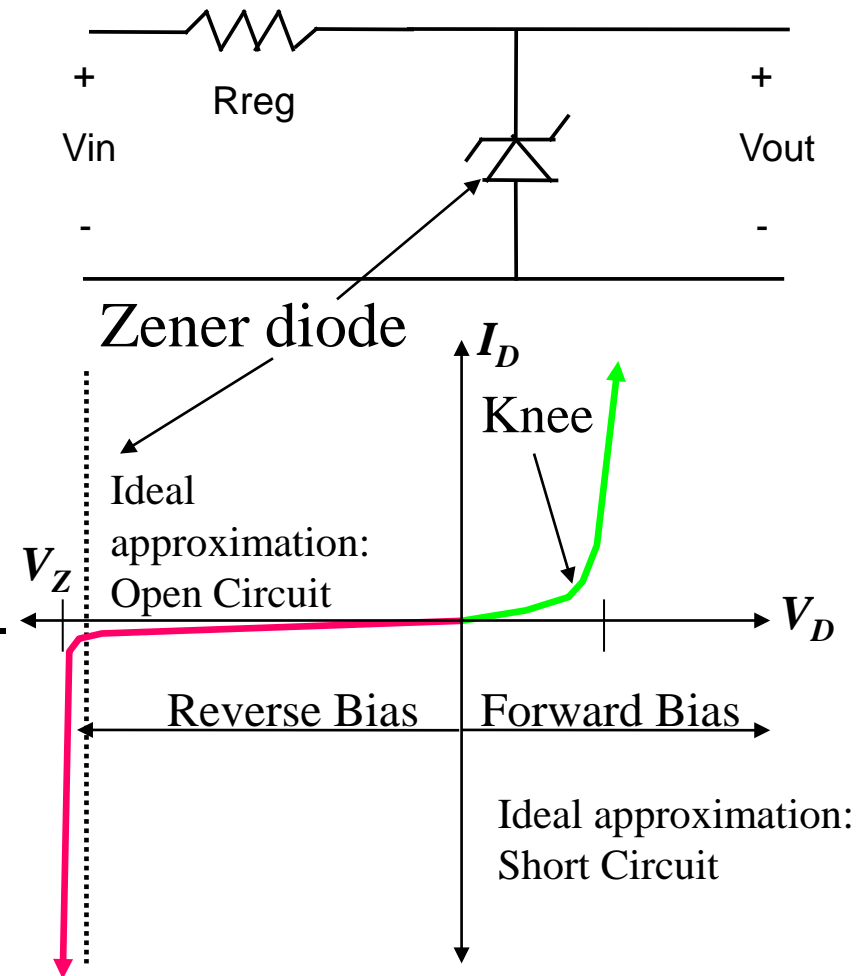➢ A DC power supply provides constant DC voltage, independent of load and input voltage fluctuations.

➢ A voltage regulator circuit is used to limit changes in output voltage.

➢ A Zener diode can be used in a voltage regulator circuit by taking advantage of the Zener diode's reverse breakdown characteristic.

➢ The regulator's resistor, Rreg, limits the current through the Zener to reduce dissipated power.

+   Rreg

Vin   Vout

-                                 -

Zener diode

I_D

Knee

V_Z Ideal approximation: Open Circuit

V_D

Reverse Bias   Forward Bias

Ideal approximation: Short Circuit

Regulation

Assume the Zener is operating in its breakdown region with a breakdown voltage of *Vz*. Show the power consumed by the Zener under a no-load condition is:

$$P_z = \frac{V_z V_{in} - V_z^2}{R_{reg}}$$
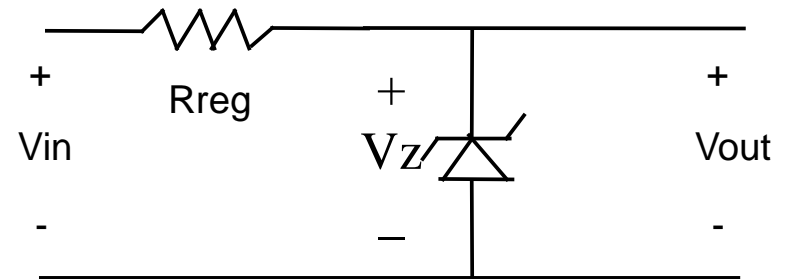
Assuming an Ideal Zener diode (zero reverse bias current, and vertical breakdown region), what is the max power delivered to a load with output voltage V_z?
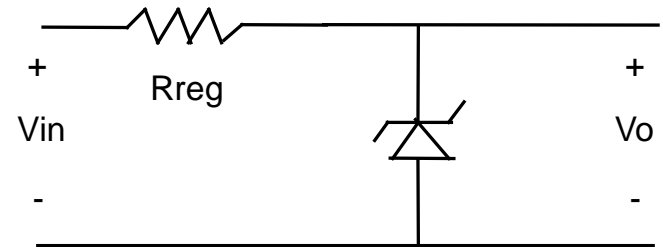
Show that the load resistance at this point is (VzRreg)/(Vin-Vz).

What happens when load resistance is less than this value?

Regulation

➢ **Performance of a regulator is typically measured in terms of** *regulation* **given by:**

$$\text{Regulation} = \frac{\langle V_{oNL} \rangle - \langle V_{oFL} \rangle}{\langle V_{oFL} \rangle}$$
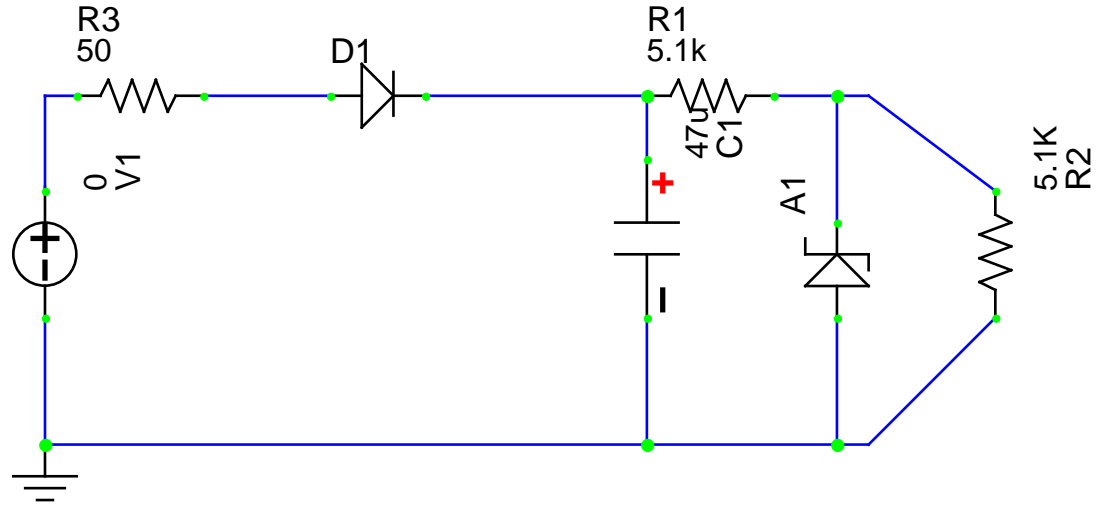

$\langle V_{oNL} \rangle$ is the average output no-load voltage (open circuit)
$\langle V_{oFL} \rangle$ is the average output full-load voltage (smallest rated resistive load)
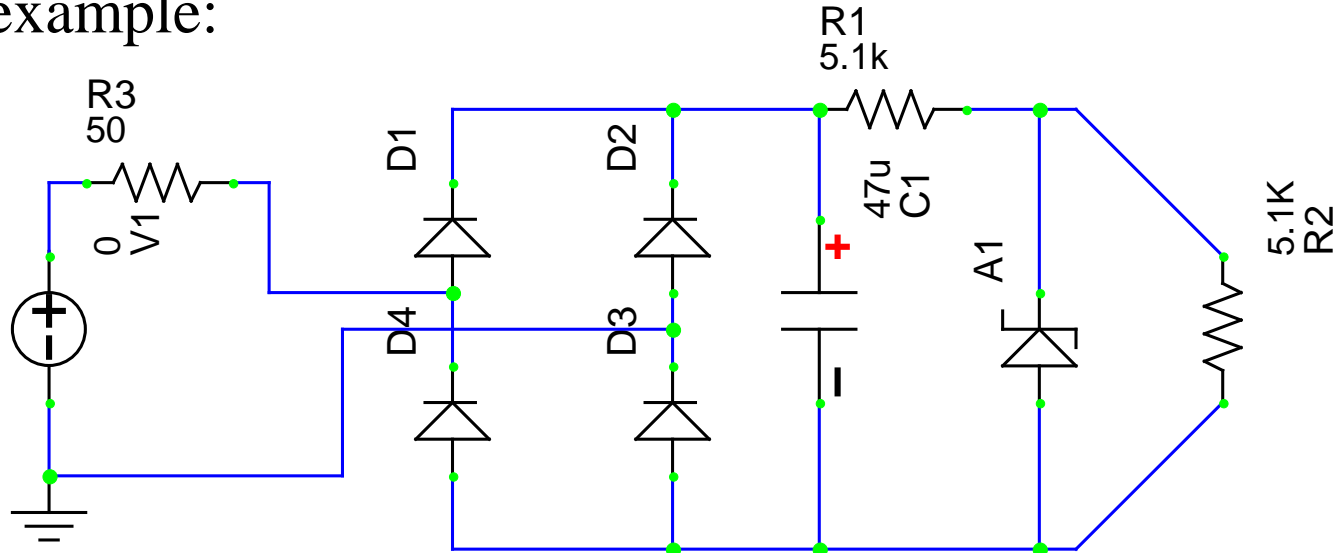Percent regulation is obtained by multiplying Regulation by 100.

Power Supply with All Stages

Half-wave example:

Full-wave example:

SPICE

Critical SPICE Features for simulating the circuits in this lab include:

➢ The **zener diode** (if not in the main parts menu, use the *browse for part* option and type in zener as a key word and apply filter. Of the several choices, select the default or generic zener).

  ➢ Must set the **breakdown voltage** for the part through the edit simulation model

➢ For input, select a **sinusoidal** (do not check use AC) and set amplitude and frequency from the **transient properties** tab options.

➢ For simulation set up select **Transient and Fourier Analysis** option, set start time, stop time and increment/step. These values must be selected to give you a clear plot in a reasonable amount of time. **Do not enable Fourier**.

➢ Use 50 Ω in series with ideal source to simulate internal resistance of the function generator.

Matlab

A Matlab function that plots a clipped waveform can be useful for computing power. For your prelab assignment you can use the function designed for this class "csinplot.m" and write a script to solve the first prelab problem.

➢ Mfiles designed to be functions act as subroutines in the workspace. Parameters are passed into the function and results are passed to the output. Intermediate values do not remain in the work space.

➢ Mfiles designed to be scripts are a sequence of Matlab commands that are executed in the order typed. All intermediate values are saved in the workspace.

➢ You need to **hand-in** (pre-lab) a printout of the script you wrote (and functions if you wrote any), along with the results it produced.

Final Notes

- ➤ Beware of grounding issues, especially on the full-wave rectifier!

- ➤ Scope settings are important to describe in the procedures sections. These are not spelled out in the labs (so you are expected to think about the best way of doing the measurements). You should indicate probe placement, coupling, measurement functions, math settings, and any other setting critical for making the measurement.

- ➤ Be sure to respond to all comments and questions in bold type in the Discussion Section.

- ➤ All measured values and requested values computed from the measured values should be in the Results Section. Describe how values were computed in the Results Section. Be explicit and brief …. use equations.