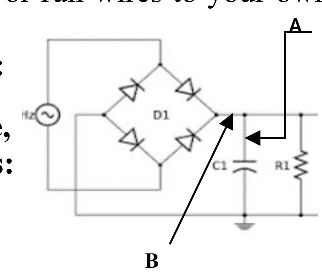
Rectifiers, Filters, and Zener Diodes

Please refer to H&H, 1.2.6, and 1.5.2 thru 1.6.5, and the Canvas module; also, Hands-On Electronics, Ch.3. Use the supplied transformer board (13 VAC nominal) for these experiments; it has a transformer with the primary wired to an AC line cord and switch; the secondary is isolated from the AC line and is wired to a PC board containing a bridge rectifier and filter capacitor. There are terminal blocks mounted on the circuit board: two terminals are connected across the filter capacitor and two terminals are connected across the transformer secondary. See the schematic below. You may use the bridge rectifier and capacitor by connecting to the + and – terminals as needed, or directly connect to the transformer secondary by using the terminals marked "AC". Be careful to not short the output since it is not current limited (there is a fuse). The 115VAC line voltage may be varied by plugging your transformer into a "Variac" variable transformer. Please read the entire lab before you start. Saturday schematics required where shown.

For current-waveform measurements, use a clamp-on current probe with an oscilloscope. READ THE INSTRUCTIONS for this instrument– NEVER CLAMP THE CURRENT PROBE ON AN UNINSULATED WIRE. **Always verify operation and calibration of the current probe by simply shorting the bench power supply and placing the current probe over the lead; set the power-supply current-limit to 1A. The deflection on the scope should correspond to the DC current display on the power supply.**

> Do **not** use the solderless breadboard for Part I of this lab; the components have heavy leads and may get hot, damaging the breadboard!! Just solder the few parts together "in air". To "load" a high-current power supply you will need high-wattage resistors. At the front of the lab by the Windows we have several variable resistors and resistor- substitution boxes that can carry high currents. It is important that you carefully observe the current rating of these adjustable loads. You will also find a few fixed resistors that you can use in various combinations.

Part 1: (A) Design and build a full-wave rectifier with a capacitor-input filter. Load the output with a current of about 1/2 amp; conduct your tests with the transformer operated on nominal line voltage (115VAC). Calculate a value for the filter cap; peak-to-peak ripple voltage should be in the range of 20% @ FL (this value is NOT critical). You may use the bridge rectifier and filter capacitor on the transformer board, or run wires to your own rectifier and filter. Make connections with the terminal blocks as described above.

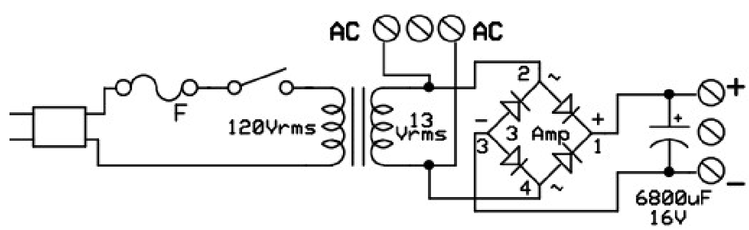


Provide a schematic and, where appropriate, record waveforms (P) of the following:

Where appropriate, use multiple scope traces, along with a DMM when appropriate, to simultaneously view waveforms (i.e., voltage and current) and DC measurements:

a. DC output (load) voltage (average). DMM is probably best here.
b. DC output (load) current (average). DMM is probably best here.
c. DC output ripple voltage (peak to peak). (P)
d. Filter capacitor peak and RMS current, point A {Use current probe on an *insulated* lead.} (P)
e. Bridge rectifier output current, point B. (P)
f. Explain the waveforms seen at points A and point B; what is the difference between them?

How do you define "output voltage"? What causes the drop in output voltage as the load increases? Beware of misleading values produced by the oscilloscope "measure" functions. Always confirm by counting gridlines.



Important hint: the amplitude of the pulse current into the filter capacitor is so large that the voltage drop across wires can be surprisingly large. For this reason, always connect your load (and especially the oscilloscope) **directly** across (and as close as possible to) the filter capacitor rather than another location closer to the diodes. In this way, the voltage drop in the conductors will be minimized -much like taking a "four-wire" measurement. Keep this detail in mind if you ever lay out a printed circuit board!

Definitions: "FL" means full load = maximum load current. **"NL"** means no load = zero load current (open circuit).

P1/3

(Provide a Sat Schematic of your rectifier and filter in Part 1, including value of filter capacitor).

Part 2: Design a *voltage doubler* that outputs a nominal 30 VDC when supplied by the transformer secondary. Maximum load current ("FL") will be 50 mA. Design for a ripple of 10-20% at FL

The formal calculations for voltage doublers are tedious and usually not worth the effort. Therefore, use a simple, reasonable approach for estimating appropriate capacitor values; **be prepared to discuss capacitor selection** (hint: work backwards). Simulation may be used for verification, but a value for capacitor ESR must be included for accurate simulation**. (Provide a Sat Schematic with capacitor values).**

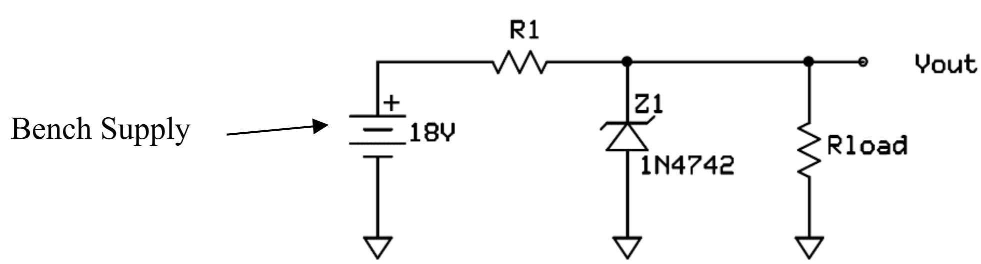
Build your circuit. Measure and record DC output voltage and ripple voltage (FL) at the nominal AC line voltage.

For the line-voltage tests you will use a "Variac" to vary the AC voltage input to your power-supply transformer. You can usually read the AC output voltage of the Variac directly from its dial or, if available, from the AC voltmeter mounted on the unit. Since your power supply already has a step-down isolation transformer, it is not necessary for you to use the "isolated" Variacs; you can use either the isolated or non-isolated version for this lab. Please keep this circuit built for later in the this lab.

Part 3: Refer to the data sheet: https://www.diodes.com/assets/Datasheets/ds18007.pdf

A. Design a simple voltage regulator, using a 1N4742A Zener diode, that will provide 12.0 VDC from a nominal 18 VDC provided by a bench supply. Calculate a suitable value for R1.

The output load will vary from no-load to 65 mA. Naturally, the supply must stay in *regulation* as the load changes (the Zener must never "*drop out*"). (Provide a Sat Schematic with value for R1).



a) Calculate the maximum worse-case power dissipated in the Zener. Using the power derating curve from the data sheet, what is the maximum allowable operating ambient temperature for your circuit (under both load conditions, NL and FL)?

b) Change the input voltage to 15.0 VDC; record the output voltage of your circuit at no-load and full load. What is happening? Record your conclusion.

B. Change the value of resistor R1 so the circuit stays in regulation at full load when the input is 15.0VDC. Record the output voltage of the new circuit at no-load and full load. Calculate the maximum worse-case power dissipated in the Zener. Using the power derating curve from the data sheet, what is the maximum allowable operating ambient temperature for your circuit (under both load conditions, NL and FL)?

C. Use measurements of the circuit in B to determine the series resistance of the Zener.

Part 4: Add a 12 V Zener diode network to the doubler from Part II to provide a 12 VDC regulated output over the conditions given below (note the varying load). **Be prepared to discuss your choice of resistor value.** For this section use the values below:

Vin = 85 to 130 Vac. Iout = 0 to 40 mA. Max ambient temp = 100^0C. Zener = 1N4742 (1W)

a) Measure load regulation (as %, NL and FL at 95 VAC), **line regulation** (as %, 95 and 130 VAC at FL), and **maximum ripple** (as Vp-p, at 115VAC, FL (of course). **At FL, what happens as Vin is reduced far below 95 VAC?** From the data, estimate Zz when operating at FL.

b) Measure and record DC output voltage and ripple voltage (@FL) at low line and high line. How does the performance of this circuit compare to the unregulated circuit in Part II?

Please be prepared to demo the above circuit during your recitation. Set it up to operate from a Variac.

Part 5: With each of these three rectifier configurations (1/2 wave, full wave, and doubler), what is the rated reverse voltage requirement and rated current requirement for each of the rectifier diodes?

The red wire said to the black wire "Why are you so sad?"

Comments on Power Supply Specifications

DC output voltage: When "DC" is specified, you can assume that this means the average DC voltage, which is what a DC voltmeter would measure. On an oscilloscope, using the grid you could measure from ground to the center of the peak-to-peak ripple. You could use the measure function, but only if you read the manual first and have a complete understanding of the measurement algorithm – and verify with the visual measurement.

Output ripple: Ripple is always specified at the maximum load, because ripple is greatest at this point. Power supply manufacturers typically specify the ripple component as an RMS value rather than a peak-to-peak value. This implies a better, lower-ripple output than is the case with a peak-to-peak measurement, but a user is always more interested in the peak-to-peak value. Ripple specifications often include "noise".

Ripple percentage may be defined as the RMS ripple voltage divided by the nominal, or average, DC output voltage, multiplied by 100%. However, stating it this way is somewhat deceiving because it minimizes the ripple; it is generally much more useful to specify the peak-to-peak ripple voltage in Vpp or mVpp, not as a percentage.

Load regulation: This is the change in output voltage as the load is varied from no-load to full-load. It is usually expressed as the output voltage change divided by the nominal output voltage, multiplied by 100%. To be of most value, this specification should be measured at the worst-case operating point of the power supply. This will generally be at the low-line condition, but the nominal and high-line conditions should be checked also.

Line regulation: This is the change in output voltage that occurs as the AC line (or other input source) is changes from the specified low-line to the specified high-line values. The test should be run at both no-load and full-load. Line regulation is usually expressed as the output voltage change divided by the nominal output voltage, multiplied by 100%. **"High Line"** is generally specified as 130 VAC and **"Low Line"** at 95 VAC.

Line/load regulation: This value represents the maximum change in output voltage as both the load and line are changed over the extent of their values. Line/load regulation is usually expressed as the total (worse- case) output voltage change divided by the nominal output voltage, multiplied by 100%.

The black wire replied, "I've been grounded".