Linear Power Supplies

Part 1:

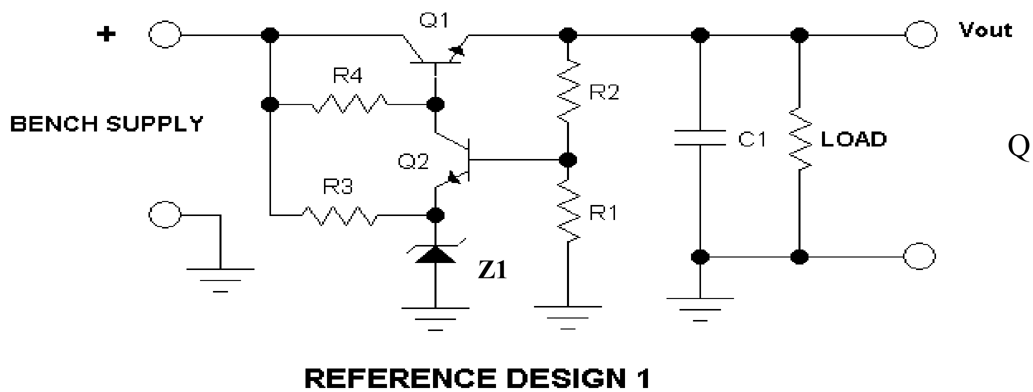
Please review the appropriate sections of H&H, Ch.9, as well as Canvas material.

The circuit shown below is a classic linear regulator. Calculate values for operation as specified. Build, test performance, and record values as requested below. Please be prepared to explain how all values were calculated. Note that this "reference design" is a starting point, but your circuit will be different; you may modify the design in any way you wish to improve performance, but no op-amps may be used. Do NOT attempt to build with plug-in proto board; solder components together using a small PCB "kluge" board (or even an "air breadboard"), and use the T-220 socket adapter for Q1. Carefully review the notes at the end of this lab.

For Saturday: Provide a preliminary schematic for the circuits in Part 1 and Part 3.

Specifications:

Vin = 12 Vdc to 18 Vdc. Vout (nominal) = 9 Vdc +/- 0.5 V. Iout = 0 to 1.5 Amp
Line + Load Regulation < 1.5% Let C1 = 100uF.



Q1 = TIP31A,B, or C

a. Measure and record Line Regulation and Load Regulation as if this were a commercial power supply. What design aspects contribute to regulation?

Reg_{line} =___________ % @ FL. Reg_{load} = __________% @ Vin = Low Line

When taking precise, quantitative DC voltage and current measurements always use a DMM, but confirm measurement validity with an oscilloscope.

b. Calculate the heat sink size for operation at 50C ambient. Assume worse-case operation.
Max Pd @ pass transistor =___________W Heat sink <_____________deg C/W.
Assume $Ø_{C\text{-}HS} = 1^0$C/W. Clearly show your work.

c. Measure input dropout voltage: $Vline_{min}$ =_________. Do you think you should measure this at no load or full load? What is the *differential* dropout voltage: Vi/o_{min} =--------------.

What circuit considerations contribute to a large (poor) I/O-differential value?

d. Carefully measure the efficiency of the supply at high line and full load: __________ %
Carefully measure the efficiency of the supply at high line and load = 0.1A: __________ %

Your power transistor will require a heatsink. For long-term, reliable operation, you would use a large heatsink with the thermal resistance that you calculated above. However, for quick measurements you can get away with a relatively small sheet- metal heatsink that you will find in the lab.

e. Add circuitry to your supply to add active current limiting to limit maximum output current to 2A. Measure and record short-circuit current. Be quick about it!

I_{SC} = __________ A

f. Why doesn't the addition of the current-sense resistor impair regulation?

g. The ratio of R2/R1 determines the output voltage. However, what are the effects of the <u>magnitude</u> of R1 and R2? How does it affect circuit performance and with what trade-offs?

h. <u>**For a 2 point bonus**</u>: How could you add fold-back current limiting to the supply? Discuss how this work and why it would improve cost, size, reliability, etc.

<u>COMMENTS ON PART 1</u>:
1. Remember that the output voltage is a multiple of the reference voltage. What does this tell you about the importance of the reference stability? Remember that Zener specifications are "best" around what value of VZ?
2. Resistor R4 must always provide enough base current for Q1. However, R4 may dissipate an unacceptable amount of power at certain operating points. Try changing the circuit to keep the maximum dissipation under one watt.
3. Once you have selected R4, you can calculate Q2's maximum collector current; then you can select the magnitude of R1 and R2.
4. To add current limiting circuitry, add a current-sense resistor at the appropriate place in the circuit. Of course, you NEVER break the ground line.

<u>Regarding Power Supply Specifications:</u>

<u>Nominal Output Voltage</u>. This value represents the target "design" voltage of the power supply. It will vary, sometimes significantly, due to component tolerance. A value for output- voltage tolerance of +/-5% is common. The precise output voltage of a power supply is, typically, not too important. If the output voltage of the power supply must be particularly exact, a voltage-adjustment potentiometer is usually provided; this can be used to adjust the output voltage as required, either at the time of manufacture or in the field. Since most power supplies can be adjusted, this is not a true measure of power supply quality and I do not place too much emphasis on this specification.

<u>Output Voltage Regulation</u> is much more important. This specification determines how much change you can expect in the output voltage as the operating conditions vary (within prescribed limits); this is a much more important measure of power- supply quality. This is because output- voltage regulation cannot be improved -either at the time of manufacture or in the field; it is determined by the design and, in a few cases, by the quality of the components. For example, the gain of the error amplifier, the series-resistance of the Zener, and the circuit- board design may have large effects on power supply regulation.

Therefore, in Lab #7, whereas the output voltage has a tolerance of +/_ 5.5%, the worst-case regulation should be better than 1.5%.

For the sake of convenience and the simplification of testing, you have operated your circuit on a bench supply in Part 1. In Part 2, you will operate your circuit on an unregulated power supply; this is a much more real-world situation.

<u>Part 2</u>.

For this part, you will, operate your regulator circuit on the "12V, 3A" transformer/bridge-rectifier/filter (with on-board filter capacitor = 6800 uF) in place of the bench supply. **How will you trigger your oscilloscope for this part of the lab**? In this part of the lab, consider circuit changes to minimize the ripple across the Zener.

a. Using the Variac AC supply, determine the AC line dropout voltage (at FL, of course). $VACin_{min}$=__________.

b. Measure ripple at Vout (at FL, of course) ____________________ $V_{pk\text{-}pk}$

c. Determine the exact AC line voltage at which your supply drops out. Note that this point is a little indeterminate and difficult to measure; how could you use your oscilloscope and observe ripple to conveniently and accurately determine the exact line voltage at which dropout occurs?
Drop-out voltage:____________ VAC,

<u>FOR YOUR RECITATION, PLEASE KEEP THE CIRCUIT IN Part 2 BUILT AND READY TO DEMO WITH A VARIAC AND SUITABLE LOAD RESISTOR,</u>

<u>Part 3</u>;

Design, build, and test a simple "LDO" (low-dropout) voltage regulator that incorporates a P-channel power MOSFET as the pass element. This can be constructed with the MOSFET and two BJTs. For stable operation, bypass the input with 47 µF and the output with a large capacitor on the order of 100 µF. It may help to find a clever location for the Zener diode.

As in Part 1, first build your circuit with a solderless breadboard, then build a final version with a soldered kluge board and a TO- 220 socket adapter.

Vin = 10 Vdc to 18 Vdc. Vout (nominal) = 9 Vdc +/- 0.5 V. Iout = 0 to 1.5 Amp
Line + Load Regulation < 1.5% Maximum quiescent current = 20mA.

Measure Line + Load regulation. Note that this can be done easily by measuring the output voltage at the two extreme operating points: high- line/no load, and low- line/full load; all you care about is the overall, worst-case change in output voltage.

Measure input dropout voltage: $Vline_{min}$ =__________. Do you think you should measure this at no load or full load? ___________. What is the *differential* dropout voltage: Vi/o_{min} =---------------.

- A point to ponder: could you use an <u>N-channel</u> MOSFET to design an LDO regulator????

Part 4; THE FOLLOWING PART IS DESIGN ONLY; INCLUDE AN ACCURATE SCHEMATIC WITH ALL COMPONENT VALUES. You are **not** required to build this circuit**:**

Design a power supply similar to the one you designed for Part 1 above, but change it to a variable supply with an adjustment range of 4V to 9V DC.

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Please Note the Following:

This lab may take some time. Please ask for help sooner rather than later.

Important considerations regarding construction.

To obtain good performance in an analog circuit that carries heavy current, it is very important that you do not have spurious voltage drops that interfere with the ability of the error amplifier to precisely compare the output voltage with the reference. It may not seem too important, but even the slight amount of resistance presented by wires and connections, when carrying high current, is enough to hurt performance. This is the reason why it is necessary that you construct your circuit very carefully. High currents traveling through critical portions of the circuit can produce significant voltage drops that may produce a surprisingly significant error in the output voltage. It is crucial that your power supply is constructed so that heavy currents are properly routed. Therefore, you must assemble your circuit on a small piece of perforated, printed-circuit "kluge" board instead of the solderless breadboard.

Also note that components that get hot or have large-diameter leads will damage the solderless breadboard.

For example, be sure you understand exactly where the error amplifier is sensing the output voltage; any voltage drops must be outside of the regulation loop. Another potential problem occurs when the load return current, flowing through ground, produces a voltage drop that, to your error amplifier, appears as a change in the reference voltage. In this example, it is very important that the anode of the reference Zener be connected to ground at such a point where this voltage drop will not cause a problem. You may have difficulty meeting the voltage regulation specifications if you do not pay attention to this issue. Think about a "star" layout or single-point grounding.

On the other hand, since these voltage drops are only a problem at higher currents, it may save you a lot of time if you first build your regulator on a solderless breadboard and test for basic operation at low currents, say < 100 mA. When you are sure it is functioning properly, you can solder the components together on a kluge pc board and test at the specified load current. This approach may be most helpful when you are developing a regulator of your own unique design.