Lab#3 DC Linear Power Supply

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Objectives: Analyze a DC linear regulator

Material: Simulated on Mindi

To hand in to Team Assignment

1- This document with the answers and measures. Copy-paste screenshots when required.
2- You provide comments to all screenshots
3- Upload the wxsch project file

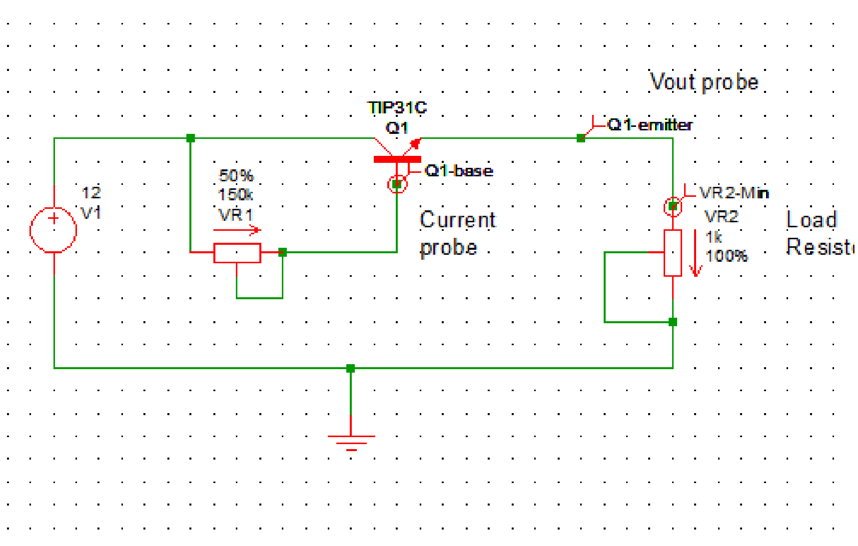
Lab preparation: Fill in the calculate column for all tables

Lab work

Part 1: Manual regulation

In this part of the lab, you are going to manually regulate a load voltage.
When the load changes, you must increase or decrease the current at the transistor to regulate the output voltage at a constant value of 6V.

- Wire the following circuit:



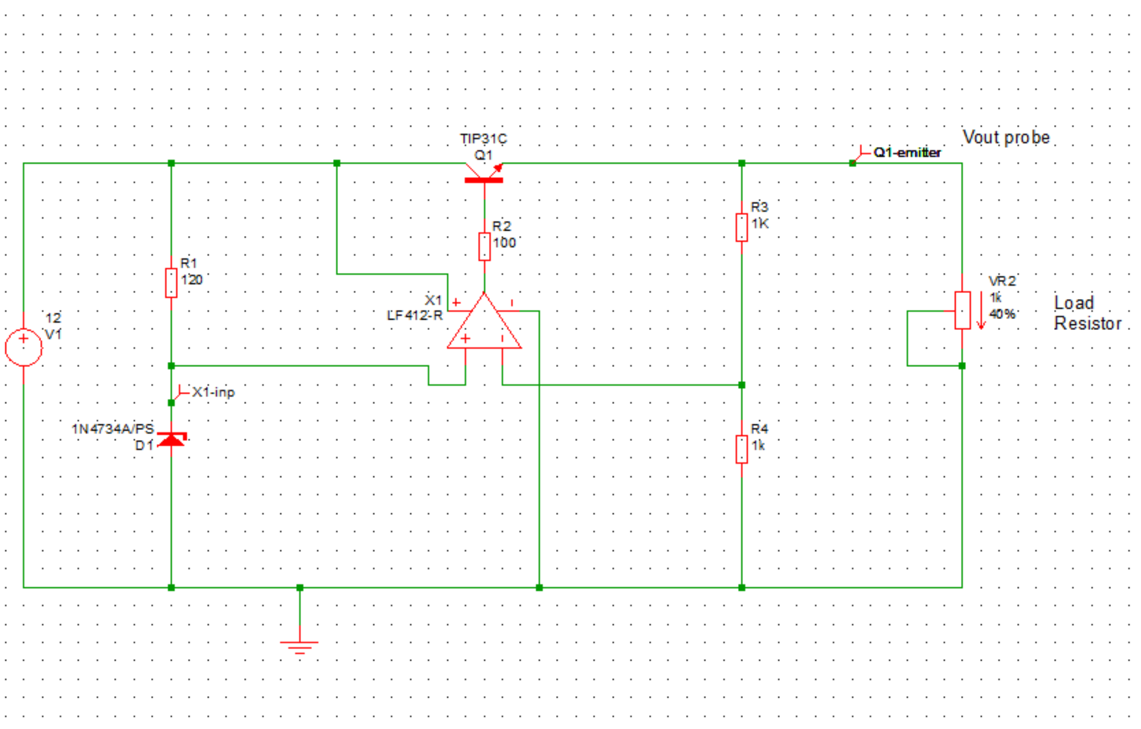
Set the load as specified in the following table. Each time you change the load value, you must re-adjust VR1 to keep the output voltage at a **constant value of 6V.**

R_{LOAD}	**VR1 %**	**I_Base** (uA)	**I_Load** (mA)	**V_{out}** (V)	**P_Q** (mWatts)
1k	70%	50.75uA	6.05mA	6.05V	35.72mW
500	40%	88.35uA	12.12mA	6.06V	71.52mW
100	9.5%	370.31uA	60.34mA	6.03V	358.03mW
50	4.54%	770.43uA	120.71mA	6.03V	715.93mW

Part 2: OP-Amp regulator

In this section you are going to replace the manual regulation with an electronic regulation. A feedback circuit with an op-amp will automatically regulate the voltage at the load.

- Wire following regulator circuit:



Find the Zener voltage for the 1n4734A:

The Zener voltage for the 1N4734A Zener diode is 5.6V

Change R4 to set Vout at 6Volts. You must provide calculation details.

$$V_{OUT} = \left(\frac{R_3}{R_4 + 1}\right) * V_{REF}$$
$$6V = \left(\frac{1k\Omega}{R_4 + 1}\right) * 5.6V$$
$$\frac{6V}{5.6V} = \frac{1k\Omega}{R_4 + 1}$$
$$1.0714 - 1 = \frac{1k\Omega}{R_4}$$
$$0.0714 = \frac{1k\Omega}{R_4}$$
$$\frac{1k\Omega}{0.0714} = R_4$$

$$R_4 = 14.005k\Omega$$

Regulation:

Re-do the regulation measures for various load values:

R_{LOAD}	Vout (V)
1k	6.03V
500	6.03V
100	6.03V
50	6.03V

Does it regulate as expected. Explain

The circuit does a fair job in regulating the voltage to somewhere close to 6V. The circuit is also able to maintain a constant ~6V regulated output as the load becomes heavier (as R_Load decreases). The weak point of this circuit is its efficiency and it will be shown in the next few questions/parts. The majority of the power lost during the regulation will be dissipated in the form of heat.

DC measure snapshot

In this section you are going to take a few measures for a specific load value.

Fill in the following table for R_{LOAD} at 100 Ohms. Assume a β of about 150

You must provide calculation in the right column (DC calculated value)

Variable	**DC measured Value**	**DC calculated value**
Vout (V_{LOAD})	6.03V	$V_{OUT} = \left(\frac{1k\Omega}{14k\Omega + 1}\right) * 5.6V = \sim 6V$
I_{LOAD}	60.30mA	$I_{LOAD} = \frac{V_{OUT}}{R_{LOAD}} = \frac{6V}{100\Omega} = 60mA$
I_E Q1	60.70mA	$I_{R4} = \frac{X1_{(-)}}{R_4} = \frac{5.6V}{1k\Omega} = 5.6mA$ $I_{R4} = \sim I_{R3} = \sim 5.6mA$ $I_E = I_{R3} + I_{Load} = 5.6mA + 60mA = \sim 65.6mA$
I_b Q1	372.49uA	$I_B = \frac{I_E}{Beta + 1} = \frac{65.6mA}{150 + 1} = \sim 434.44uA$
V_{Zener}	5.628V	$V_{Zener} = 5.6V\ (from\ datasheet)$
$V^+ - V^-$ X1	V+ = 5.6283647V V- = 5.628447V Vdiff = -0.000083V	$V_+ = V_{Zener} = 5.6V$ $V_- = \sim V_+ = \sim 5.6V$ $V_{diff} = V_+ - V_- = 5.6V - \sim 5.6V = \sim 0V$
V_{CE} Q1	Vc = 12V Ve = 6.0303354V Vce = 5.9696646V	$V_{CE} = V_1 - V_{OUT} = 12V - 6V = 6V$
I in+ X1	988.93fA (= 0A)	$I_{in+} = \sim 0 = \sim 0A$

Power probe and efficiency

In this part you are going to measure the efficiency of the circuit. Keep R_{LOAD} at 100 Ohms

- Click Menu: Tools -> Efficiency Calculator -> Add Power probe
- Place one probe at the source and one probe at the load
- Click Menu: Tools -> Efficiency Calculator -> Define Input Output probes
- Click Menu: Tools -> Efficiency Calculator -> Calculate efficiency

Measure Pin, Pout and efficiency. You must provide a screenshot of the generated report.

Efficiency and Power Loss Breakdown Report

Input Probes:	Power
P_Source	1.38582W

Output Probes:	Power
P_Load	363.649mW

Efficiency Summary:

Efficiency	26.24%
Input power	1.38582W
Output power	363.649mW
Dissipated Power	1.02217W

Efficiency of the circuit with the 100 Ohm load attached. The measured efficiency is around 26% which is very poor. A detailed explanation is provided in the third question under "After lab questions".

You must give a demo before leaving the classroom.

After lab questions

The purpose of a regulator is to regulate. Does it regulate? Explain.

This circuit does a fair job in regulating the voltage to an acceptable level. Although the efficiency is not the greatest (as shown before), it will regulate the source voltage to the desired output voltage (output voltage depends on the value of R4). The circuit will still provide the same voltage across different loads attached to the circuit, although efficiency will differ according to the load.

What is the purpose of the Zener diode

The purpose of the Zener diode in a circuit like this (voltage regulator circuit) is used as a voltage reference. It can also be used to generate a low-power stabilized voltage from a higher voltage source.

What is the efficiency of the circuit when the load is at 100 Ohms

With a 100 Ohm load attached to the circuit like in Part 2, the measured efficiency is around 26%. This is a very poor result as a well-designed circuit like this one should have an efficiency rating close to 100% as possible. In terms of practicality, this circuit is not a very good one to use just to regulate a voltage due to its poor efficiency.

Where is the lost power dissipated? Which component?

The lost power will get dissipated through Q1 (the transistor in the two circuits above). The transistor in the circuit is the one driving the load and the heat dissipated will increase as the load becomes heavier (in the circuits above, it's when the value of R_Load decreases). If the transistor is mounted to a heatsink, it will ease in the dissipation of heat for the transistor.

Find the value of Vout if the resistor Rb (R2) is disconnected? Explain the result.

When R2 is disconnected from the transistor Q1, the base-emitter junction of the transistor is no longer forward biased causing the transistor to operate in the cut-off region. In this state, Vout is almost 0V (actual result is around ~10mV). Furthermore, the voltage across the collector and emitter (Vout) of Q1 is almost equal to the supply voltage (almost 12V).

Find the value of Vout if the resistor R4 is disconnected? Explain the result. When R4 is disconnected from the voltage-divider circuit with R3, Vout (emitter of Q1) will be the same value as the non-inverting input of the Op-Amp (+ of X1). This is because the inverting input of the Op-Amp (which is connected through R3 to the emitter of Q1) is almost equal to the non-inverting input of the Op-Amp. So, in this case, we know that the non-inverting input is equal to around ~5.6V (Vref), therefore the inverting input must be equal to almost around ~5.6V. With this information and that we know there is no voltage divider, we know that Vout must equal to around the same voltage as the non-inverting input of the Op-Amp. In this case, around ~5.6V (Vref).