ECE 220 Lab 3

Thevenin Equivalent Circuits
Constant Current Source Transistor Circuit

In this lab you will predict (in the prelab) and measure (in the lab) the Thevenin parameters of a DC transistor dimmer ckt, as well as build and test a constant current source using an NPN transistor. Some of the lab skills revisited are:

- Measuring voltages and currents using the DMM
- Measuring resistance using the DMM. (Your TA will explain how an ohmmeter works.)

Each student will be given a 1-hour practical test during his/her lab session[1]. Consequently, the experimental section of this lab assignment is relatively short. **The practical test is worth 70 points, the prelab 30 points, and the lab 40 points.**

Prelab & PSpice (30 points) – PRINT ALL PSPICE SCHEMATICS

Part 1: Estimating R_{Th} and R_N from load parameters.

(a) Fig. 1a shows a load R_L connected to a Thevenin ckt. Derive an expression for R_{Th} in terms of R_L and the ratio V_{Th}/V_L. (You will need this expression for R_{Th} in one of the lab experiments, where you will apply a load R_L and measure V_L.)

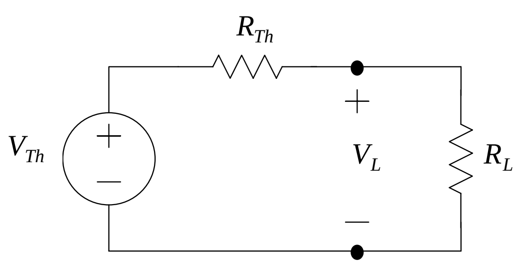


Fig. 1a Thevenin source circuit and load.

(b) Fig. 1b shows a load R_L connected to a Norton ckt. Write an expression for the load current I_L as a function of R_L. Hence find an expression for the gradient of this function, dI_L/dR_L. Next show that, when $R_N>>R_L$, the gradient is approximately constant and is only a function of I_N and R_N. (This gives us a useful way to find R_N from the gradient of a plot of I_L vs. R_L.)

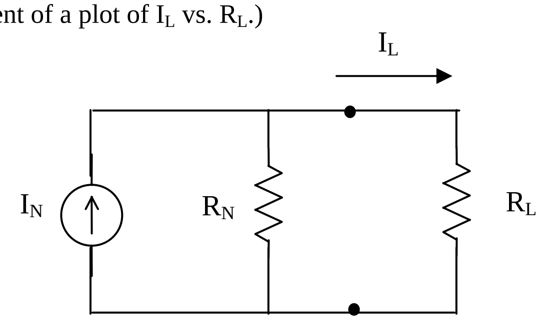


Fig. 2b Norton source circuit and load.

Part 2: Has been deleted.

[1] Discussed on page 2 of course syllabus

Part 3: Constant Current Source Transistor Circuit[2]

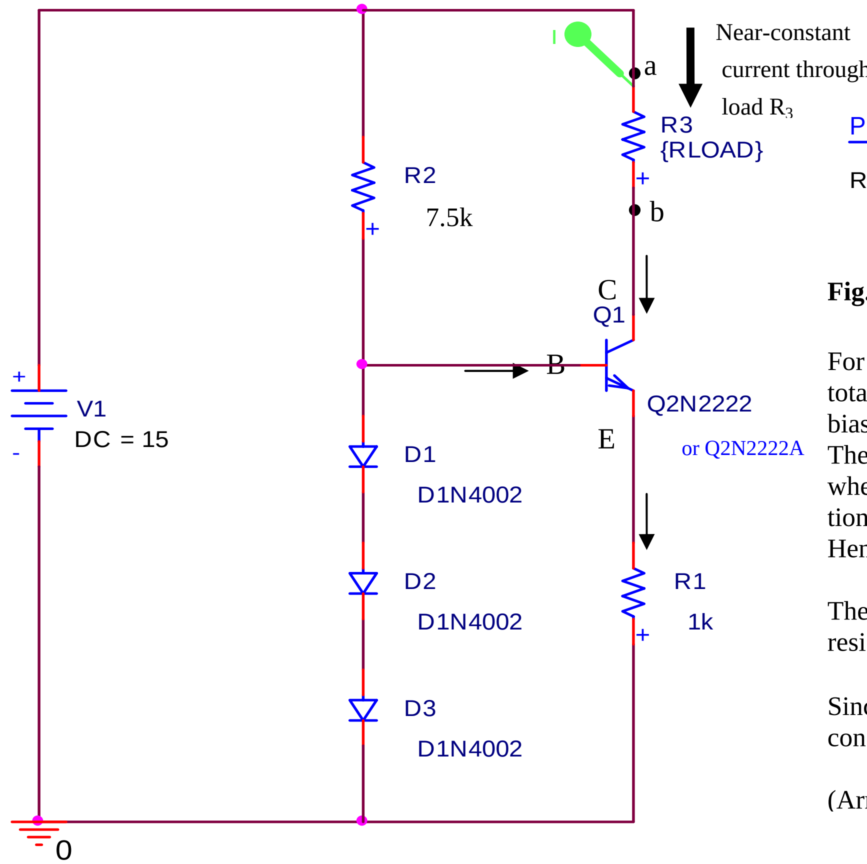


Fig. 3 Constant current source circuit

For a given value of the bias resistor R2, the total voltage drop across the three forward-biased diodes is relatively constant; call this v_D. The voltage at the emitter (E) is then v_D - v_{BE}, where v_{BE} is across a forward biased p-n junction and is fairly stable in the 600-700 mV range. Hence, the emitter current is:

$$i_E = (v_D - v_{BE})/1k$$

The collector current i_C flowing through the load resistor (shown as R3) is:

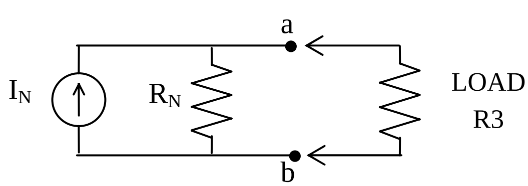
$$i_C = i_E - i_B$$

Since $i_B << i_E$, then $i_C \approx (v_D - v_{BE})/1k$ is relatively constant even as the load resistor is varied.

(Arrows indicate direction of current flow.)

The purpose of this exercise is to simulate the ckt and estimate its Norton equivalent ckt parameters, I_N and R_N, seen by the load R3.

i.e.



Create the PSPICE schematic in Fig. 3. R3 is to be varied using a DC SWEEP and has the value RLOAD. Each diode drops ~600-700mV, depending on the value of R2. Three diodes are used here to simulate an LED, which drops between 1.5-2.5V. (An LED will be used in the lab.)

(a) With the load set at 5kΩ (as shown in Fig. 3), run a BIAS POINT simulation to compute all ckt voltages and currents. Record these values and verify that they agree with the equations and other information discussed in the caption to Fig. 3.

(b) Run a DC SWEEP of R3 as described in Part 3 of Prelab 1. Plot the load current as you linearly sweep the load from 1Ω to 10kΩ. Notice that the load current is not really constant. Using the method derived in Part 1(b) of this prelab, estimate values for I_N and R_N from the plot. (*Hint:* R_N is in the MΩ range.)

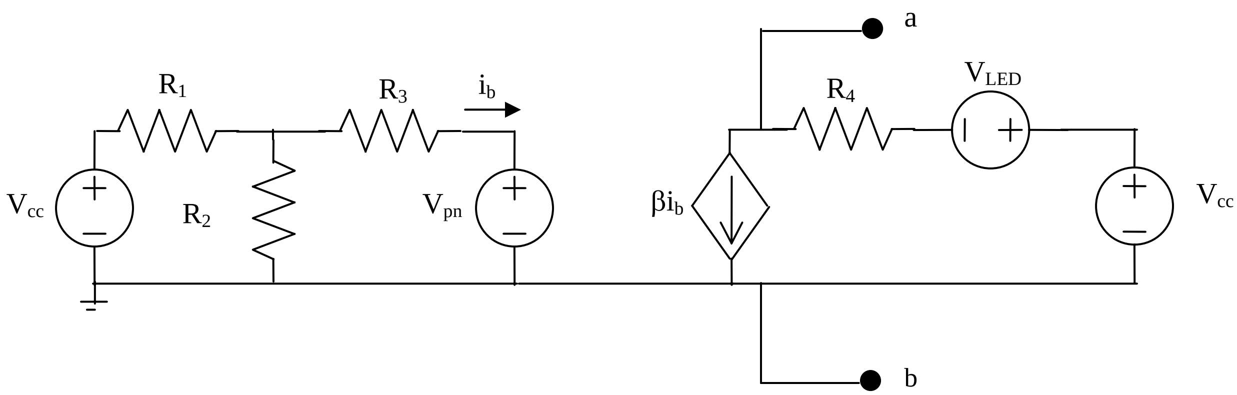
(c) What is the value of R_N for an ideal current source? Discuss how close this ckt is to the ideal current source.

(d) Change R2 to the next standard resistor value above 7.5kΩ, and repeat Part (a) above. Do the same with R2 set at the next standard resistor value below 7.5kΩ. Explain why the value of the current source (current through R_3) is a function of R2. (*Hint:* look up the shape of the i-v curve for a semiconductor diode.)

---

[2] Used extensively in ckt design using MOSFET/CMOS integrated ckt technology, covered in ECE 301/351a.

Part 4: Thevenin Equivalent Circuit of Transistor Dimmer Circuit



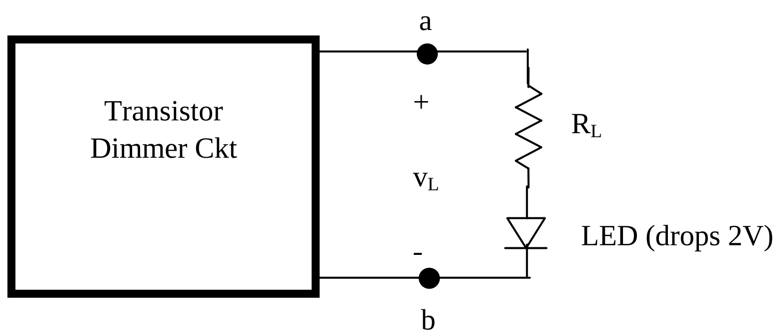
V_{cc}	Supply voltage
V_{pn}	Voltage drop across forward-biased pn-junction
β	Current gain (collector current ÷ base current)
V_{LED}	Voltage drop across forward-biased LED

Fig. 4 DC model of transistor dimmer ckt (seen in Labs 1 & 2). The ckt schematic is shown in the *Experiments* section. The potentiometer used in Lab 1 has been replaced by fixed resistors.

(a) Compute the Thevenin parameters (V_{Thev}, R_{Thev}) seen at terminals a-b in the **ckt model** of Fig. 4. (Express your answers using the resistor values and the parameters listed in the table above as variables.)

(b) Hence compute (V_{Thev}, R_{Thev}) using the following values: V_{cc}=10V, V_{pn}=682mV, β=value from Prelab 1, V_{LED}=2V, R_1=21kΩ, R_2=5kΩ, R_3=47kΩ, R_4=1kΩ. (Same values used in Lab 2 prelab.)

(c) Use your Thevenin equivalent ckt parameters from (b) to calculate v_L with four different loads: R_L =300Ω , 470Ω, 680Ω, 910Ω. (An LED is also connected in series with the load resistor as shown.)



(d) Build the **ckt model** of Fig. 4 using PSpice and verify all values found in (b) and (c). To obtain V_{Thev}, run a BIAS POINT simulation and find the open-ckt voltage at terminals a-b. Print this schematic with bias voltages and currents displayed. Next, short a-b and run a BIAS POINT simulation to find the short-ckt current i_{SC}. Note that since a short ckt wire has no pins on it, i_{SC} must be found by applying KCL at terminal a. Then R_{Thev} is easily obtained from the value of i_{SC}. For Part (c), run a DC SWEEP with R_L set as a GLOBAL PARAMETER. In the sweep type box, select VALUE LIST and enter the specific values of R_L listed in (c) to be used for the simulation. (The entries must be separated by commas.) On running the simulation the PROBE window will display a continuously interpolated plot even though the parameter was swept for discrete values. Display the original data points by clicking on MARK DATA POINTS in the PROBE OPTIONS window under TOOLS/OPTIONS on the schematic window. The data points will appear as small black dots on the plot. Toggle cursors on and label these data points on the plot. Print the plot with these points displayed.

Experiments (40 points)

Part 1. Measuring the Thevenin resistance of the function generator

No experiment

Part 2: Resistor Interface Circuit

No experiment

Part 3: Constant Current Source Transistor Circuit

Build the ckt of Fig. 3, using a single forward-biased red LH3330 LED in place of the three diodes. (Hence, expect your measured voltages and currents to differ from those of the prelab.) The supply rail V_{cc} is 15V.

(a) Connect a 10kΩ pot as a variable load resistor, and measure this load resistance and the corresponding load current for ten settings of the pot in the 0-10kΩ range.

(b) Reduce the supply rail V_{cc} and observe the effect on the current source performance. How low can V_{cc} go before the ckt fails to work as designed?

Question 3:

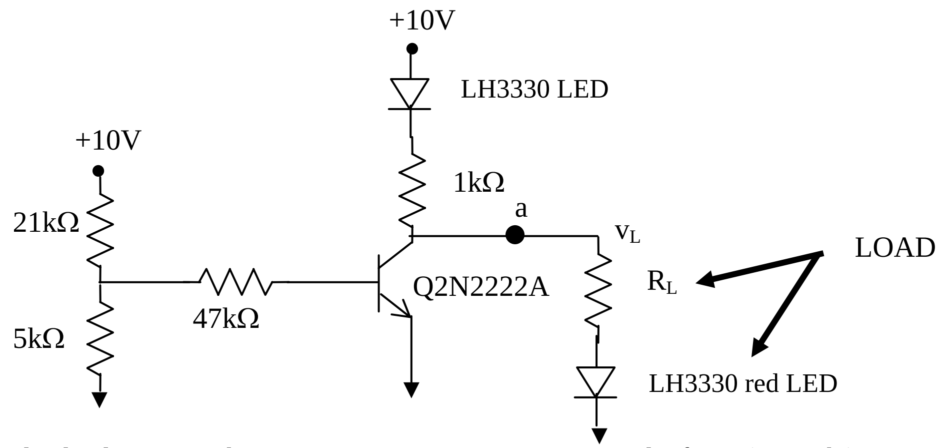
(i) From your measured data estimate the Norton parameters I_N and R_N as you did in the prelab.

(ii) List the performance parameters of your current source:

- Load range (in kΩ) over which ckt provides a nearly constant current
- Value of constant current (called "rated current")
- % current variation about rated current over load range
- Minimum supply rail voltage for this rated current and load range

Part 4: Thevenin Equivalent Circuit of Transistor Dimmer Circuit

Build the ckt shown, taking care to set the supply voltage accurately.



(a) Measure the load voltage v_L with R_L = 300Ω , 470Ω, 680Ω, 910Ω and infinity (open-ckt). Measure and record the value of R_L each time. For each R_L value, also measure the voltage dropped across each of the two LED's.

Question 4:

(i) From your measured data set estimate one pair of Thevenin parameters (V_{Thev}, R_{Thev}) for the ckt at terminals a-b (b is ground). (Remember that the load LED can be represented by a voltage source. See also Part 1 of the prelab.)

(ii) Compare your data and the resulting Thevenin parameters with those predicted in Parts 4(b) and 4(c) of the prelab, and give reasons for possible discrepancies.