Lab# 1 BJT transistor

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Objectives:

- Use MPLAB-Mindi simulator
- Measures on a BJT transistor

Material: Simulated on Mindi

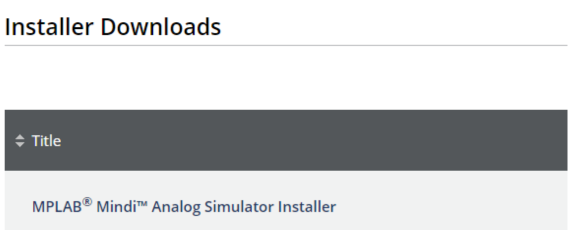
To hand in to Team Assignment

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 work

Part 1: Installation

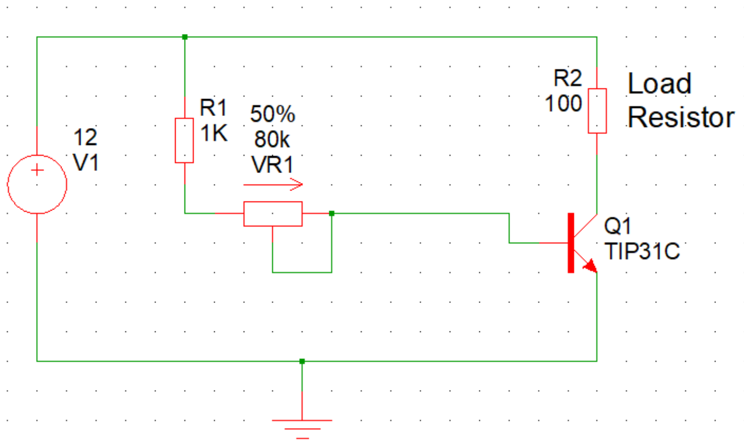
- Go to https://www.microchip.com/mplab/mplab-mindi
- Click on MPLAB® Mindi™ Analog Simulator Installer somewhere in the middle of the page. You might have to login or open a Microchip account.



It will take about 5 minutes to install Mindi

Part 2: Draw schematics

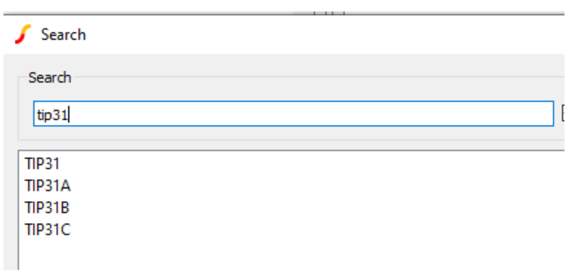
- File -> New -> SIMetrix Schematics
- File -> Save Schematics As -> Lab1
- Wire the following circuit:



Place parts:

To select a part:

Place -> Search part …



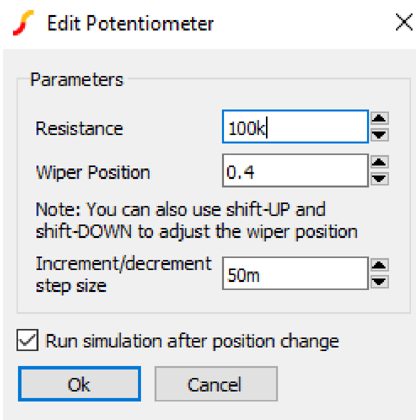
Place -> Passive -> specific component

Example: Place-> Passive -> Potentiometer

You can rotate, mirror or flip the part before placing it on the schematic using the appropriate toolbar button or the keys **F5**, **F6** or **shift-F6** respectively

To edit the potentiometer (or any part for that matter):

1. Select component by right clicking on it
2. Left click and select edit part



Check the “Run simulation after position change” box to enable automatic simulation whenever the wiper position changes.

Probes:

To add a voltage probe:

Probe->Place Fixed Voltage Probe…

To add a current probe:

Probe->Place Fixed Current Probe…

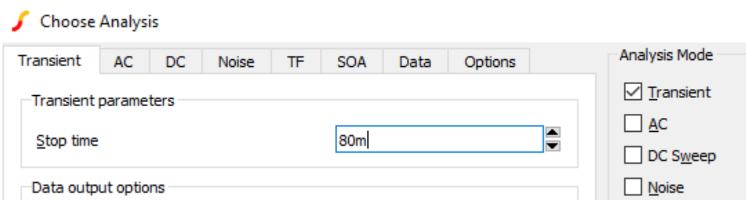
Note: the probe MUST be connected to a component lead. It does NOT work if connected to a wire!

Part 3: Simulation

Choose the type of analysis:

- Click Menu: Simulator -> Choose Analysis

  Analysis mode: Transient
  Stop time: 80 mS



Run the simulator:

- Click Menu: Simulator -> Run Schematics (or F9 key)

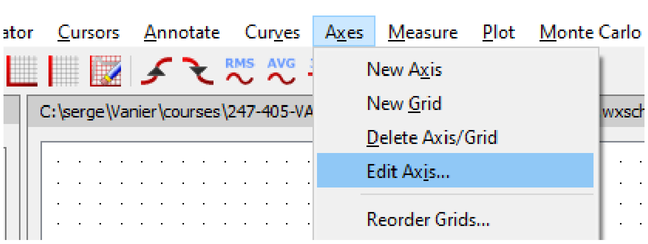
You must generate the following four signals on four different stacked graphics:

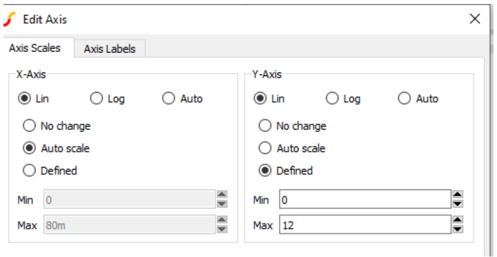
I_{LOAD} , V_{CE} , V_{BE} and I_{Base}

The axis ranges must be as follows:

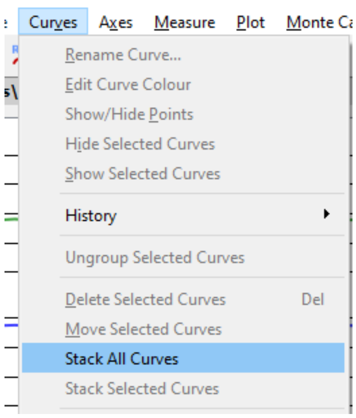
From -100uA to 1000uA for I_{Base}
From -1mA to 150mA for I_{LOAD}
From -1V to 12V for V_{CE}
From 0V to 1V for V_{BE}

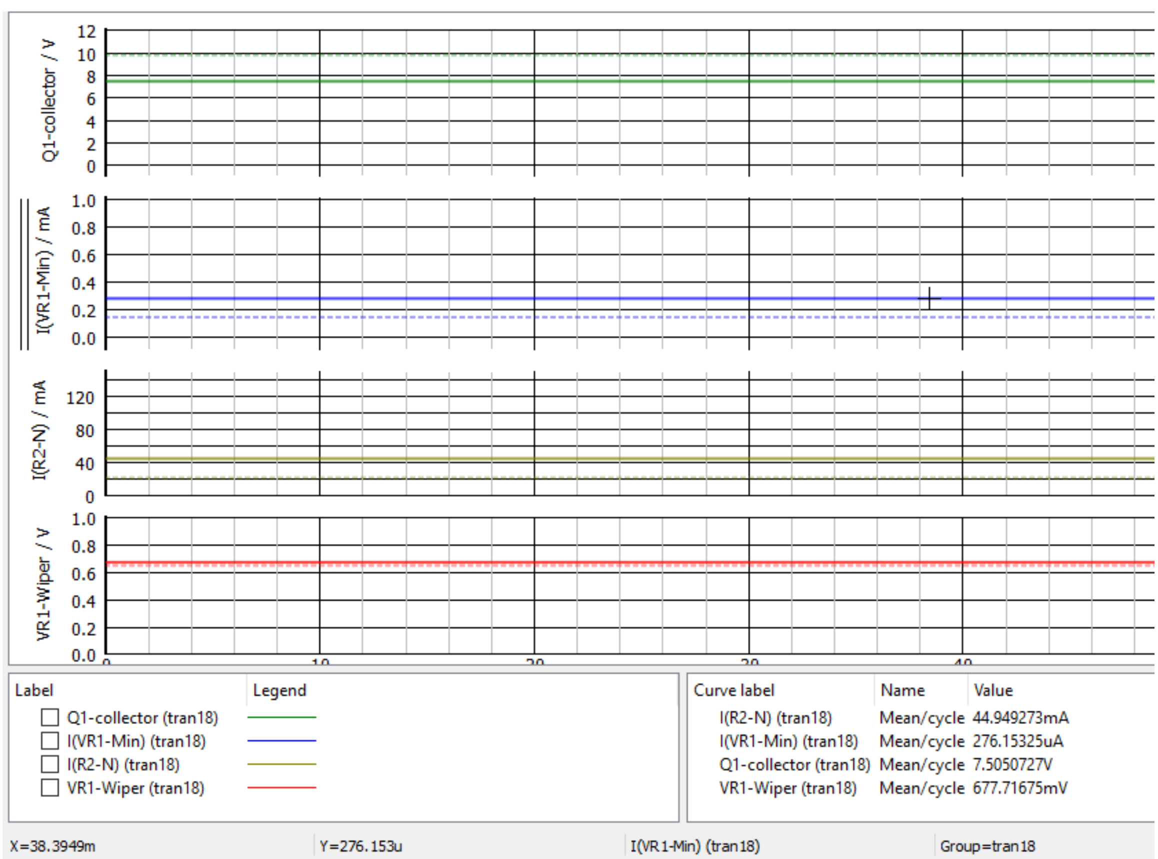
For example, to set the axis from 0 to 12V:





Also, all curves must be stacked:

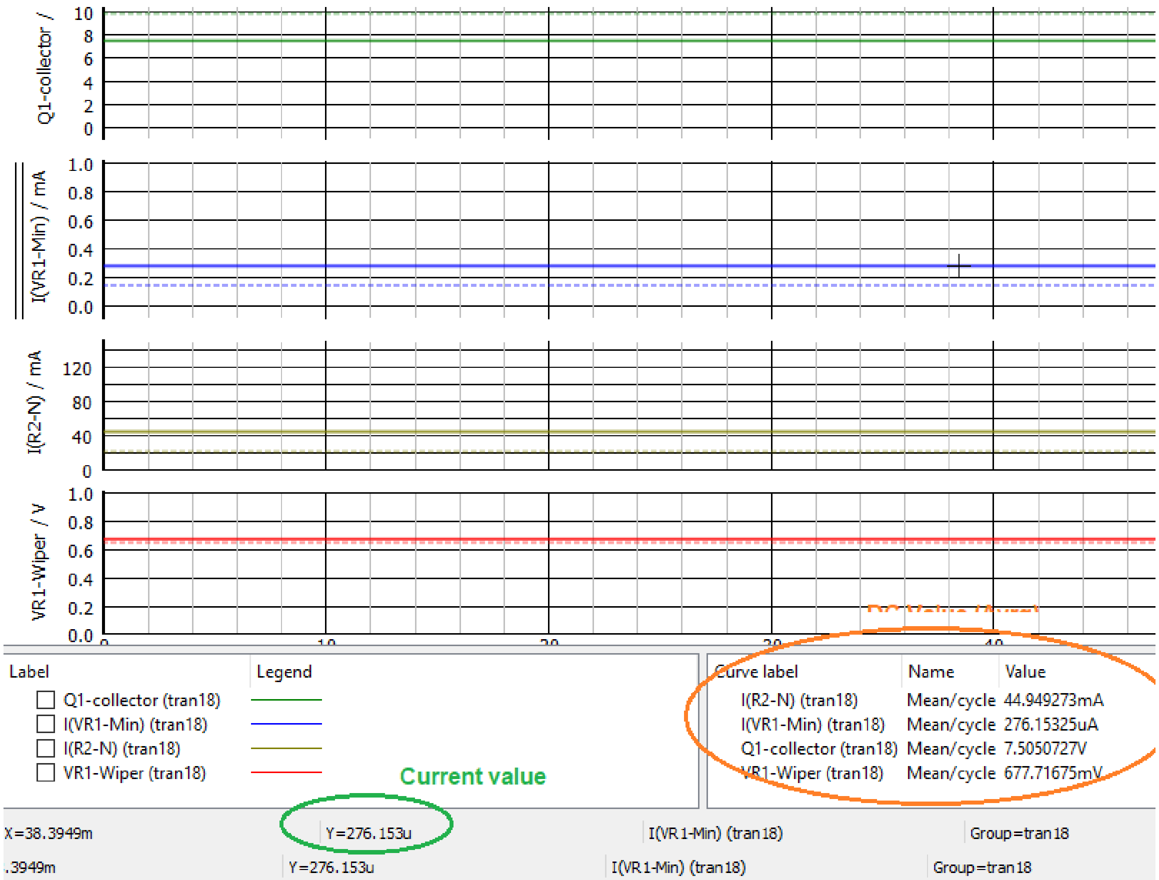




To measure, select the curve and then read the Y value (see green circle below).

To list all the DC values, click on AVG:

Then select all four signals (see orange circle below):



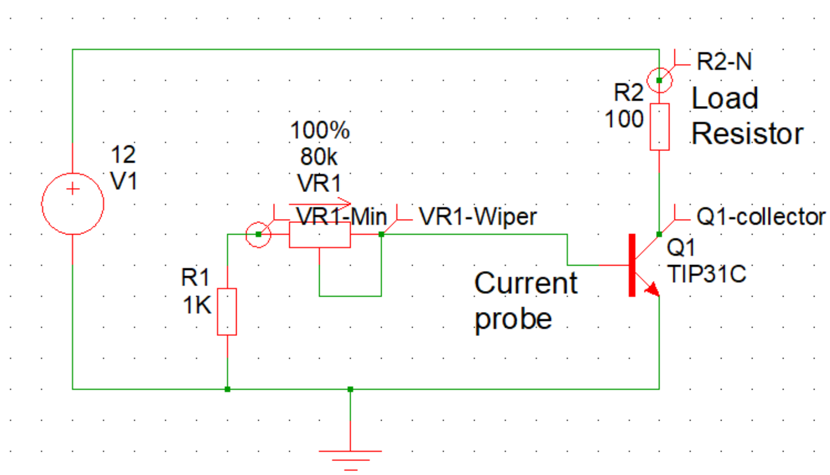
Part 2: Measures

Complete the following table for different values of Vce. To change Vce, you must change the potentiometer's wiper value.

Don't forget that: $V_{LOAD} = 12V - V_{CE}$

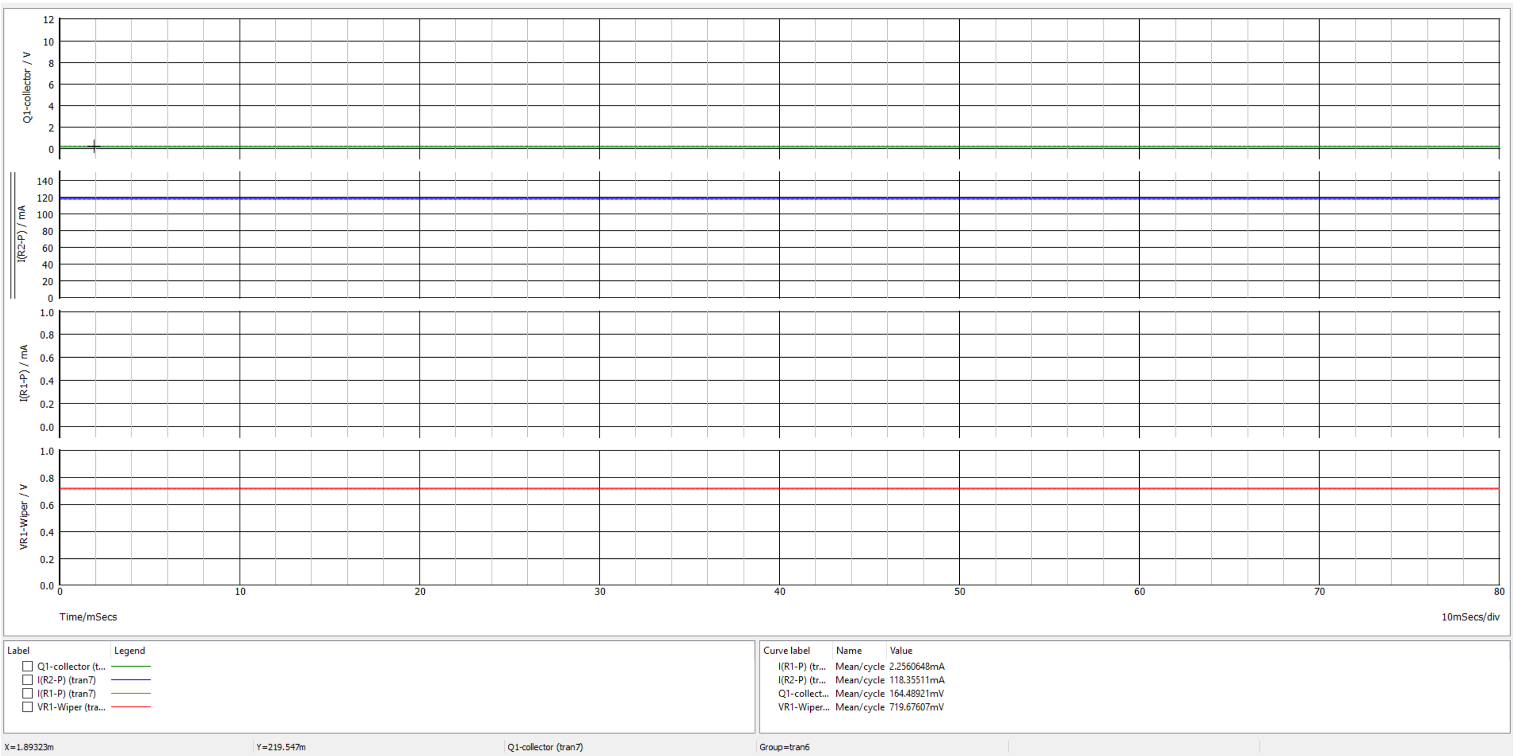
Vce (V)	I_{B1} (uA)	I_{LOAD} (mA)	V_{BE} (mV)	V_{LOAD} (V)	P_{LOAD} (mWatts)	P_{Q1} (mWatts) *(Vce * ILoad)*	**Transistor state** - Saturated - Active region - Cutoff region
0 (164.48mV)	2.25mA	118.35mA	0.7V	12V	1.42W	19.46mW	Saturated
4	500uA	79.11mA	0.7V	8V	632.88mW	322.76mW	Active region
9	185uA	29.62mA	0.7V	3V	88.86mW	267.46mW	Active region
12*	-15.00nA (0A)	15.01nA (0A)	0V	0V	0W	0W	Cutoff region

* Disconnect the base lead from the resistor and connect it to the ground- see example:



In your report, you must provide a screenshot of all four curves when Vce = 4V

Graph when Vce is 0V

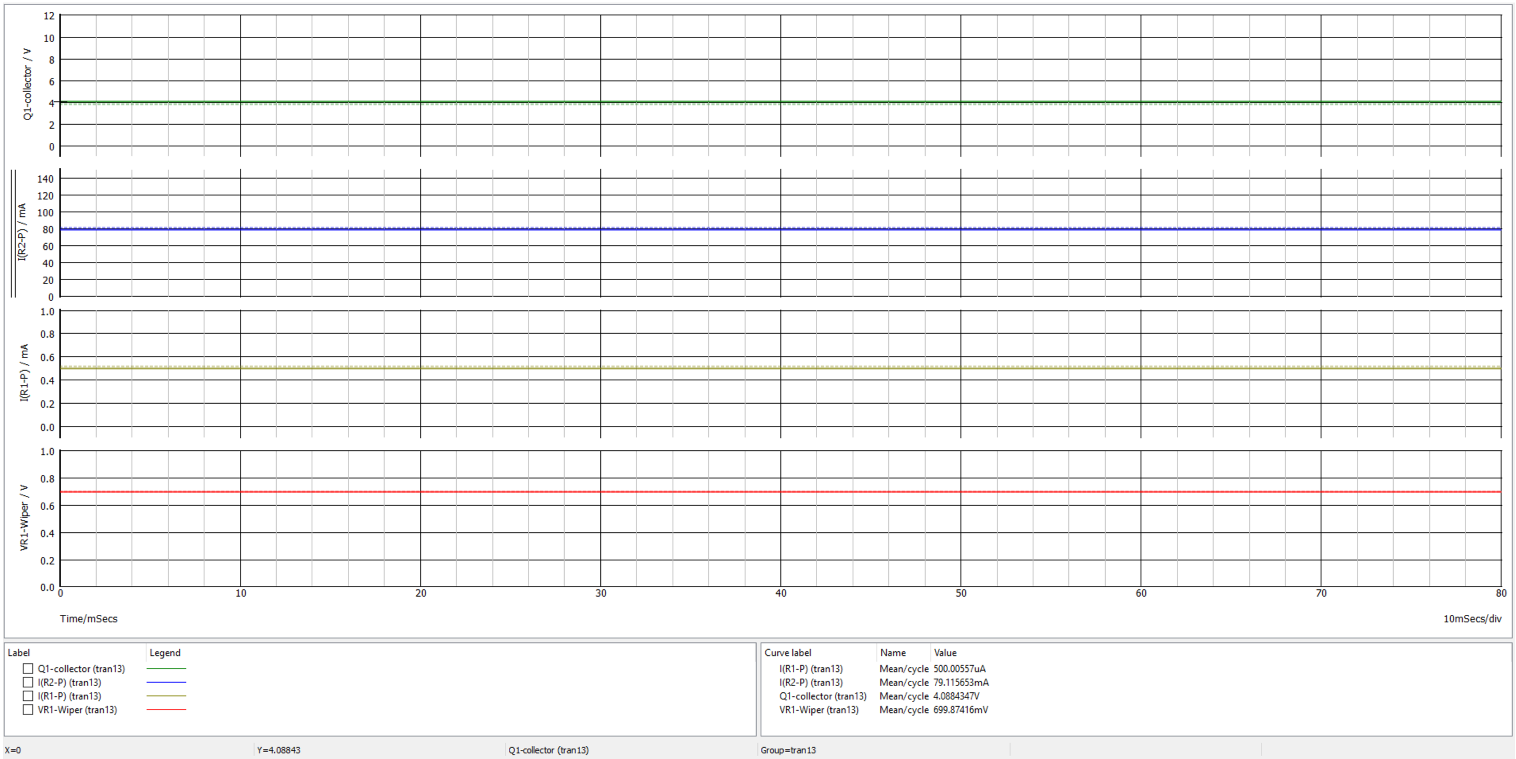


<u>First graph (from top) - green</u>: collector-emitter voltage (Vce), <u>second graph - blue</u>: collector/load current (Ic), <u>third graph</u>: base current (Ib) and <u>fourth graph - red</u>: base-emitter voltage (Vbe). Here, it is clear that the transistor is saturated (base-emitter voltage is around 0.7V), and the load is drawing the full power (seen at Ic). Base current and base-emitter voltage are at their highest values. Readings of all four graphs are shown at bottom right. The wiper of the potentiometer is almost set at 0%.

<u>Readings (Vce = 0V)</u>:

<u>Vce</u>: 164.48921mV *(almost 0V)* -> Starting value (used to compare)
<u>Ic</u>: 118.35511mA -> Starting value (used to compare)
<u>Ib</u>: 2.2560648mA *(not shown in graph above)* -> Starting value (used to compare)
<u>Vbe</u>: 719.67607mV *(almost 0.7V)* -> Starting value (used to compare)

Graph when Vce is 4V

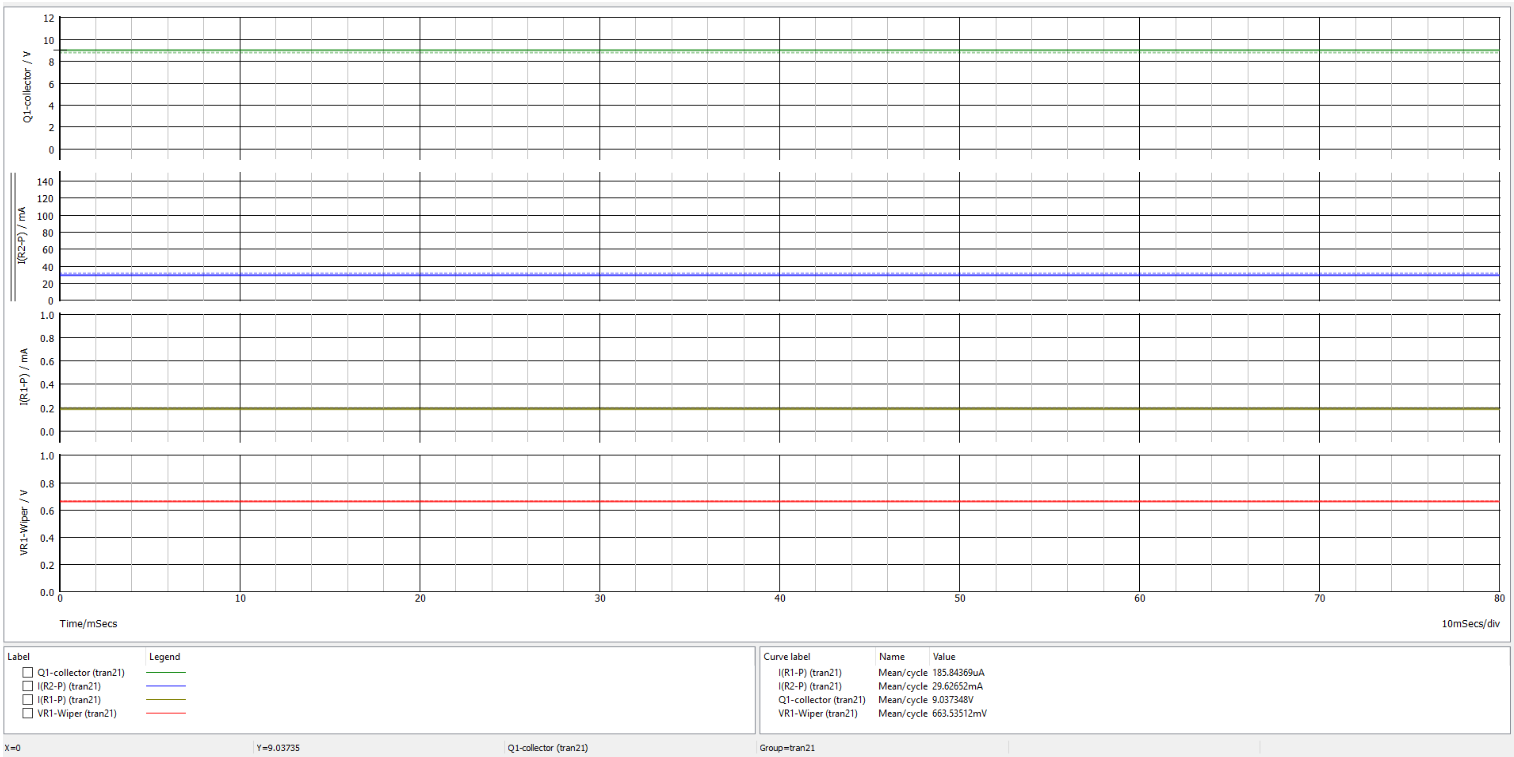


<u>First graph (from top) - green</u>: collector-emitter voltage (Vce), <u>second graph - blue</u>: collector/load current (Ic), <u>third graph - yellow</u>: base current (Ib) and <u>fourth graph - red</u>: base-emitter voltage (Vbe). Here, it is clear that the transistor is operating in the active region (base-emitter voltage is around 0.7V), and the load is drawing less power then when collector-emitter voltage was 0V (seen at Ic). Base current and base-emitter voltage dropped than when Vce was 0V. Readings of all four graphs are shown at bottom right. The wiper of the potentiometer is raised above 0% than from previous page.

<u>Readings (Vce = 4V) – *(comparisons made with previous readings)*</u>:

<u>Vce</u>: 4.0884347V -> Value increased
<u>Ic</u>: 79.115653mA -> Value dropped
<u>Ib</u>: 500.00557uA -> Value dropped
<u>Vbe</u>: 699.87416mV *(almost 0.7V)* -> Value dropped

Graph when Vce is 9V

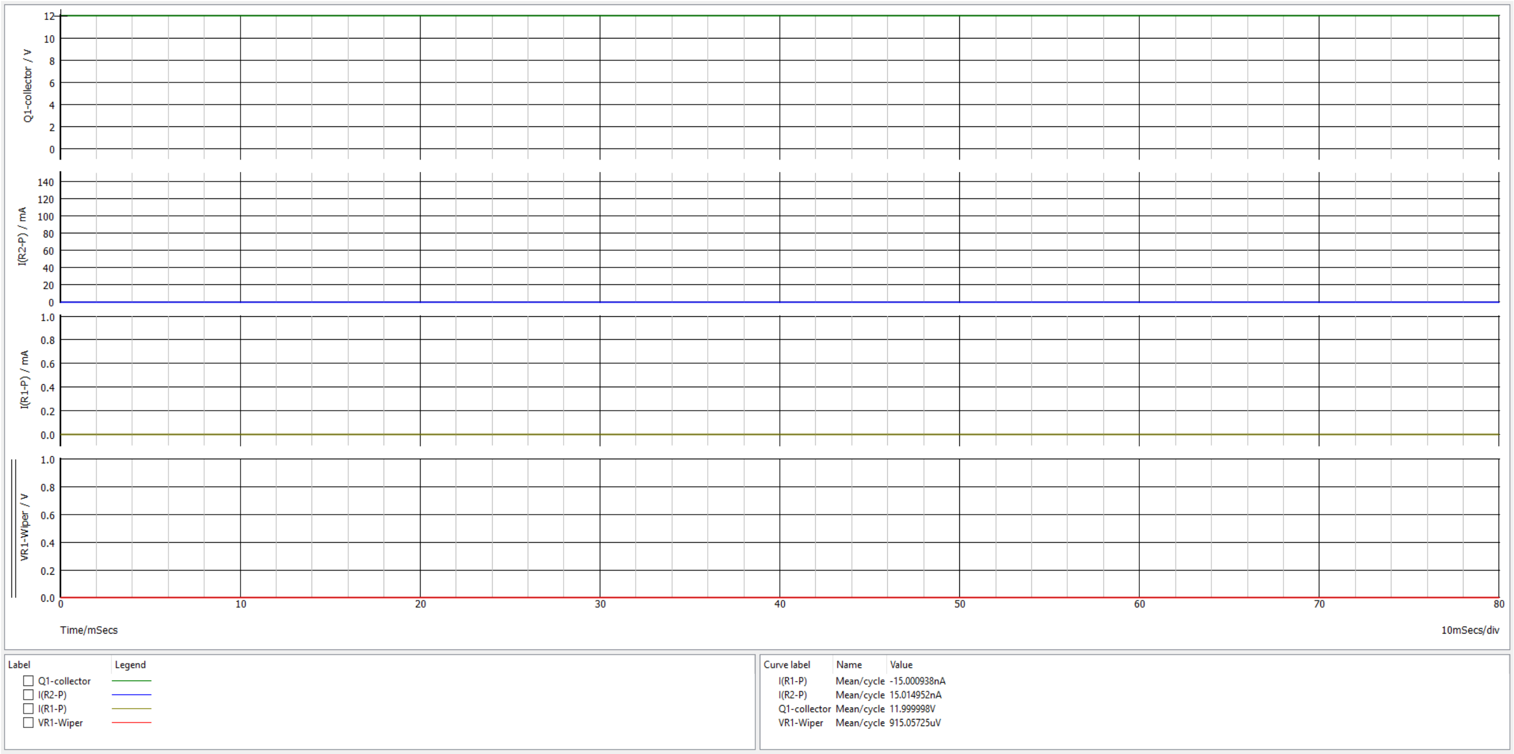


First graph (from top) - green: collector-emitter voltage (Vce), second graph - blue: collector/load current (Ic), third graph - yellow: base current (Ib) and fourth graph - red: base-emitter voltage (Vbe). Here, it is clear that the transistor is operating in the active region (base-emitter voltage is around 0.7V), and the load power has dropped once again and is not drawing the full power than seen with first reading (seen at Ic). Base current and base-emitter voltage have dropped further than when Vce was 4V. Readings of all four graphs are shown at bottom right. The wiper of the potentiometer is raised even further than in the previous page.

Readings (Vce = 9V) – *(comparisons made with previous readings)*:

Vce: 9.037348V -> Value increased
Ic: 29.62652mA -> Value dropped
Ib: 185.84369uA -> Value dropped
Vbe: 663.53512mV *(almost 0.7V)* -> Value dropped

Graph when Vce is 12V



First graph (from top) - green: collector-emitter voltage (Vce), second graph - blue: collector/load current (Ic), third graph - yellow: base current (Ib) and fourth graph - red: base-emitter voltage (Vbe). Here, it is clear that the transistor is operating in the cut-off region (base-emitter voltage is not 0.7V!), and the load is drawing no power (seen at Ic). Base current and base-emitter voltage has dropped completely to 0 compared to previous readings. Readings of all four graphs are shown at bottom right. The base of the transistor is tied to the emitter (grounded).

Readings (Vce = 12V) – *(comparisons made with previous readings)*:

Vce: 11.999998V -> Value increased
Ic: 15.014952nA *(negligible – 0A)* -> Value dropped
Ib: -15.000938nA *(negligible – 0A)* -> Value dropped
Vbe: 915.05725uV *(negligible – 0V)* -> Value dropped

During lab questions:

For what value of Vce does the transistor heat the most? Explain.

When Vce is around 4V, the transistor will heat the most because it is drawing 322.76mW of power (highest out of all the values).

Does the power at the transistor exceed the maximum allowed? Explain.

The power at the transistor does not exceed the maximum allowed because the maximum power the TIP31C NPN transistor allows is 2W of power (without a heatsink) and 40W of power (with a heatsink). The maximum seen here is 322.76mW.

From the table, find β and compare with the data sheet.

Hfe = 79.11mA / 500uA = 158.22 (when Vce = 4V)

Hfe = 29.62mA / 185uA = 160.10 (when Vce = 9V)

Do you think this is a good method to control a load? Explain.

In contrast to a relay (mechanical switch), using this method to control a load is a good way because it provides faster switching than a relay. In terms of efficiency, this method is not efficient because the transistor will dissipate a lot of heat.

If not, give a better alternative.

A better alternative to this method is to use PWM (pulse width modulation) to control the load.

You must give a demo before leaving the classroom.