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Mạch điện - Điện tử

Báo cáo Lab 3

Bipolar Junction Transistor

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Mục lục

1 BJT in Saturation Mode

Change the value of **R1 to 1k** and run the simulation again. Capture the simulation results and explain the values of I_B, I_C, V_{CE}. The default transistor gain is $\beta = 100$, and the saturated voltage $V_{CE(Sat)} = 0.65V$ and $V_{BE} = 0.7V$.
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Kết quả trong PSpice được giải thích như sau:

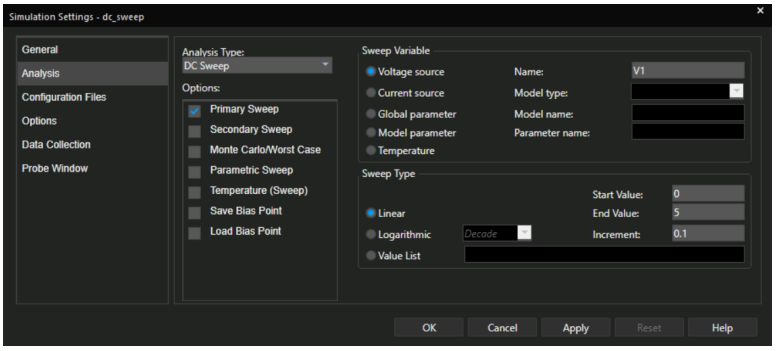
- Áp dụng định luật Ohm, $I_B = \frac{V_{BB} - V_{BE}}{R_1} = \frac{5-0.7}{1000} = 4.3$ mA
- Giả sử transistor ở vùng tích cực, $I_C = \beta \cdot I_B = 100 \cdot 4.3 = 0.43$ A
- Cuối cùng, để kiểm chứng giả định trên, $V_{CE} = V_{CC} - I_C \cdot R_2 = 10 - 0.43 \cdot 100 = -32$ V

Vì $V_{CE} < 0$, giả định trên là sai. Con transistor ở vùng bão hòa. Do đó, I_C được xác định như sau:

$$I_C = \frac{V_{CC} - V_{CE(Sat)}}{R_2} = \frac{10 - 0.65}{100} = 93.5mA$$

2 DC Sweep Simulation

The schematic in the first exersice with **R1 = 1k** is re-used in this exercise. However, a DC-Sweep simulation mode is performed with V1 is varied from 0V to 5V (0.1V for the step), as follows:



Hình 2.1: *DC-Sweep profile for simulation*

Run the simulation and trace for the current I_C according to the value of V1. Capture your screen and plot it in the report. Please increase the width of the curve.

3 BJT used as a Switch

For a given BJT circuit, determine R1 and R2 to have IC saturated at 50mA. In this saturation mode, $V_{CE(Sat)}$ is 30mV. Assume that V_{BE} = 0.7V and the current gain β = 100.

Hình 3.1: *BJT used as switch in saturation mode*

Present your solution to determine R1 and R2. Perform the simulation in PSpice to confirm the results. Capture the screen in PSpice and present in the report.

Solution:

$I_B = I_C/\beta$= 50 / 100 = 0.5 mA

R_1 = (V_{BB} - V_{BE})/I_B = (5 - 0.7)/(0.5 $*10^-3$) = 8600 Ω

R_2 = (V_{CC} - V_{CE})/I_C = (10 - 0.03)/0.05 = 199.4 Ω

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4 PNP Circuit

Figure 4.1 shows a very typical PNP transistor circuit. Calculate I_B, I_E, and I_C then simulate the circuit to double-check your calculation. Assume the current gain $\beta = 100$.

Hình 4.1: A PNP Circuit

4.1 Theoretical calculation

Notes:
Explanations, formulas, and equations are expected rather than only results.

V_{EB} = ...

I_B = ...

I_C = ...

I_E = ...

4.2 Simulation

Your image goes here

4.3 Comparison

I_B (In theory) = ... I_B (simulation) = ...

I_C (In theory) = ... I_C (simulation) = ...

I_E (In theory) = ... I_E (simulation) = ...

5 BJT's logic gate application

Figure 5.1 describes a straightforward NOT gate theoretical implementation using an NPN bipolar junction transistor. In the circuit, the NPN junction transistor operates in the saturation mode.

Hình 5.1: NPN theoretical NOT gate

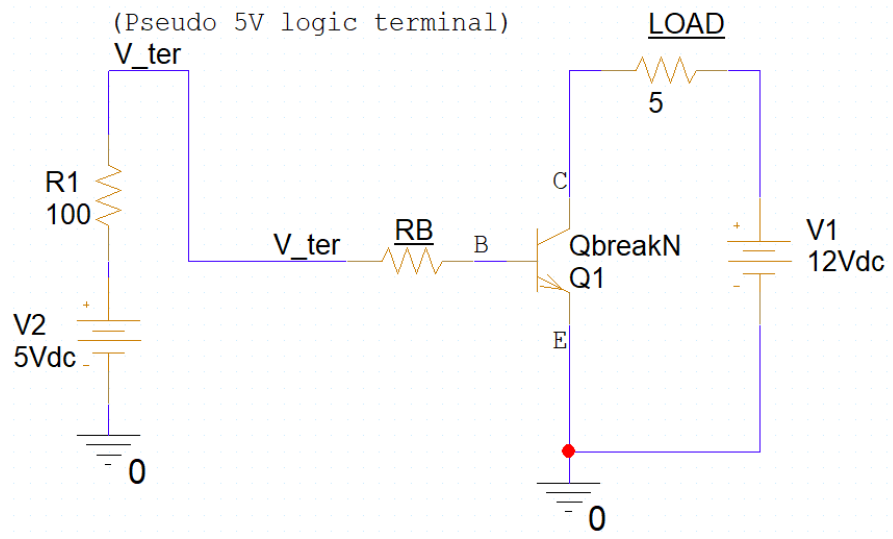
V1 = 0 When the source is off, the voltage would be 0V.
V2 = 5 When the source is on, the voltage would be 5V.
TD = 0 Delay time. This exercise assumes that there is no delay.
TR = 5ns The rise time of the pulse (from off to on stage).
TF = 3ns The fall time of the pulse (from on to off stage).
PW = 50ms Pulse width: The time in which the source keeps on.
PER = 100ms The period of the signal.

Tips:

To get the Voltage Pulse Source component in the PSpice for TI, go to ***Place -> Pspice Compoment... -> Source -> Voltage Sources -> Pulse.***

6 Drive a device with an NPN BJT

This exercise has a $5V$ logic output (the V_{ter} in Figure 6.1) that can source up to $10mA$ of current without a severe voltage drop and stand a maximum current of $20mA$. If the logic terminal sources a current larger than $20mA$, it would be damaged. Or, if it sources a current larger than $10mA$, the V_{ter} voltage will drop to less than $4V$. We should avoid this drop in many cases. However, this logic terminal has to be used to drive an electrical component with an equivalent internal resistance of 5 ohms (the LOAD in Figure 6.1) and requires a current of at least $300mA$ and not exceeding $500mA$ to function normally. Given that we have an NPN transistor with the current gain β equals 100, the maximum I_C current is $400mA$, and the barrier potential at the BE junction is $V_{BE} = 0.7V$, select a resistor available in the market to replace the resistor R_B revealed in Figure 6.1. to make the circuit function well. After that, perform a simulation to double-check your selection.



Hình 6.1: Select a resistor available in the market for R_B

6.1 Theory calculations

Notes:

Explanations, formulas, and equations are expected rather than only results.

Ta có $I_C = \beta I_B$

Theo giới hạn của TẢI và bóng bán dẫn, ta có:

$$300\,\text{mA}\,(\text{min}) < I_C < 400\,\text{mA}\,(\text{max})$$
$$3\,\text{mA}\,(\text{min}) < I_B < 4\,\text{mA}\,(\text{max})$$

Với $I_B(\text{min}) = 3\,\text{mA}$ ta có:

$$R_B(\text{max}) = \frac{V_2 - I_B R_1 - V_{BE}}{I_B} = 1333.3\,\Omega$$

Với $I_B(\text{max}) = 4\,\text{mA}$ ta có:

$$R_B(\text{min}) = \frac{V_2 - I_B R_1 - V_{BE}}{I_B} = 975\,\Omega$$

Vậy:

$$975\,\Omega\,(\text{min}) < R_B < 1333.3\,\Omega\,(\text{max})$$

R_B được chọn là: $1100\,\Omega$

6.2 Simulation

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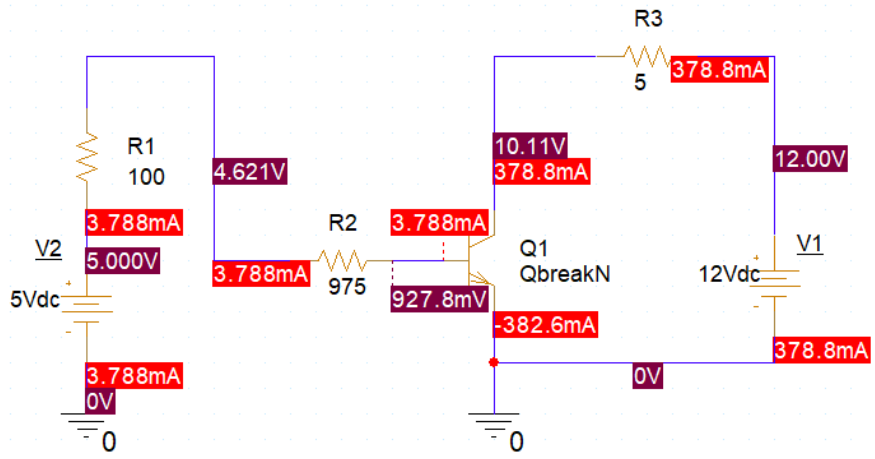
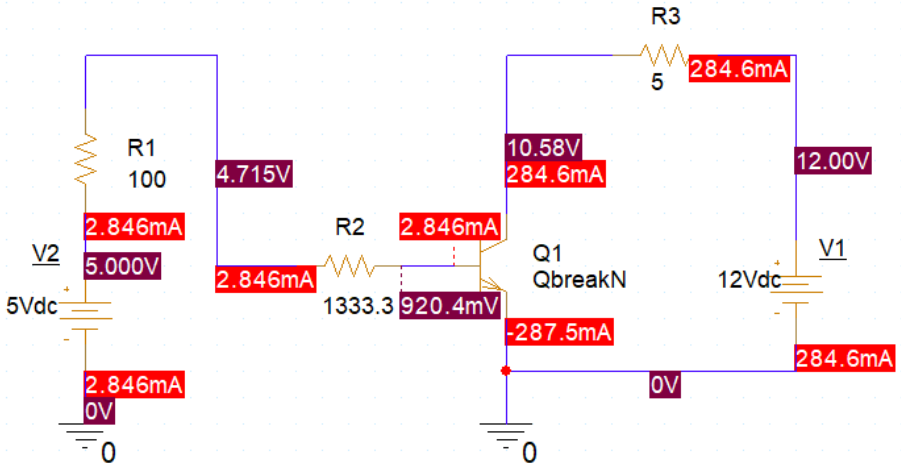
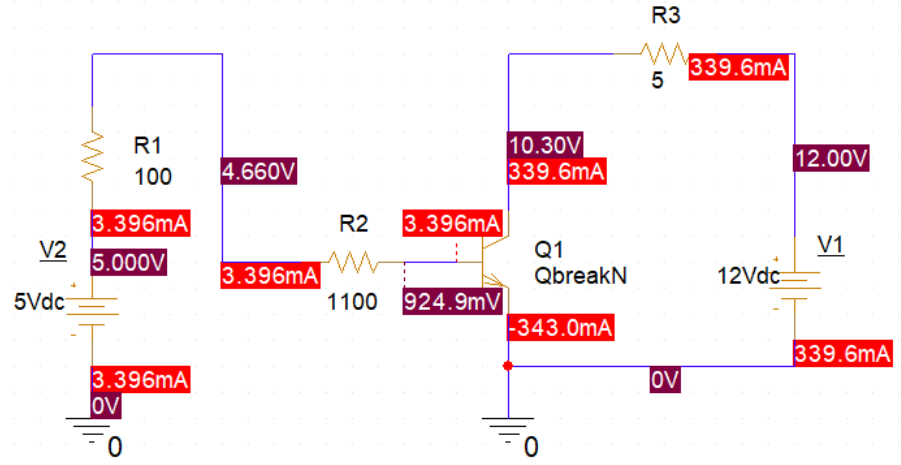
$R_B(min) = 975$



$R_B(max) = 1333.3$



$R_B(selected) = 1100$

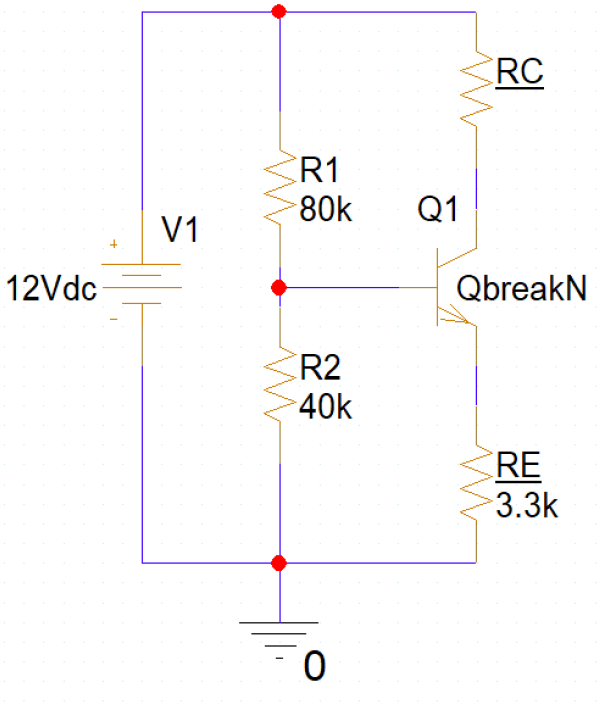


6.3 Compare

		Theory			PSpice		
	R_B	V_{BE}	I_B	I_C	V_{BE}	I_B	I_C
$R_B(min)$	975 Ω	0.7 V	4 mA	400 mA	0.928 V	3.788 mA	378.8 mA
$R_B(max)$	1333.3 Ω	0.7 V	3 mA	300 mA	0.920 V	2.846 mA	284.6 mA
$R_B(selected)$	1100 Ω	0.7 V	3.58 mA	358 mA	0.925 V	3.396 mA	339.6 mA

7 Simple bias configuration

The circuit given in Figure 7.1 is known as a simple kind of NPN bias configuration. First, students simulate the circuit with two values of RC, respectively 10 Ohms and 1k Ohms. Then, give your statement on the change of the current I_E and explain the phenomena.



Hình 7.1: Simple bias configuration

7.1 Simulation

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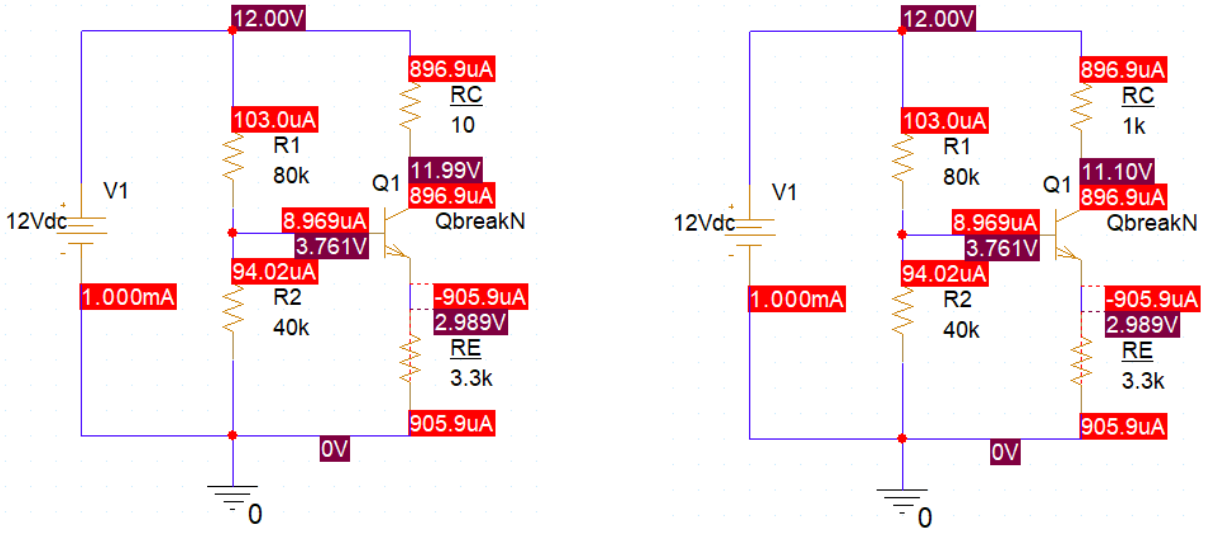
Step 1: Simulate the circuit with R_C = 10 Ohms.

Step 2: Simulate the circuit with R_C = 1k Ohms.



$R_C = 10\,\Omega$ $R_C = 1\,\text{k}\Omega$

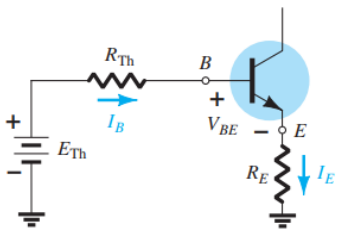
Hình 7.2: Result from simulation

Nhận xét: Giá trị I_E không thay đổi

7.2 Circuit analysis

Conduct some theoretical calculation to explain for the phenomena you have observed from the simulation.

Theo định lý Thevenin, ta có mạch tương đương:



$$R_{TH} = \frac{R_1 \cdot R_2}{R_1 + R_2} = \frac{80k \cdot 40k}{80k + 40k} = 26.66k\Omega$$

$$E_{TH} = \frac{V_{CC}}{R_1 + R_2} \cdot R_2 = \frac{12}{80k + 40k} \cdot 40k = 4\,(\mathrm{V})$$

Theo Ohm's Law, KCL, KVL:

$$E_{TH} = R_{TH} \cdot I_B + V_{BE} + R_E \cdot I_E \quad (1)$$

$$I_E = (\beta + 1) I_B \quad (2)$$

Từ (1) và (2) ta có:

$$I_E = \frac{(E_{TH} - V_{BE}) \cdot (\beta + 1)}{R_{TH} + (\beta + 1) R_E}$$

Vậy, I_E không phụ thuộc vào R_C