

Question 1: Transistor Analysis (3 Marks)

A common-emitter NPN transistor is used as a switch in a circuit to control an LED. The transistor's base is driven through R_B by a digital signal that switches between 0 V (LOW) and 5 V (HIGH). The LED is connected in series with a resistor R_C and the collector terminal of the transistor, with the LED anode towards the supply. The emitter terminal is grounded. The LED requires 15 mA of current to turn on fully.

The following parameters are given:

- $\beta_{\text{sat}} = 15$
- $V_{CC} = 12 \text{ V}$
- The LED forward voltage $V_{\text{LED(ON)}} = 2 \text{ V}$
- Base-emitter voltage drop $V_{BE} = 0.70 \text{ V}$
- Collector-emitter saturation voltage $V_{CE(\text{sat})} = 0.20 \text{ V}$.

Analyse the information provided to answer the following questions.

- What is the value of the collector resistor R_C required to obtain the specified LED current when the transistor is saturated and the base-drive signal is HIGH? (1 mark)
- What is the largest value of the base resistor R_B that supplies the required base current under the stated forced-gain model when the base-drive signal is HIGH? (1 mark)
- What is the total power P_Q dissipated by the transistor in saturation, including both transistor current paths, using the resistor from part (b)? (1 mark)

Here are some useful equations:

- Common-emitter current gain $\beta = \frac{I_C}{I_B}$,
- and when saturated $\beta_{\text{sat}} = \frac{I_{C(\text{sat})}}{I_B}$.

Enter your answers to Question 1 (a–c) in Table 1. Round final answers to two decimal places and include units. Use calculated resistor values; no preferred-value selection is required.

Table 1: Answer to Question 1 (a–c).

Question	Answer
1 (a)	$R_C =$
1 (b)	$R_B =$
1 (c)	$P_Q =$

Question 2: Transistor Analysis (3 Marks)

A common-emitter NPN transistor is used as a switch in a circuit to control an LED. The transistor's base is driven through R_B by a digital signal that switches between 0 V (LOW) and 3.3 V (HIGH). The LED is connected in series with a resistor R_C and the collector terminal of the transistor, with the LED anode towards the supply. The emitter terminal is grounded. The LED requires 20 mA of current to turn on fully.

The following parameters are given:

- $\beta_{\text{sat}} = 20$
- $V_{CC} = 6 \text{ V}$
- The LED forward voltage $V_{\text{LED(ON)}} = 2.2 \text{ V}$
- Base-emitter voltage drop $V_{BE} = 0.70 \text{ V}$
- Collector-emitter saturation voltage $V_{CE(\text{sat})} = 0.20 \text{ V}$.

Analyse the information provided to answer the following questions.

- What is the value of the collector resistor R_C required to obtain the specified LED current when the transistor is saturated and the base-drive signal is HIGH? (1 mark)
- What is the largest value of the base resistor R_B that supplies the required base current under the stated forced-gain model when the base-drive signal is HIGH? (1 mark)
- What is the total power P_Q dissipated by the transistor in saturation, including both transistor current paths, using the resistor from part (b)? (1 mark)

Here are some useful equations:

- Common-emitter current gain $\beta = \frac{I_C}{I_B}$,
- and when saturated $\beta_{\text{sat}} = \frac{I_{C(\text{sat})}}{I_B}$.

Enter your answers to Question 2 (a–c) in Table 2. Round final answers to two decimal places and include units. Use calculated resistor values; no preferred-value selection is required.

Table 2: Answer to Question 2 (a–c).

Question	Answer
2 (a)	$R_C =$
2 (b)	$R_B =$
2 (c)	$P_Q =$

Question 3: Transistor Analysis (3 Marks)

A common-emitter PNP transistor is used as a switch in a circuit to control an LED. The emitter connects to the 15 V supply. The collector connects through a resistor R_C and the LED to ground, with the LED anode towards the collector. The transistor's base is driven through R_B by an ideal digital source that switches between 0 V (LOW) and 15 V (HIGH). The LED requires 25 mA of current to turn on fully. Treat I_C and I_B as positive current magnitudes.

The following parameters are given:

- $\beta_{\text{sat}} = 10$
- $V_{CC} = 15 \text{ V}$
- The LED forward voltage $V_{\text{LED(ON)}} = 2 \text{ V}$
- Emitter-base voltage drop $V_{EB} = 0.70 \text{ V}$
- Emitter-collector saturation voltage $V_{EC(\text{sat})} = 0.20 \text{ V}$.

Analyse the information provided to answer the following questions.

- What is the value of the collector resistor R_C required to obtain the specified LED current when the transistor is saturated and the base-drive signal is LOW? (1 mark)
- What is the largest value of the base resistor R_B that supplies the required base current under the stated forced-gain model when the base-drive signal is LOW? (1 mark)
- What is the total power P_Q dissipated by the transistor in saturation, including both transistor current paths, using the resistor from part (b)? (1 mark)

Here are some useful equations:

- Common-emitter current gain $\beta = \frac{I_C}{I_B}$,
- and when saturated $\beta_{\text{sat}} = \frac{I_{C(\text{sat})}}{I_B}$.

Enter your answers to Question 3 (a–c) in Table 3. Round final answers to two decimal places and include units. Use calculated resistor values; no preferred-value selection is required.

Table 3: Answer to Question 3 (a–c).

Question	Answer
3 (a)	$R_C =$
3 (b)	$R_B =$
3 (c)	$P_Q =$

Lab activity: Build and test a transistor switch

Figure 1 shows an NPN transistor controlling an LED. Build the circuit in the lab using components from your electronics kit or the Skills Lab store. Use the supply, base-drive and LED-current specifications from Question 2 to select R_C and R_B .

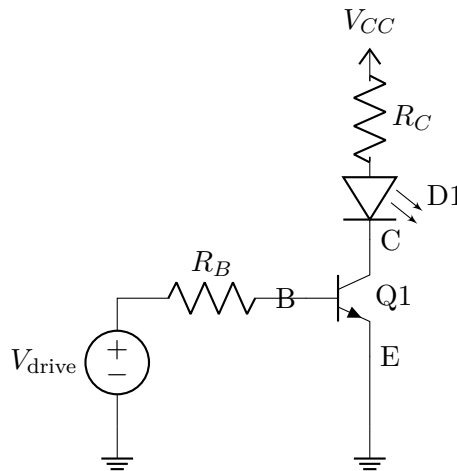


Figure 1: NPN LED switch. The base-drive source and collector supply share ground.

Build

1. Identify $Q1$'s terminals from the datasheet for the actual transistor. Check the transistor, LED, resistor and drive-source ratings. Calculate R_C and R_B , then select available values and recalculate the expected currents.
2. Switch off both supplies before wiring. Connect both supply returns and the emitter to ground. Connect the LED anode towards V_{CC} and the cathode towards the collector. Include both resistors.
3. Ask a tutor to check the circuit. Set supply current limits for the selected components. Energise the circuit with the base-drive source at LOW.

Test and compare

1. Apply LOW and HIGH. Record the LED state, V_{BE} and V_{CE} for each level.
2. Measure the voltage across each resistor. Use those voltage drops and the actual resistor values to determine I_B and I_C .
3. Compare predictions and measurements. Increase R_B within the component and drive-source limits. Observe whether the transistor leaves saturation and explain the change within your group.

Keep calculations and measurements in your own notes. No final answers or worked tutorial solutions are supplied.

Further reading: Build Electronic Circuits: transistor-switch guide. Example datasheets: onsemi 2N3904 (NPN) and onsemi 2N3906 (PNP). Use the datasheet for your actual device.