Transistor Circuits I

Common-Base, DC operation
The humble transistor

Q1
Emitter (E)
Collector (C)
Base (B)
Transistor basics

• Emitter to base junction is forward biased (normally)
• Collector to base junction is reverse biased (normally)
• Transistors are current operated devices, so KCL should be applied first:

\[-I_E = I_C + I_B\]
• Leakage current: $I_{CBO}$ (Emitter open)
  – Usually is considered negligible, but can affect things when $I_C$ is small
Basics continued

• \( h_{FB} = \alpha = \frac{I_C}{I_E} \) \((\alpha \leq 1)\)

• \( h_{FE} = \beta = \frac{I_C}{I_B} \) \((\beta \) has no definitive limit)\)

• The symbols \( h_{FB} \) and \( h_{FE} \) are BJT parameters; the \( h \) means Hybrid parameter. The subscript \( FB \) means Forward current transfer ratio of the common, or grounded, Base circuit, whereas \( FE \) means Forward current transfer ratio of the common, or grounded, Emitter circuit.
Basic configuration of Common-Base

![Diagram of a Common-Base configuration with components RE, VEE, Q1, VCC, and RC.]
If $V_{EE} = 20V$ and $V_{EB}$ is negligible, find $I_E$ when $R_E$ equals (a) 80kΩ, (b) 40kΩ, (c) 20kΩ, (d) 10kΩ, (e) 5kΩ, and (f) 1kΩ.
Work for first circuit

Formula is $I_E = \frac{V_{EE}}{R_E} = \frac{20V}{R_E}$

- (a) $I_E = \frac{20V}{80k\Omega} = 0.25mA = 250\mu A$;
- (b) $I_E = \frac{20V}{40k\Omega} = 0.5mA = 500\mu A$;
- (c) $I_E = \frac{20V}{20k\Omega} = 1mA$;
- (d) $I_E = \frac{20V}{10k\Omega} = 2mA$;
- (e) $I_E = \frac{20V}{5k\Omega} = 4mA$;
- (f) $I_E = \frac{20V}{1k\Omega} = 20mA$
Use approximation for $V_{EB}$

If $V_{EB} = 0.7V$, rework previous values to determine $I_E$ in each instance.

- Formula is now $I_E = \frac{V_{EE} - V_{EB}}{R_E} = \frac{20V - 0.7V}{R_E} = \frac{19.3V}{R_E}$

- (a) $I_E = \frac{19.3V}{80k\Omega} = 241.25\mu A$;

- (b) $I_E = \frac{19.3V}{40k\Omega} = 482.5\mu A$;

- (c) $I_E = \frac{19.3V}{20k\Omega} = 965\mu A$;

- (d) $I_E = \frac{19.3V}{10k\Omega} = 1.93mA$;

- (e) $I_E = \frac{19.3V}{5k\Omega} = 3.86mA$;

- (f) $I_E = \frac{19.3V}{1k\Omega} = 19.3mA$
Proving the point
(Measuring (a))
Measuring (b)

Diagram showing a circuit with components such as resistors, capacitors, and a multimeter reading 483.946 uA.
Measuring (c)
Measuring (d)
Measuring (e)
Measuring (f)
PNP versions

[Diagram of a PNP transistor circuit with labels VEE, RE, RC, Q1, VCC, and a closed loop with VEE and VCC connections]
If $R_E = 10k\Omega$ and $V_{EB} = 0V$, what are the values of $I_E$, $I_C$ and $V_{CB}$ when $R_C$ equals (a) 5k$\Omega$, (b) 8k$\Omega$, (c) 10k$\Omega$, (d) 12k$\Omega$. Assume $h_{FB} = \alpha = 1$. 
Points to ponder

• Since $I_E$ will remain constant, use the value found from calculating through the derivation of Ohm’s Law: 
$\frac{V_{EE}}{R_E} = \frac{18V}{10k\Omega} = 1.8\text{mA}$.

Additionally, we are treating $\alpha$ as 1, which means using the formula $\frac{I_C}{I_E} = 1$ translates into $I_E$ and $I_C$ being equal. Therefore, the value of $I_C$ for all changes of $R_C$ remains a constant 1.8mA (so long as saturation is avoided...).
Additional points

• Following KVL, \( V_{CC} = V_{RC} + V_{CB} \). Since \( V_{RC} = I_C R_C \) (Ohm’s Law), substituting this into the original formula gives us \( V_{CC} = I_C R_C + V_{CB} \). Reworking the equation to solve for \( V_{CB} \) yields \( V_{CB} = V_{CC} - I_C R_C \) (You can use the absolute value for \( V_{CC} \) when calculating, but remember to include polarity when writing the final answer).
Work through for circuit

- (a) \( V_{CB} = V_{CC} - I_C R_C = 22 - (1.8\text{mA})(5k\Omega) = 22 - 9 = -13\text{V} \) (Remember the polarity of \( V_{CC} \) is negative...)
- (b) \( V_{CB} = V_{CC} - I_C R_C = 22 - (1.8\text{mA})(8k\Omega) = 22 - 14.4 = -7.6\text{V} \)
- (c) \( V_{CB} = V_{CC} - I_C R_C = 22 - (1.8\text{mA})(10k\Omega) = 22 - 18 = -4\text{V} \)
- (d) \( V_{CB} = V_{CC} - I_C R_C = 22 - (1.8\text{mA})(12k\Omega) = 22 - 21.6 = -0.4\text{V} \)
Third circuit

- If $V_{CC} = 24V$, find (a) the saturation current, $I_{C(sat)}$. If $V_{EB} = 0.7V$, what are the values of $I_E$, $I_C$, and $V_{CB}$ when $R_E$ equals (b) 20kΩ, (c) 10kΩ, and (d) 5kΩ. Assume $\alpha_{DC} = 1$. 
$I_{C(sat)}$ and some constants in our calculations

- (a) $I_{C(sat)} = \frac{V_{CC}}{R_C} = \frac{24V}{5\text{k}\Omega} = 3\text{mA}$

- $V_{RE} = V_{EE} - V_{EB} = 20 - 0.7 = 19.3V$ (technically this should be written as -19.3V since $V_{EE}$ is negative in polarity)
Calculating the rest

• (b) \( I_E = \frac{V_{RE}}{R_E} = \frac{19.3V}{20k\Omega} = 965\mu A \) \( \therefore I_C = 965\mu A; \)

\( V_{CB} = V_{CC} - I_C R_C = 24 - (965\mu A)(8k\Omega) = 24 - 7.72 = 16.28V \)
And the beat goes on...

- (c) \( I_E = \frac{V_{RE}}{R_E} = \frac{19.3V}{10k\Omega} = 1.93\text{mA} \) \( \therefore I_C = 1.93\text{mA} \)

\( V_{CB} = V_{CC} - I_C R_C = 24 - (1.93\text{mA})(8k\Omega) \)

\( = 24 - 15.44 = 8.56V \)
And on...

• (d) $I_E = \frac{V_{RE}}{R_E} = \frac{19.3V}{5k\Omega} = 3.86\text{mA}$  \therefore I_C = 3\text{mA} \text{ (this cannot be exceeded)}$; $V_{CB} = V_{CC} - I_C R_C = 24 - (3\text{mA})(8k\Omega) = 24 - 24 = 0\text{V}$
Measure to make sure (a)
Any questions?

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