EE210: Microelectronics-I

Lecture-26 :Common Collector Amplifier-2

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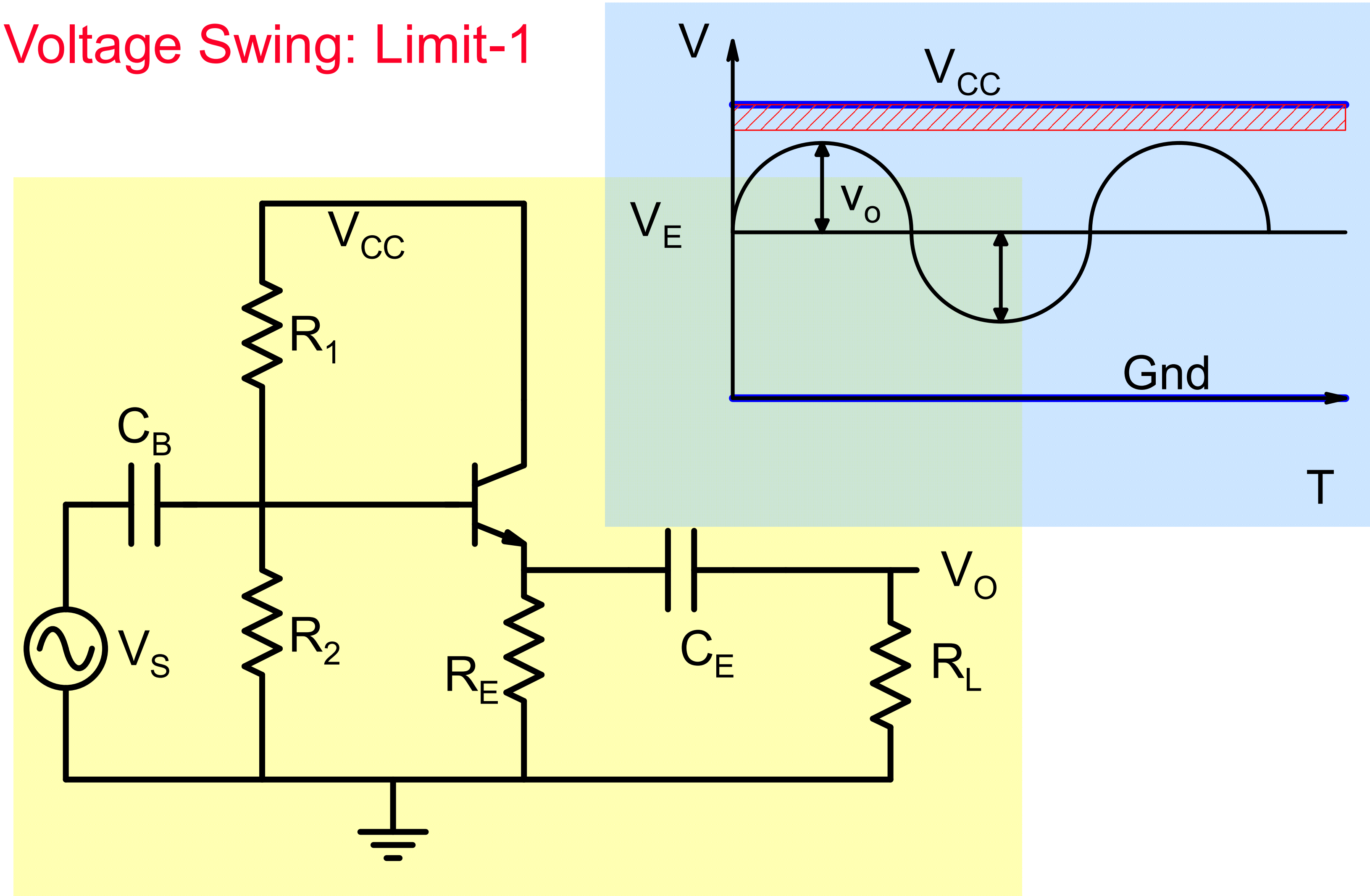
Output Voltage Swing

Output Voltage Swing: Limit-1

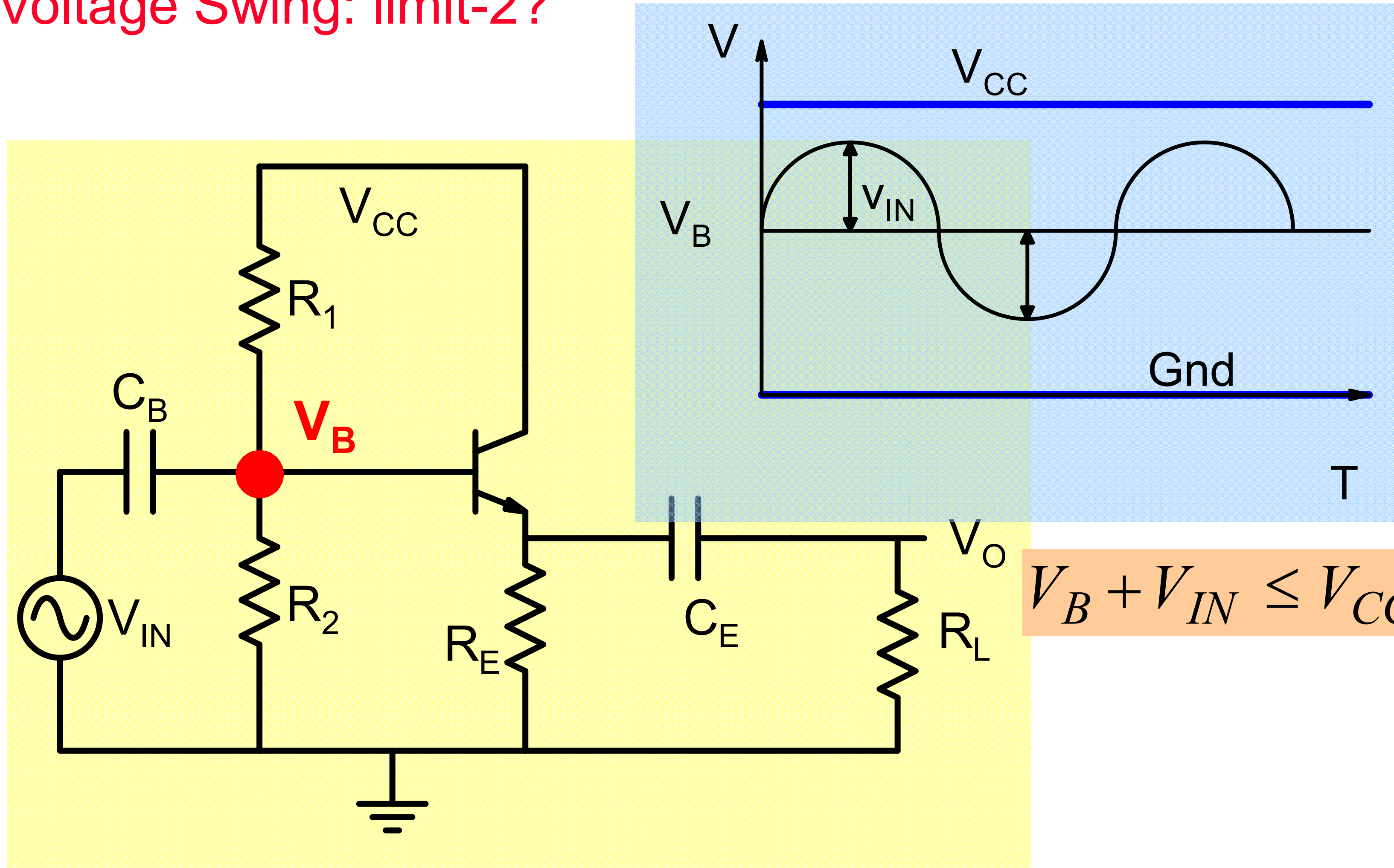


One constraint: Transistor should stay out of saturation

$$V_{CC} - (V_E + V_O) \geq V_{CEsat}$$

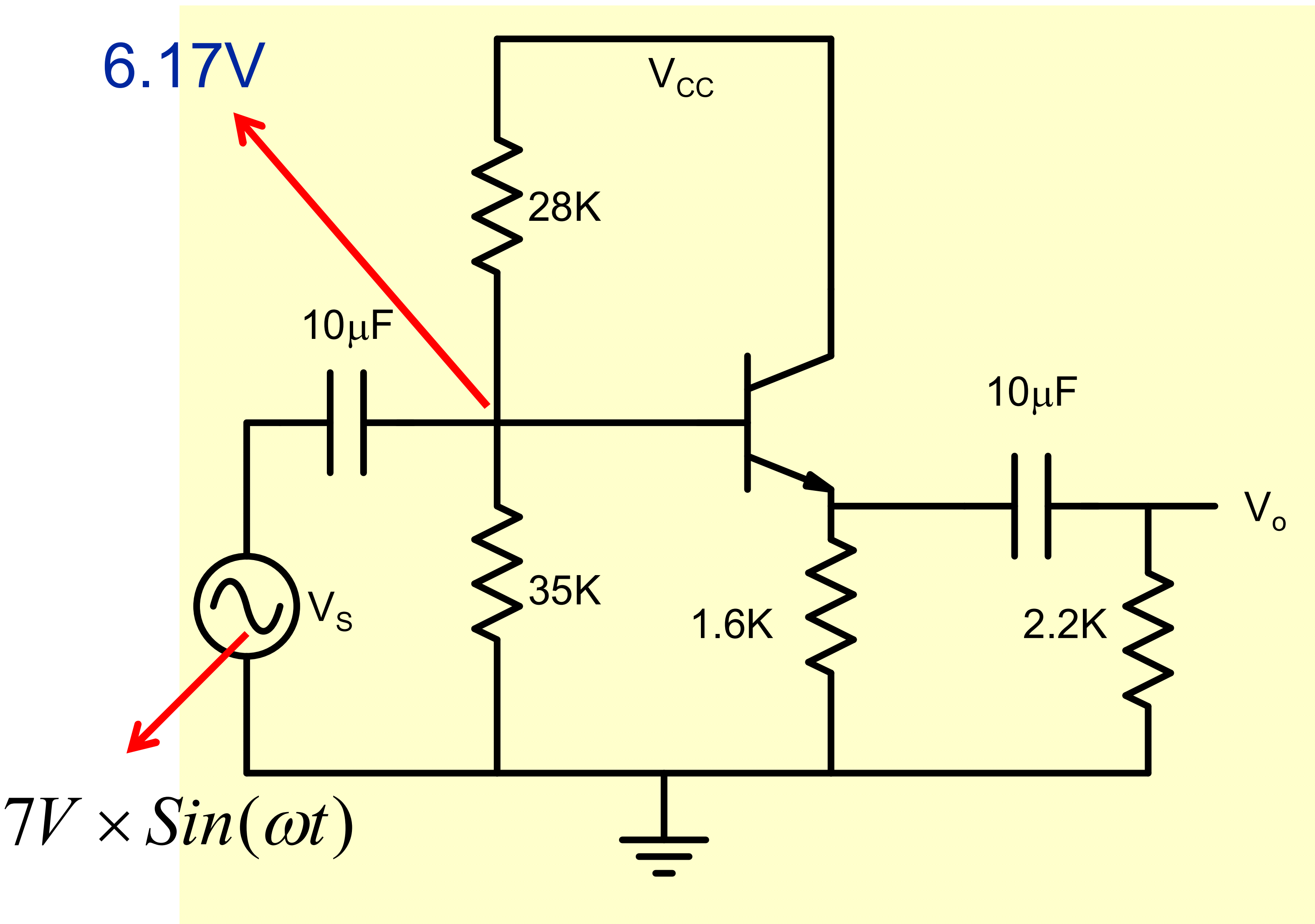
$$V_O \leq V_{CC} - V_{CEsat} - I_{CQ} R_E$$

Output Voltage Swing: limit-2?

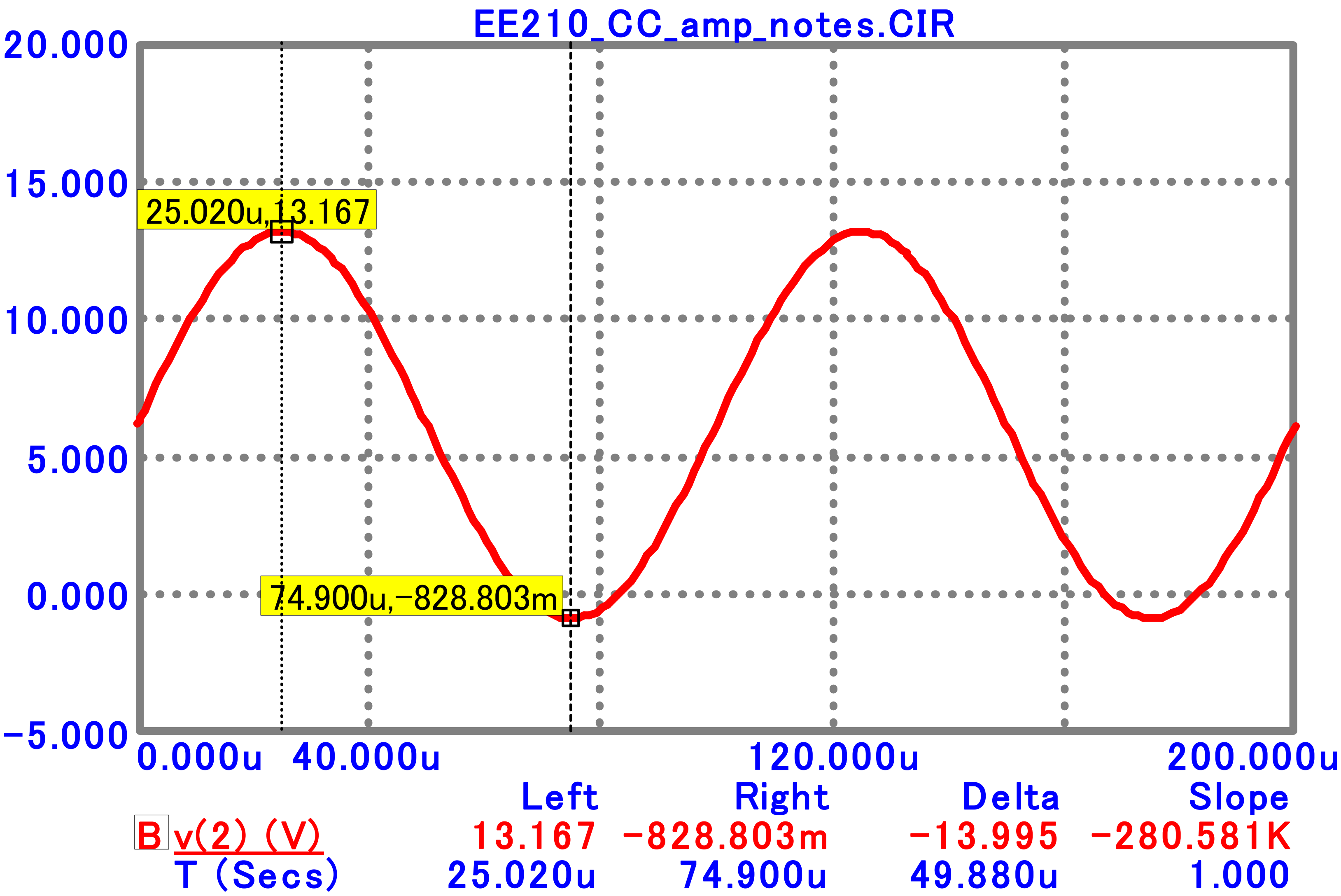


$$V_B + V_{IN} \leq V_{CC}$$

Constraint-2: Maximum voltage at base is always less than V_{CC} ?

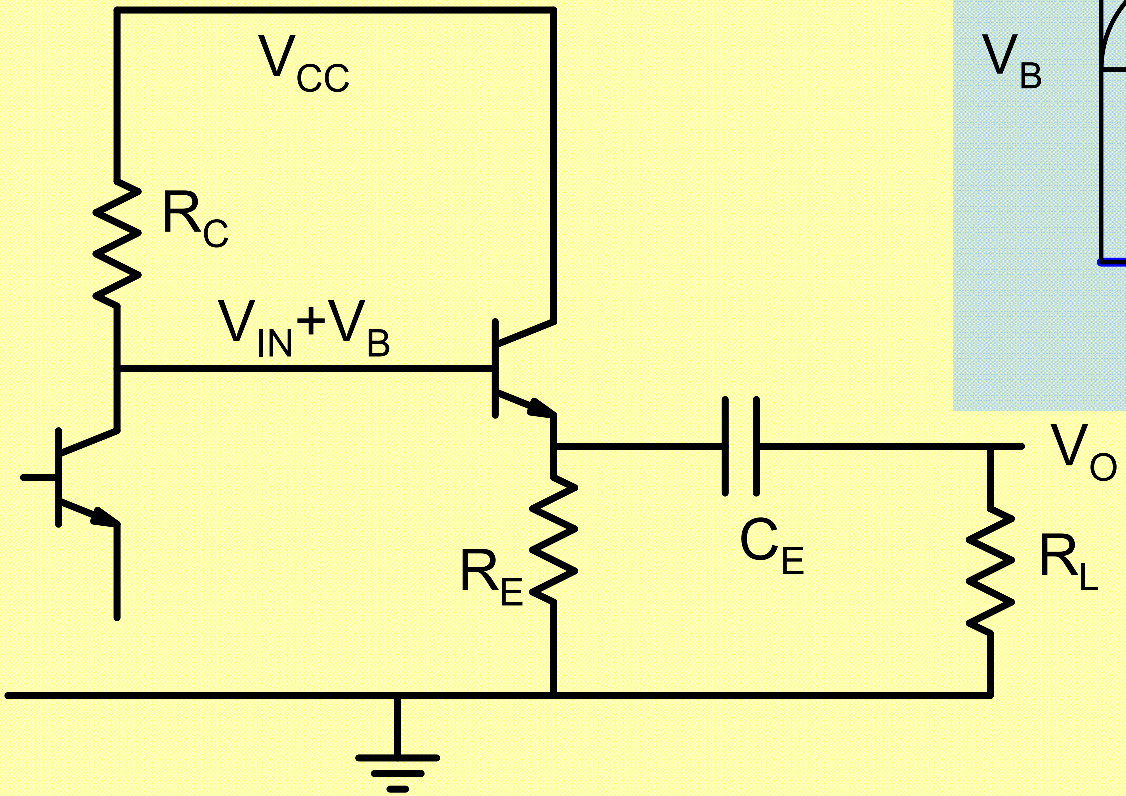


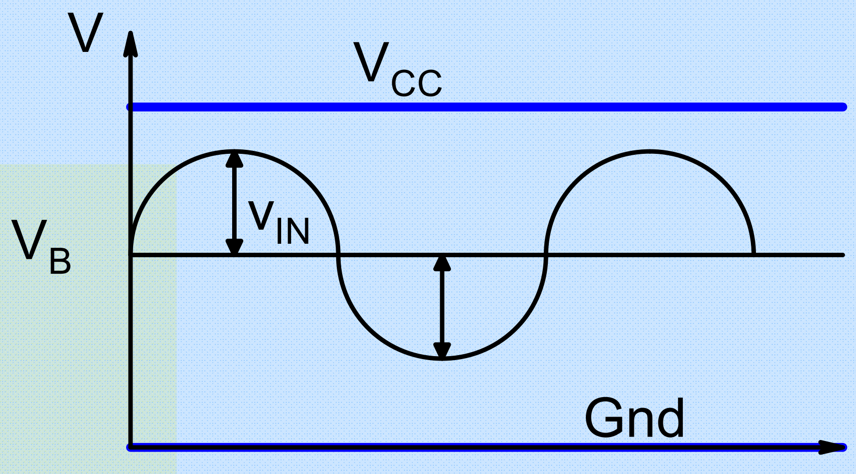
G-Number



Voltage can exceed +12V supply voltage

Output Voltage Swing: limit-2 in direct coupled case.





$$V_B + V_{IN} \le V_{CC}$$

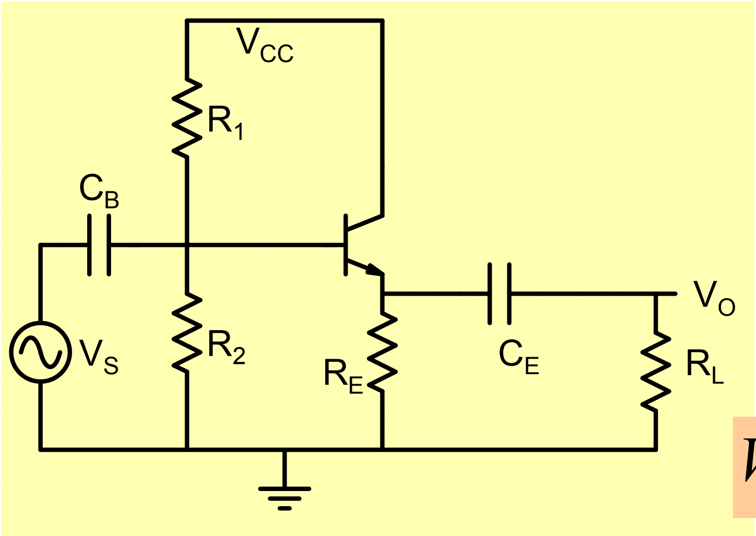
$$V_B = I_{CQ}R_E + V_{BE}$$

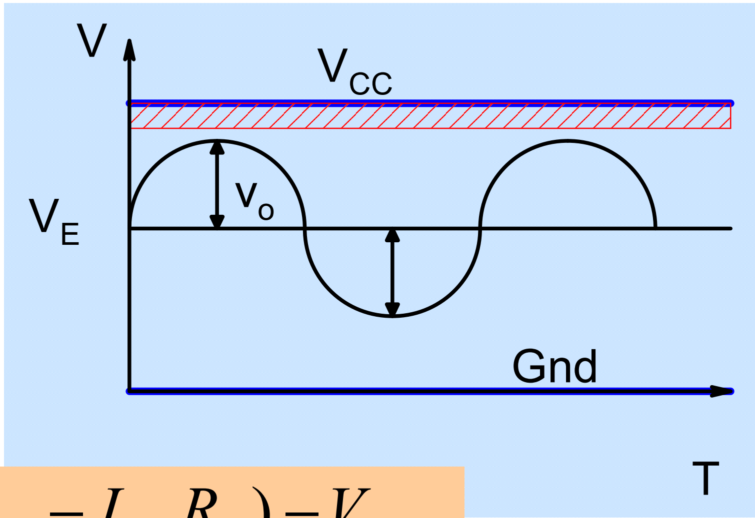
$$v_{in} \sim v_O$$

Constraint-2: Maximum voltage is always less than V_{CC}

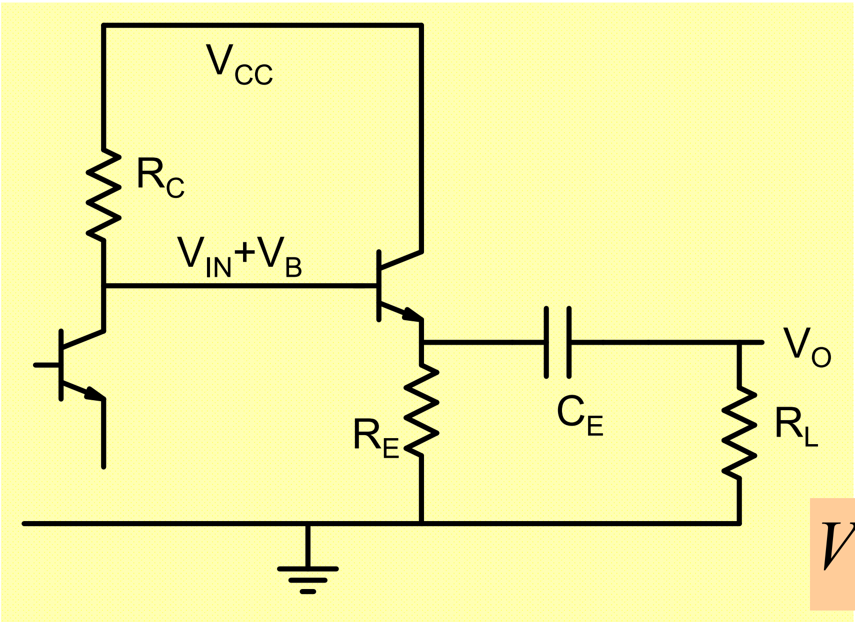
$$I_{CQ}R_E + V_{BE} + v_O \le V_{CC}$$

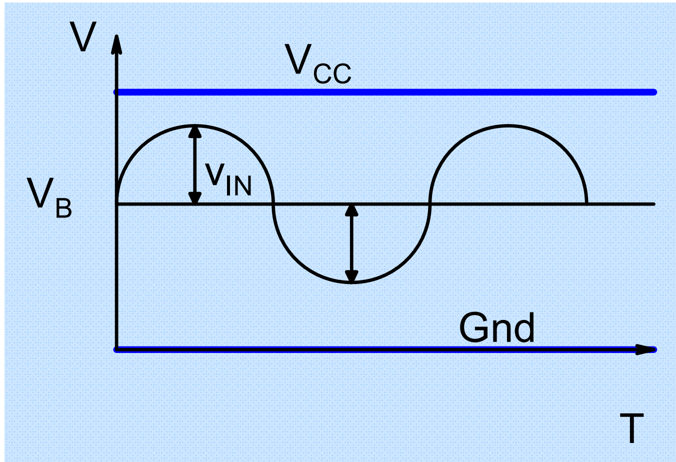
$$v_O \le V_{CC} - V_{BE} - I_{CQ}R_E$$





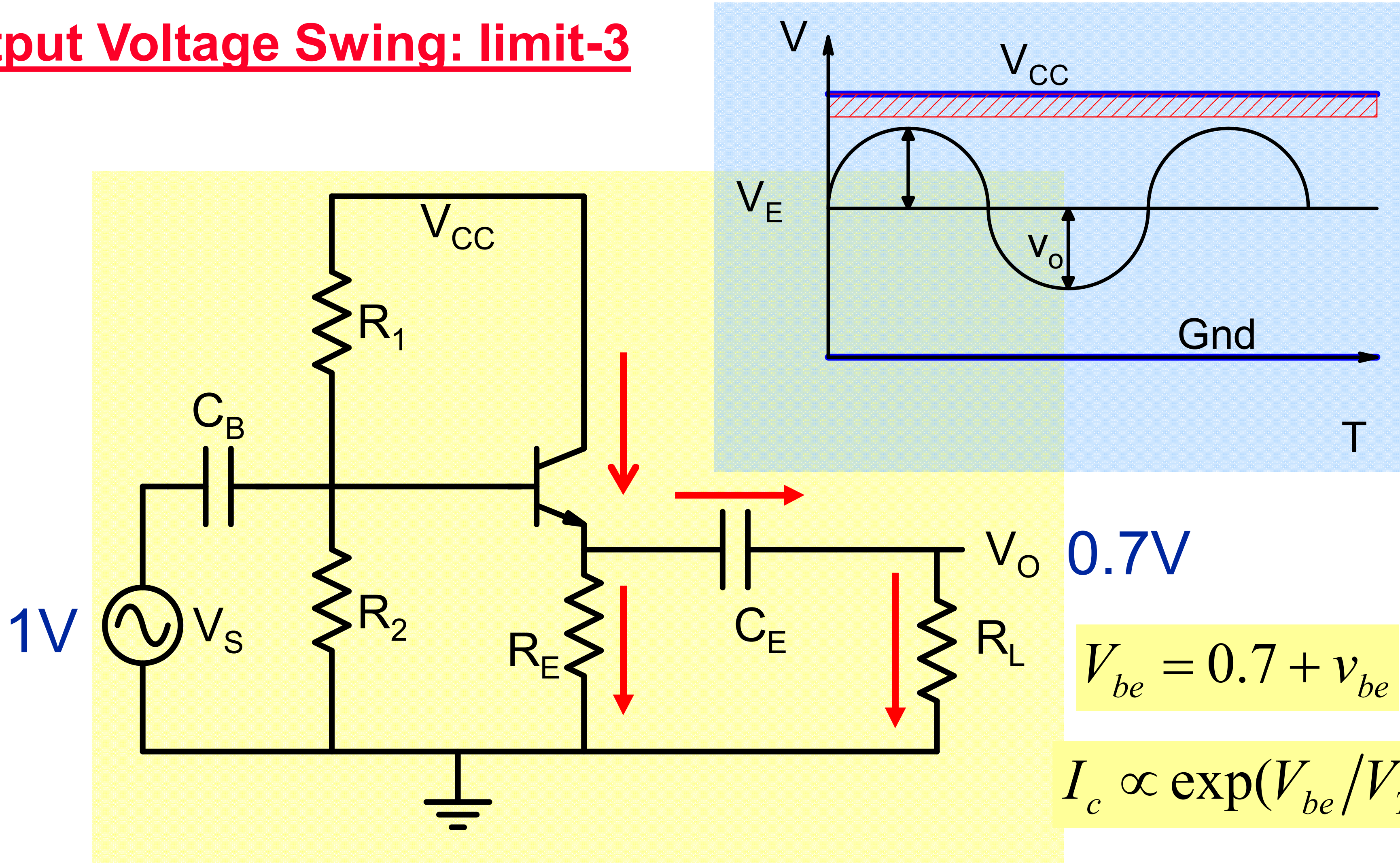
$$V_O \le (V_{CC} - I_{CQ}R_E) - V_{CEsat}$$





$$V_O \le (V_{CC} - I_{CQ}R_E) - V_{BE}$$

Output Voltage Swing: limit-3



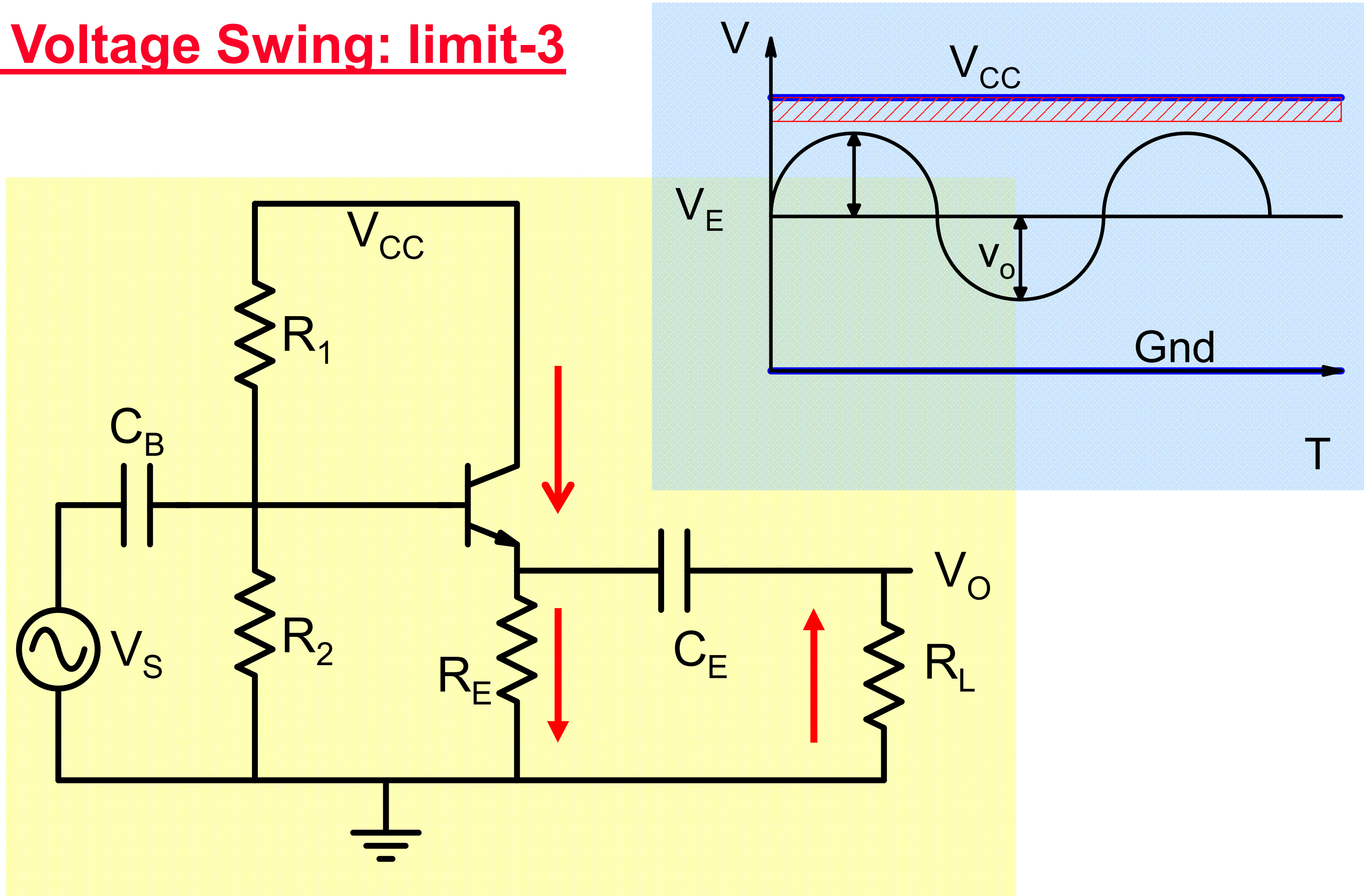
$$V_{be} = 0.7 + v_{be}$$

$$I_c \propto \exp(V_{be}/V_T)$$

Constraint-3 : There should be enough drive current

$$I_c = \frac{V_E + v_O}{R_E} + \frac{v_O}{R_L}$$

Output Voltage Swing: limit-3



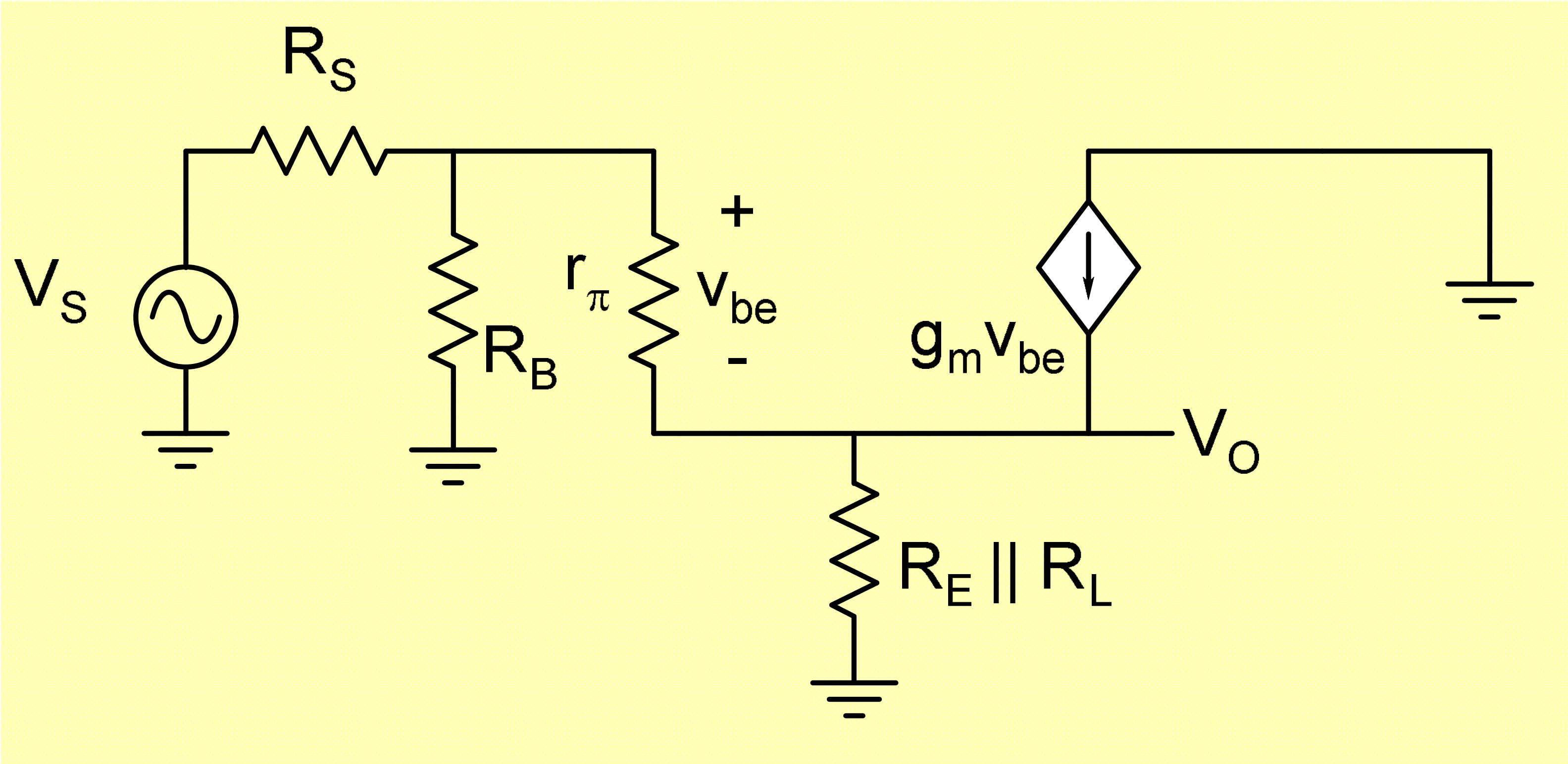
Constraint-3 : There should be enough drive current

$$\frac{V_E - v_O}{R_E} = \frac{v_O}{R_L} + I_c$$

$$\frac{I_{CQ}R_E - v_O}{R_E} \geq \frac{v_O}{R_L}$$

$$v_O \leq I_{CQ} R_E \| R_L$$

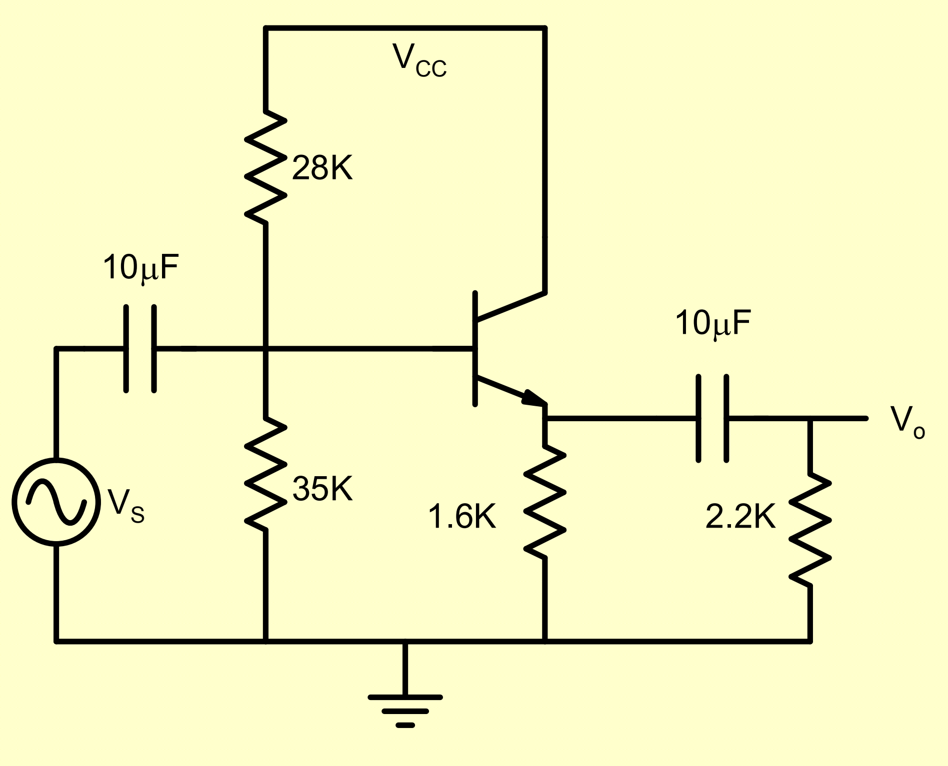
Nonlinearity leading to harmonic distortion



$$v_S' = i_b R_S' + v_{be} + v_O \approx v_O$$

Thus transfer characteristics is expected to be quite linear

Example



$$\beta = 100$$

$$I_{CQ} = 3.4mA; V_{CEQ} = 6.5V$$

$$A_V = 0.99;$$

$$R_{in} = 13.4K\,(R_B = 16k)$$

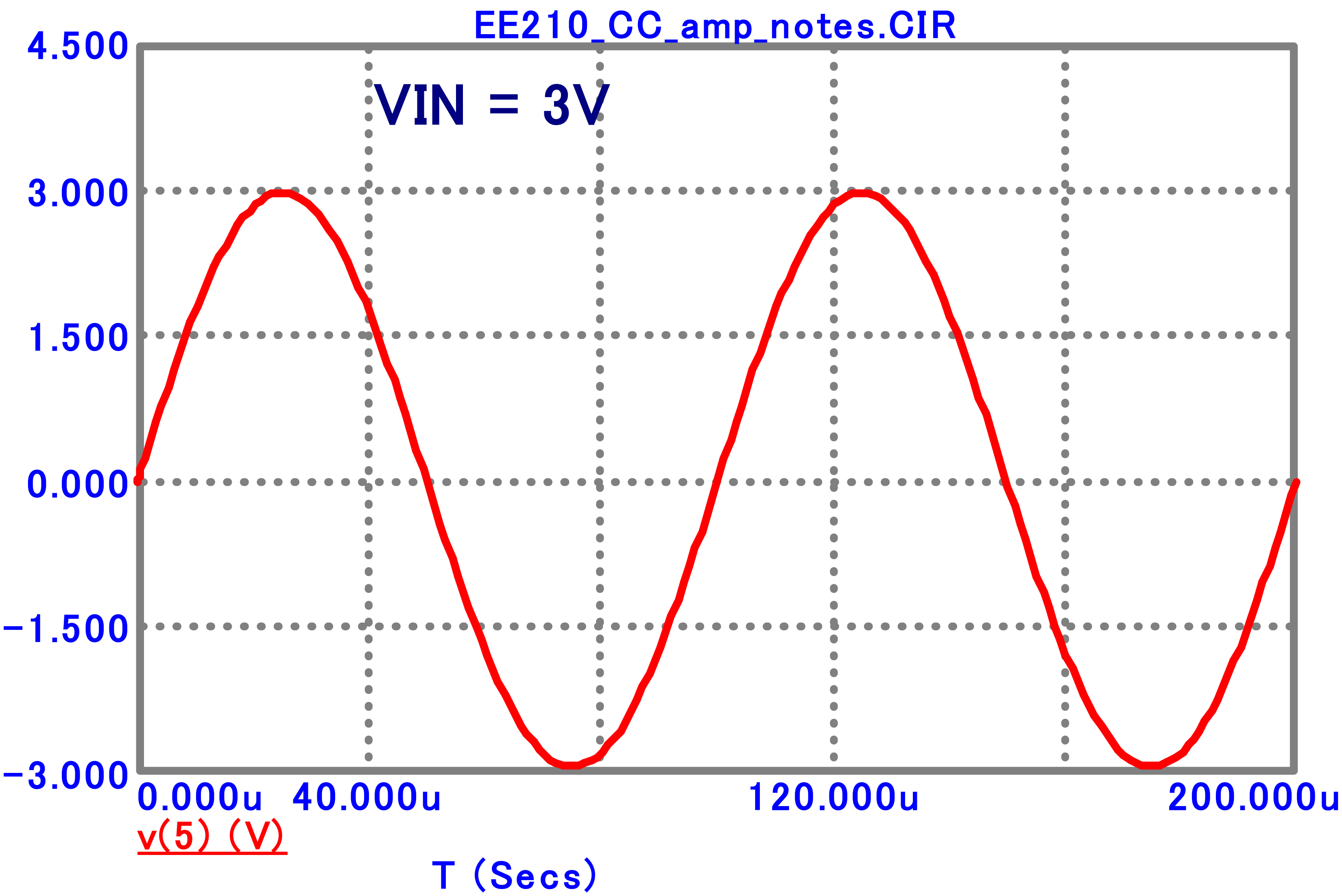
$$R_O = 9.5\Omega$$

$$V_O \le V_{CC} - V_{BE} - I_{CQ}R_E = 5.85V$$

$$V_O \le I_{CQ}R_E \| R_L = 3.2V$$

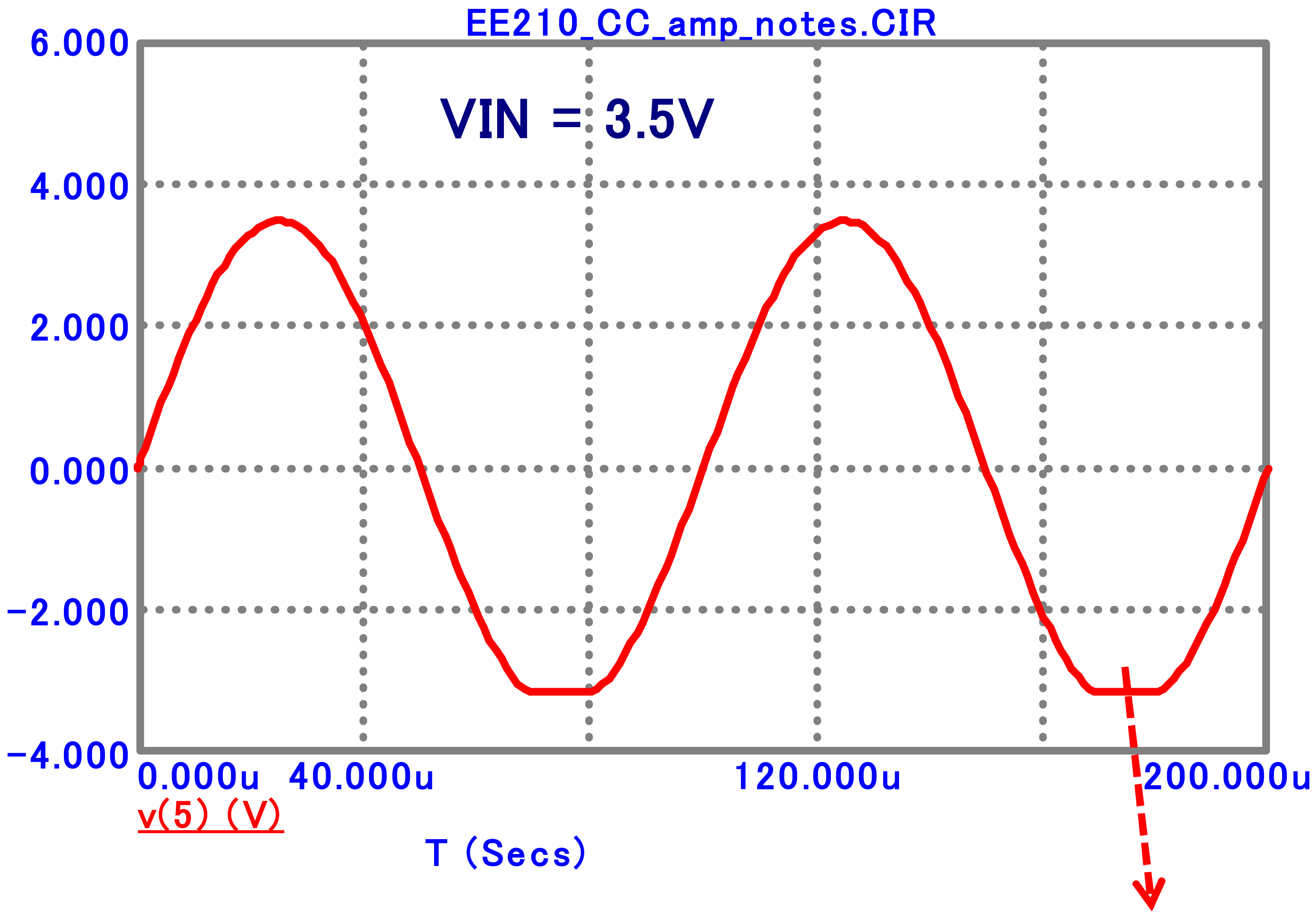
$$V_{OM} \sim 3.2V$$

G-Number



THD ~0.5%

G-Number



THD ~2.6%

Due to current limitations

G-Number

Design for Maximum Voltage Swing

$$V_O \le I_{CQ} R_E \| R_L$$

$$V_O \le V_{CC} - V_{BE} - I_{CQ} R_E$$

$$V_O = Min\{V_{CC} - V_{BE} - I_{CQ} R_E ; I_{CQ} R_E \| R_L\}$$

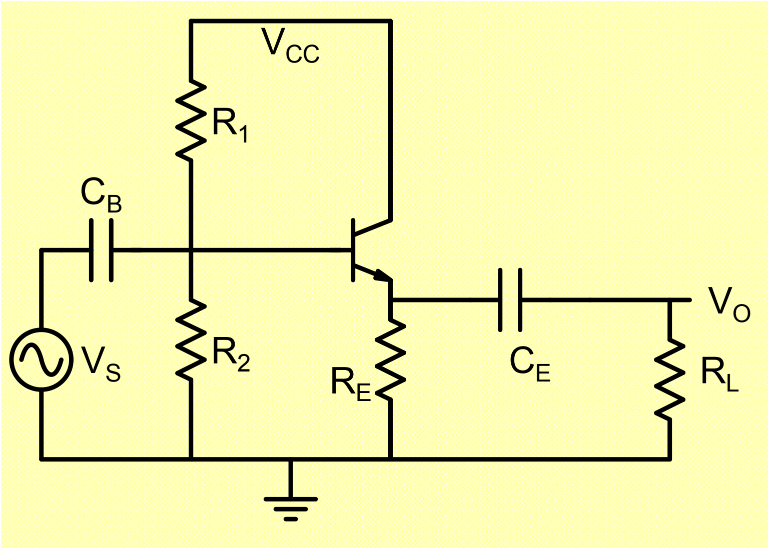
$$V_{CC} - V_{BE} - I_{CQ} R_E = I_{CQ} R_E \| R_L$$

$$I_{CQ} = \frac{V_{CC} - V_{BE}}{R_E} \times \frac{1 + R_E / R_L}{2 + R_E / R_L}$$

$$V_O = \frac{V_{CC} - V_{BE}}{2 + R_E / R_L}$$

$$V_O \le I_{CQ} R_E \| R_L$$

Design For Maximum Voltage Swing



$$V_O = \frac{V_{CC} - V_{BE}}{2 + R_E / R_L}$$

$$I_{CQ} = \frac{V_{CC} - V_{BE}}{R_E} \times \frac{1 + R_E / R_L}{2 + R_E / R_L}$$

Design criterion: Choose $R_E << R_L$

$$v_{om} \sim 5.6 \quad \text{for } \mathrm{V_{CC}} = 12\mathrm{V}$$

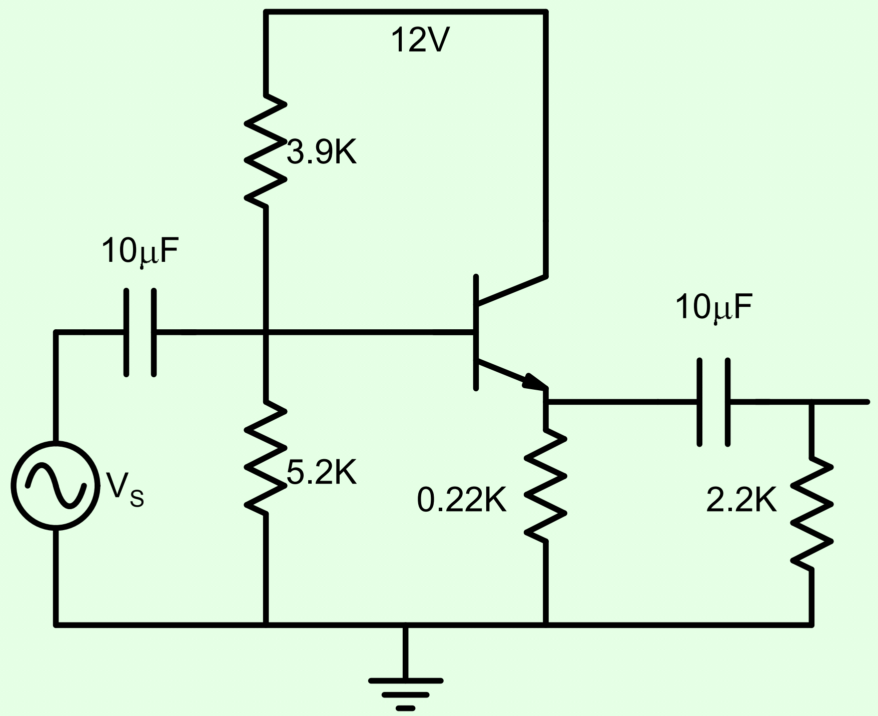
However, this makes I_{CQ} large leading to high power dissipation and lower input resistance

$$V_O = \frac{V_{CC} - V_{BE}}{2 + R_E / R_L}$$

$$I_{CQ} = \frac{V_{CC} - V_{BE}}{R_E} \times \frac{1 + R_E / R_L}{2 + R_E / R_L}$$

For $R_E << R_L$:

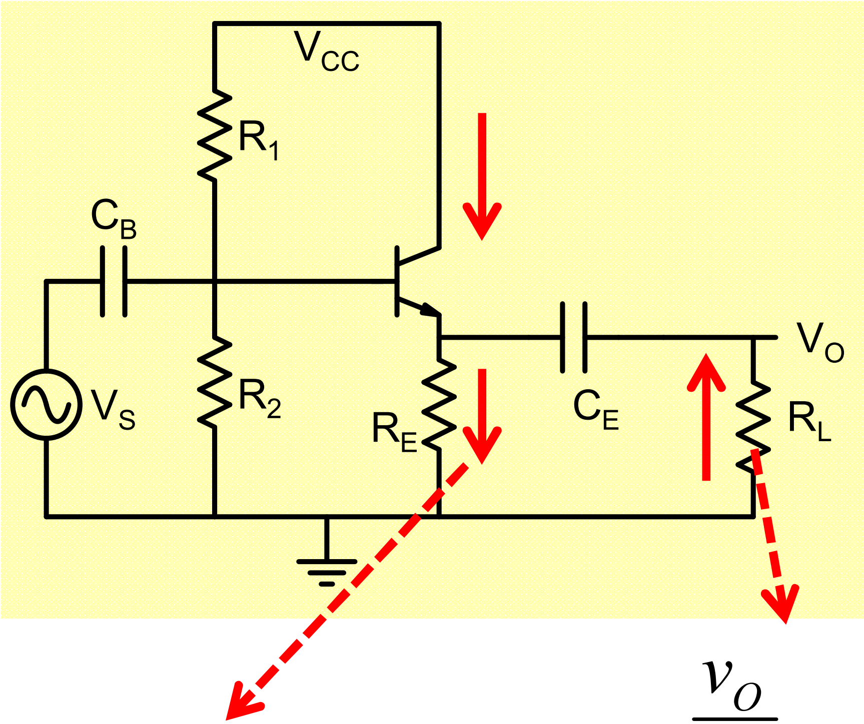
$$I_{CQ} \sim \left(\frac{V_o}{R_L} \right) \times \left(\frac{R_L}{R_E} \right)$$



$$I_{CQ} = 25mA; V_{CEQ} = 6.5V$$

$$A_V = 0.98; R_{in} = 2K; R_O = 3\Omega$$

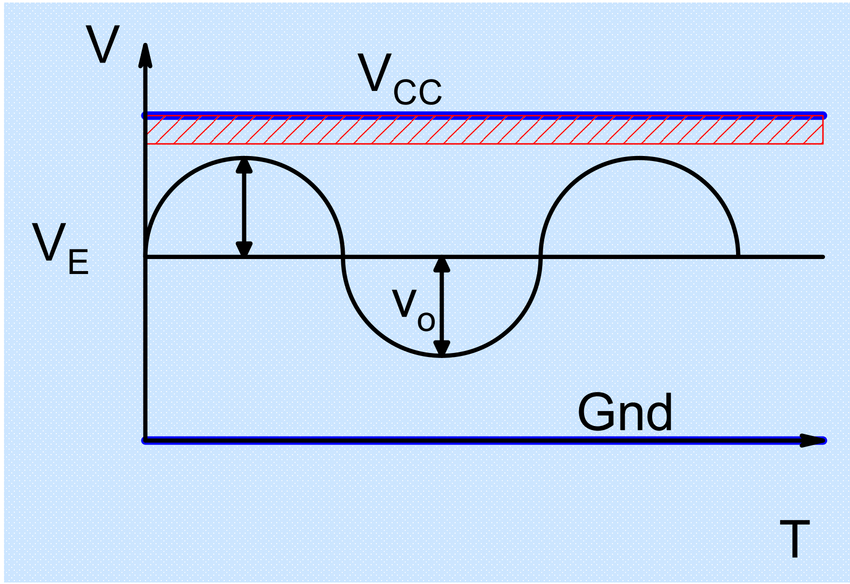
$$V_{om} = 5.6V$$

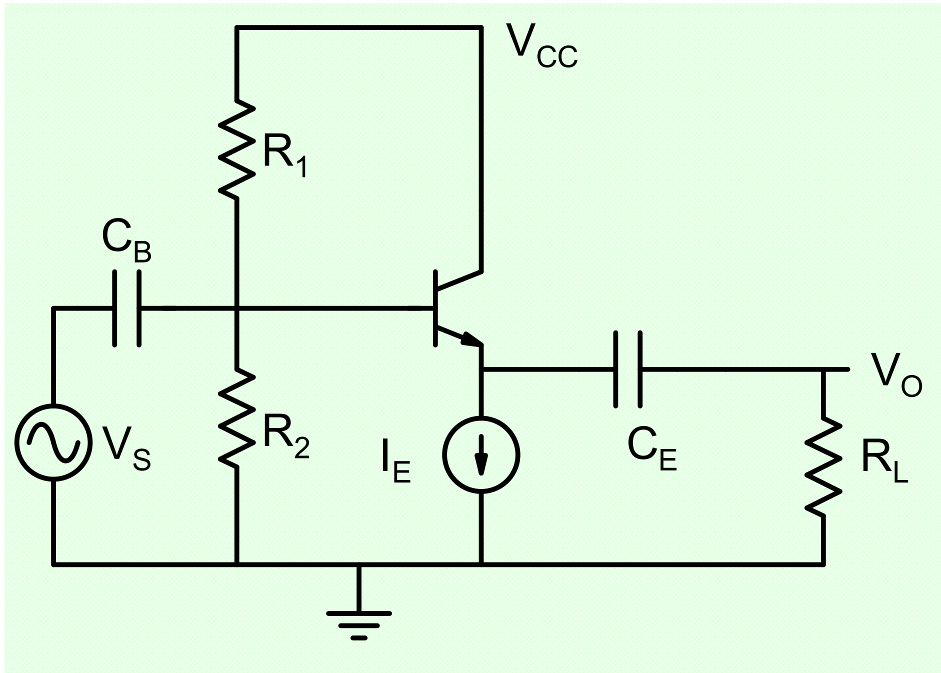


$$\frac{V_E - v_O}{R_E}$$

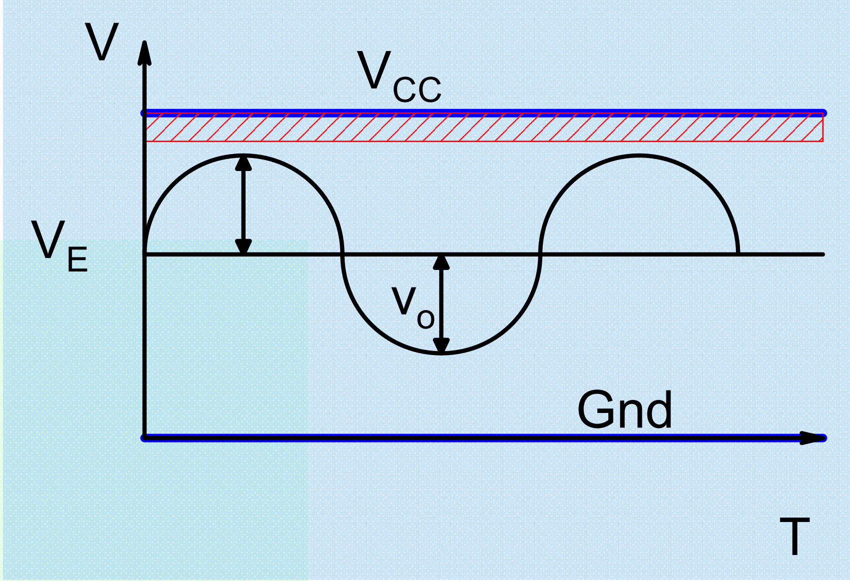
$$= I_{CQ} - \frac{v_o}{R_E}$$

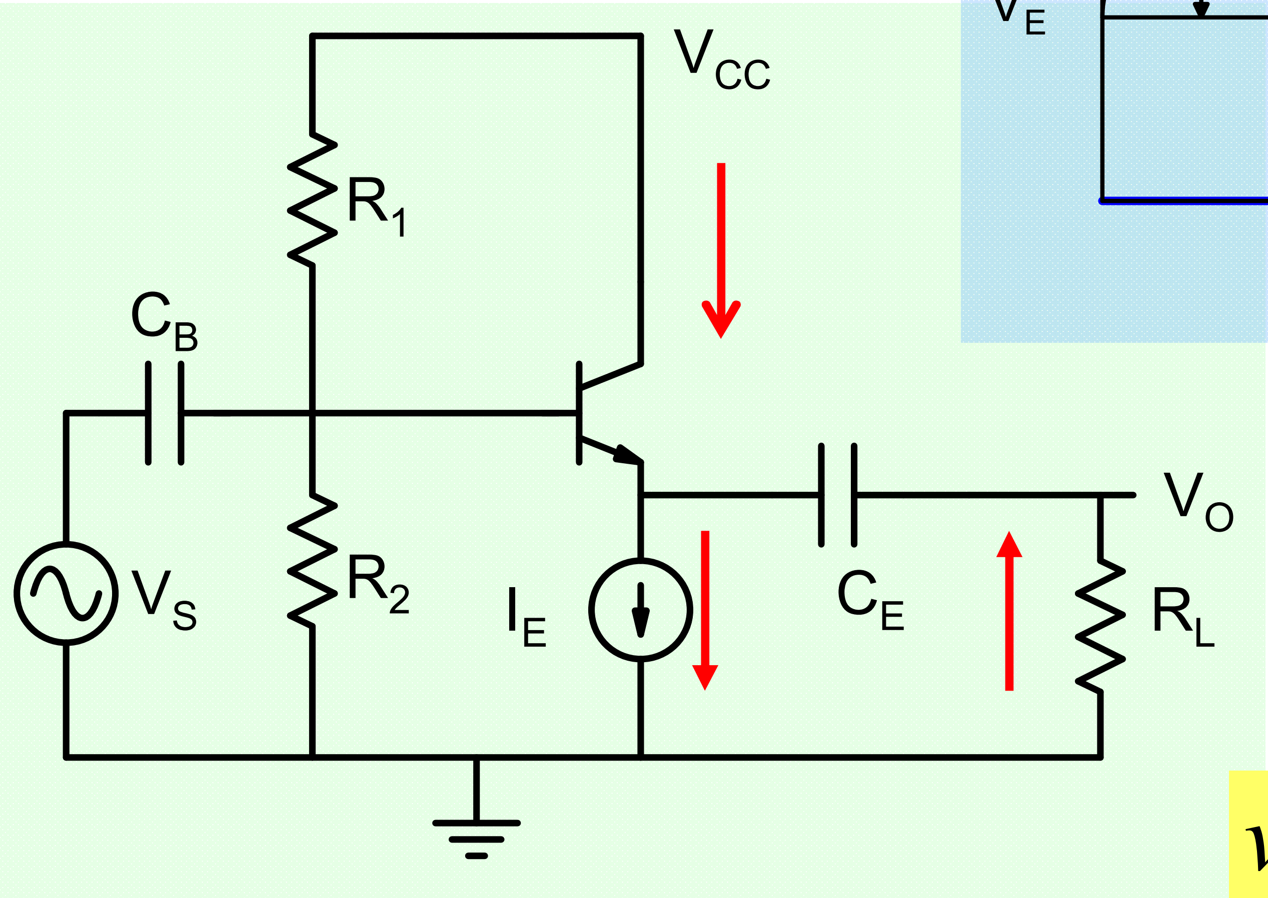
$$\frac{v_O}{R_L}$$





Current Source Biasing





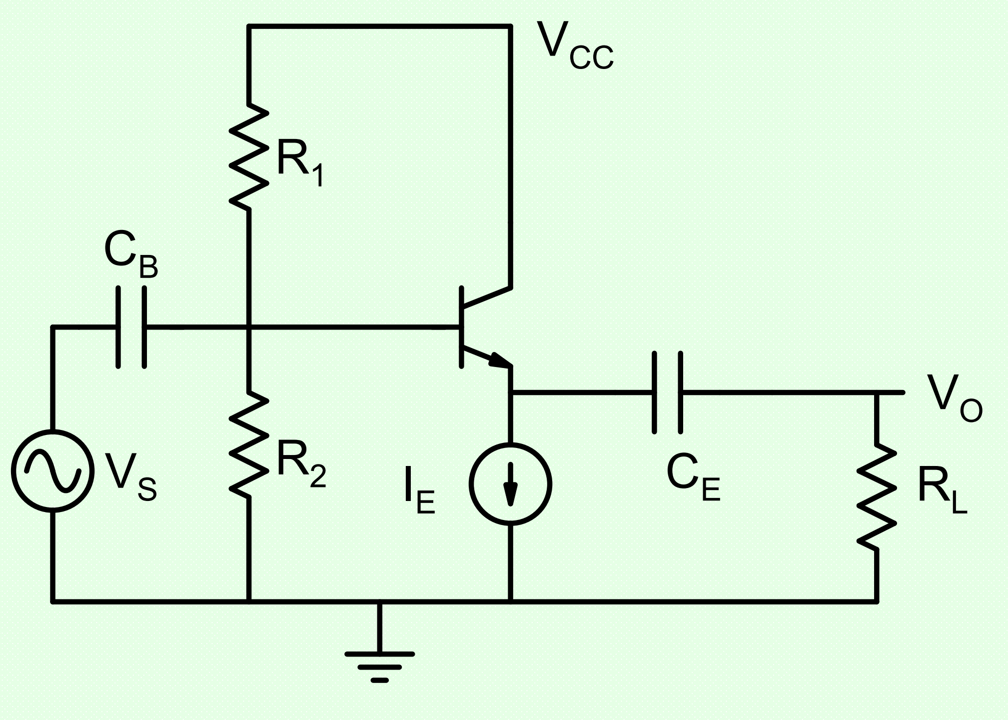
$$v_O \le I_{EQ} R_L$$

$$I_E = \frac{v_O}{R_L} + I_c$$

$$I_E \ge \frac{v_O}{R_L}$$

$$V_E - v_O \ge 0$$

Maximum Voltage Swing



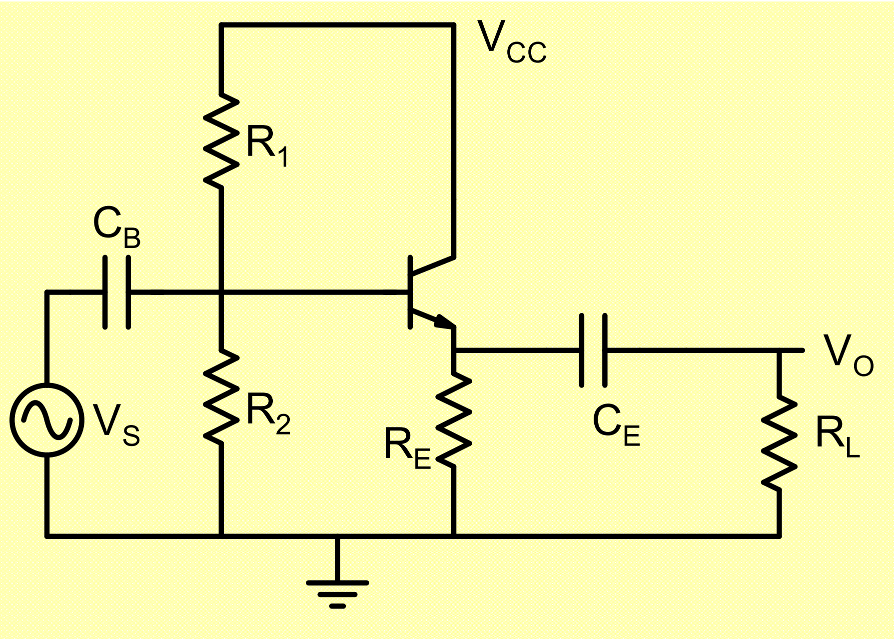
$$V_O \leq V_{CC} - V_{BE} - V_E$$

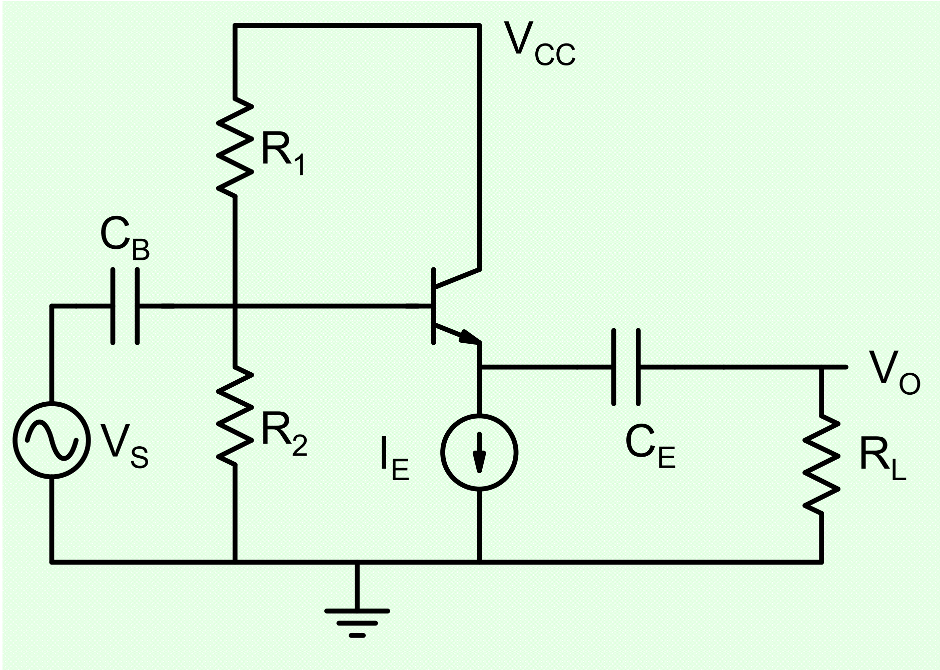
$$V_E - v_O \geq 0$$

$$V_O = V_E = \frac{V_{CC} - V_{BE}}{2}$$

$$v_O \leq I_{EQ} R_L \Rightarrow I_{EQ} \geq \frac{V_O}{R_L}$$

Design for Maximum Voltage Swing





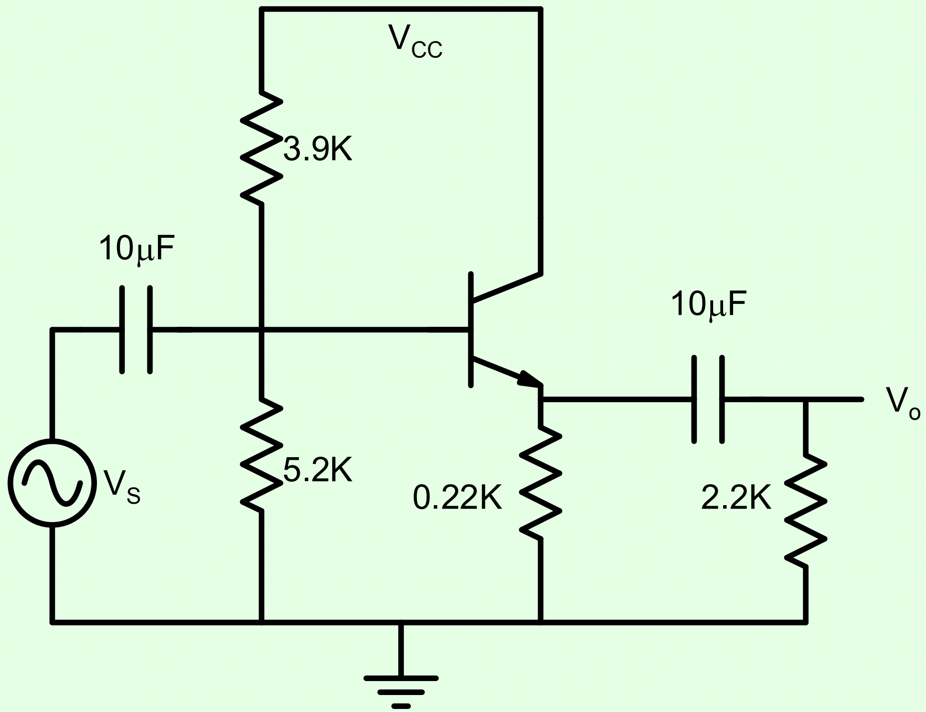
$$I_{CQ} = \frac{V_{CC} - V_{BE}}{R_E} \times \frac{1 + R_E / R_L}{2 + R_E / R_L}$$

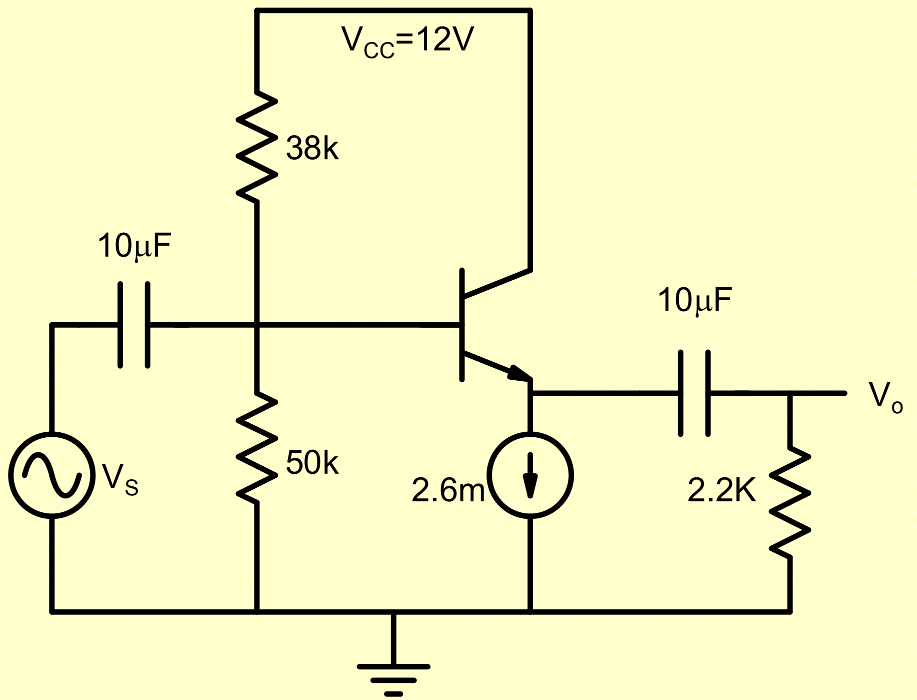
$$V_O = \frac{V_{CC} - V_{BE}}{2 + R_E / R_L}$$

$$\text{For } R_E << R_L : I_{CQ} = \frac{V_{CC} - V_{BE}}{2R_E}$$

$$V_O = \frac{V_{CC} - V_{BE}}{2}$$

$$I_E \cong \frac{V_{CC} - V_{BE}}{2R_L}$$





$$I_{CQ} = 25mA; V_{CEQ} = 6.5V$$

$$A_V = 0.98; R_{in} = 2K; R_O = 3\Omega$$

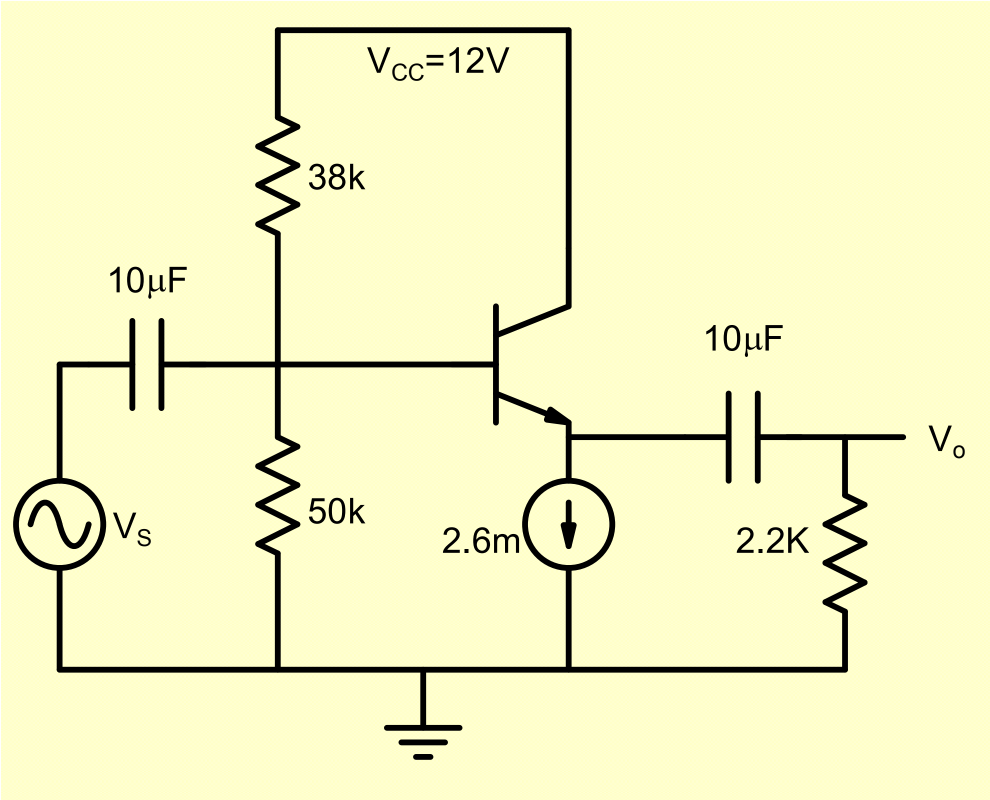
$$V_{om} = 5.6V$$

$$I_{CQ} = 2.6mA; V_{CEQ} = 6.5V$$

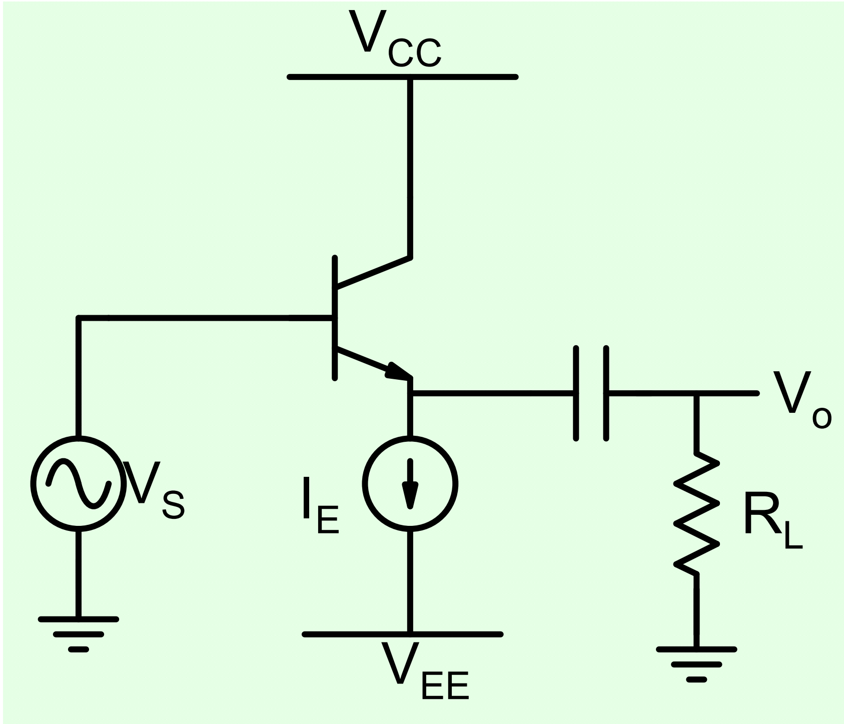
$$A_V = 0.99; R_{in} = 19.7K; R_O = 9.5\Omega$$

$$V_{om} = 5.6V$$

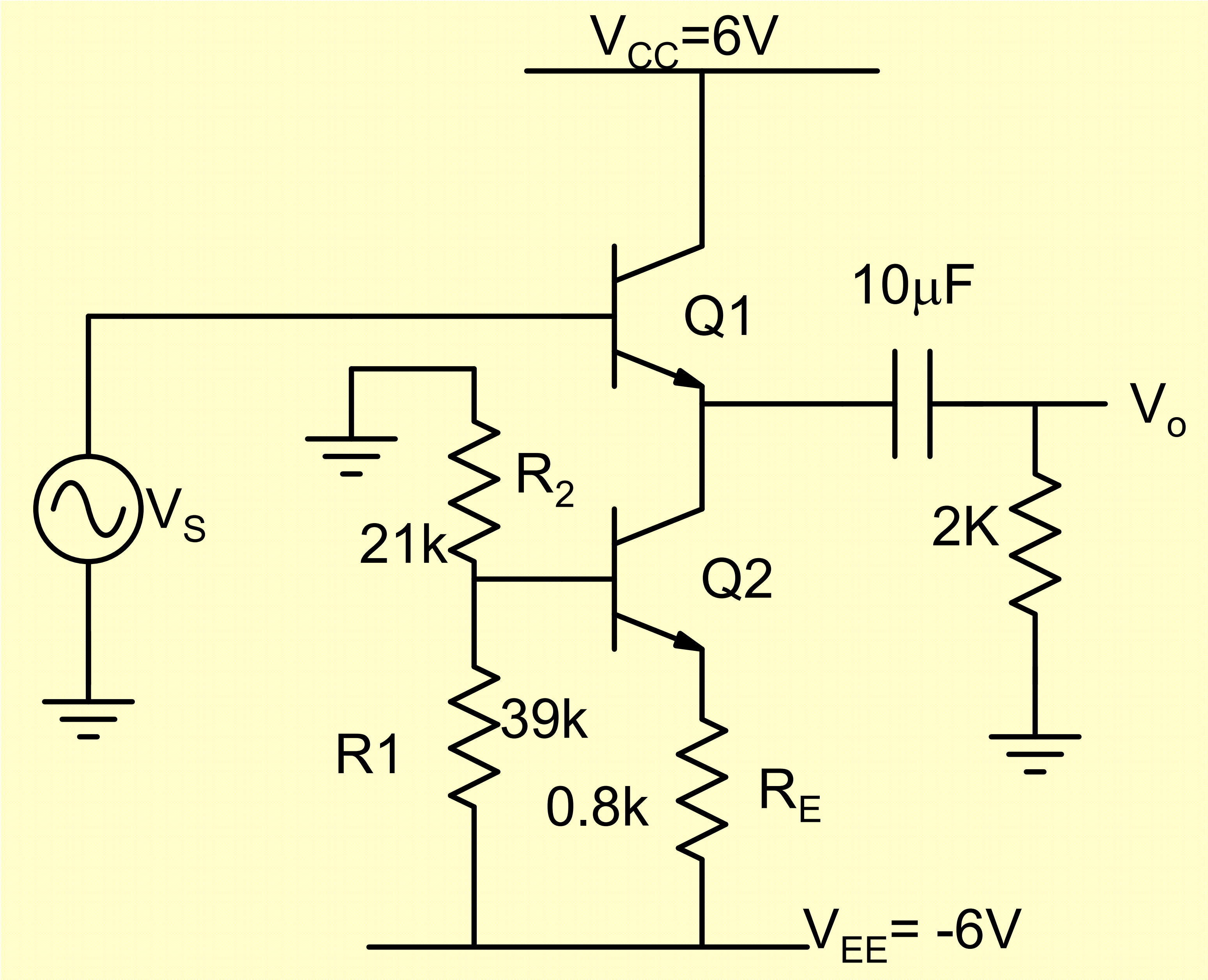
G-Number



VCC=12V
38k
10μF
10μF
Vo
VS
50k
2.6m
2.2K



VCC
Vo
VS
IE
RL
VEE



VCC=6V
Q1
10μF
Vo
R2
21k
VS
Q2
2K
39k
R1
0.8k
RE
VEE= -6V