EE210: Microelectronics-I

Lecture-17 : BJT Amplifier-part-6
Amplifier Analysis

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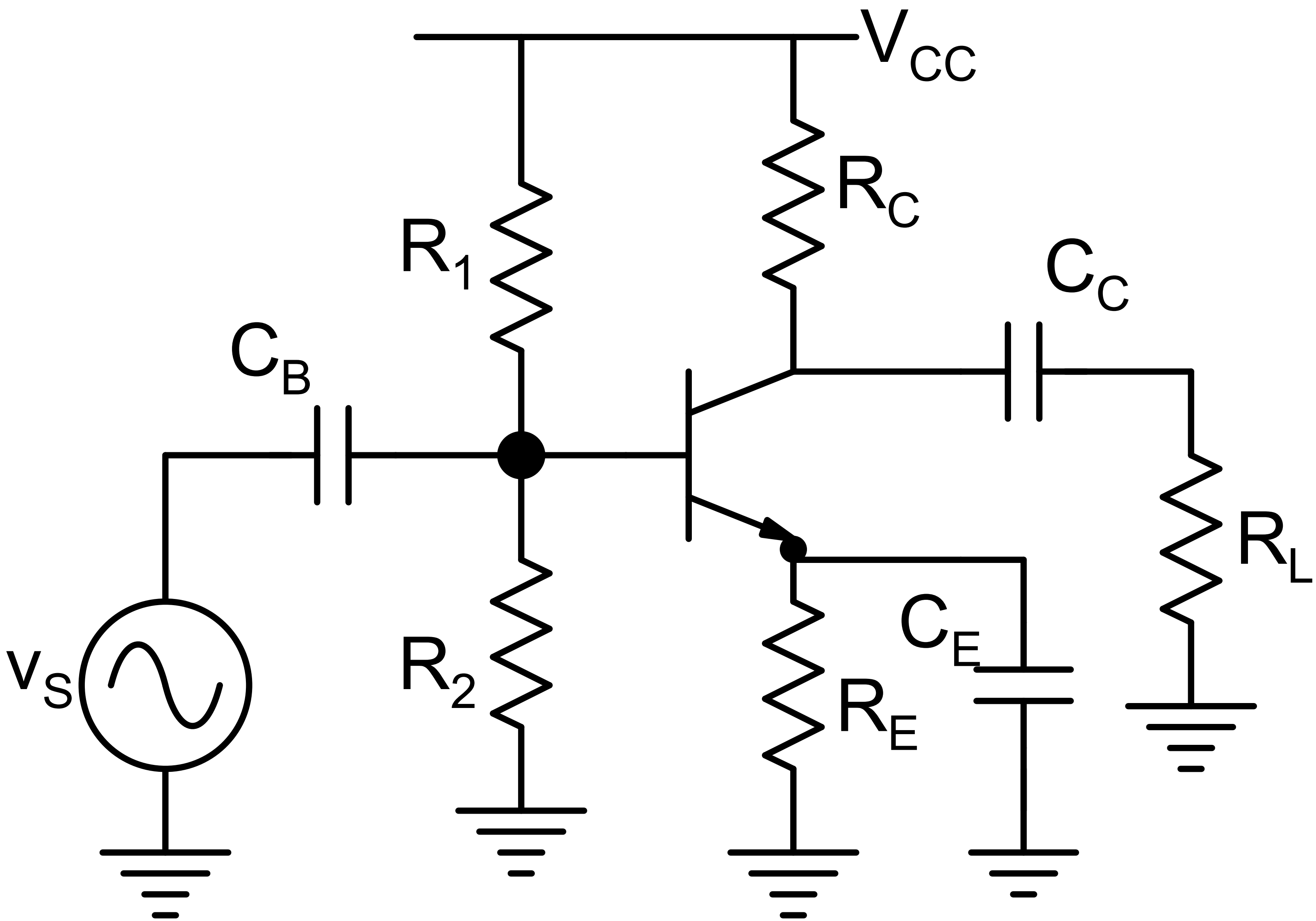
Dept. of EE, IIT Kanpur



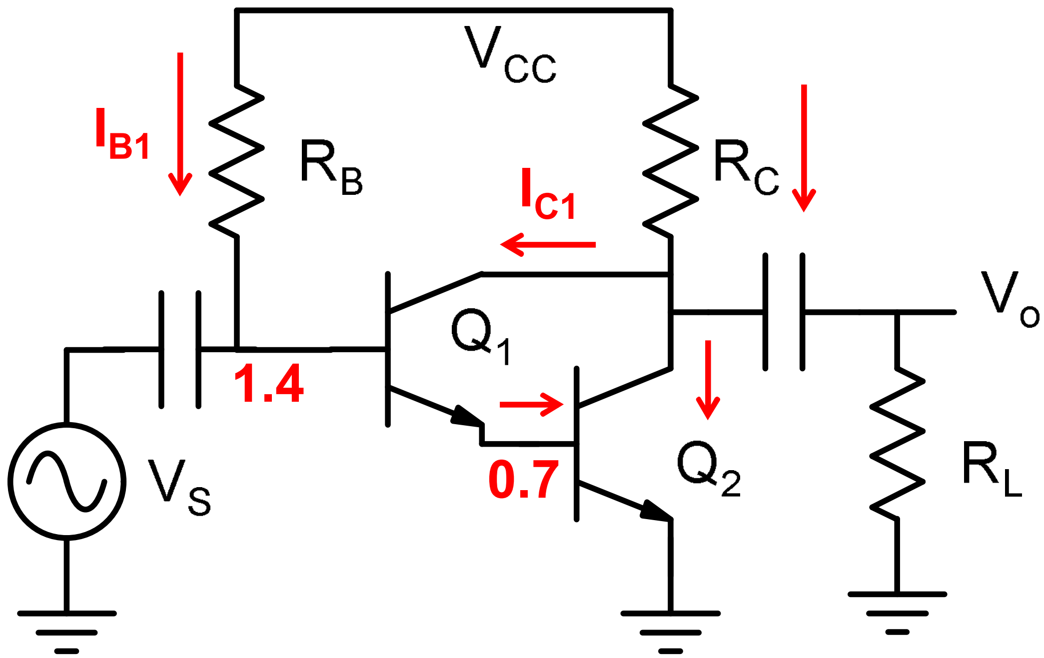
G-Number

Is there a better way of remembering ?

A 10-step approach for drawing the CE amplifier

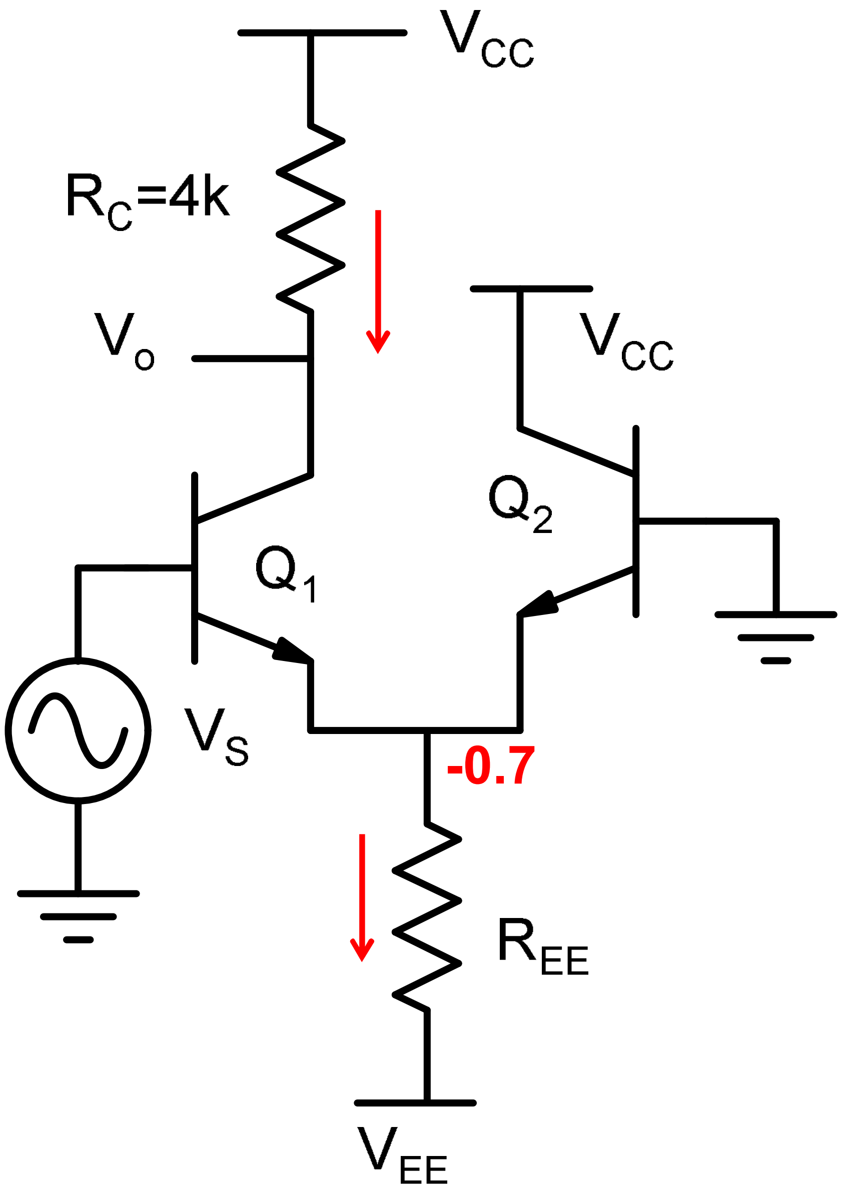
dc Analysis

Example-1

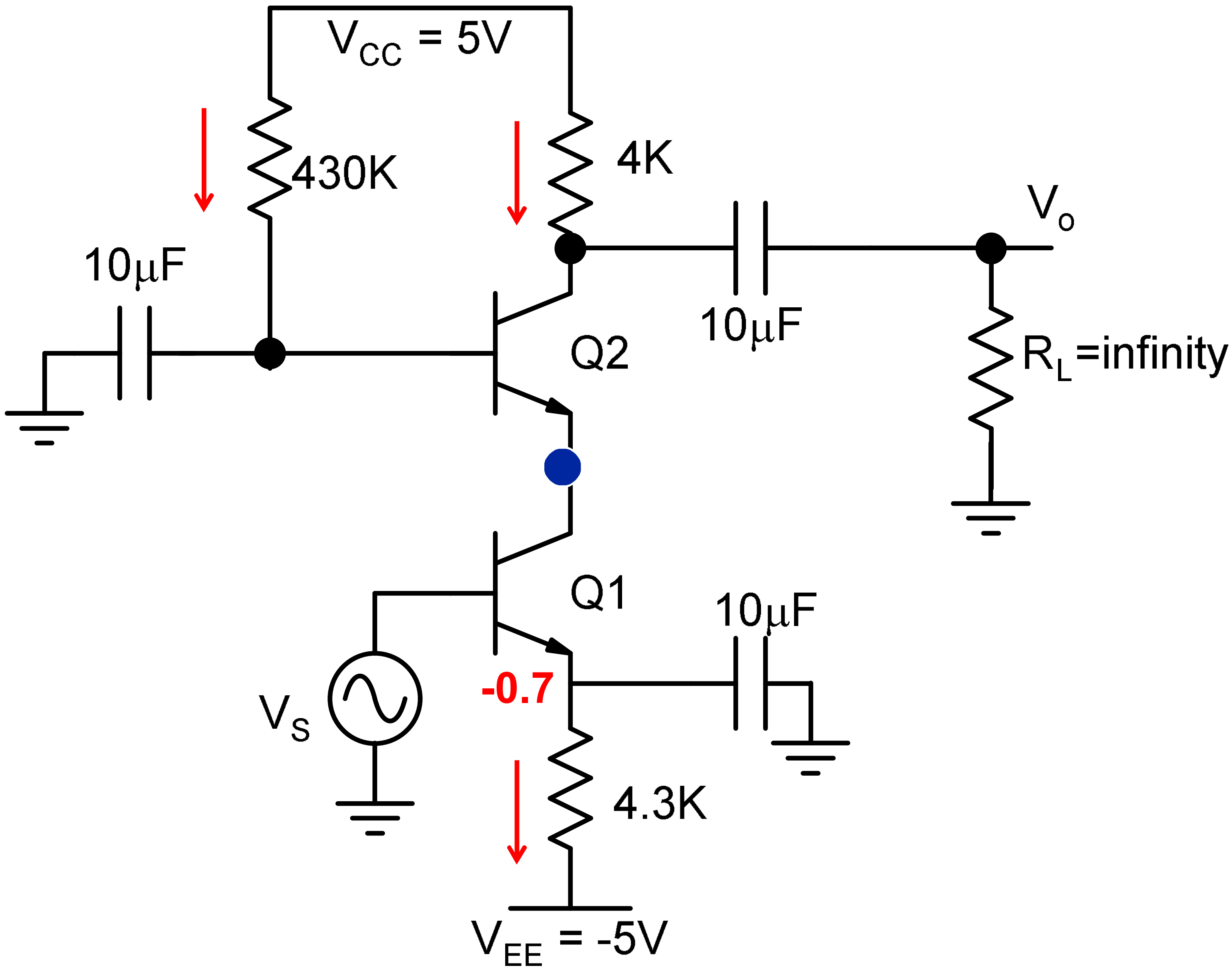


$$V_{BE} \sim 0.7V \ , \ I_C = \beta \times I_B$$

Example-2

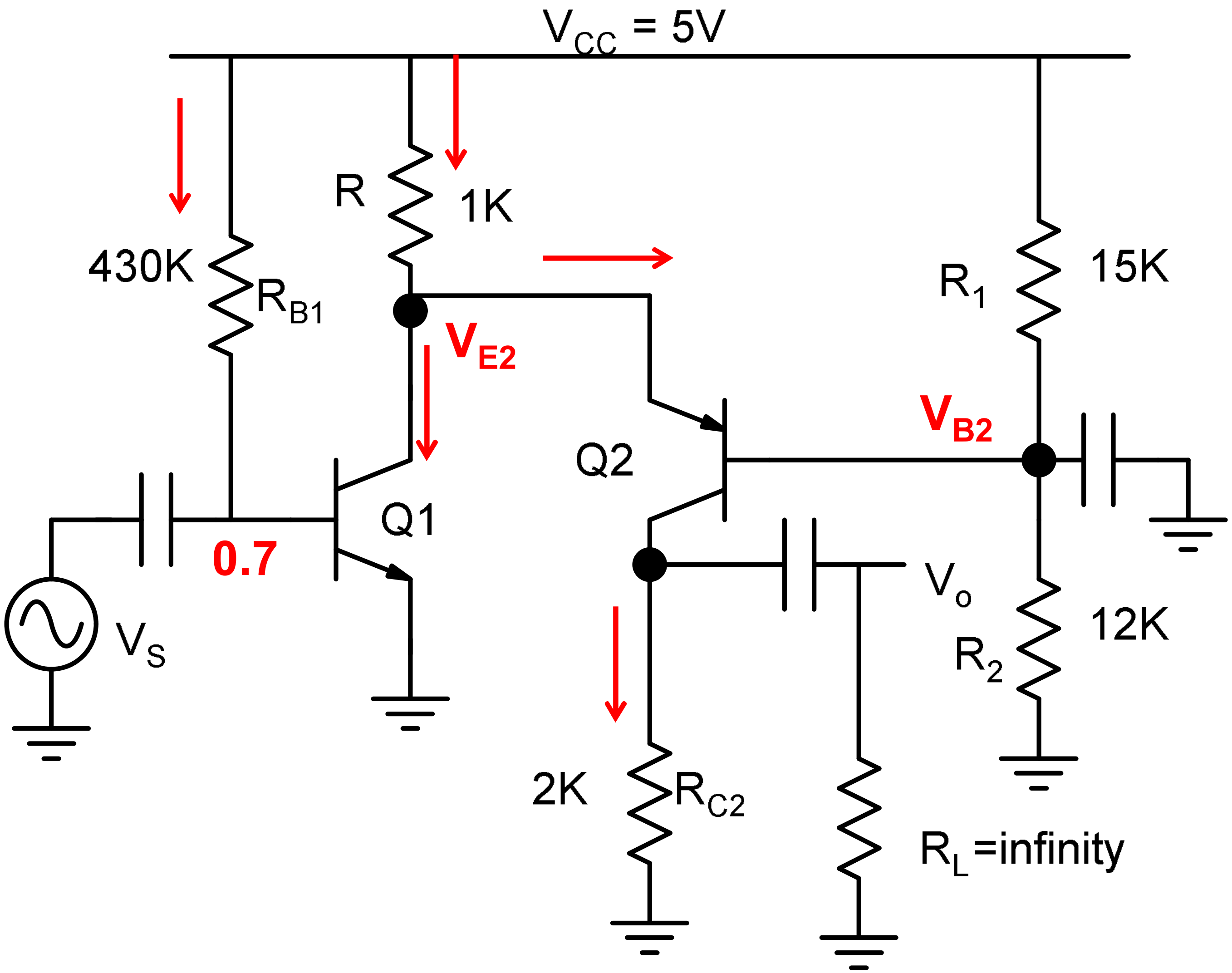


Example-3



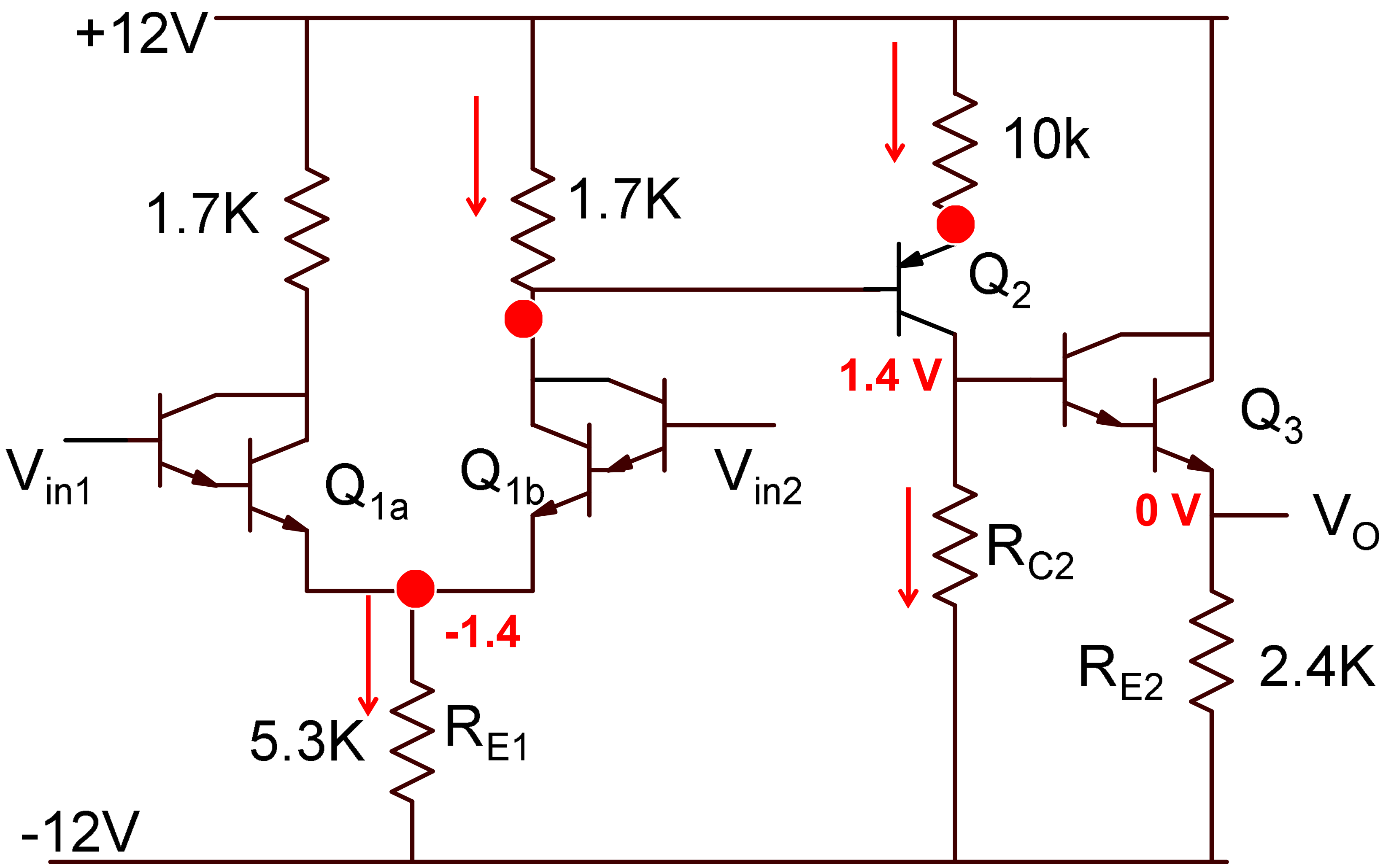
V_{CC} = 5V
430K
4K
10μF
V_o
10μF
Q2
R_L=infinity
Q1
10μF
-0.7
V_S
4.3K
V_{EE} = -5V

Example-4



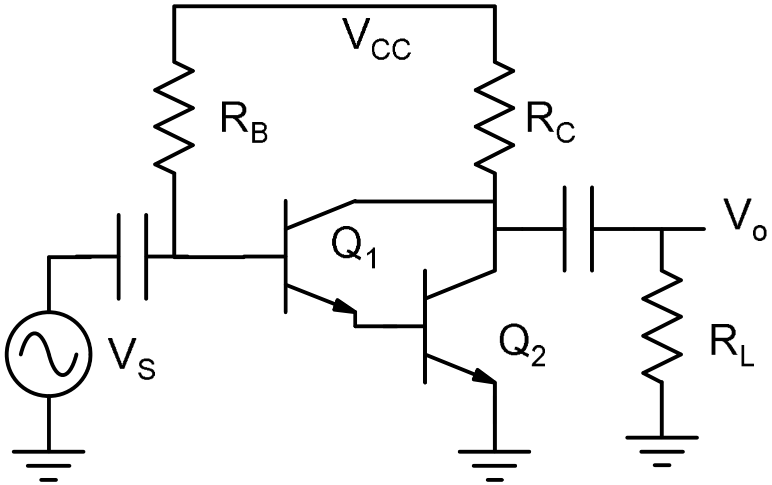
V_{CC} = 5V
430K
R_{B1}
R
1K
V_{E2}
0.7
Q1
V_S
Q2
R_1
15K
V_{B2}
V_o
12K
R_2
2K
R_{C2}
R_L=infinity

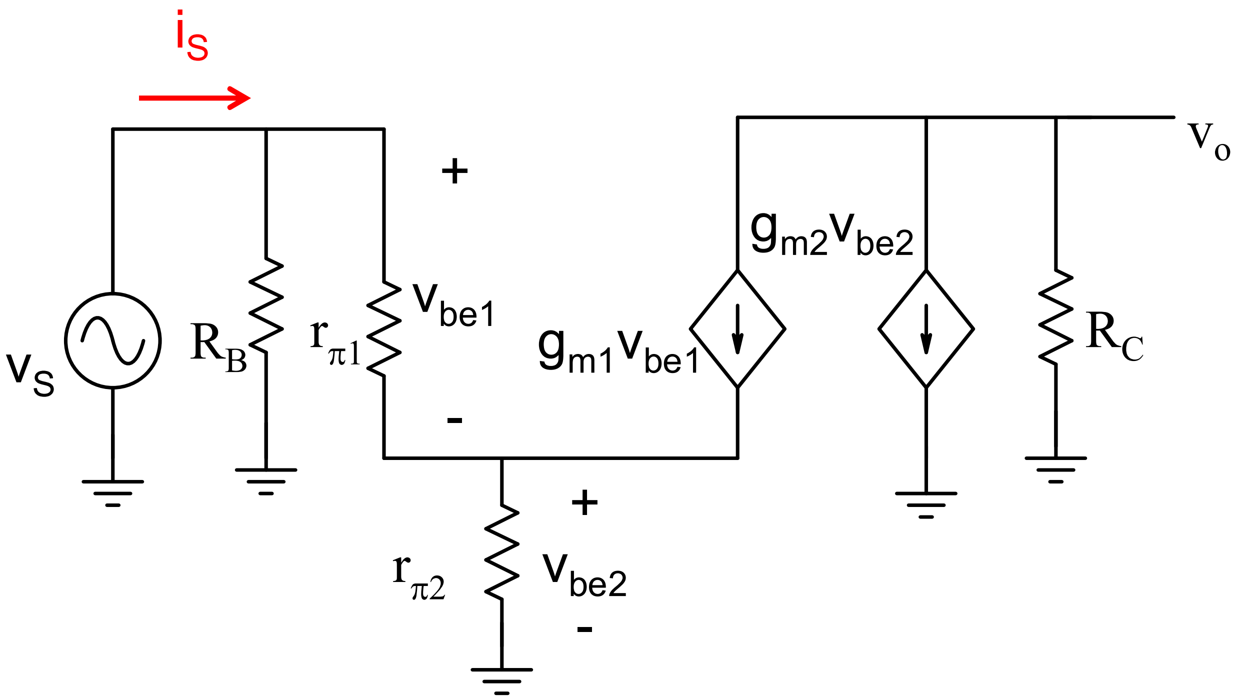
Example-5 For what value of R_{C2}, is Vo = 0V ?



Example-1

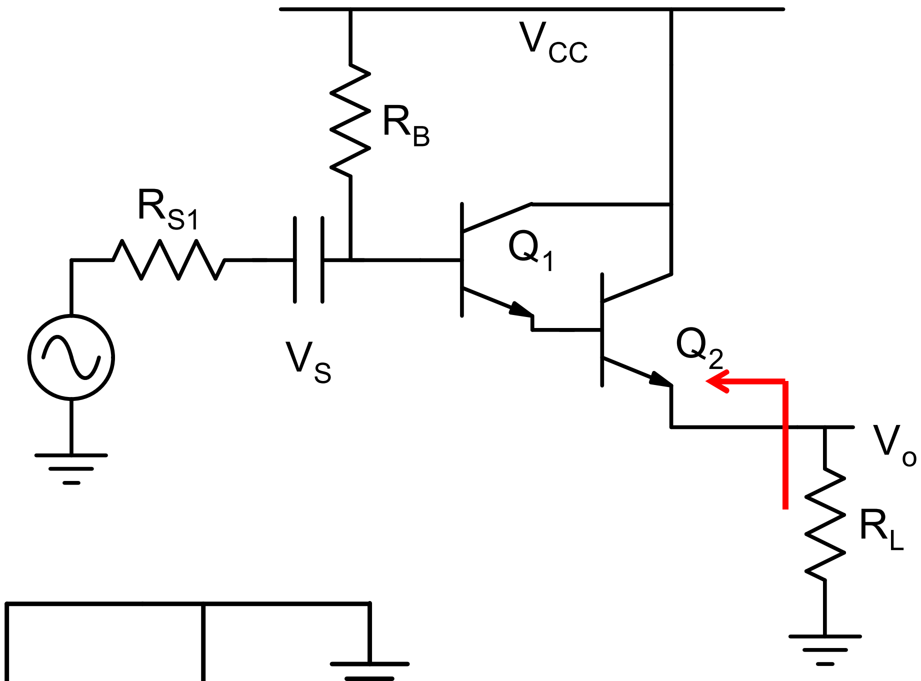
Determine input resistance of the amplifier shown below

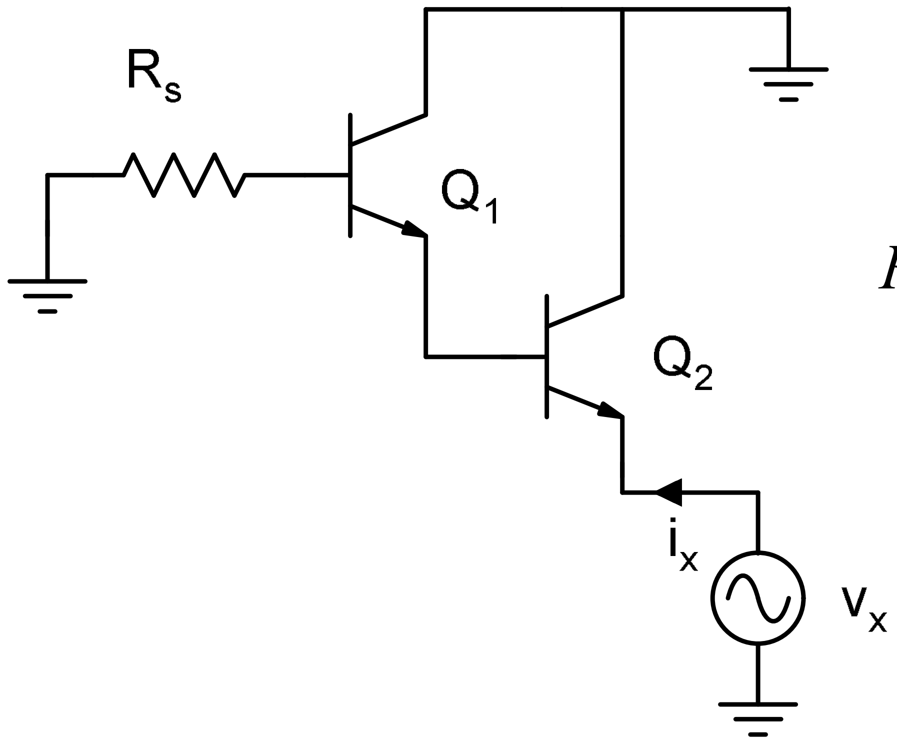




$$R_{in} = \frac{v_s}{i_s}$$

Example-2





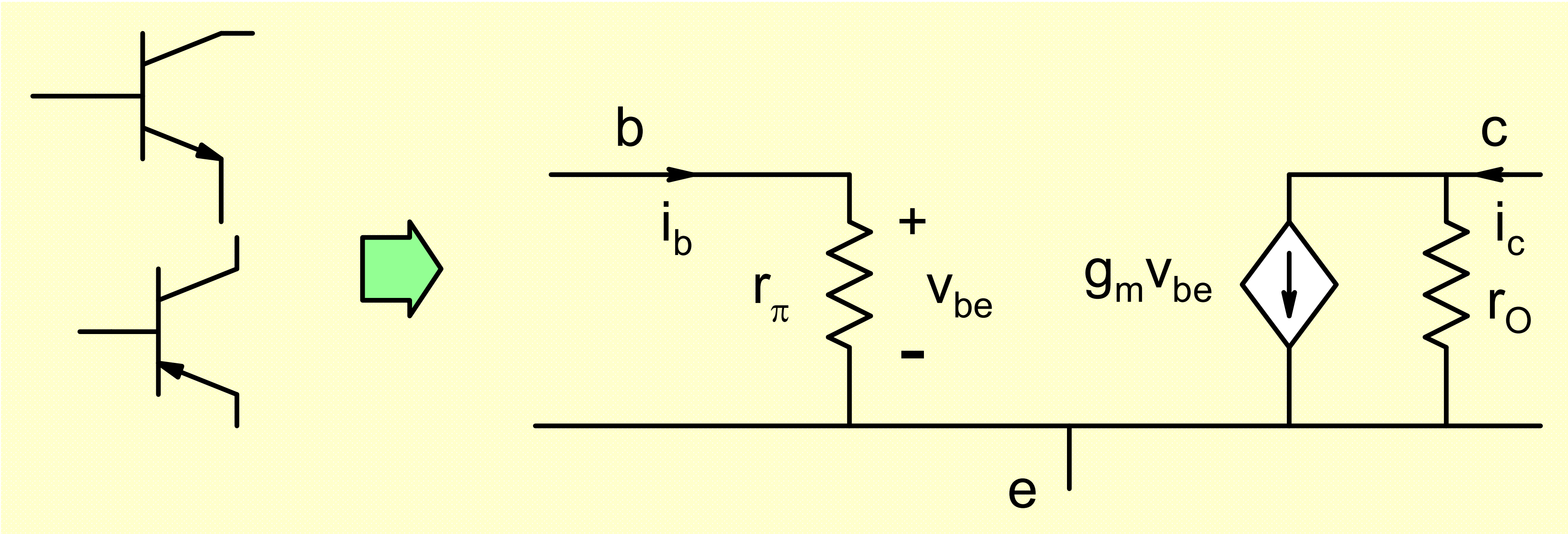
$$R_o = \frac{v_x}{i_x}$$

$$R_O = \frac{R_s}{\beta_1 \beta_2} + \frac{1}{g_{m1}\beta_2} + \frac{1}{g_{m2}}$$

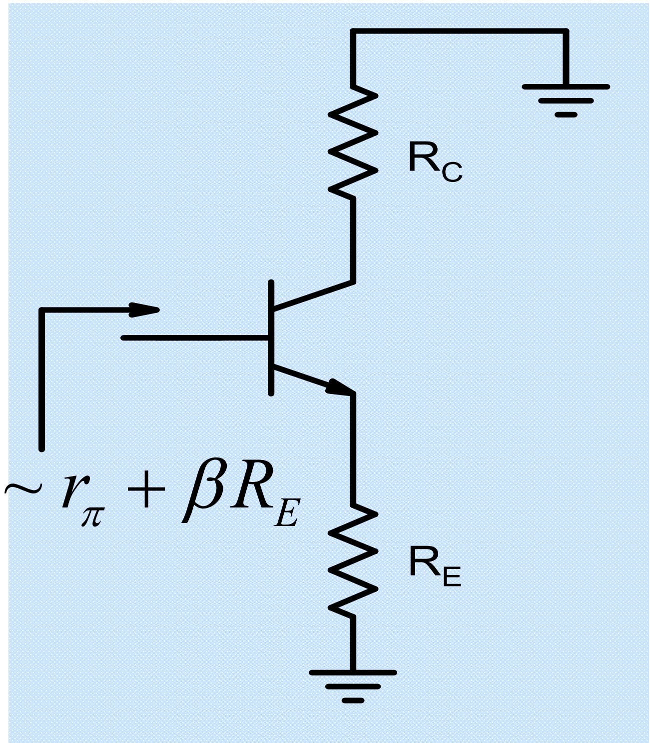
Is there a "better" way of carrying out small signal analysis ?

- Simpler

- Less error prone

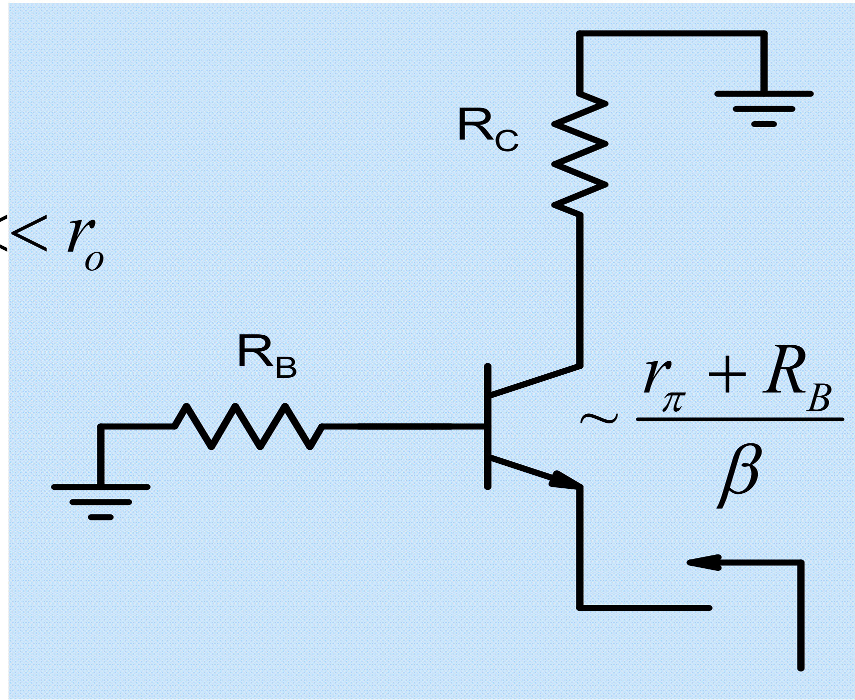


NPN and PNP models are identical

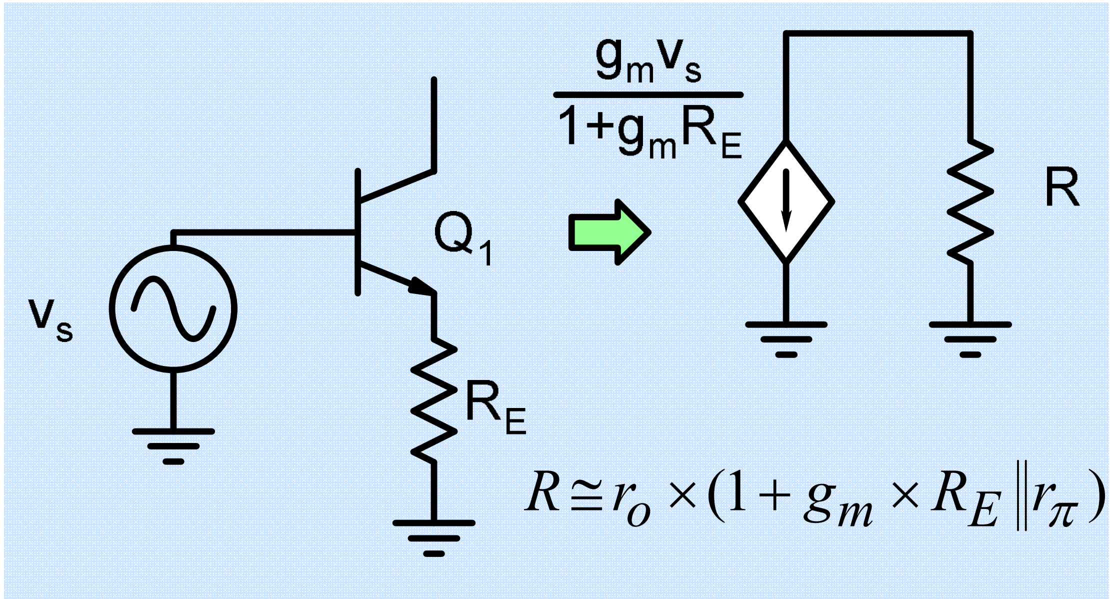


RC
RE
$\sim r_\pi + \beta R_E$

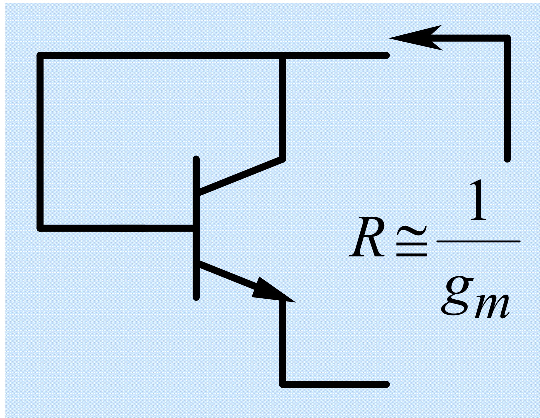
$$R_C, R_E, R_B << r_o$$



RC
RB
$\sim \frac{r_\pi + R_B}{\beta}$

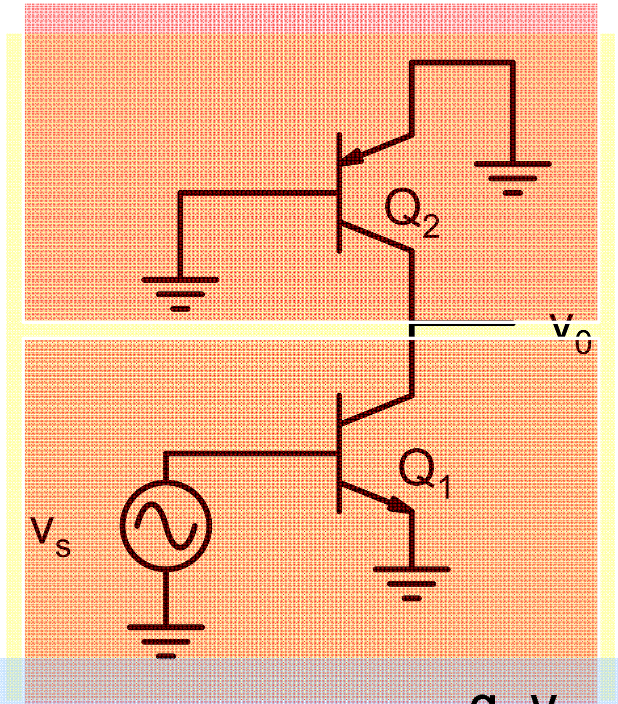


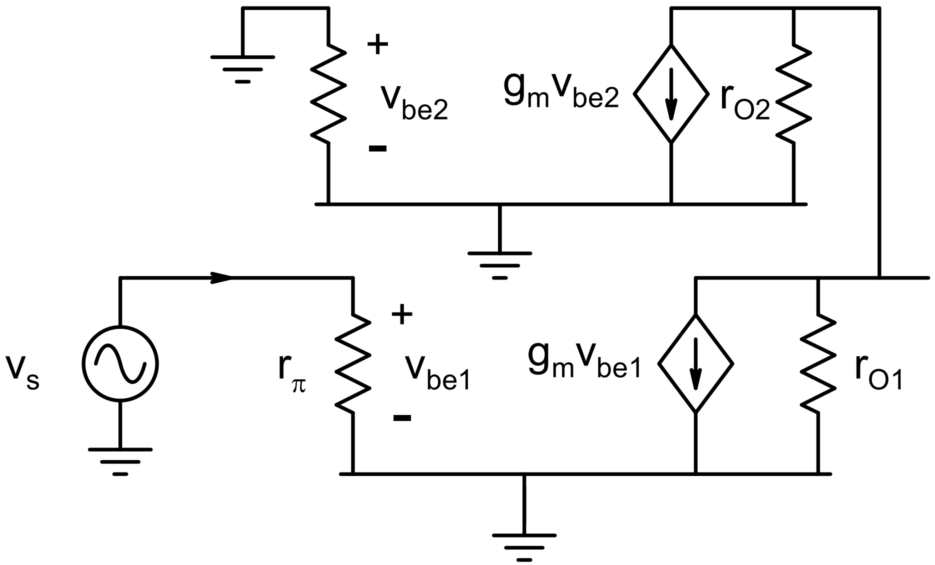
$\frac{g_m v_s}{1+g_m R_E}$
R
Q1
vs
RE
$R \cong r_o \times (1 + g_m \times R_E \| r_\pi)$

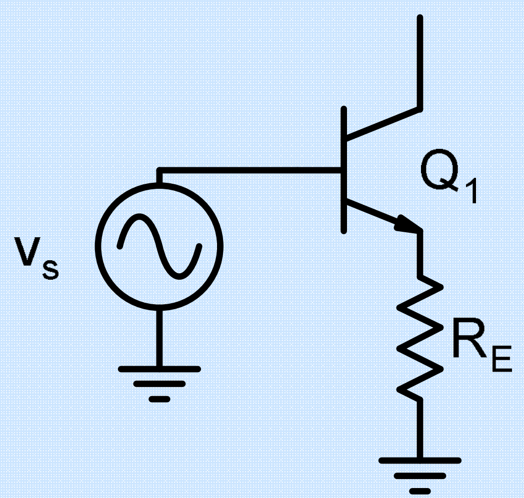


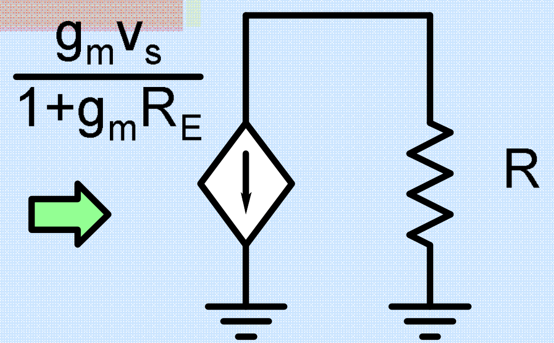
$R \cong \frac{1}{g_m}$

Example-1

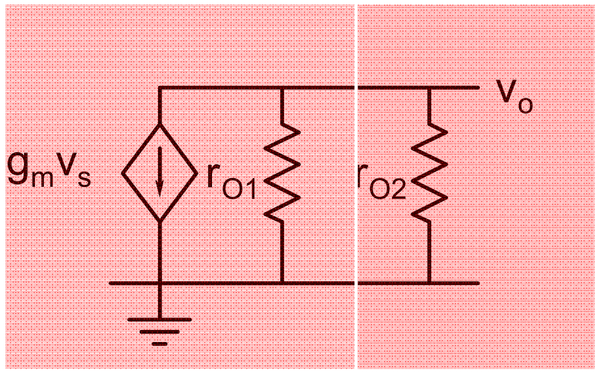




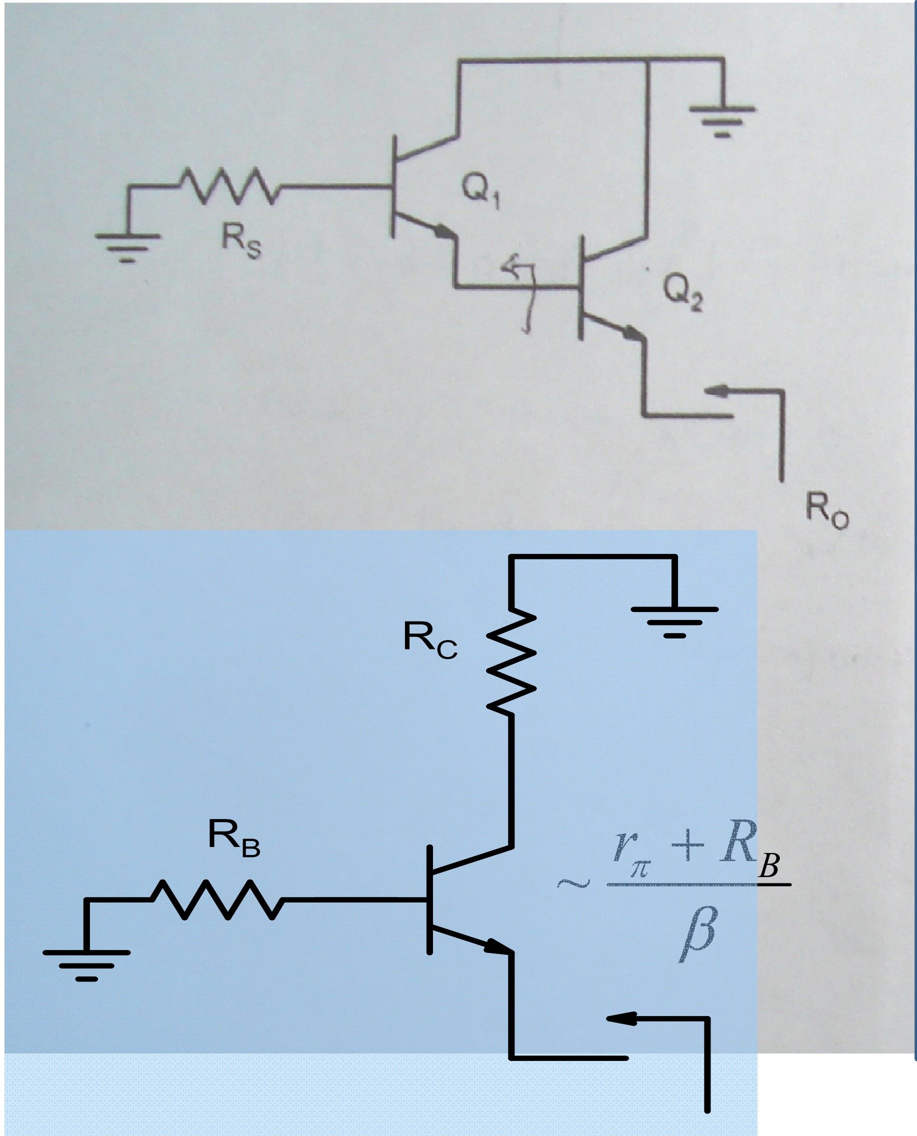




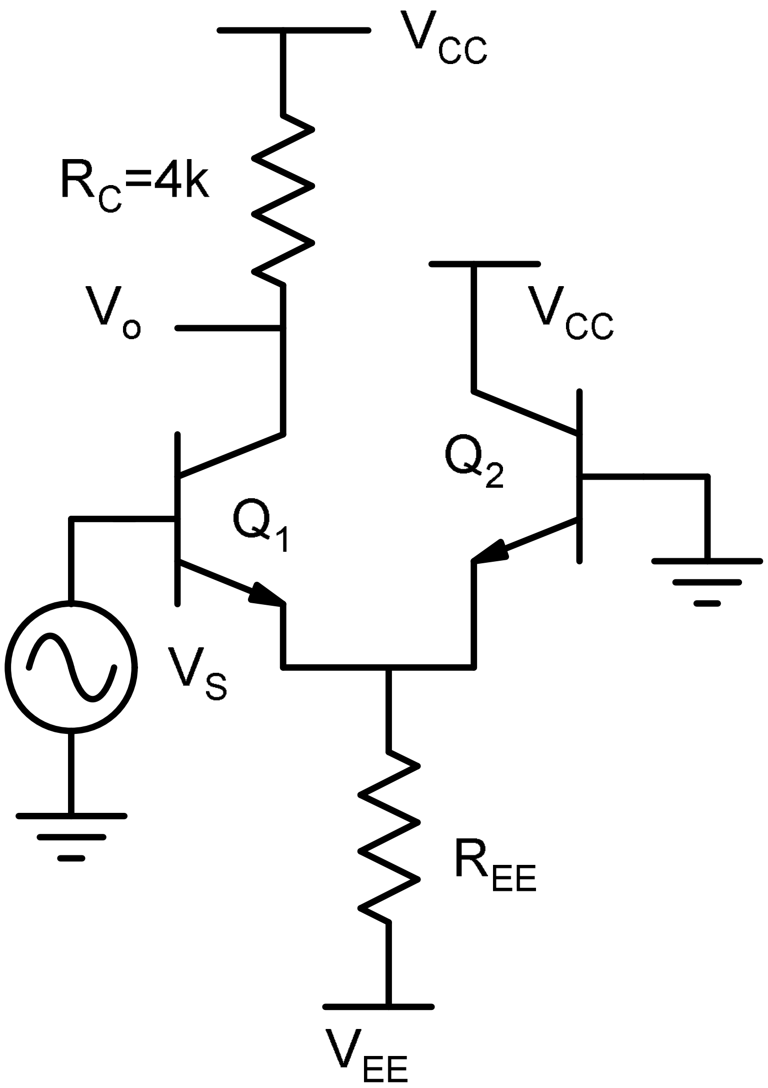
$$R \cong r_o \times (1 + g_m \times R_E \| r_\pi)$$

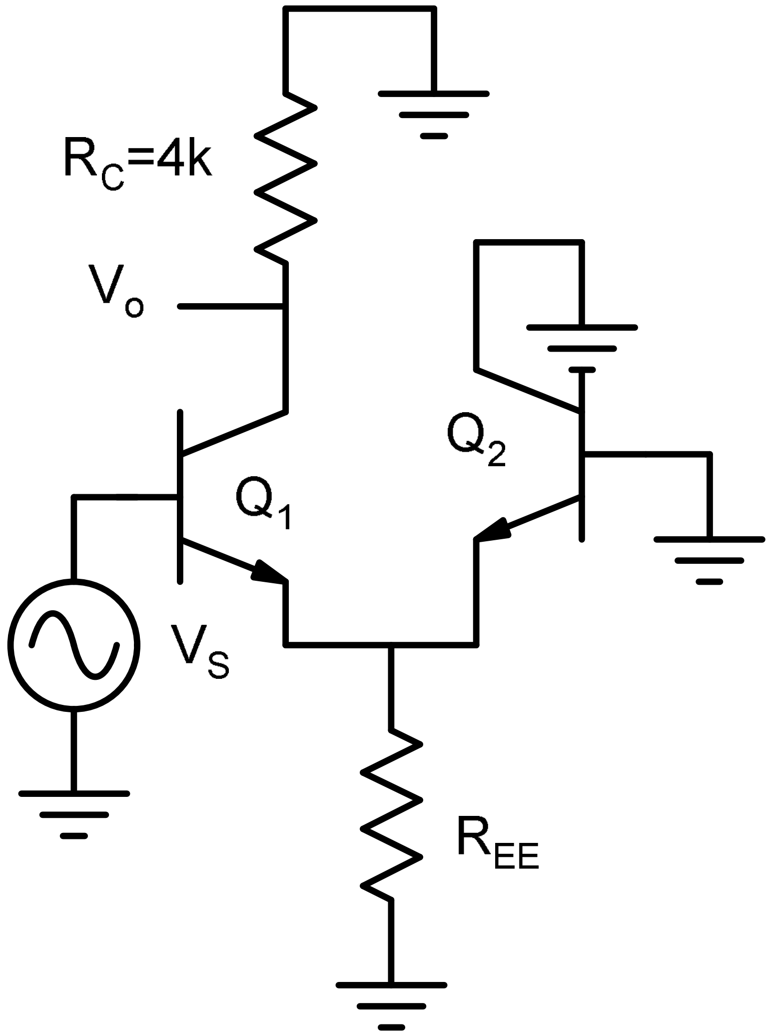


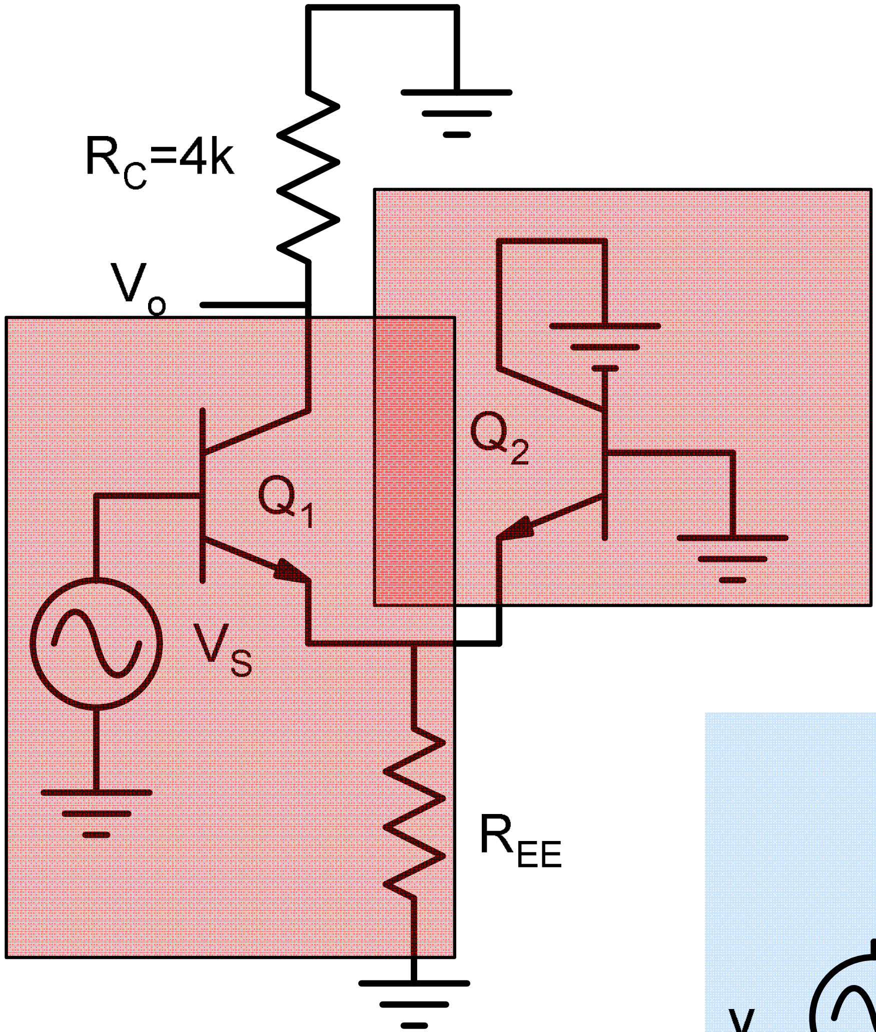
Example-2

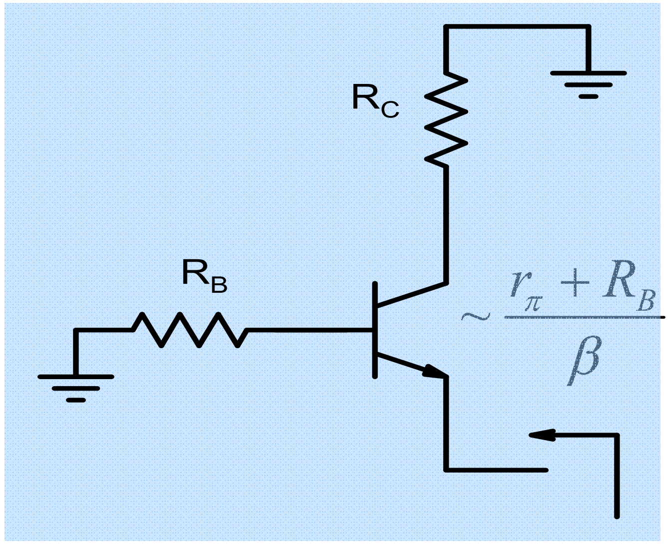


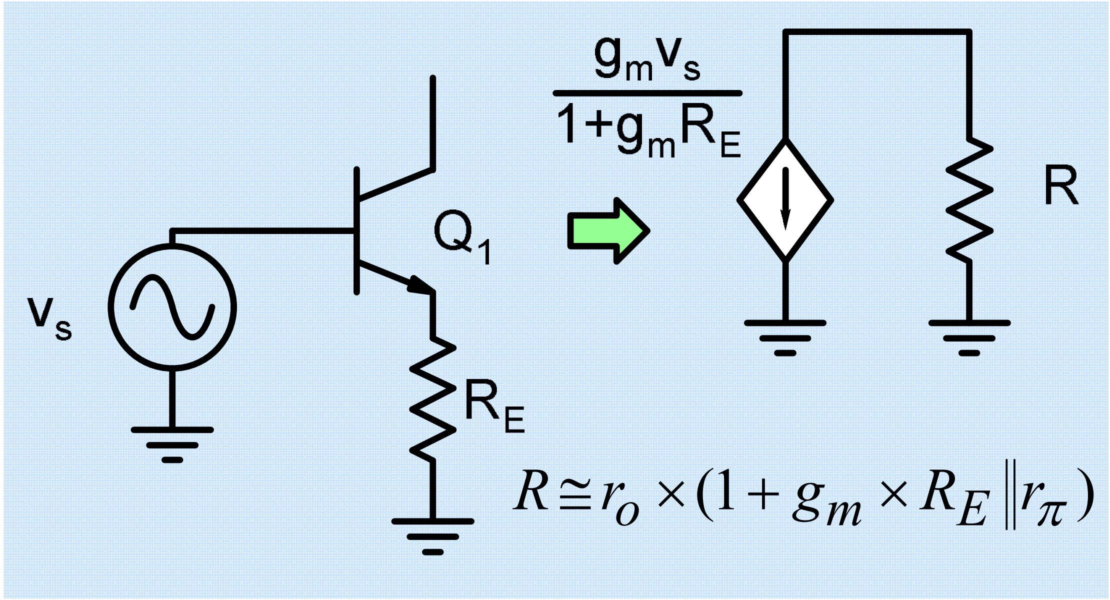
Example-3



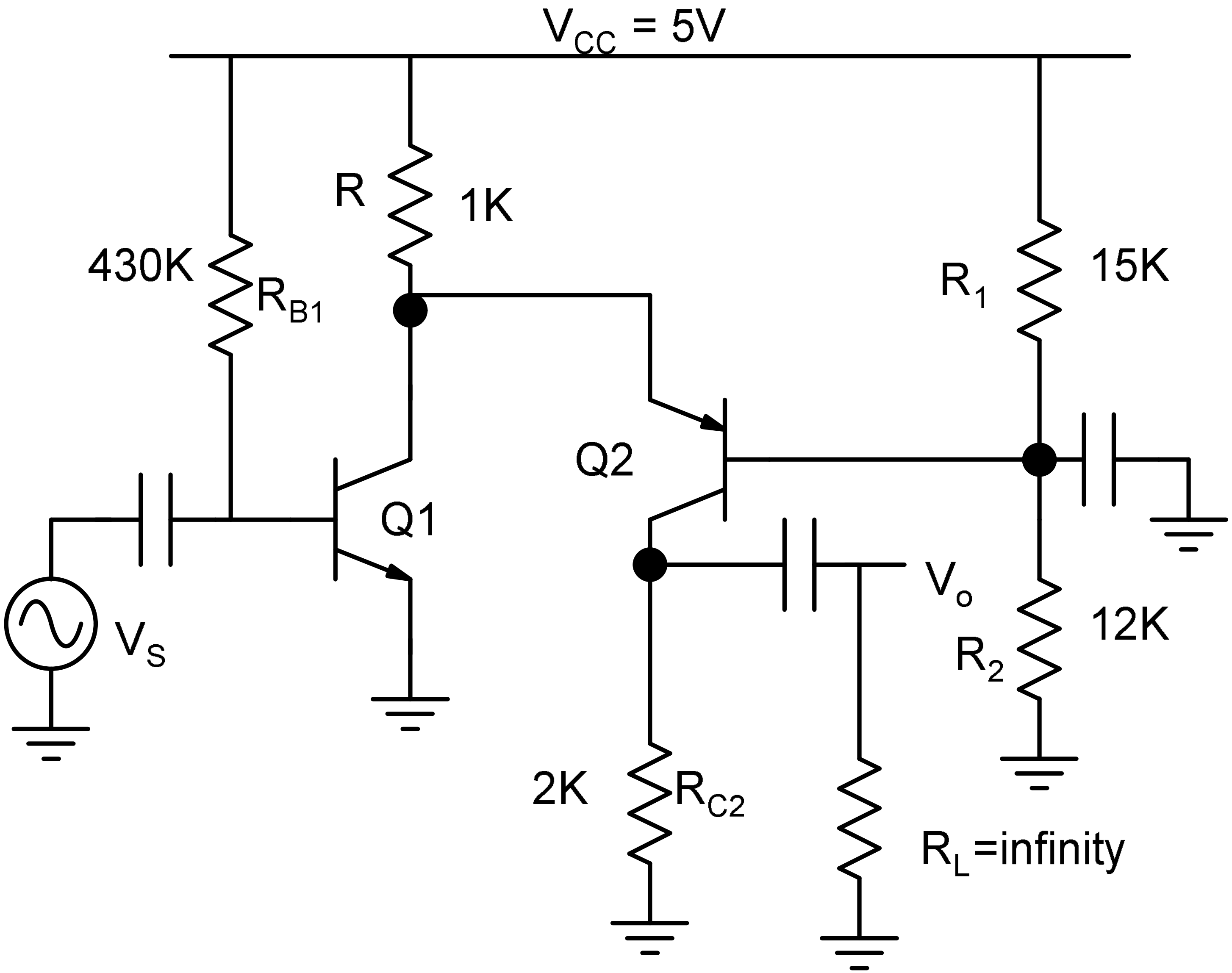


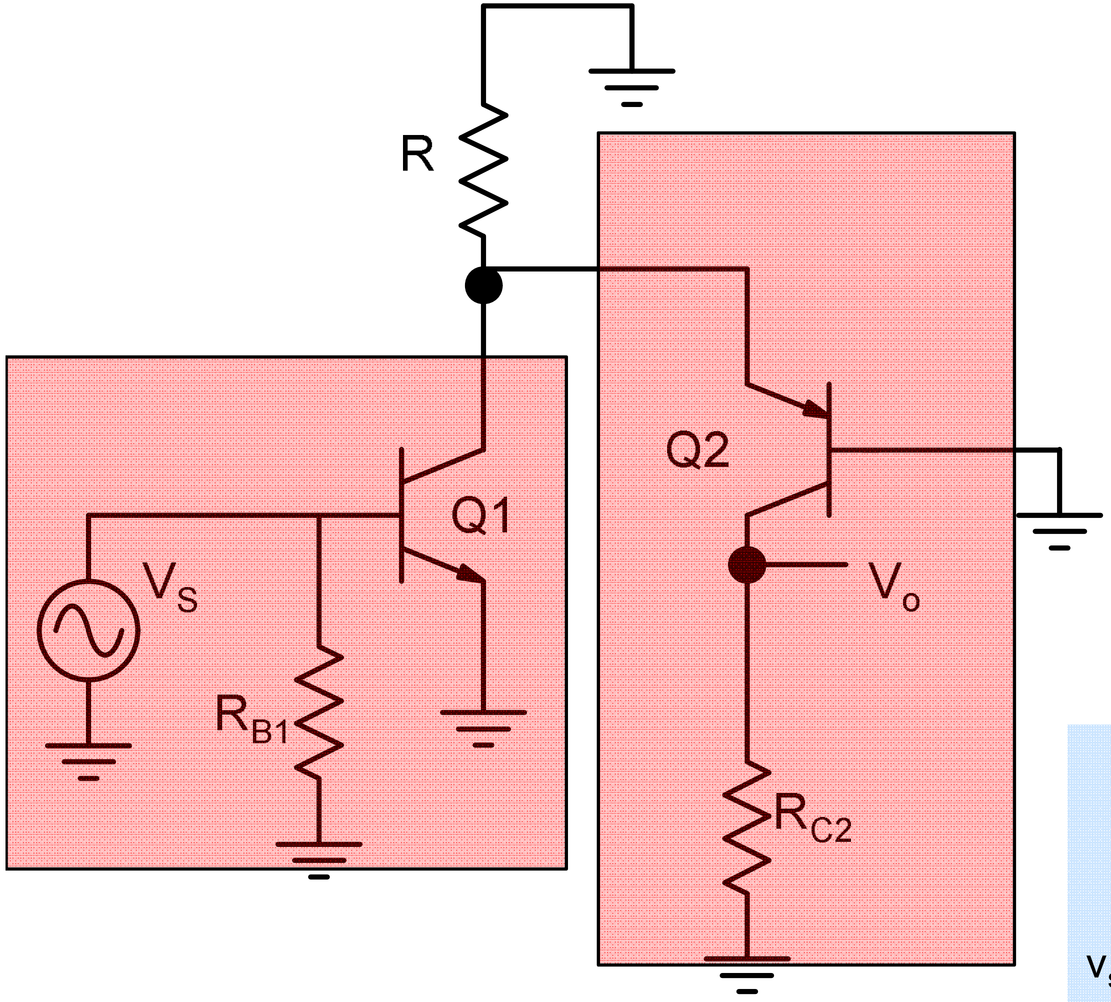

R_C=4k
V_o
Q_2
Q_1
V_S
R_EE

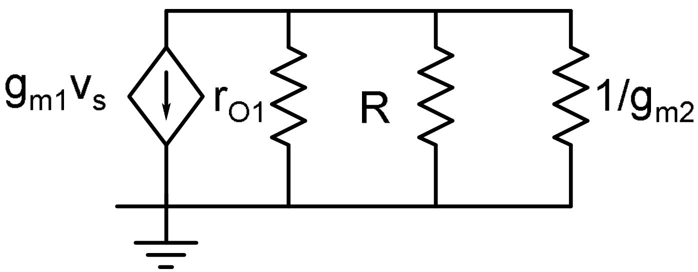

R_C
R_B
$\sim \dfrac{r_\pi + R_B}{\beta}$

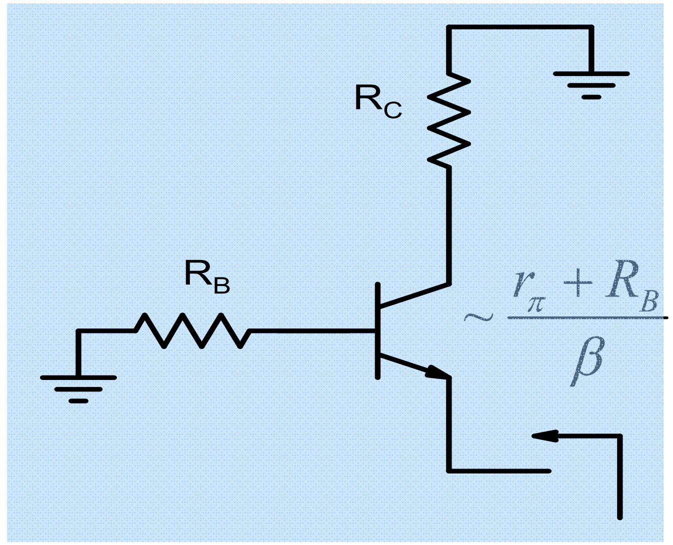

$\dfrac{g_m v_s}{1+g_m R_E}$
R
Q_1
v_s
R_E
$R \cong r_o \times (1 + g_m \times R_E \| r_\pi)$

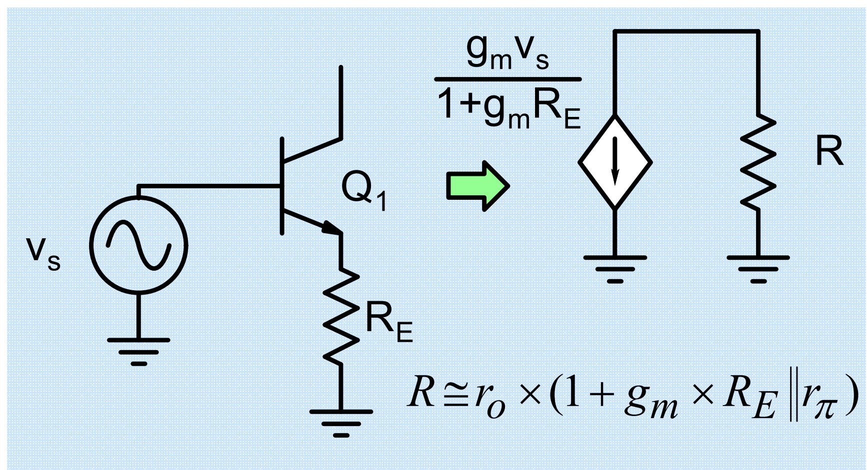
Example-4



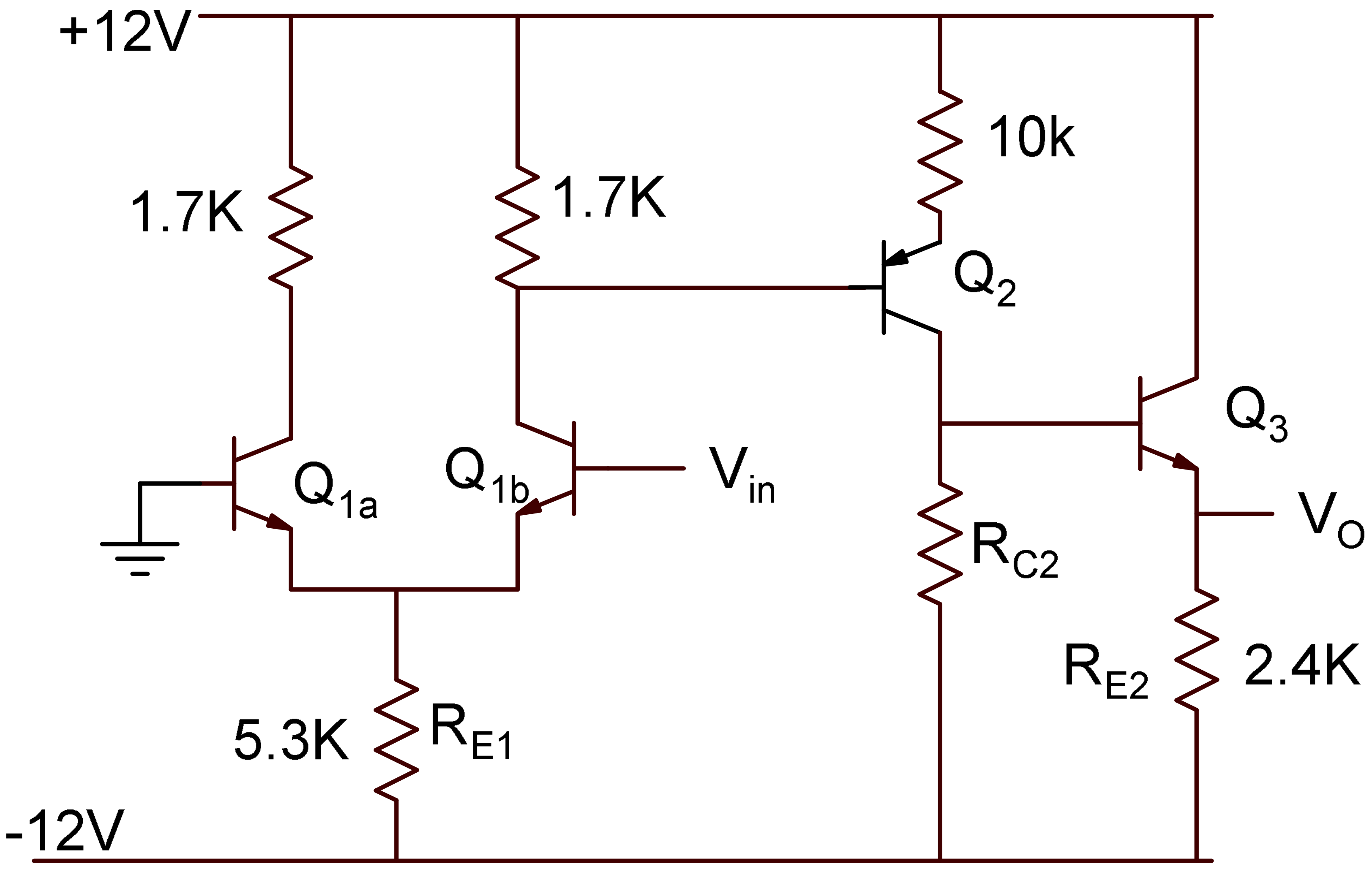

R
Q2
Q1
V_S
V_o
R_{B1}
R_{C2}

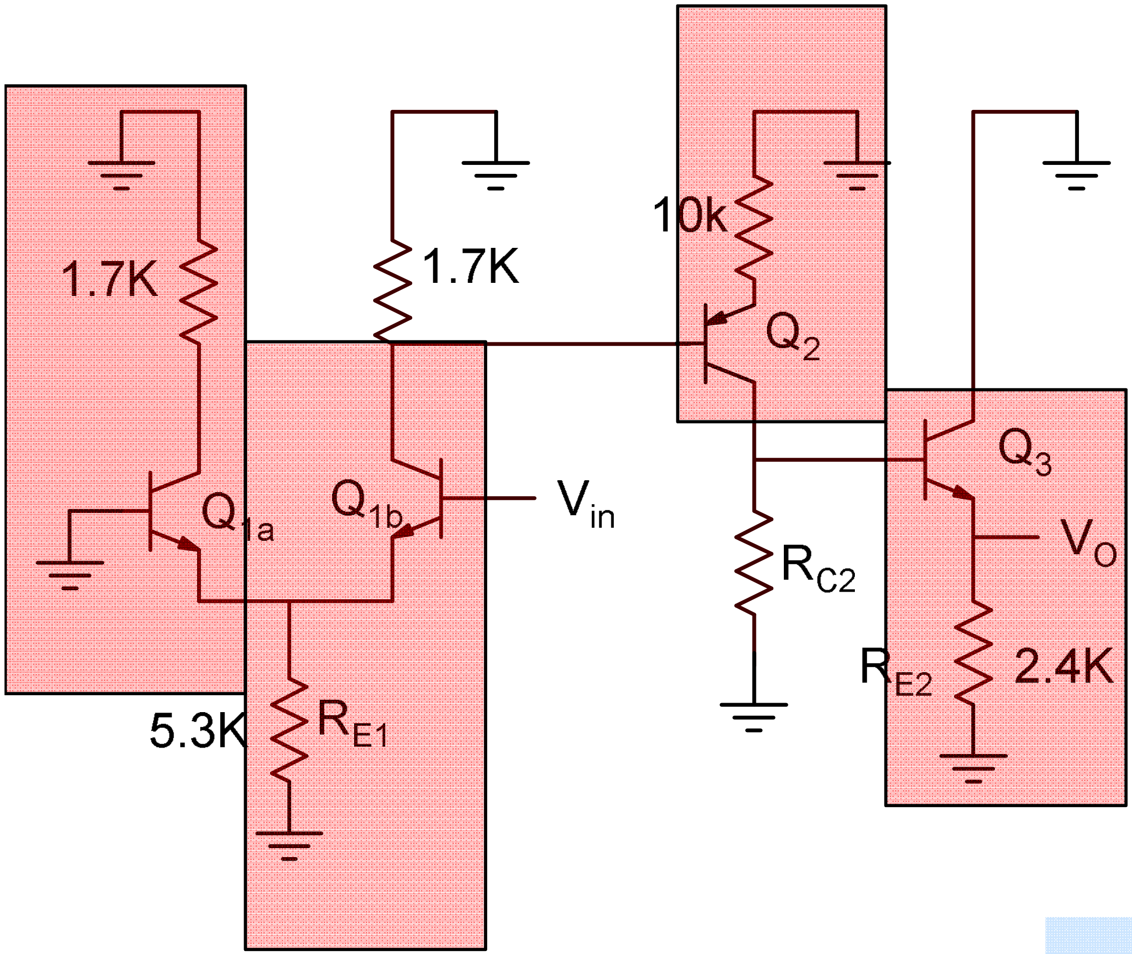

$g_{m1}v_s$
r_{O1}
R
$1/g_{m2}$

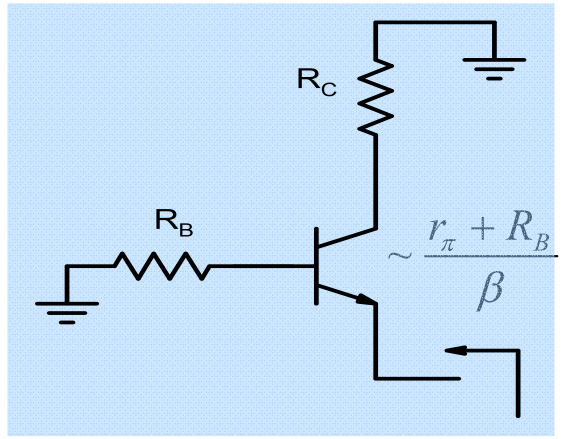

R_C
R_B
$\sim \frac{r_\pi + R_B}{\beta}$

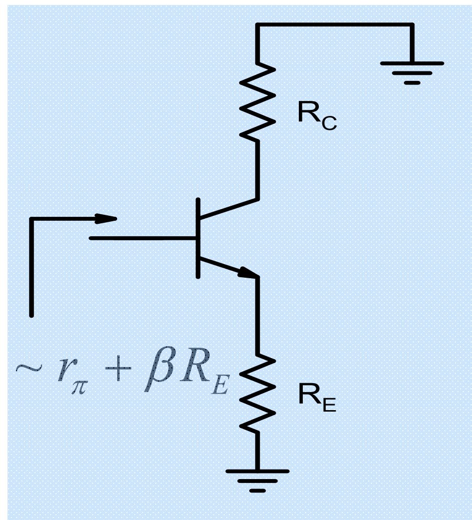

$\frac{g_m v_s}{1+g_m R_E}$
R
Q_1
v_s
R_E
$R \cong r_o \times (1 + g_m \times R_E \| r_\pi)$

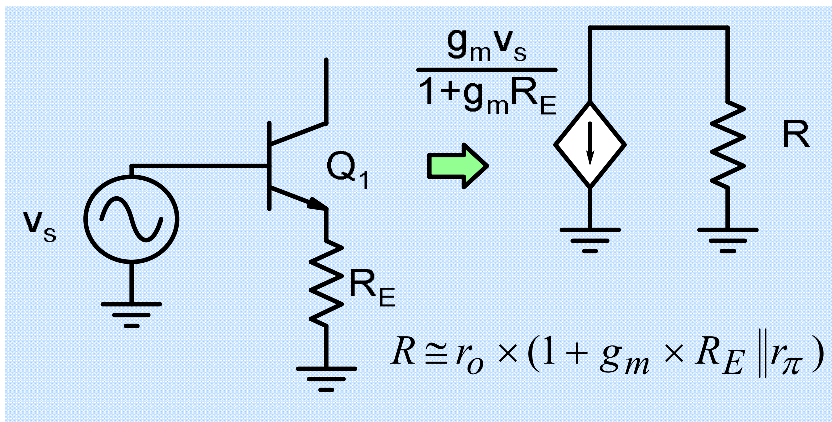
Example-5



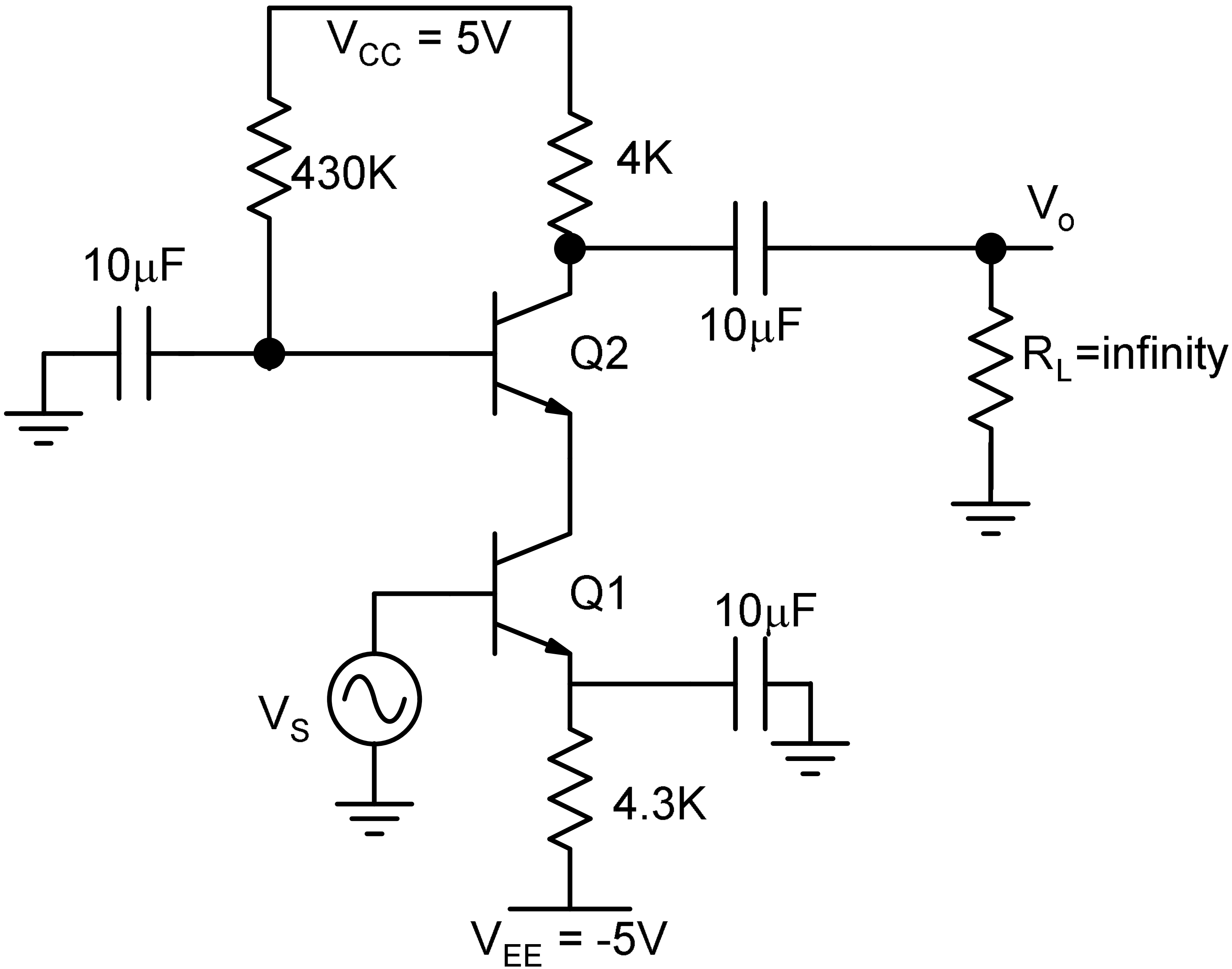

1.7K
1.7K
10k
Q_2
Q_3
Q_{1a}
Q_{1b}
V_{in}
R_{C2}
V_O
R_{E2}
2.4K
5.3K
R_{E1}


R_C
R_B
$\sim \frac{r_\pi + R_B}{\beta}$

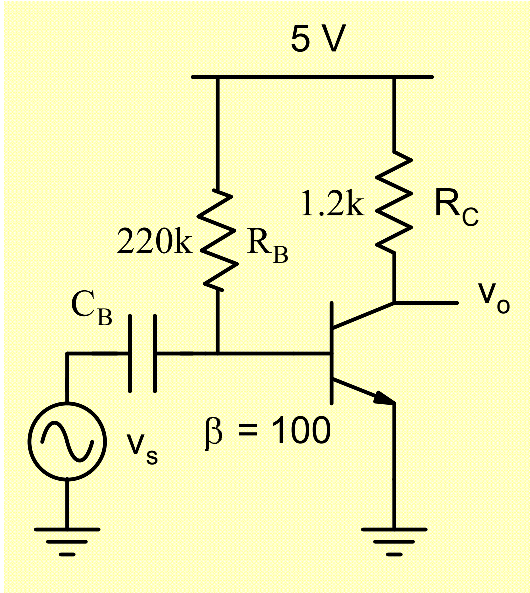

R_C
$\sim r_\pi + \beta R_E$
R_E

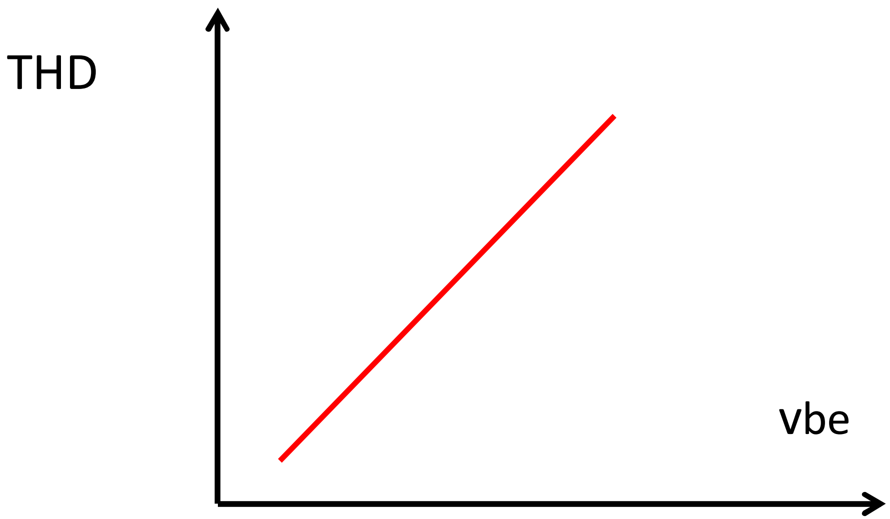

$\frac{g_m v_s}{1+g_m R_E}$
R
Q_1
v_s
R_E
$R \cong r_o \times (1 + g_m \times R_E \| r_\pi)$

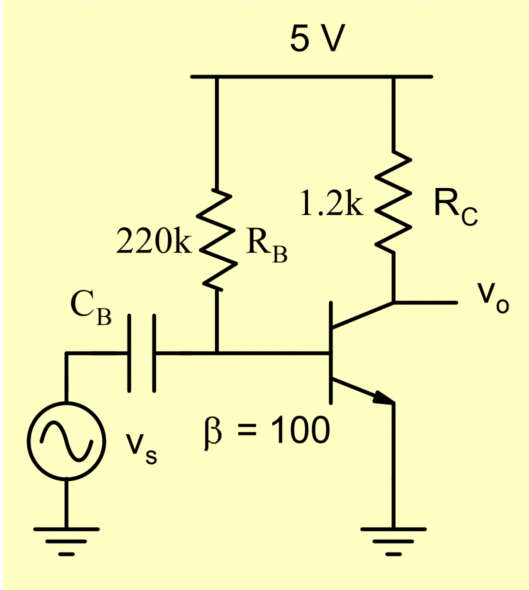
Example-6

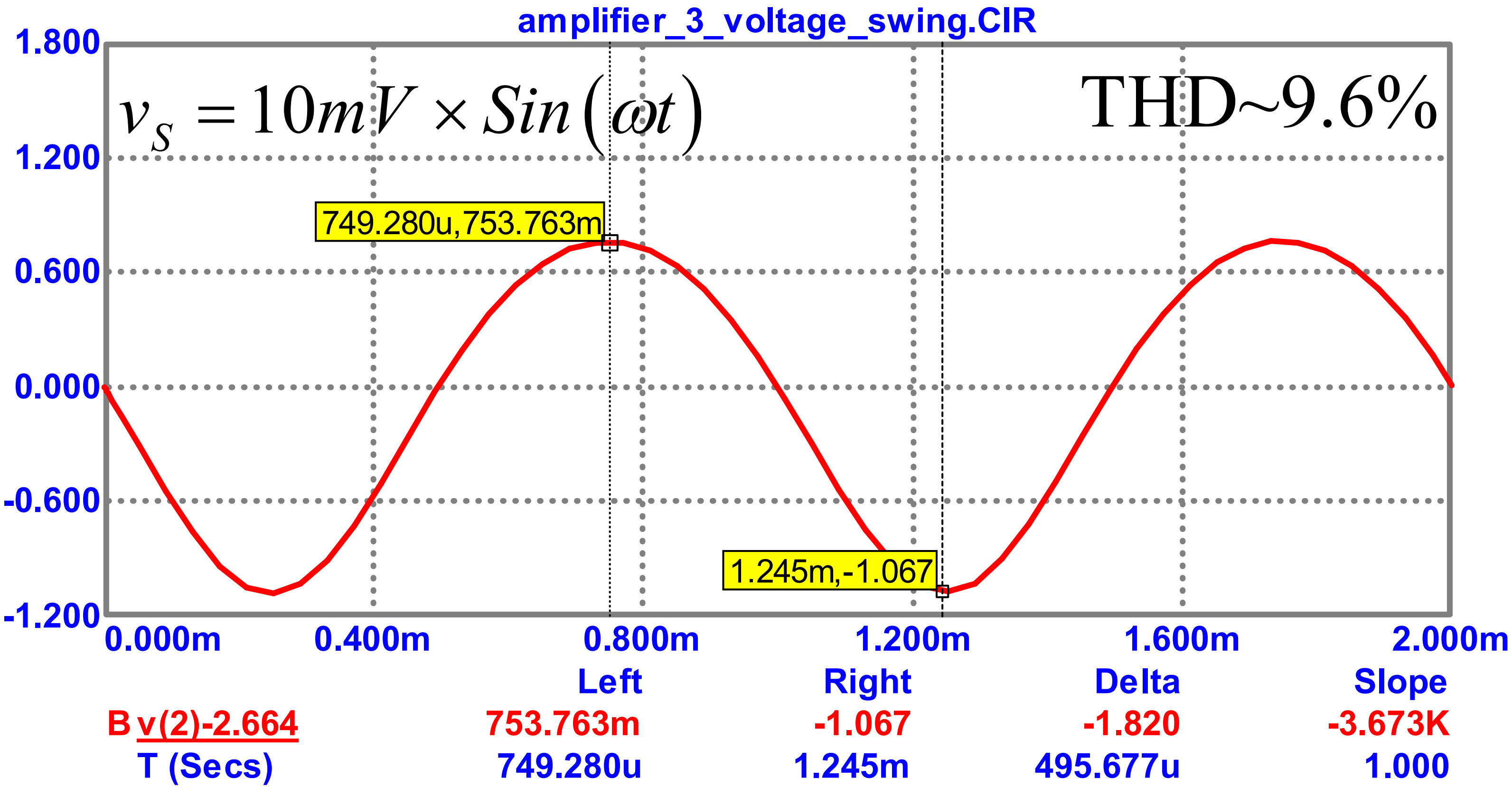


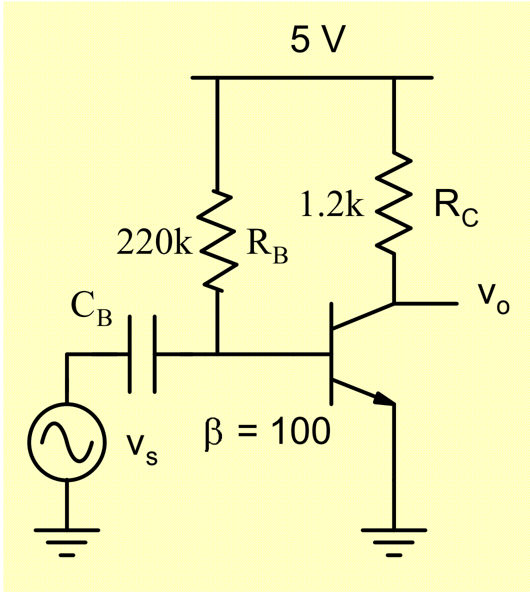
COMMON EMITTER AMPLIFIER WITH EMITTER DEGENERATION


5 V
1.2k
R_C
220k
R_B
C_B
v_o
β = 100
v_s

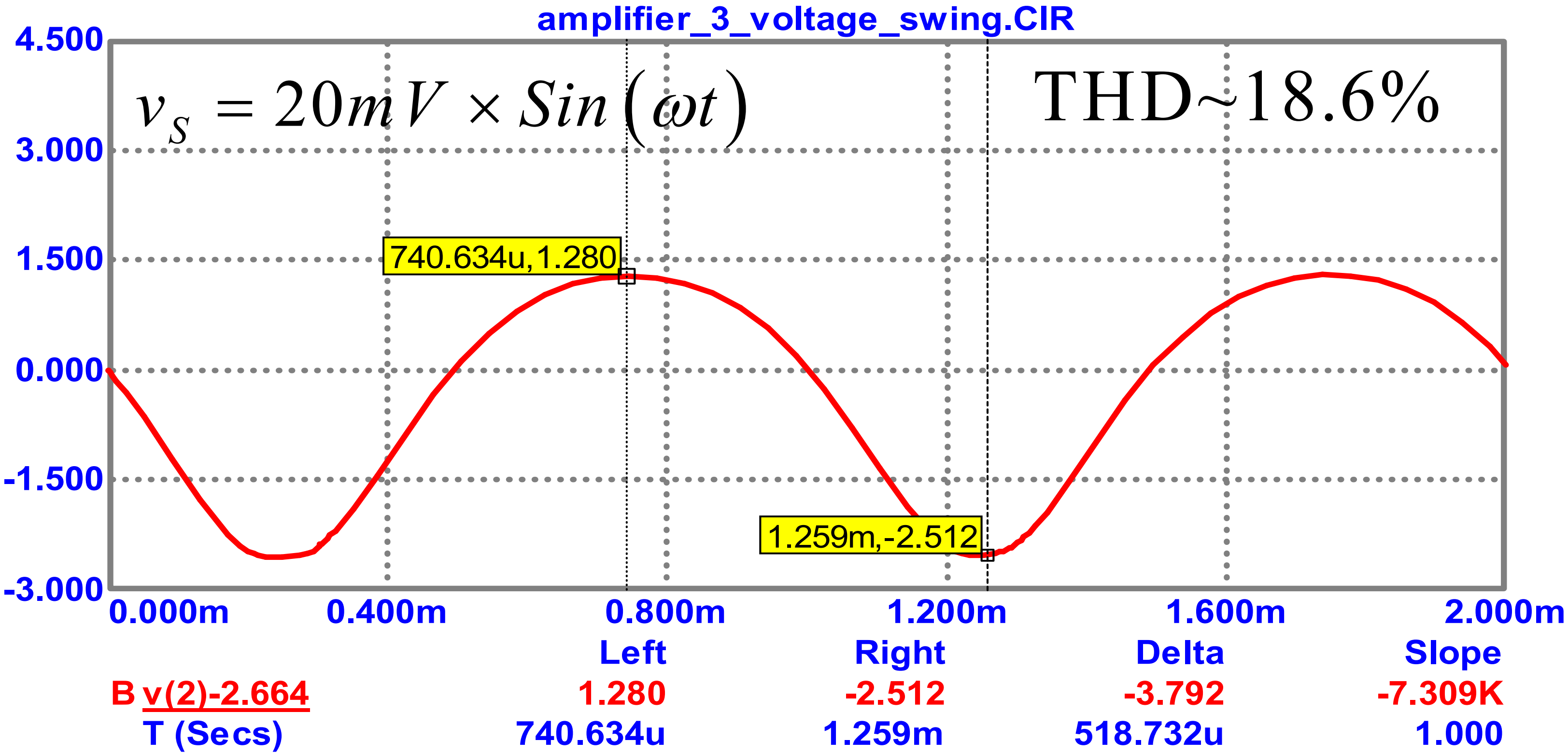

THD
vbe


5 V
220k
R_B
1.2k
R_C
v_o
C_B
v_s
β = 100


amplifier_3_voltage_swing.CIR
$v_S = 10mV \times Sin(\omega t)$
THD~9.6%
749.280u,753.763m
1.245m,-1.067
1.800
1.200
0.600
0.000
-0.600
-1.200
0.000m
0.400m
0.800m
1.200m
1.600m
2.000m
Left
Right
Delta
Slope
B v(2)-2.664
753.763m
-1.067
-1.820
-3.673K
T (Secs)
749.280u
1.245m
495.677u
1.000



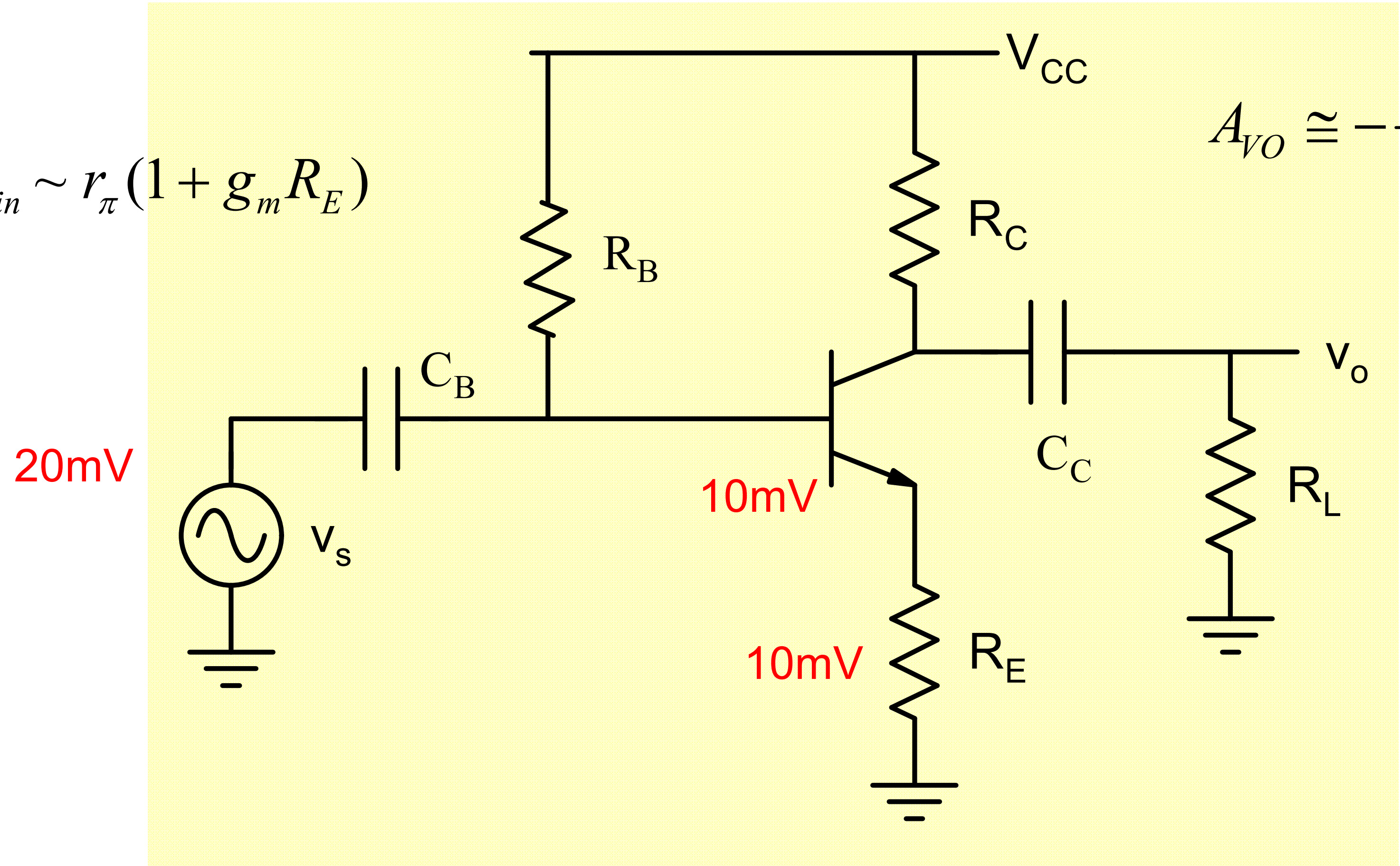
5 V
1.2k
R_C
220k
R_B
C_B
v_o
v_s
β = 100



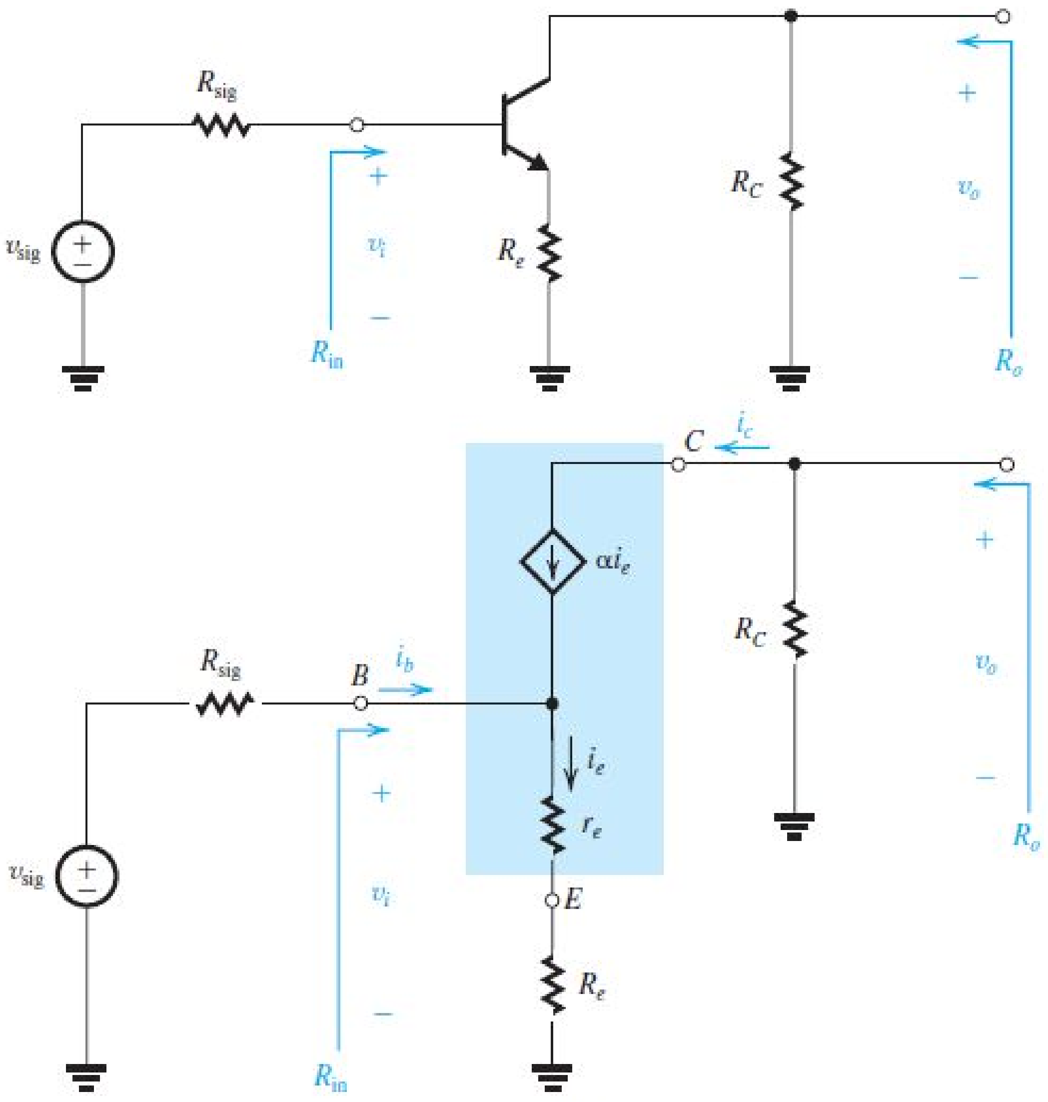
amplifier_3_voltage_swing.CIR
$v_S = 20mV \times Sin(\omega t)$
THD~18.6%
740.634u,1.280
1.259m,-2.512
4.500
3.000
1.500
0.000
-1.500
-3.000
0.000m
0.400m
0.800m
1.200m
1.600m
2.000m
Left
Right
Delta
Slope
B v(2)-2.664
1.280
-2.512
-3.792
-7.309K
T (Secs)
740.634u
1.259m
518.732u
1.000

$$R_{in} \sim r_\pi (1 + g_m R_E)$$

$$A_{VO} \cong -\frac{g_m R_C}{1 + g_m R_E}$$



$$v_{be} = \frac{v_S}{1 + g_m R_E}$$



(b)

Figure 6.52 The CE amplifier with an emitter resistance R_e; (a) Circuit without bias details; (b) Equivalent circuit with the BJT replaed with its T model.

G-Number

Another important consequence of including the resistance R_e in the emitter is that it enables the amplifier to handle larger input signals without incurring nonlinear distortion. This is because only a fraction of the input signal at the base, v_i, appears between the base and the emitter. Specifically, from the circuit in Fig. 6.52(b), we see that

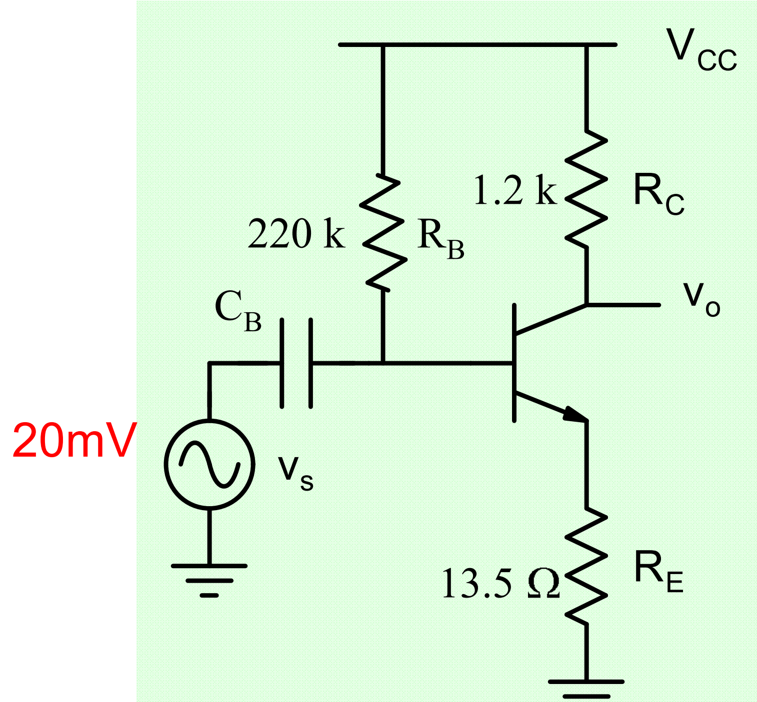
$$\frac{v_\pi}{v_i} = \frac{r_e}{r_e + R_e} \simeq \frac{1}{1 + g_m R_e} \tag{6.89}$$

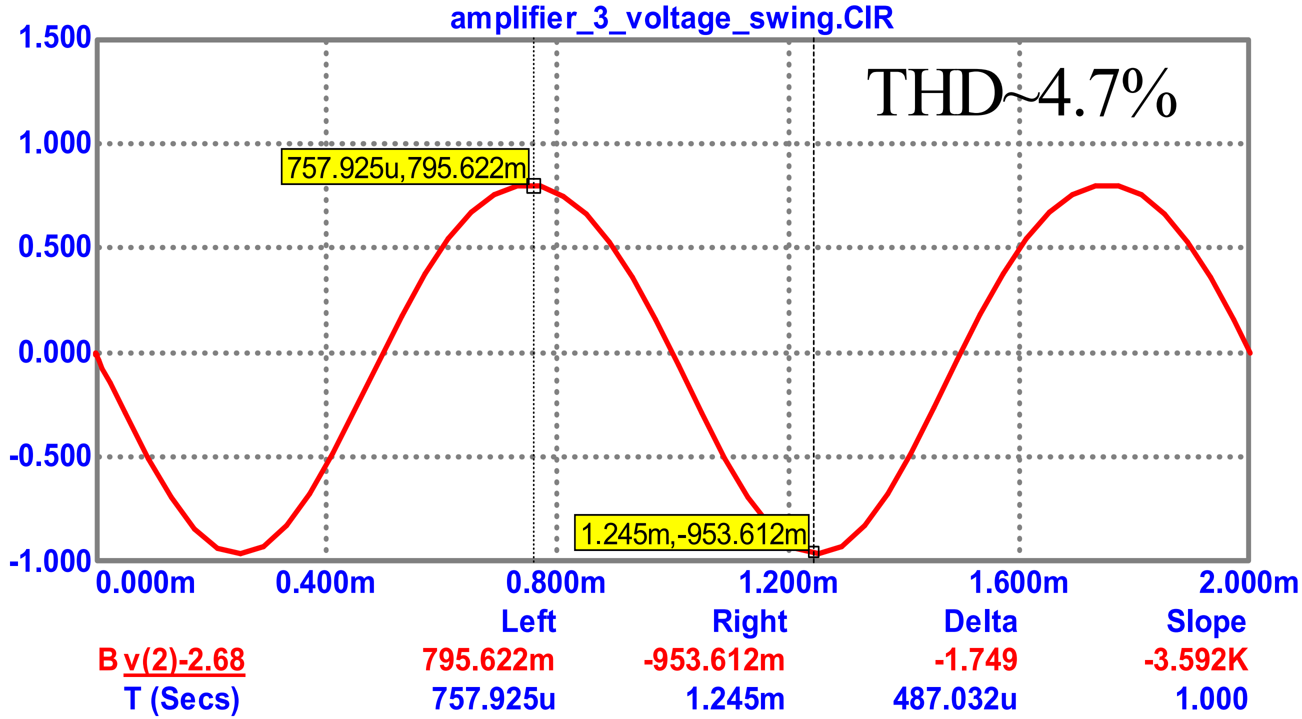
Thus, for the same v_π, the signal at the input terminal of the amplifier, v_i, can be greater than for the CE amplifier by the factor $(1 + g_m R_e)$.

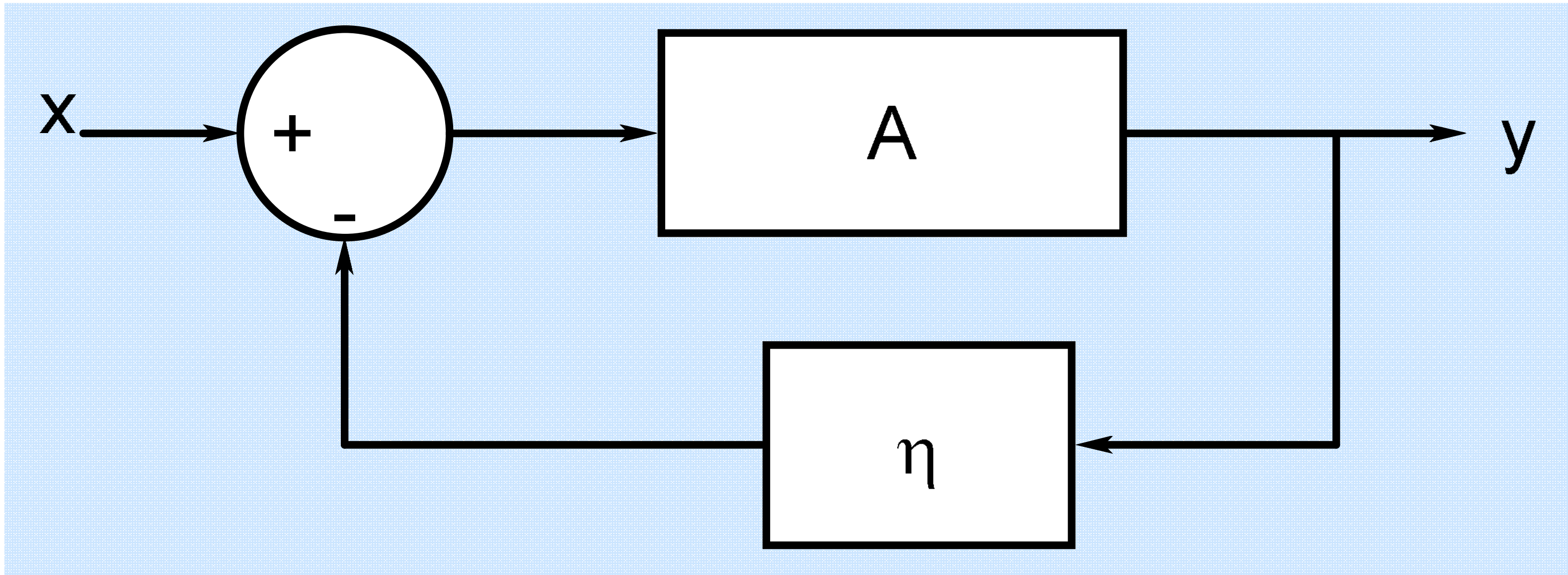
To summarize, including a resistance R_e in the emitter of the CE amplifier results in the following characteristics:

1. The input resistance R_{in} is increased by the factor $(1 + g_m R_e)$.
2. The voltage gain from base to collector, A_v, is reduced by the factor $(1 + g_m R_e)$.
3. For the same nonlinear distortion, the input signal v_i can be increased by the factor $(1 + g_m R_e)$.
4. The overall voltage gain is less dependent on the value of β.
5. The high-frequency response is significantly improved (as we shall see in Chapter 9).

Sedra and Smith

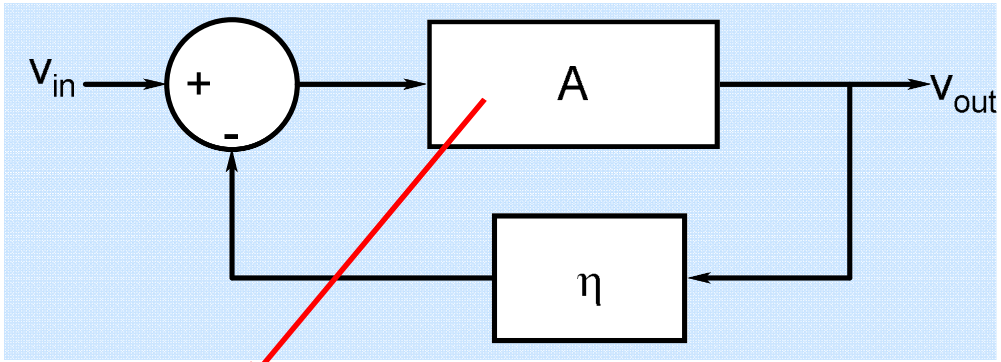

V_CC
220 k
R_B
1.2 k
R_C
C_B
v_o
20mV
v_s
13.5 Ω
R_E

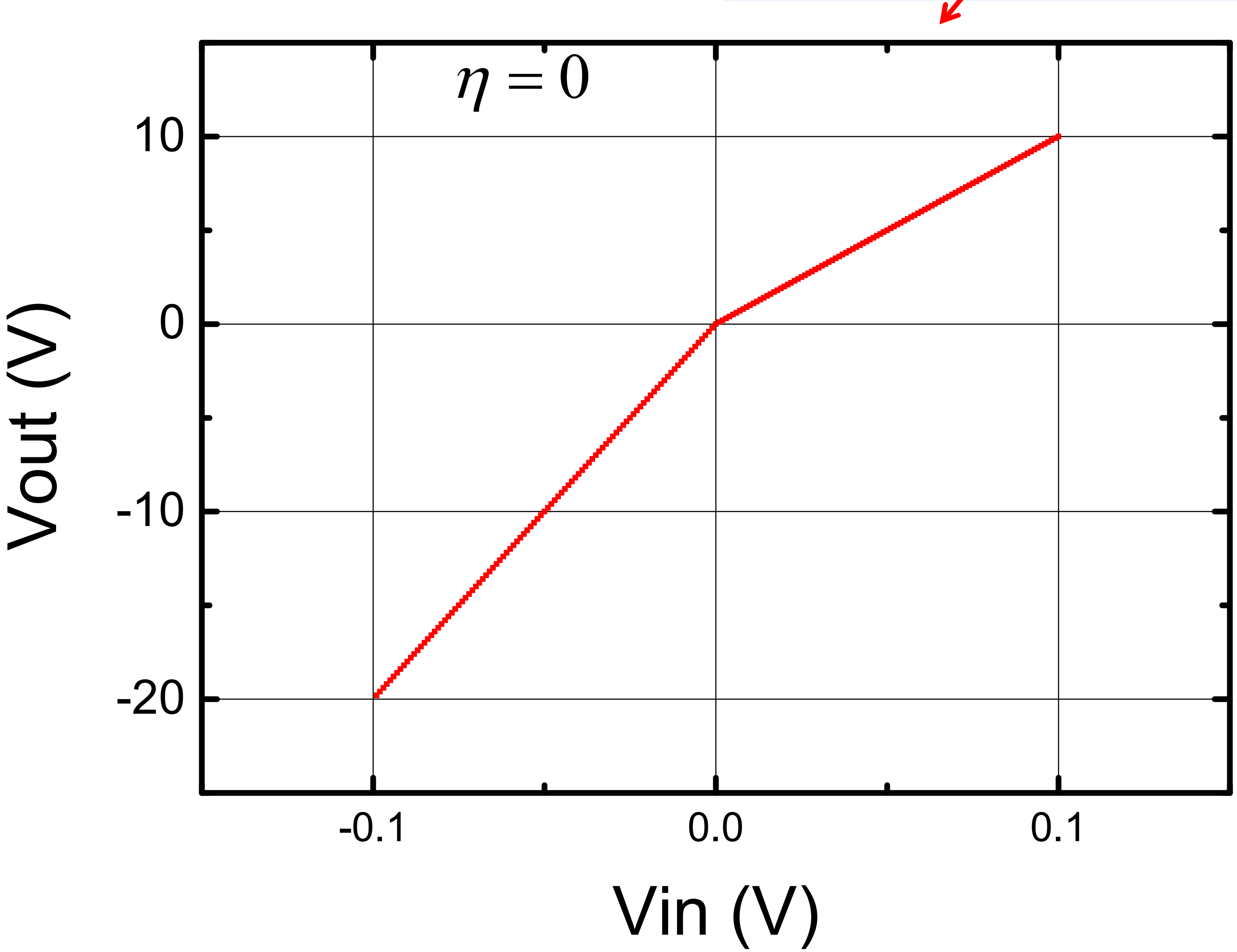

amplifier_3_voltage_swing.CIR
THD~4.7%
757.925u,795.622m
1.245m,-953.612m
1.500
1.000
0.500
0.000
-0.500
-1.000
0.000m
0.400m
0.800m
1.200m
1.600m
2.000m
Left
Right
Delta
Slope
B v(2)-2.68
795.622m
-953.612m
-1.749
-3.592K
T (Secs)
757.925u
1.245m
487.032u
1.000



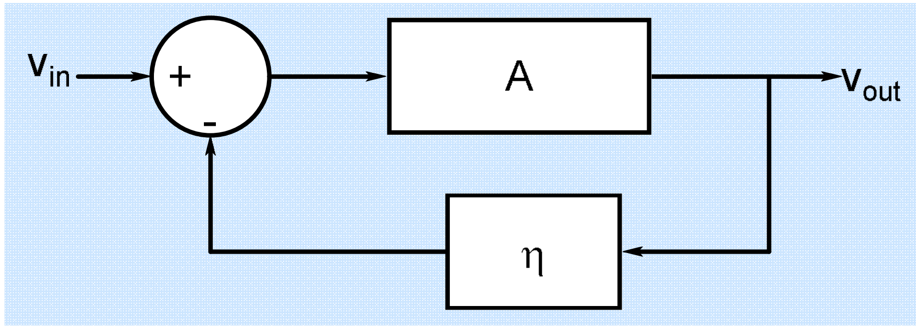
$$\frac{y}{x} = \frac{A}{1 + \eta A}$$

Harmonic distortion occurs due to nonlinearity. Negative feedback helps in reducing non-linearity

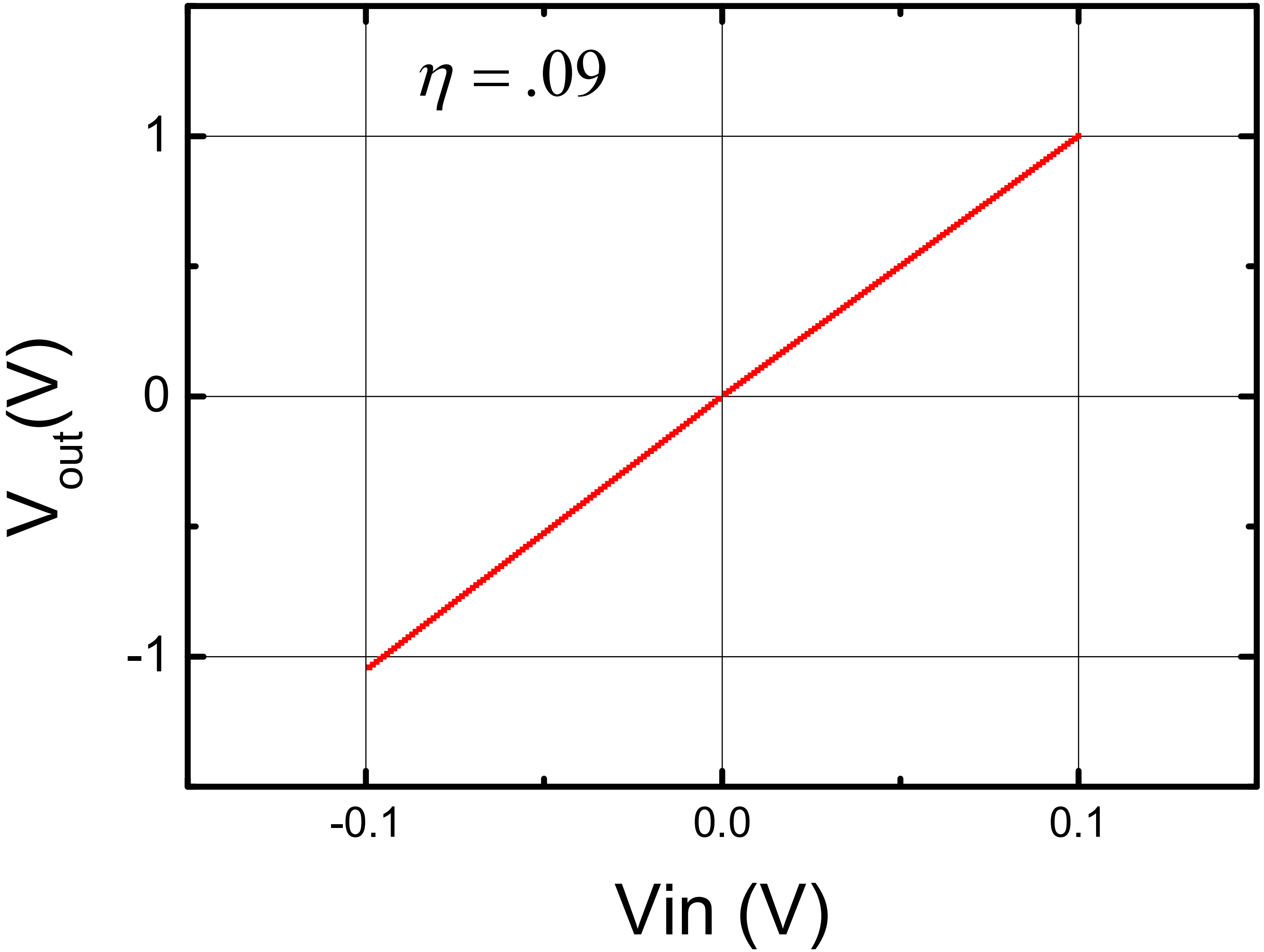


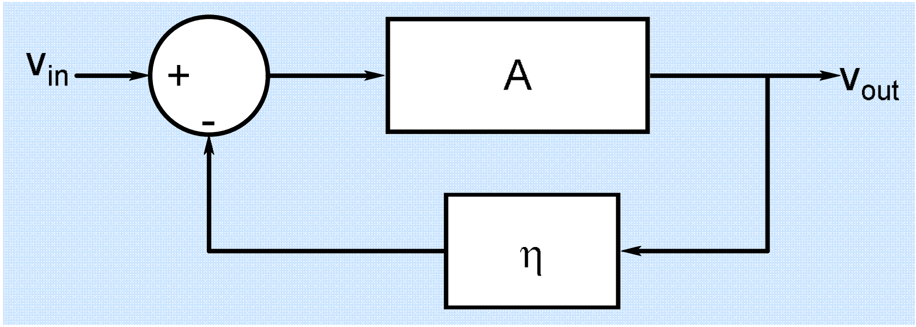


$$\frac{v_{out}}{v_{in}} = \frac{A}{1+\eta A}$$



$$\frac{v_{out}}{v_{in}} = \frac{A}{1+\eta A}$$





$$\frac{v_{out}}{v_{in}} = \frac{A}{1+\eta A}$$