EE210: Microelectronics-I

Lecture-22 :CE Amplifier-10

Problems

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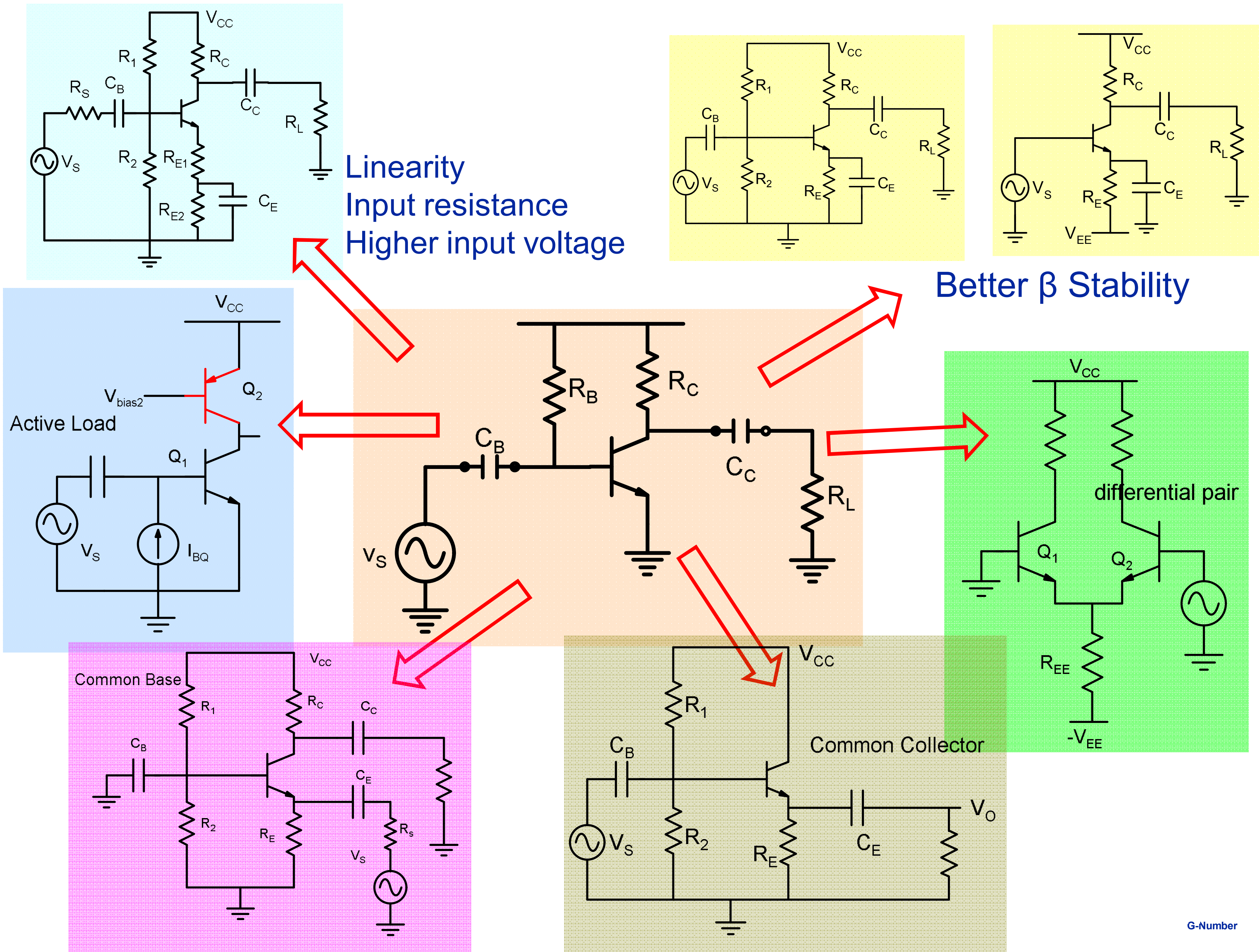
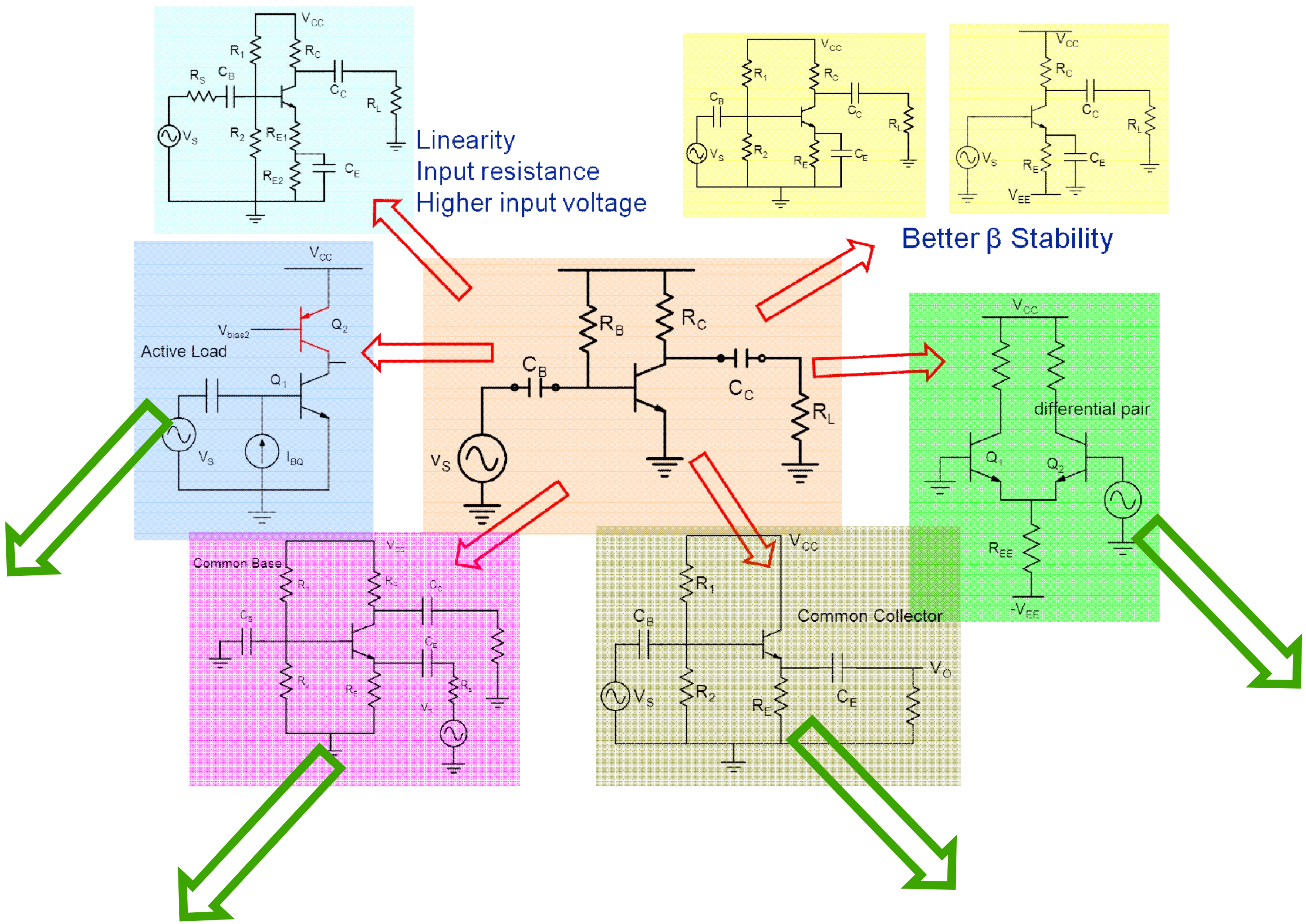
Today's Problems are a result of yesterday's Solutions !


Linearity
Input resistance
Higher input voltage
Better β Stability
Active Load
differential pair
Common Base
Common Collector
V_CC
R_1
R_2
R_S
R_C
R_E
R_E1
R_E2
R_B
R_L
R_EE
C_B
C_C
C_E
V_S
V_EE
-V_EE
V_bias2
Q_1
Q_2
I_BQ
V_O


Linearity
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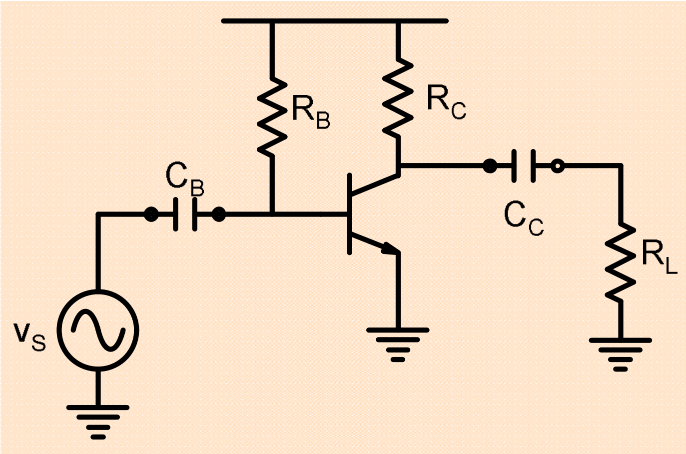
R_B
R_C
C_B
C_C
R_L
V_S
R_1
R_2
R_E
C_E
R_S
R_{E1}
R_{E2}
V_{EE}
V_{bias2}
Q_1
Q_2
I_{BQ}
R_{EE}
$-V_{EE}$
V_O

Problem-1: How can we obtain higher voltage gain without requiring very high supply voltage?

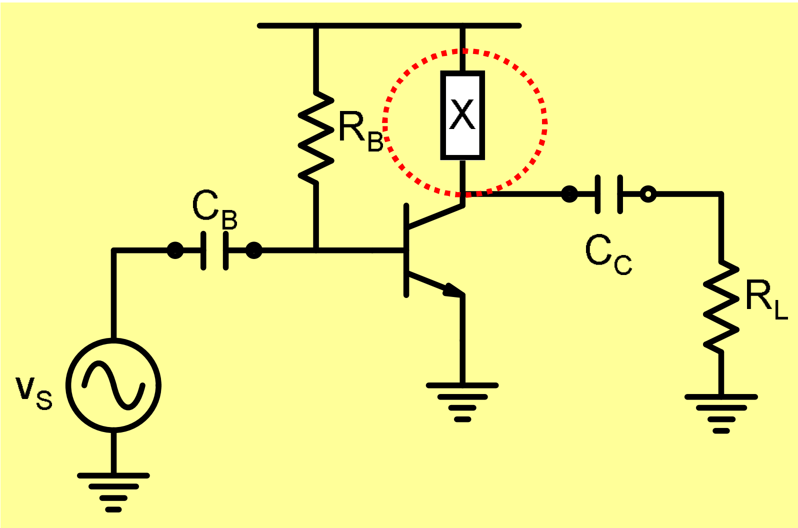


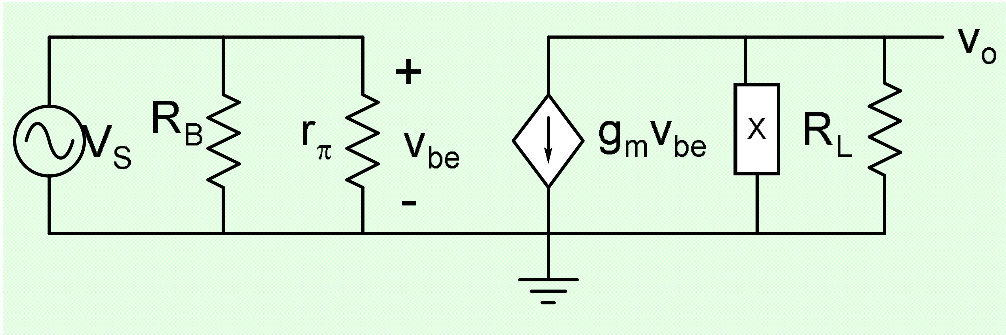
$$A_V = -\frac{I_{CQ}}{V_T} \times R_C \| R_L$$

$$A_V < \frac{I_{CQ} R_C}{V_T}$$

For $A_V = 10^3$, $V_{CC} > 26$ V

For $V_{CC} = 1.5$ V, $A_V < 50$

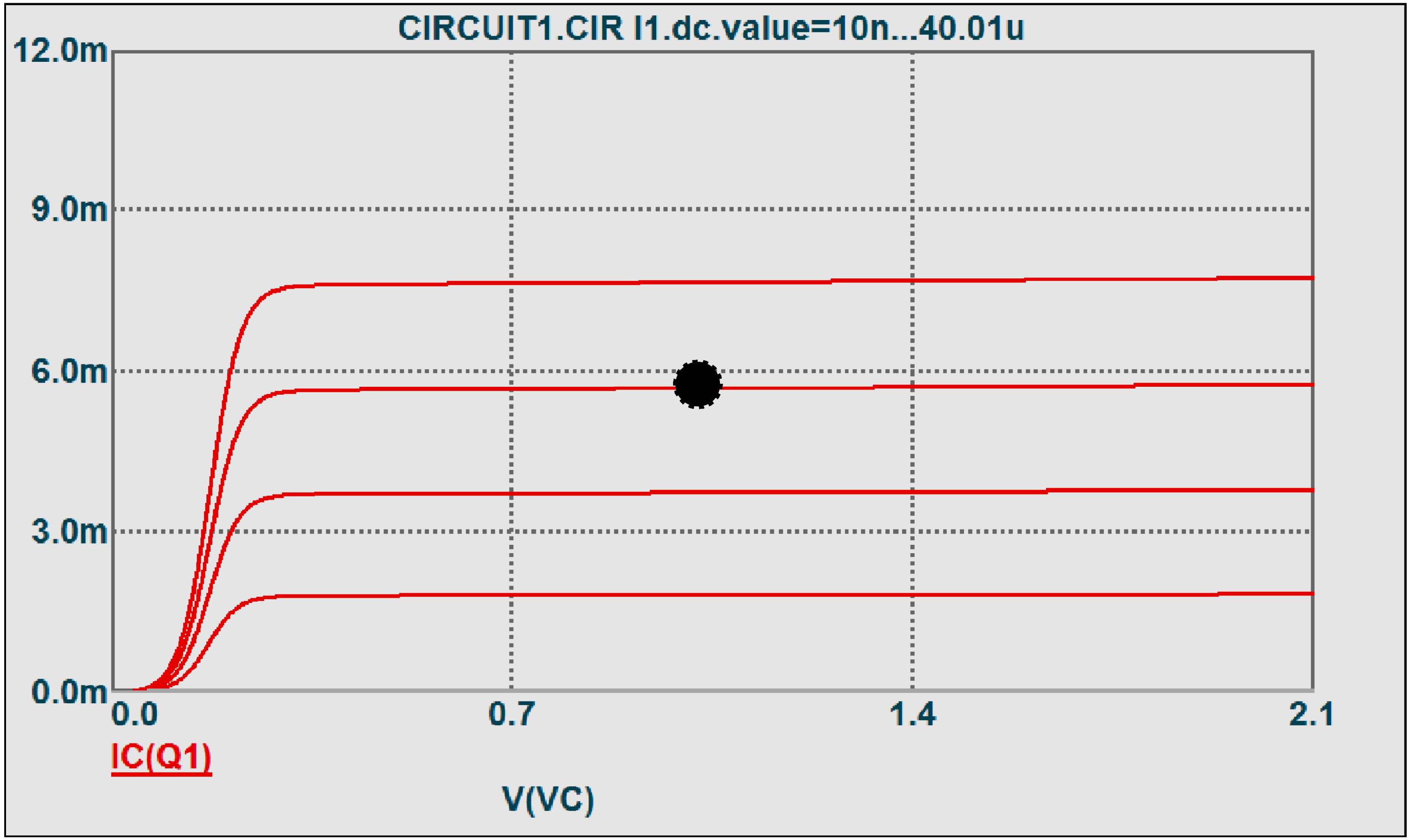




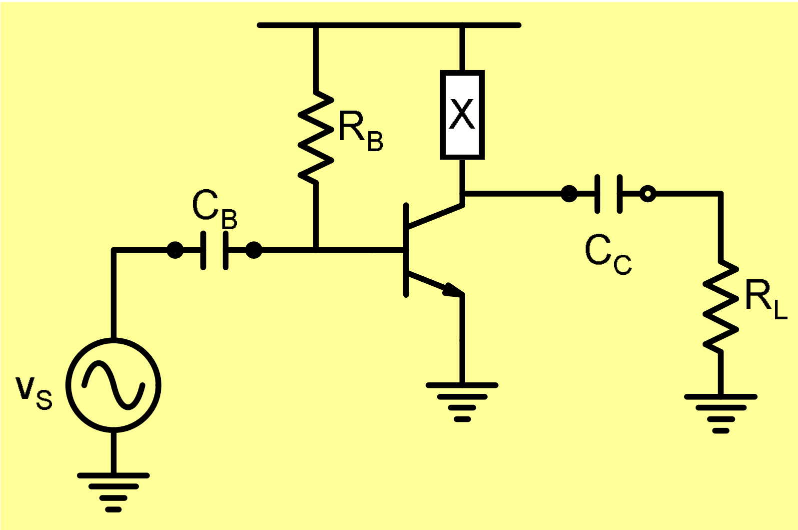
$$A_V < g_m \times r_X$$

We want an element that has high small signal resistance but small dc voltage drop across it.

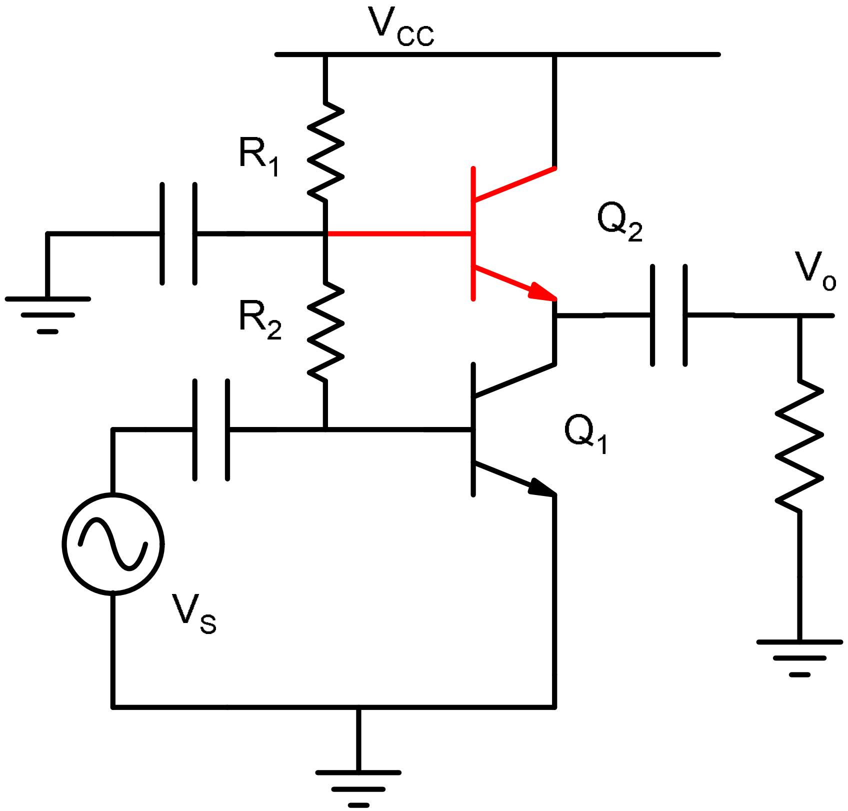
A Transistor has this desired property and can serve as an excellent ‘load’ element



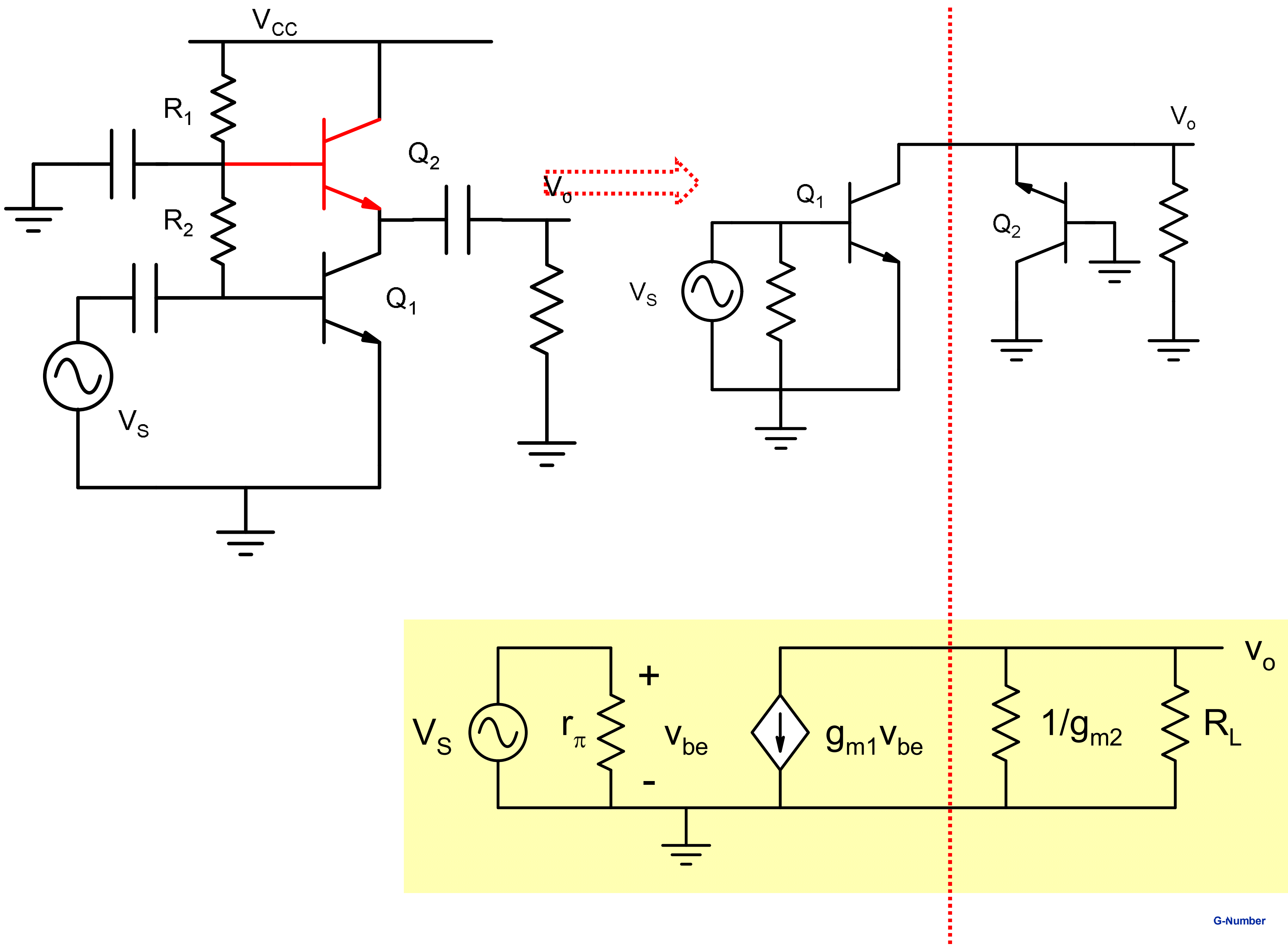
Many high voltage gain amplifiers have active load !



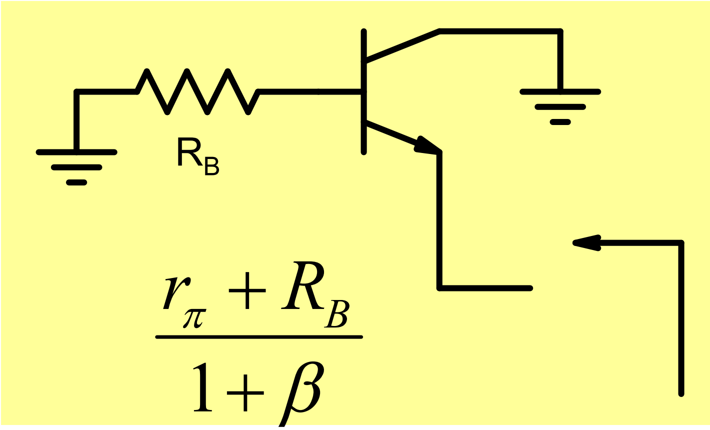
X
R_B
C_B
C_C
R_L
v_S

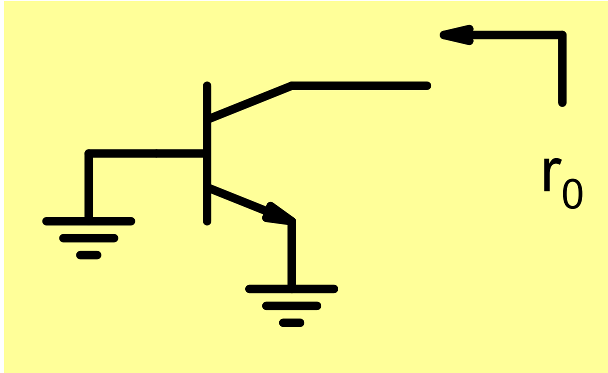


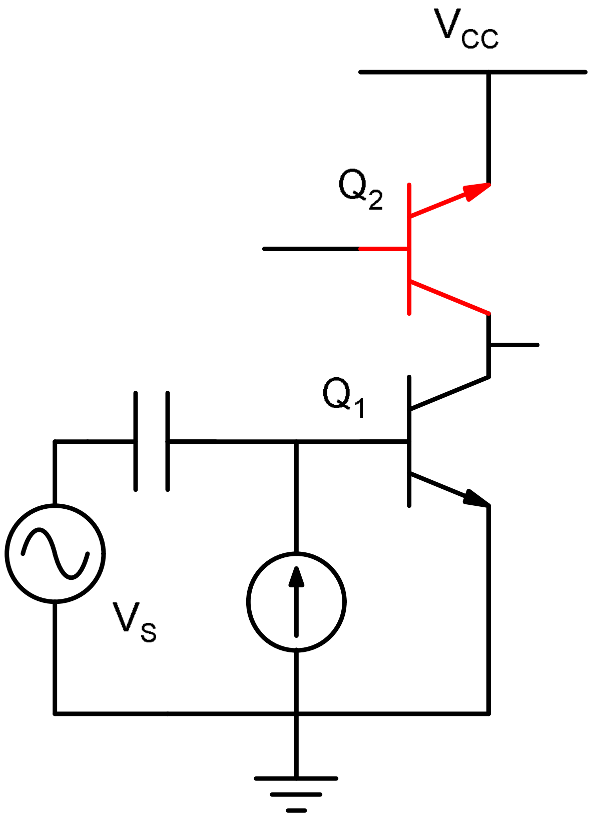
V_{CC}
R_1
R_2
Q_2
Q_1
V_o
V_S

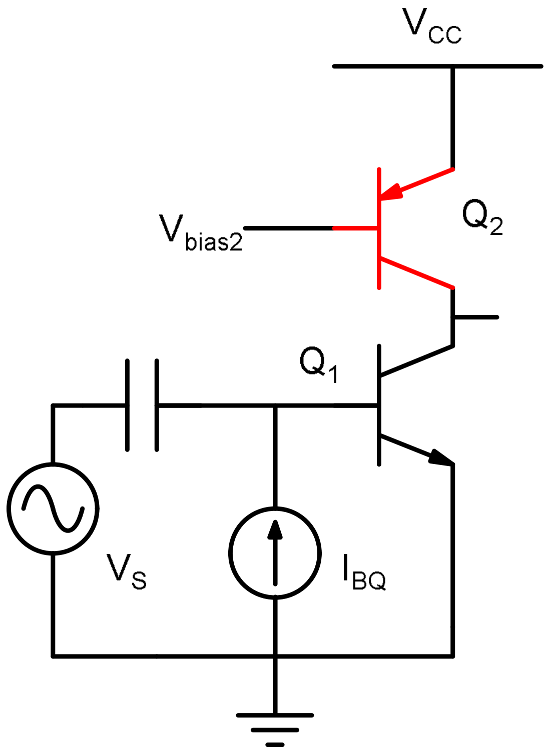


G-Number

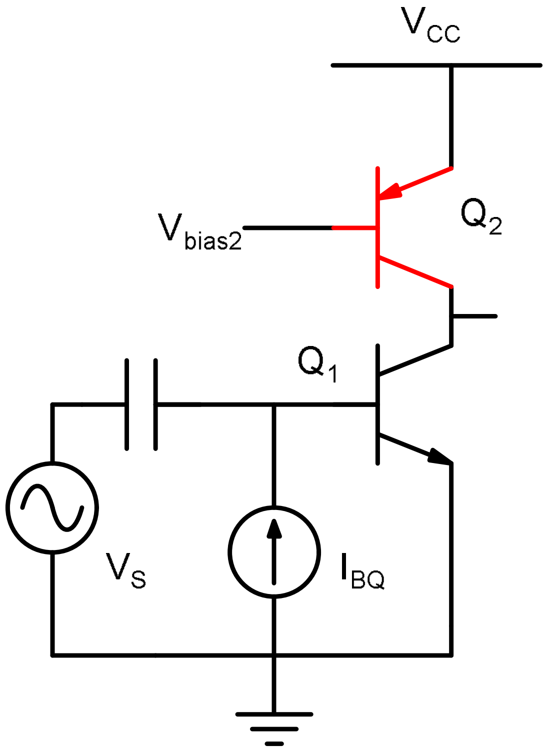


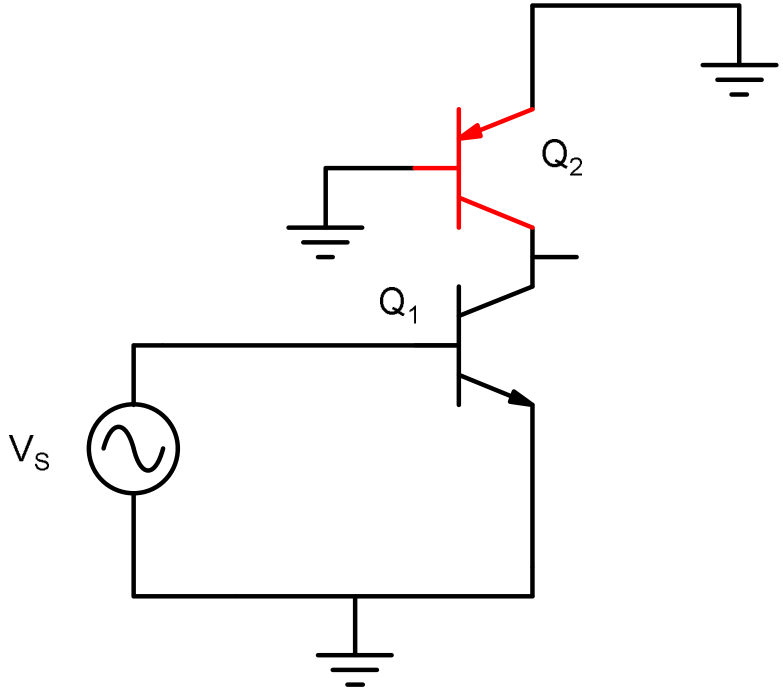


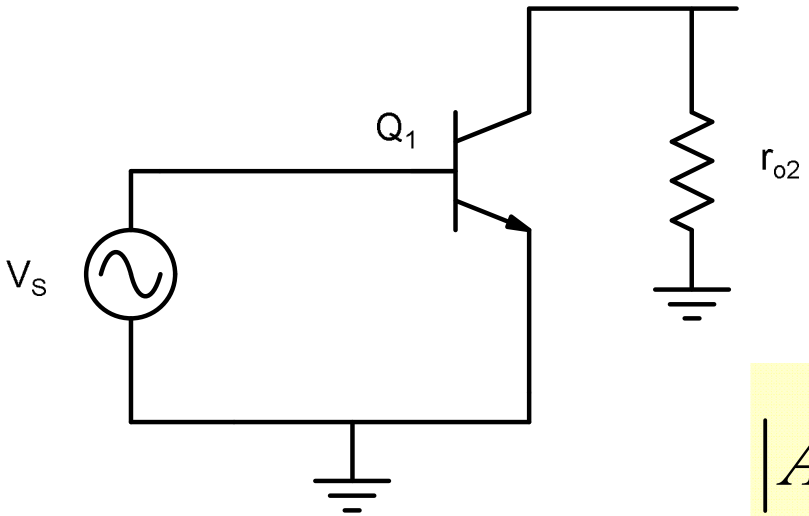




G-Number



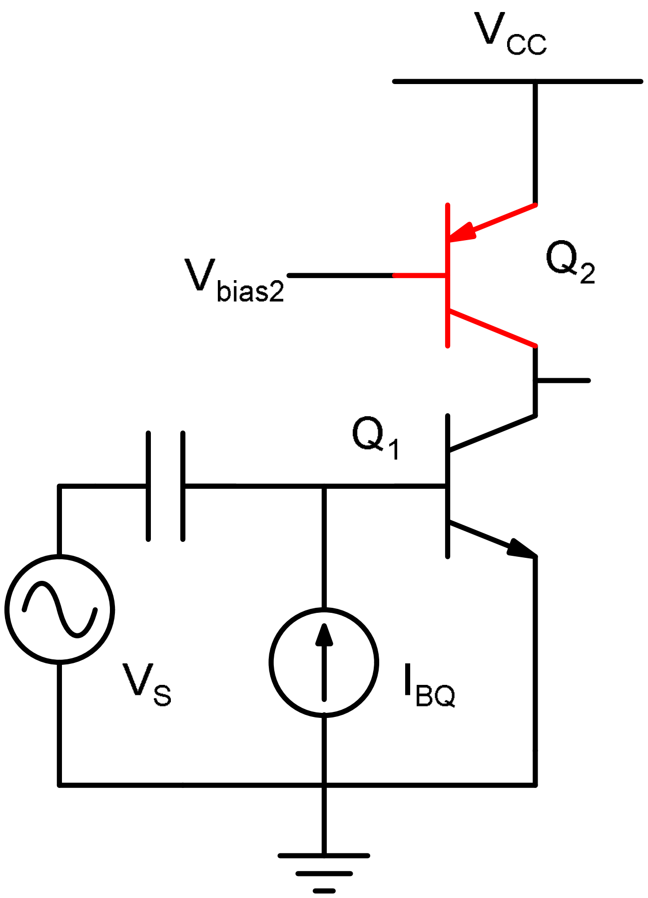




$$\left|A_V\right| = g_m \times r_{o1} \| r_{o2}$$

$$r_{o1} = \frac{V_{AN}}{I_{CQ}}; r_{o2} = \frac{V_{AP}}{I_{CQ}}$$

$$\left|A_V\right| = \frac{1}{V_T} \times \frac{V_{AN} \times V_{AP}}{V_{AN} + V_{AP}}$$



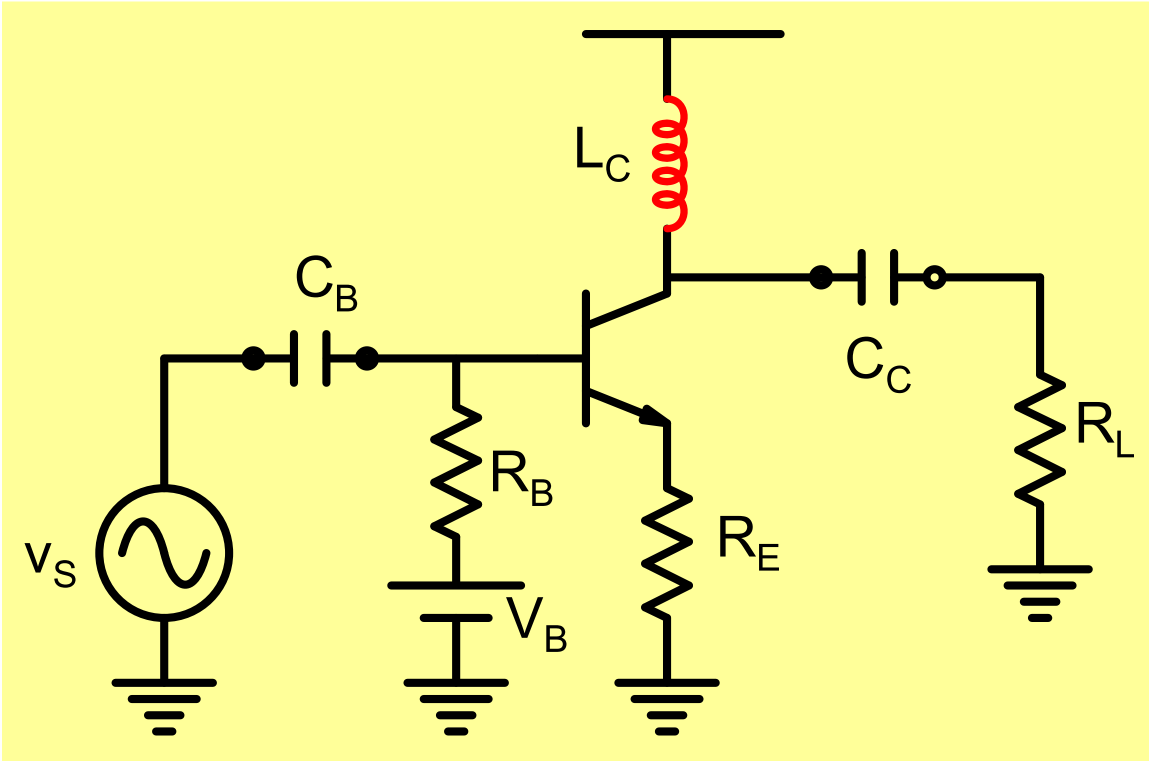
$$\left|A_V\right| = \frac{1}{V_T} \times \frac{V_{AN} \times V_{AP}}{V_{AN} + V_{AP}}$$

For $V_{AN} = V_{AP} = 100$, $A_V = 1.9 \times 10^3$

independent of supply voltage

Alternative Solution

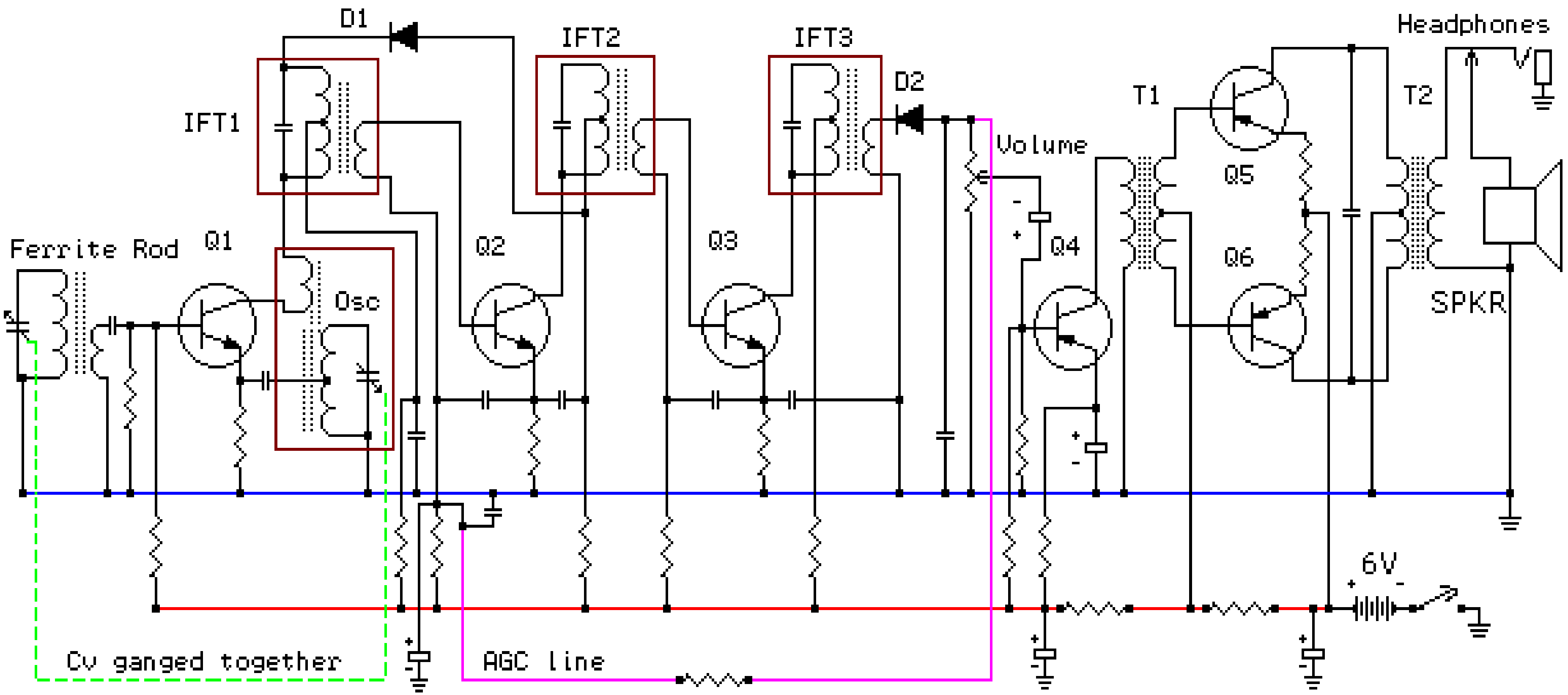
An Inductor has zero dc drop but can have high ac impedance !



$$\omega L >> R_L$$

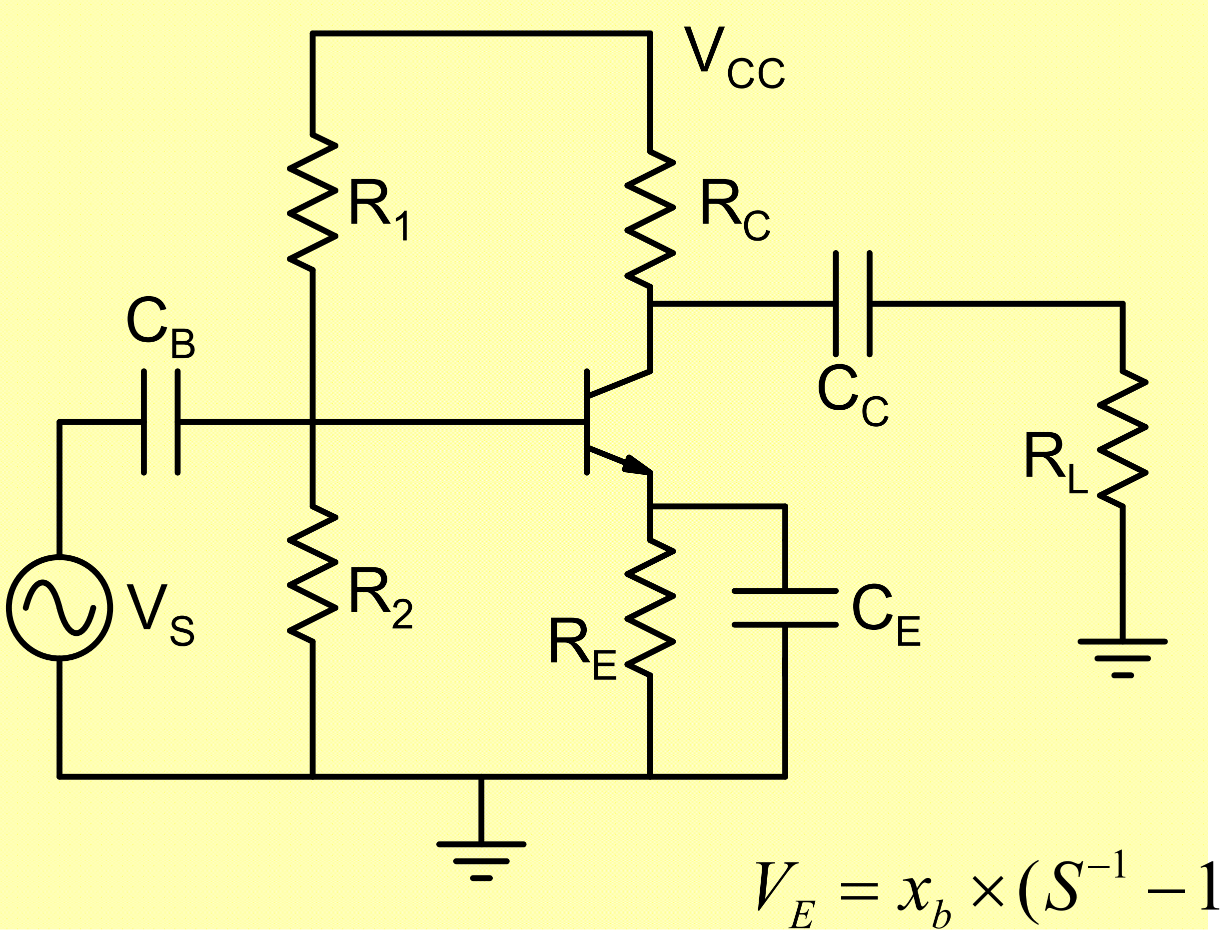
$$f = 1K; R_L = 1K \Rightarrow L > 1.6H!!$$

AM radio receiver circuit



Note the use of lots of transformers

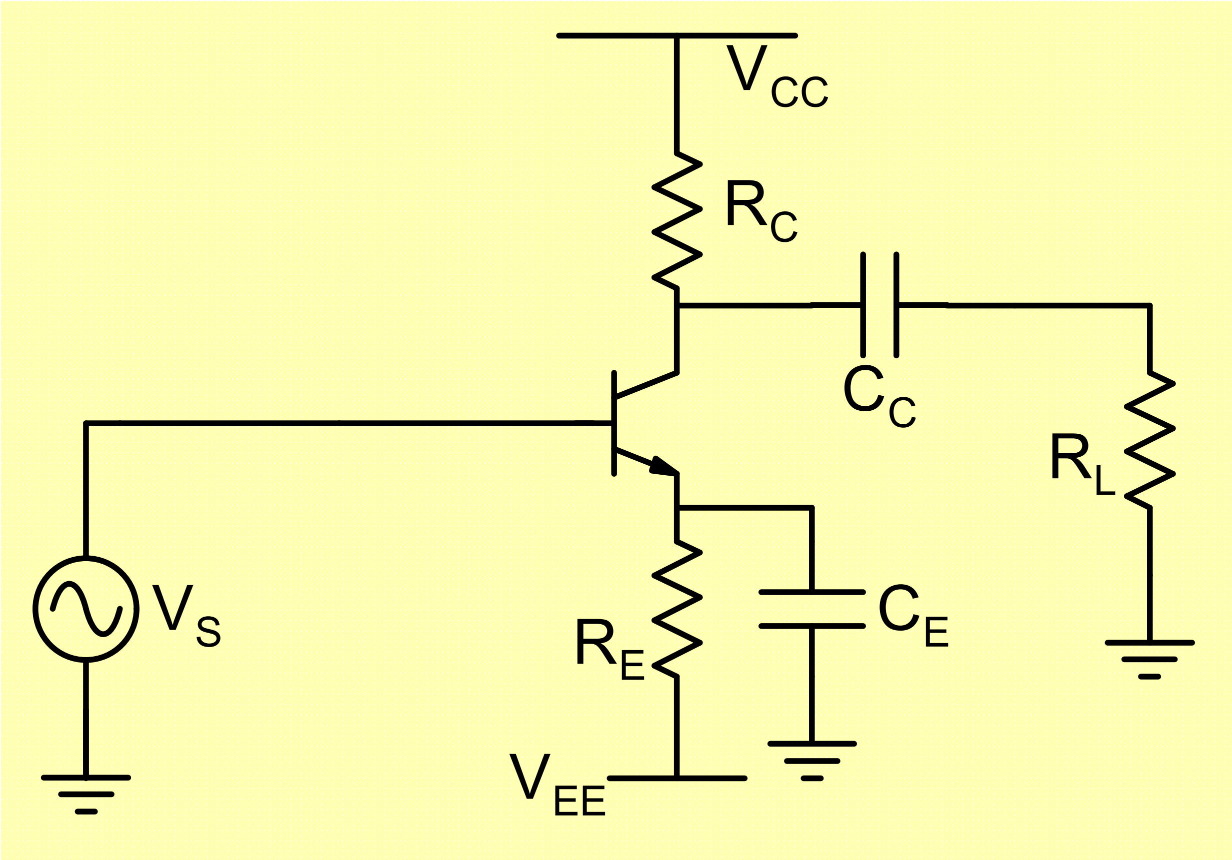
Problem-2: Is there a way of eliminating R_B?



$$V_E = x_b \times (S^{-1} - 1) \times V_T$$

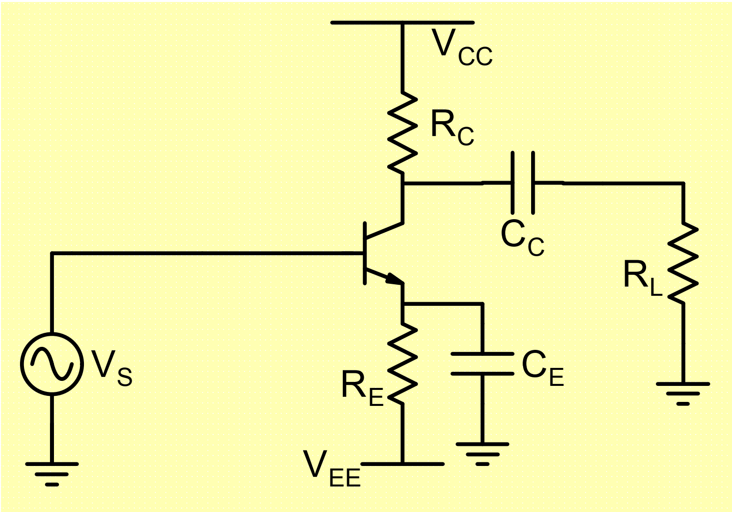
$$R_{in} = r_\pi \| R_B$$

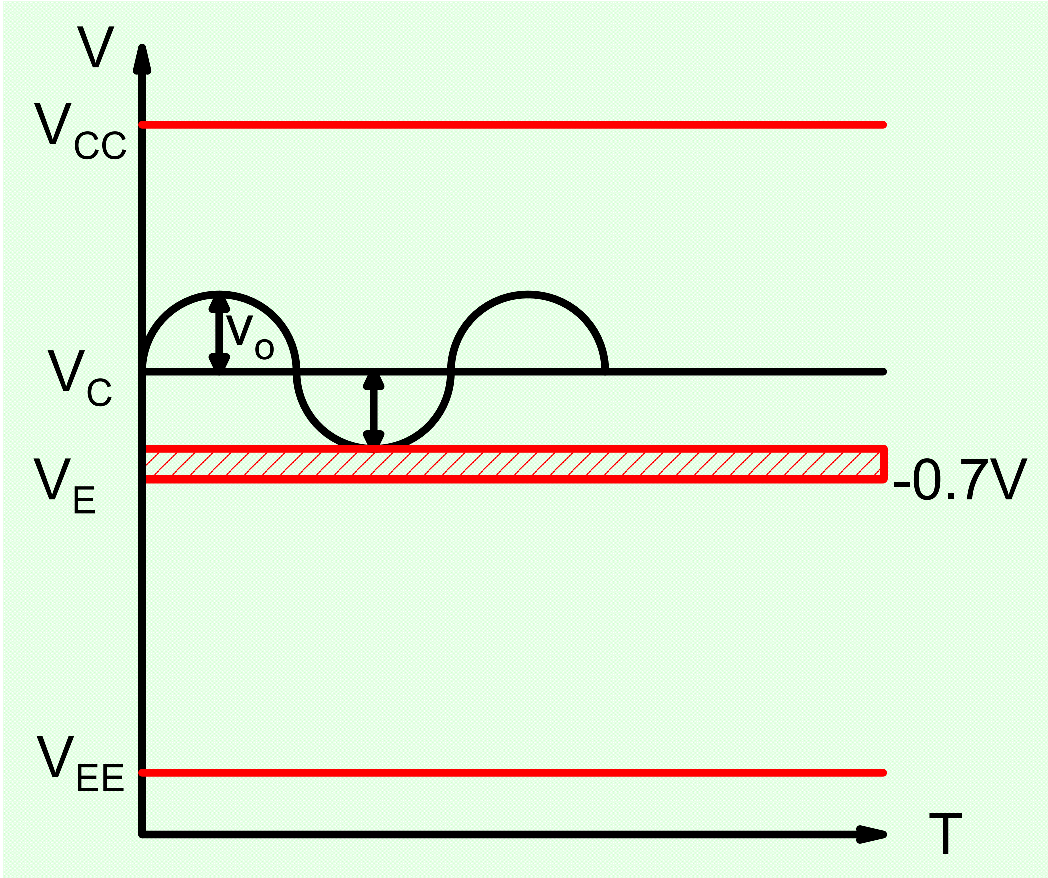
$$S = \frac{\Delta I_{CQ} / I_{CQ}}{\Delta\beta / \beta} = \frac{1}{1 + \frac{\beta R_E}{R_B}}; \quad x_b = \frac{R_B}{r_\pi}$$



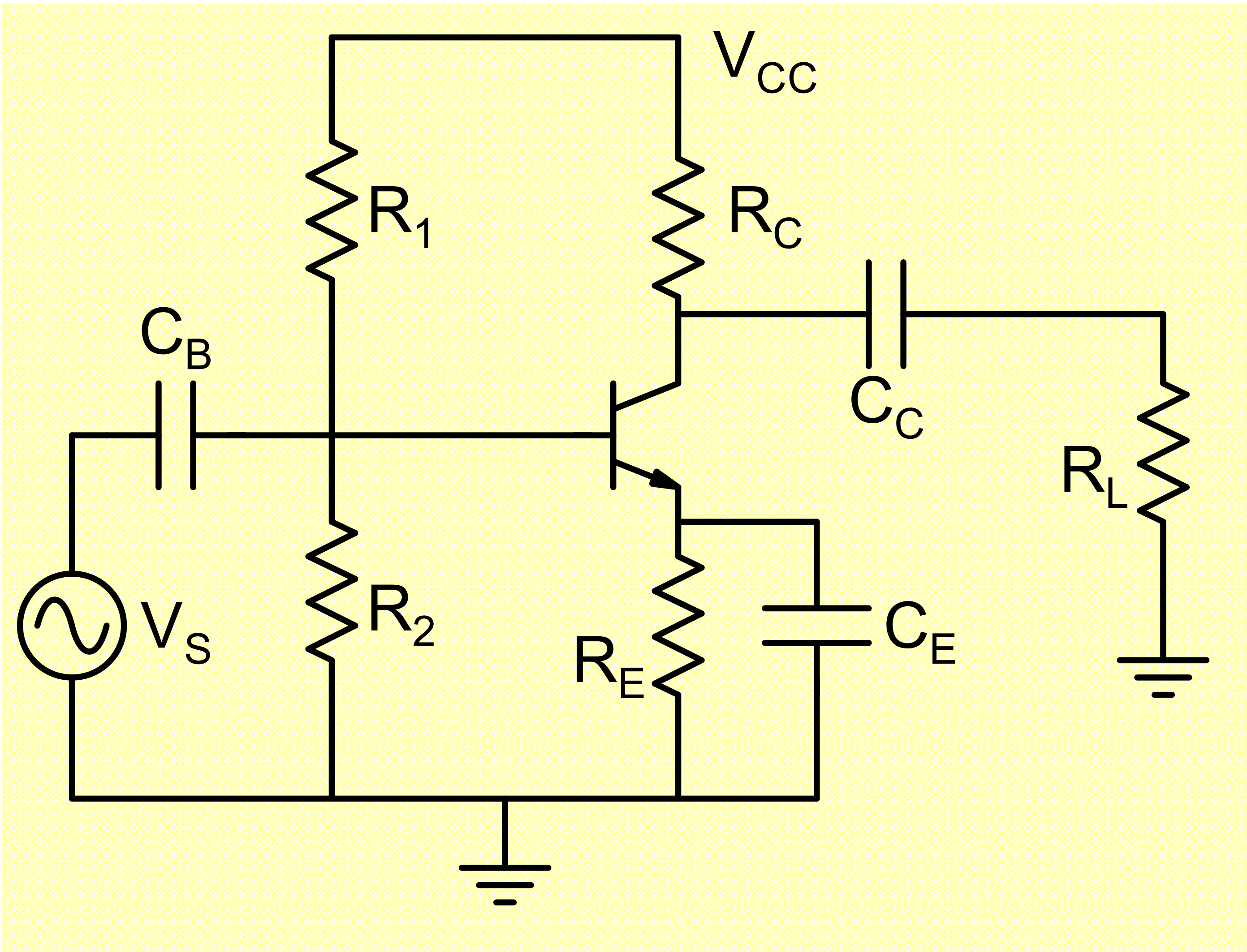
But requires a separate negative power supply !

Voltage swing in the negative direction is far from negative supply rail

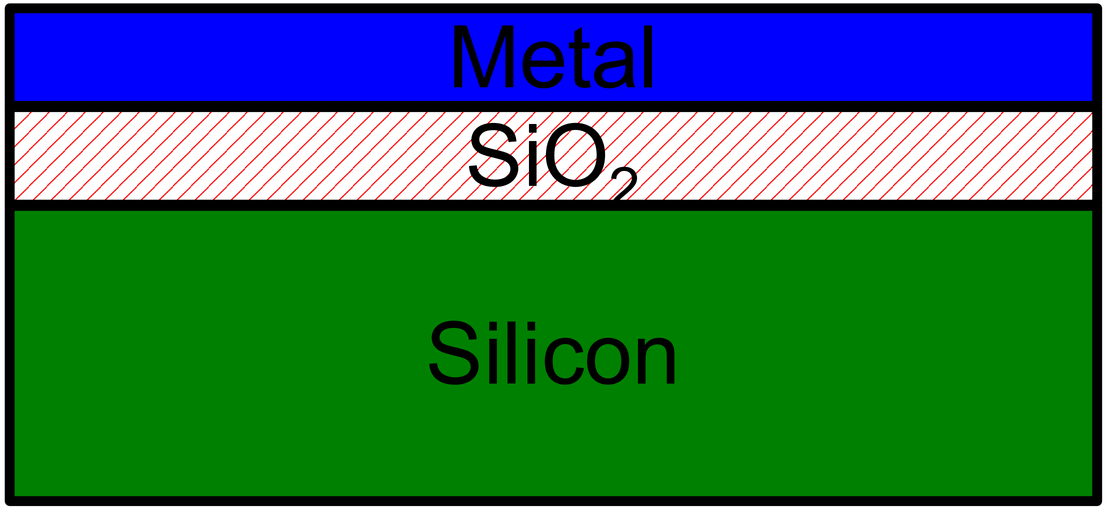




Problem-3 : Is there a way of biasing without use of coupling capacitors?



Making large capacitors (μF) on chip is impossible !



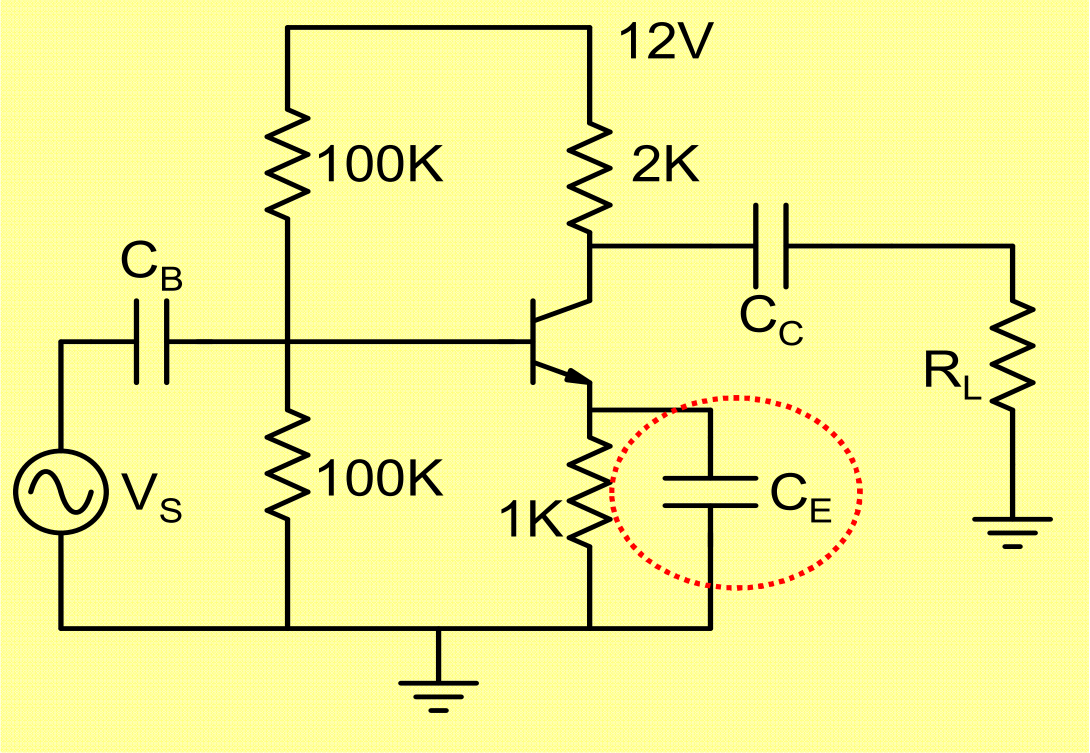
$$C = \frac{\varepsilon_{ox}}{t_{ox}} \times Area$$

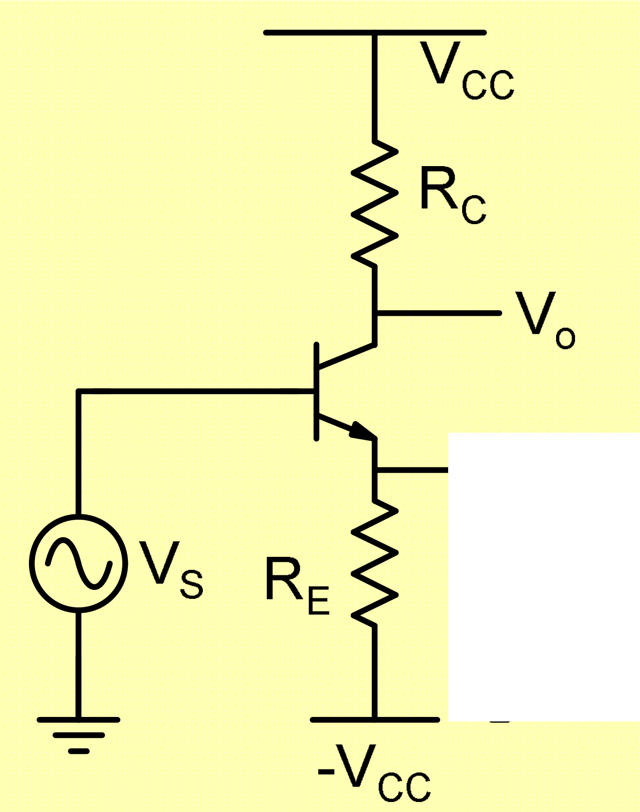
$$\varepsilon_{ox} = 3.9 \times 8.85 \times 10^{-14} F/cm \; ; \; t_{ox} = 20nm$$

$$\text{Area} = \; 57 \; cm^2 \text{ !! for } 10\mu\text{F capacitor}$$

One can only make capacitors of the order of a few picofarads on chip

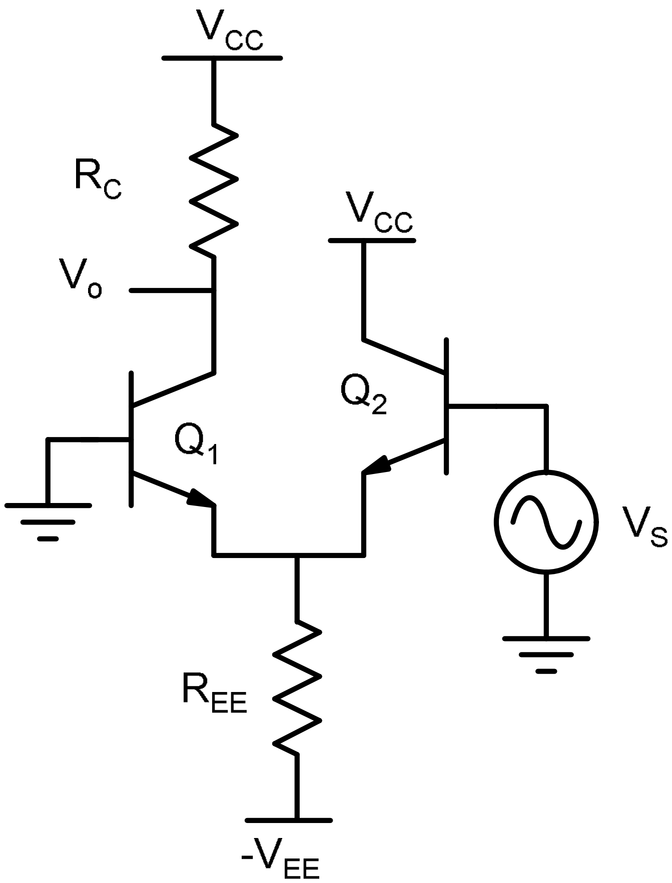
This would lead to an unacceptably large lower cutoff frequency



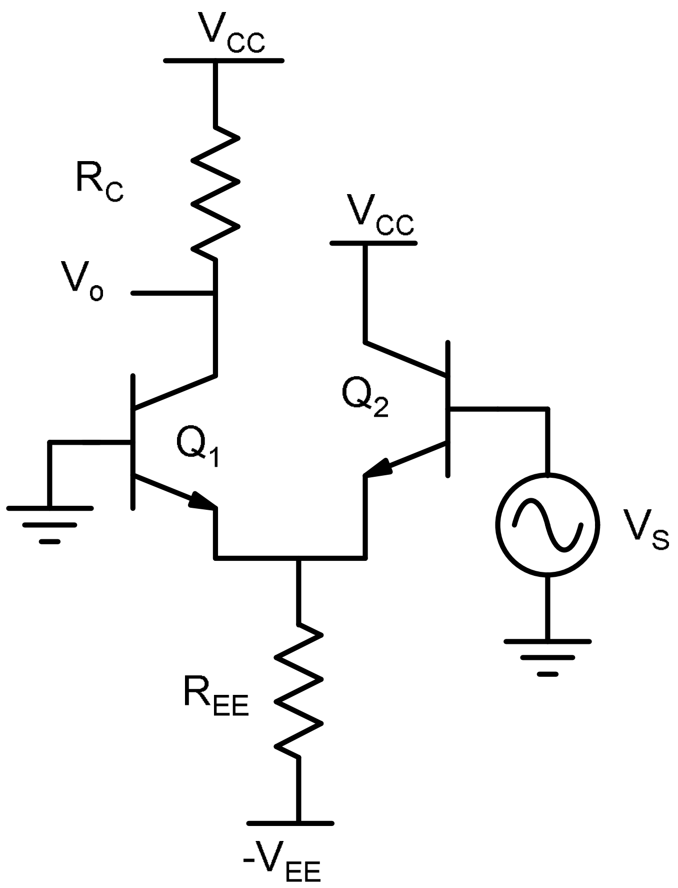


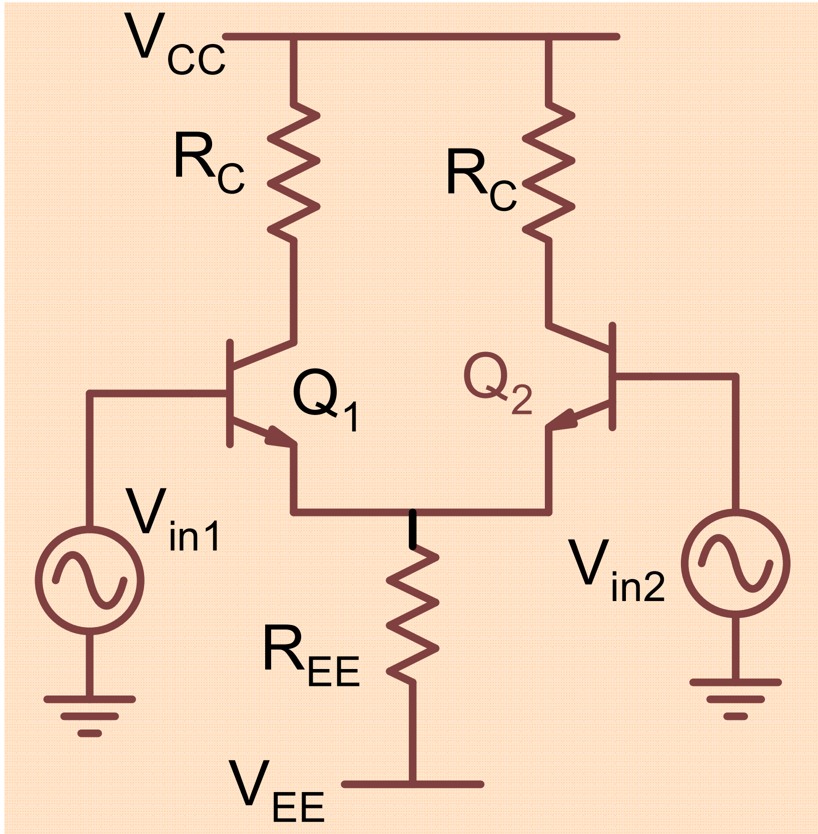
$$|A_V| = \frac{g_m R_C}{1 + g_m R_E} \sim \frac{R_C}{R_E}$$

$$\sim \frac{I_{CQ} R_C}{I_{CQ} R_E} \sim 1$$



$$|A_V| = 0.5 g_m R_C$$

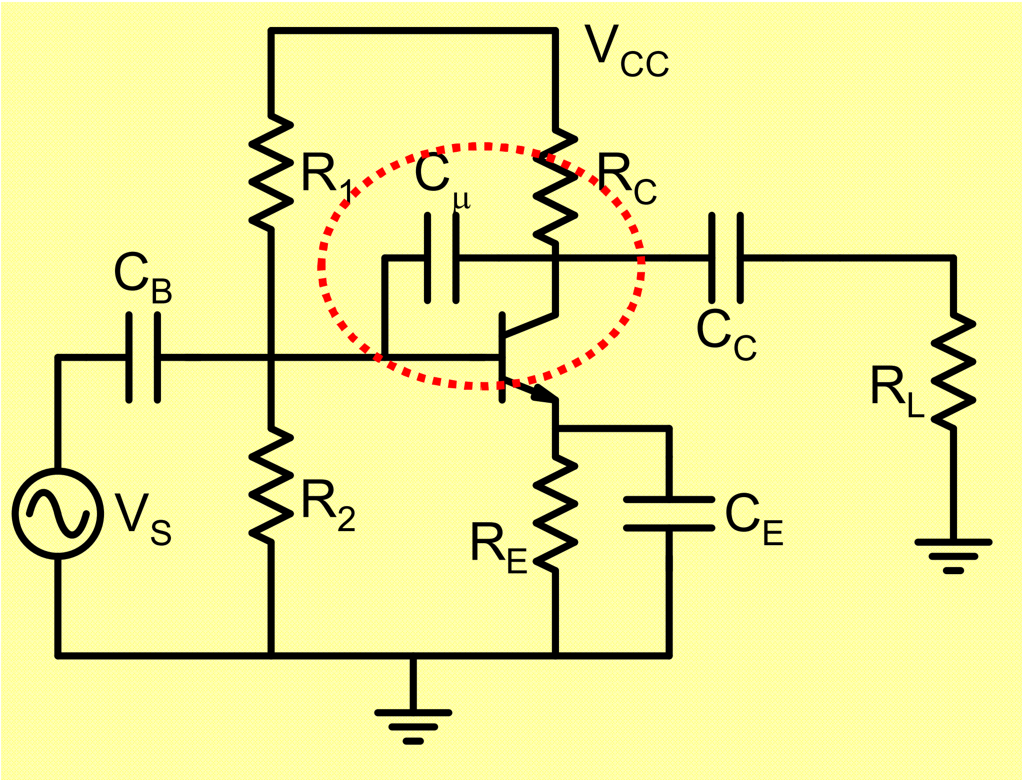




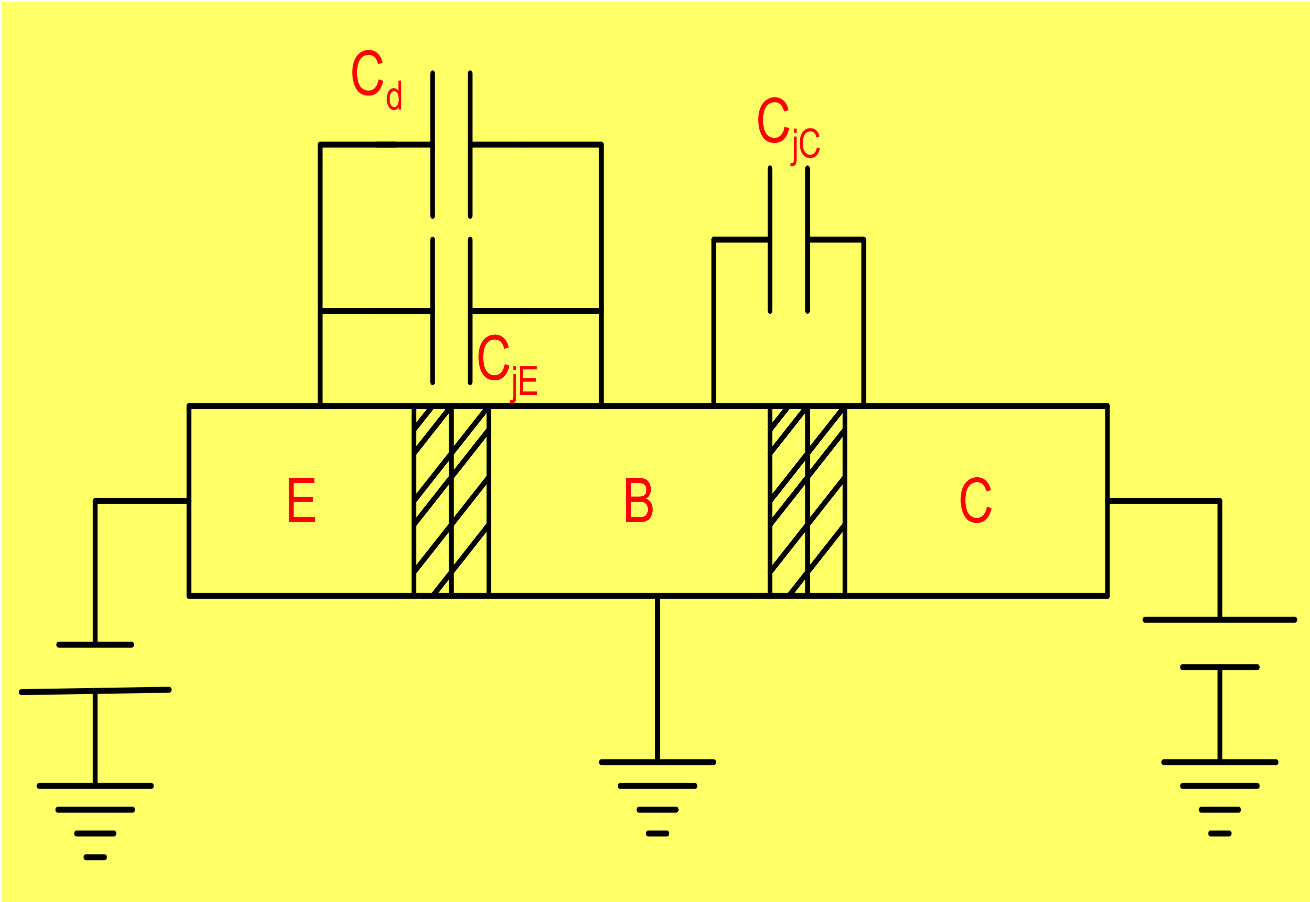
Differential amplifier

Problem-4: Can one get rid of Miller's capacitance which reduces bandwidth at high gain

$$\omega_H \cong \frac{1}{(R'_S \| r_\pi)\{C_\pi + C_\mu(1+g_m R'_C)\} + R'_C C_\mu}$$

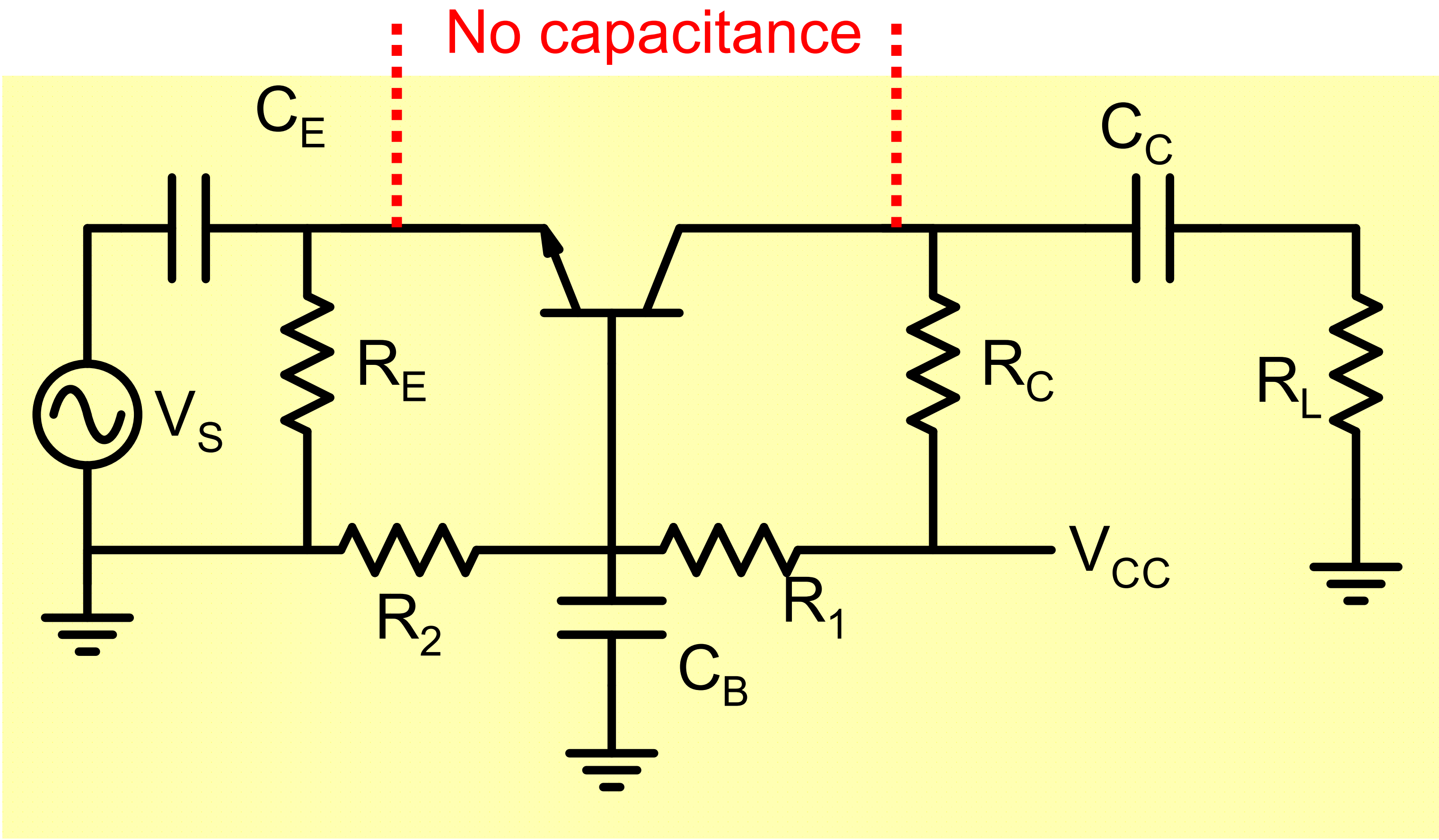


Look for an amplifier circuit in which there is no capacitance between input and output ports

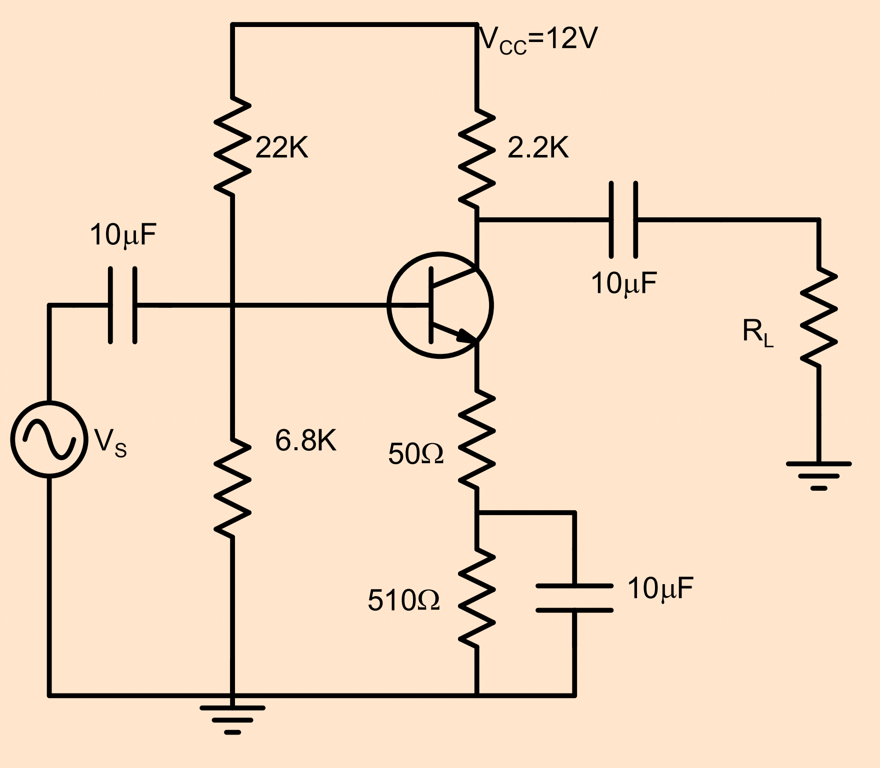


Note that there is no capacitance between emitter and collector

Natural solution is a Common Base (CB) Amplifier



Problem-5: Driving low impedance loads is a problem !



$$A_V = I_{CQ} R_C \| R_L$$

$$R_L = 2.2k; I_{CQ} = 3.4mA; P_{\sup ply} = 46mW$$

$$A_V = 18.2; R_{in} = 2.76K; R_O = 2.2K$$

$$v_{om} = 2V @ THD = 1.8\%;$$

$$P_{L\max} = \frac{v_{om}^2}{2R_L} = 0.9mW$$

$$\eta = \frac{P_L}{P_{\sup ply}} \times 100 \sim 2\%$$

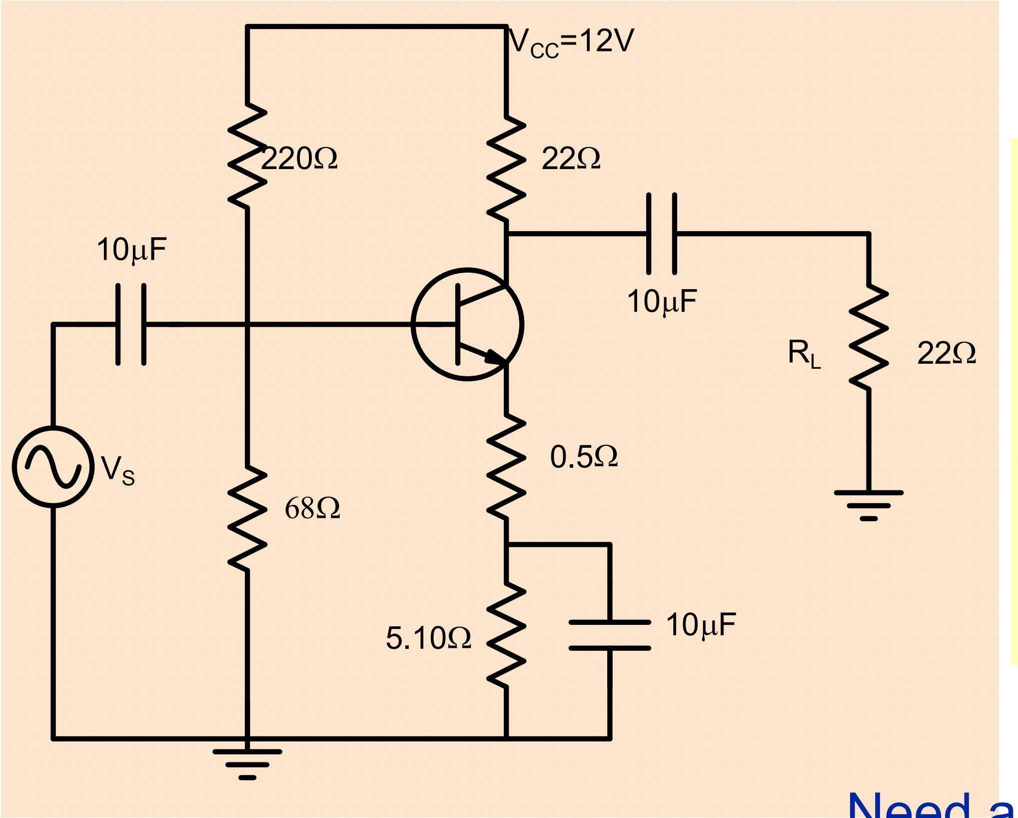
$$f_L = 0.3kHz$$

$$R_L = 22\Omega$$

$$A_V = 0.36; R_{in} = 2.76K; R_O = 2.2K$$

$$v_{om} \sim 40mV @ THD = 1.8\%$$

$$f_L = 0.3kHz$$



$$R_L = 22\Omega; I_{CQ} = 247mA; P_{supply} = 3.47W$$

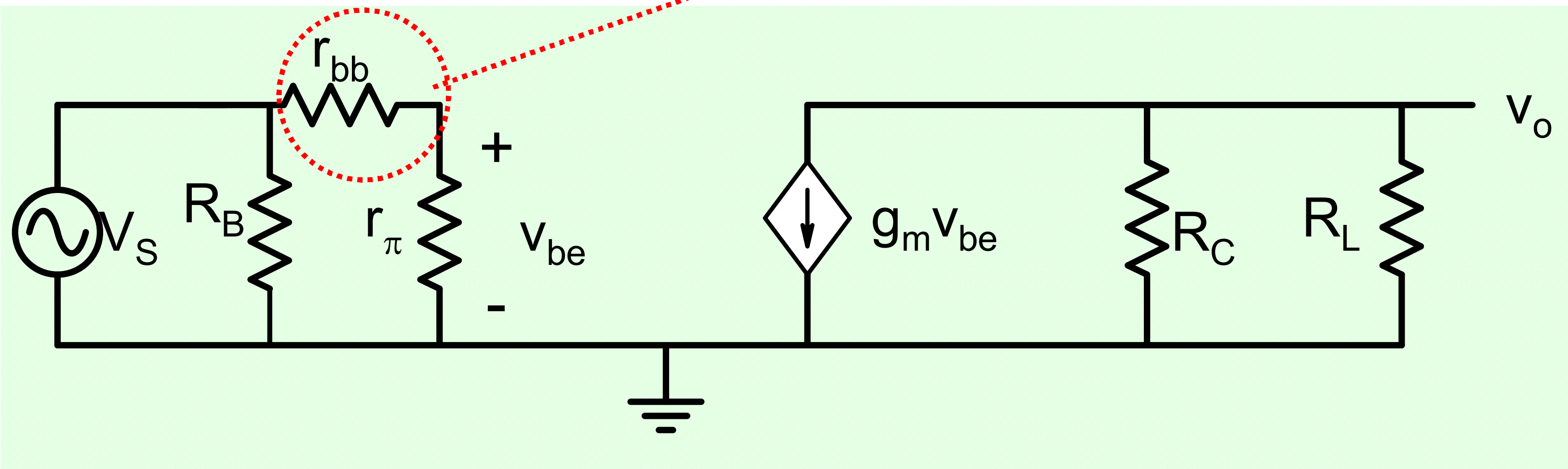
$$A_V = 4.2; R_{in} = 43\Omega; R_O = 22\Omega$$

$$v_{om} \sim 2.6V \ @ \ THD = 1.8\%$$

$$P_{L\max} = \frac{v_{om}^2}{2R_L} = 0.15W$$

$$f_L = 8.3kHz$$

Need a transistor with lower base resistance



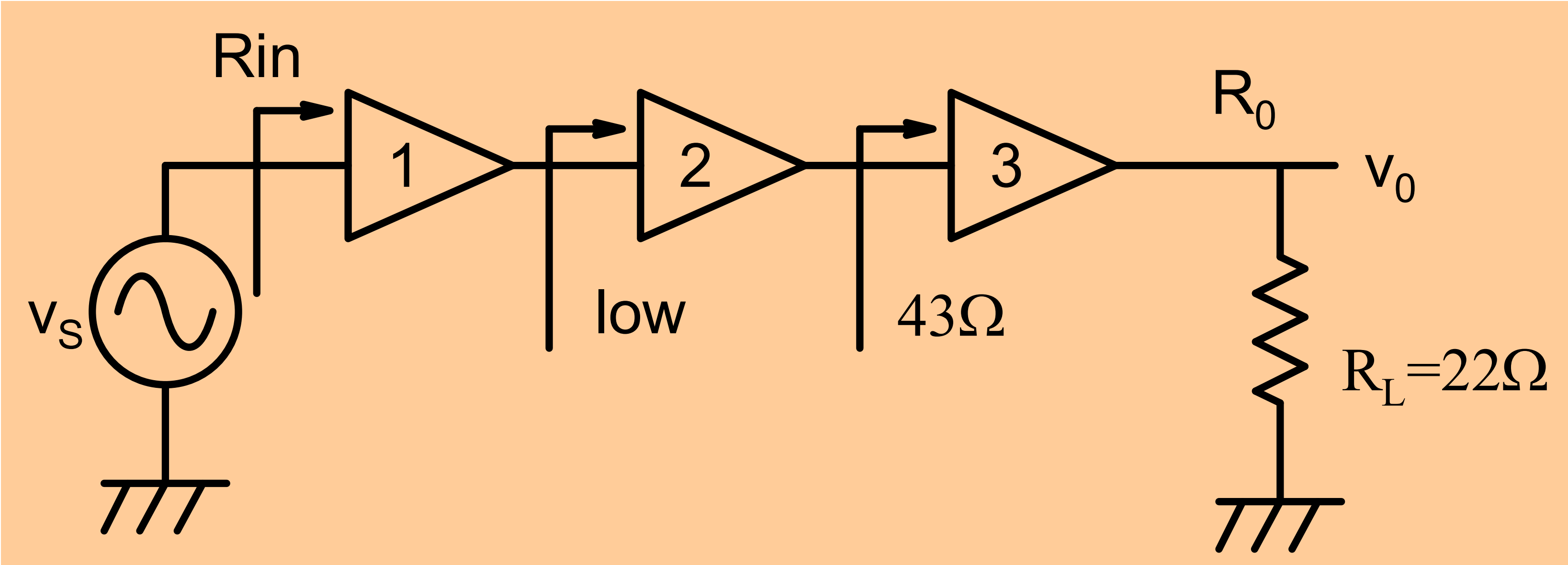
G-Number

CE amplifier has great difficulty driving low load resistances

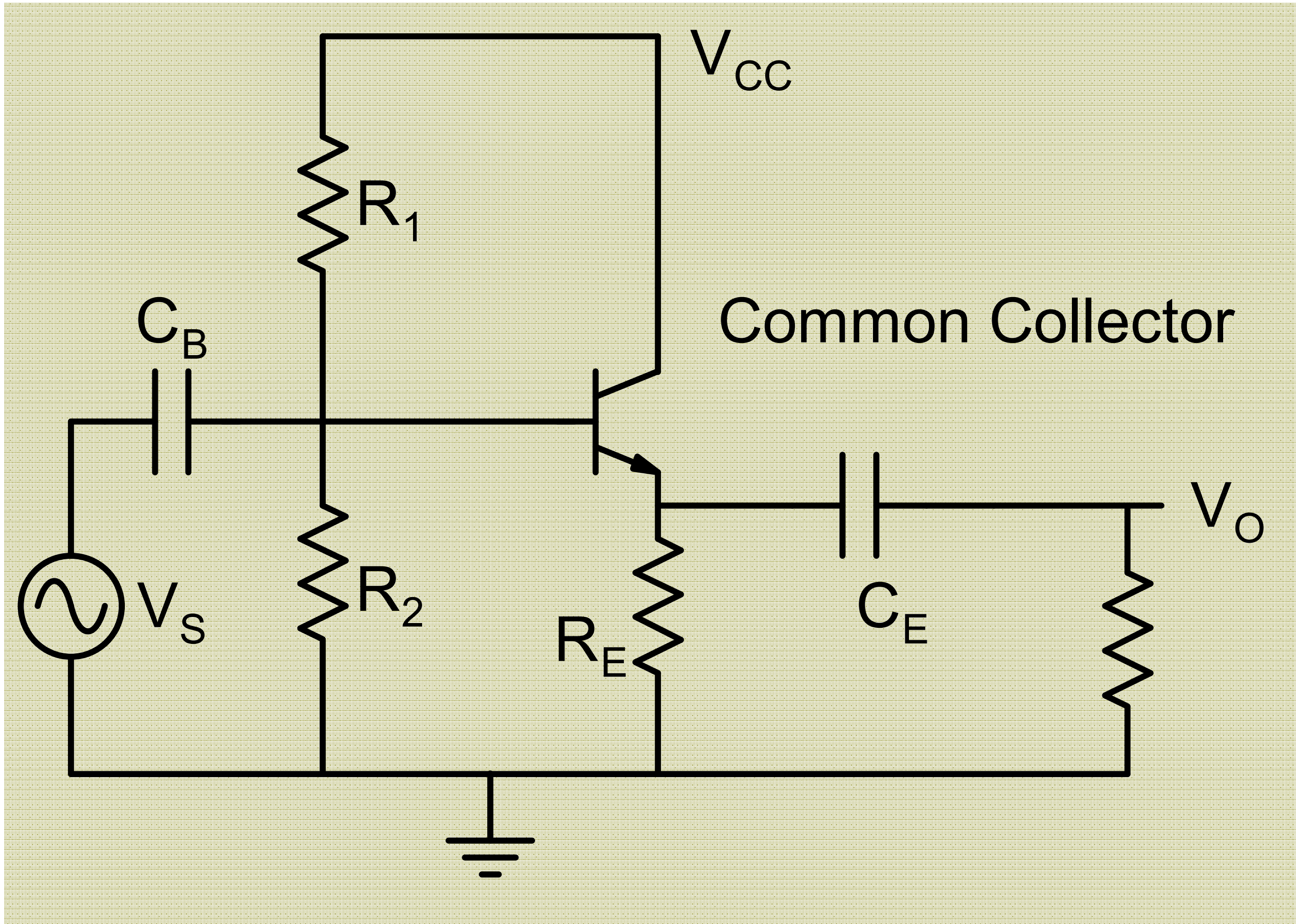
1. High current requirement

2. Very inefficient

The stages driving the output stage suffer also



Challenge: How can we drive low impedance loads without requiring excessive bias current leading to high power dissipation - and despite large current, obtain high input resistance



V_{CC}
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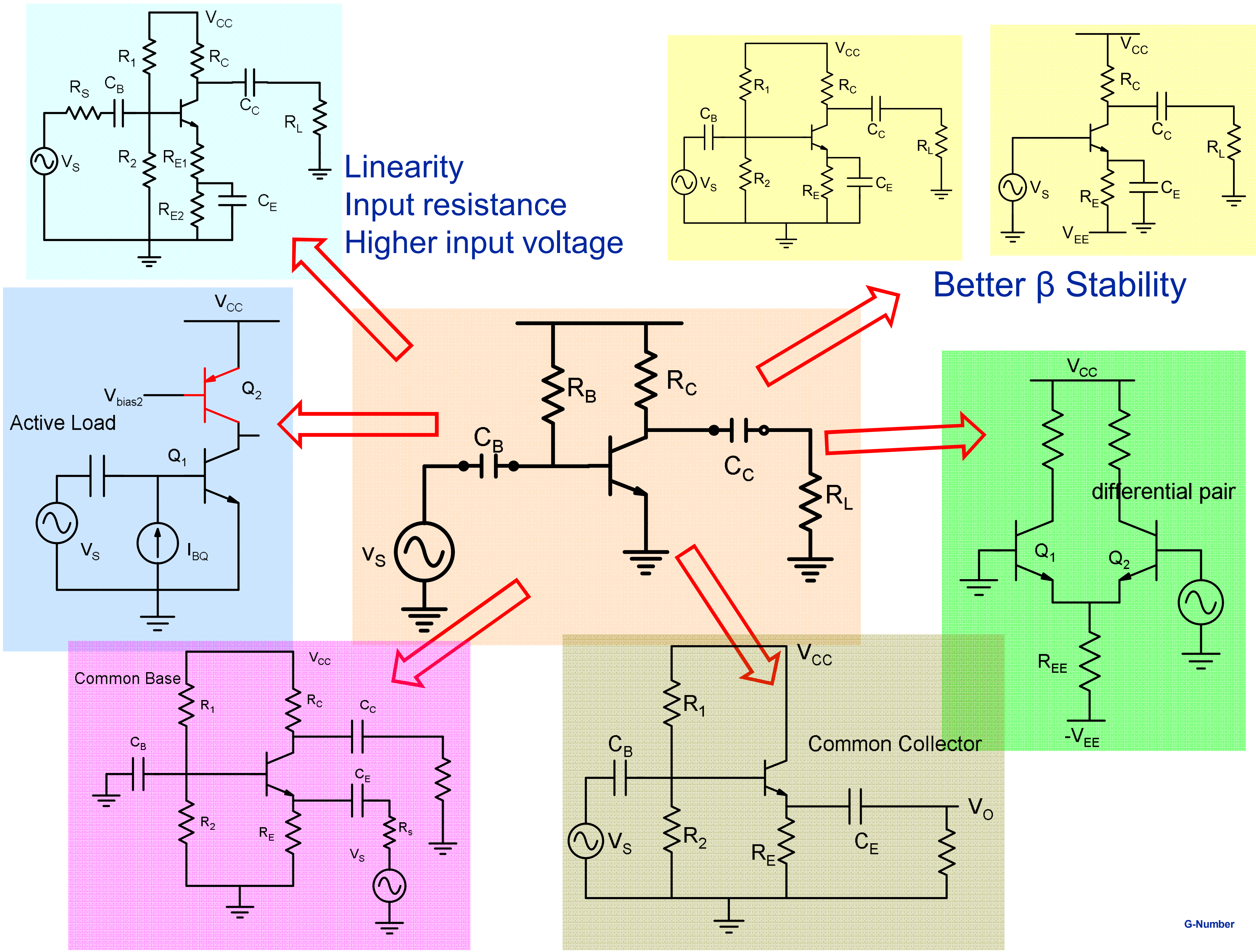
V_O
V_S
R_2
R_E
C_E



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G-Number