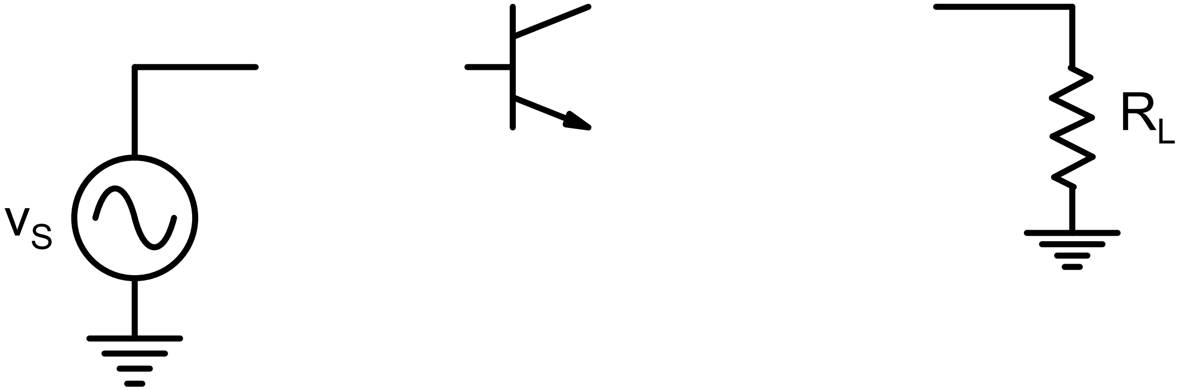
EE210: Microelectronics-I

Lecture-13 :BJT Amplifier-part-2

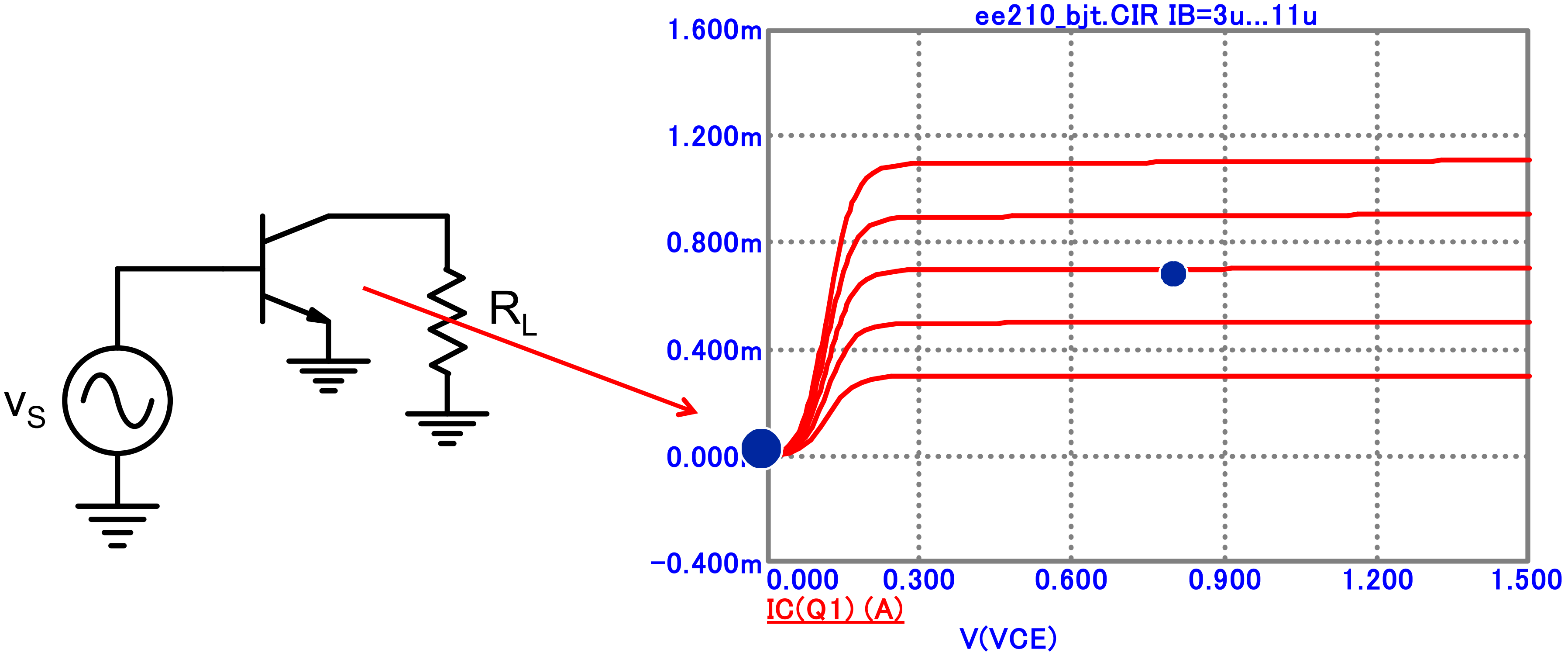
https://youtu.be/NldhPUiV5Gg

B. Mazhari
Dept. of EE, IIT Kanpur

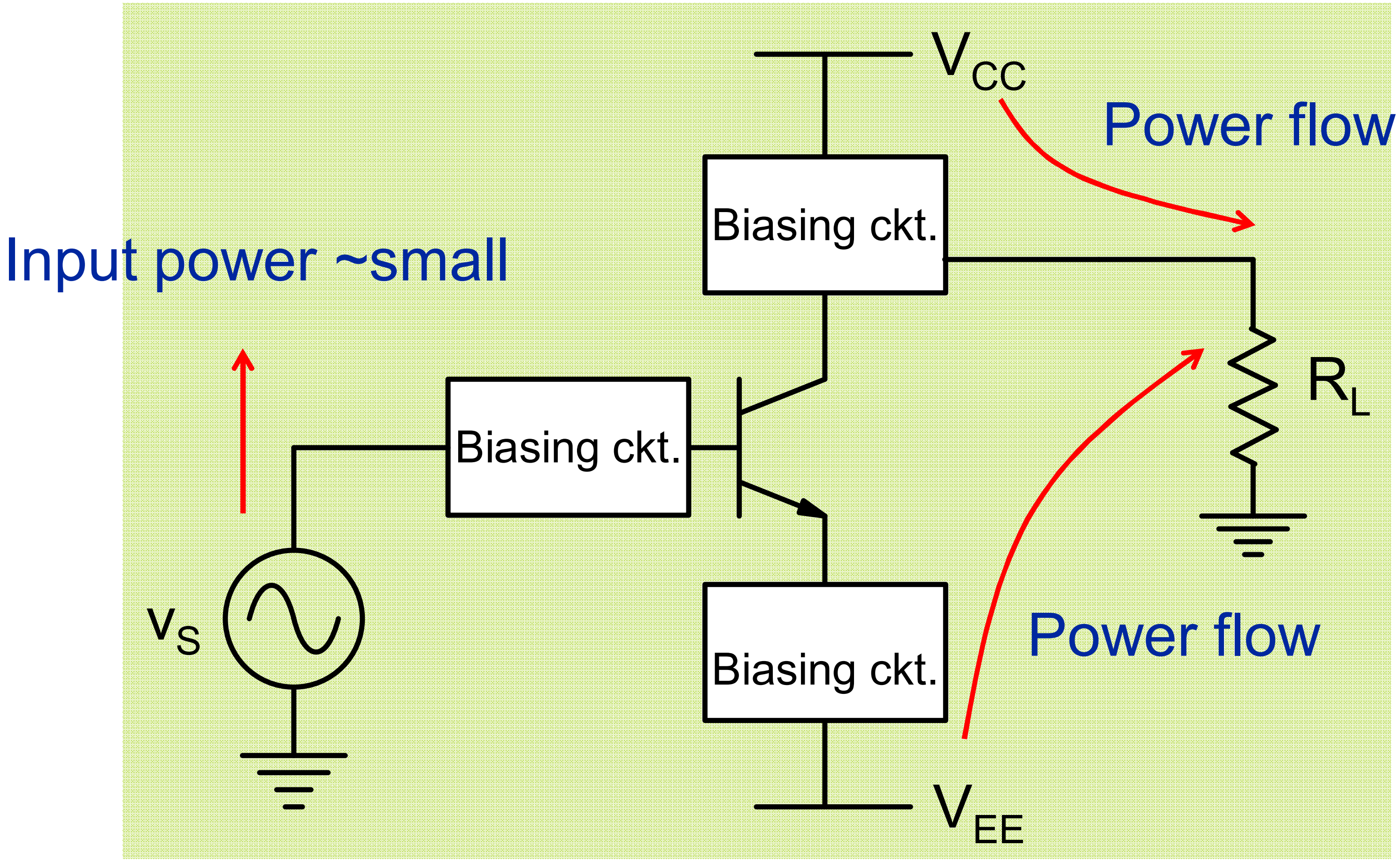
Biasing



v_S
R_L

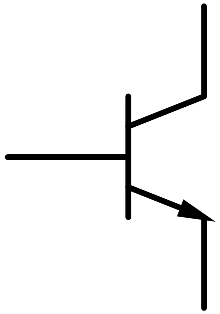


v_S
R_L
ee210_bjt.CIR IB=3u...11u
1.600m
1.200m
0.800m
0.400m
0.000
−0.400m
0.000
0.300
0.600
0.900
1.200
1.500
IC(Q1) (A)
V(VCE)



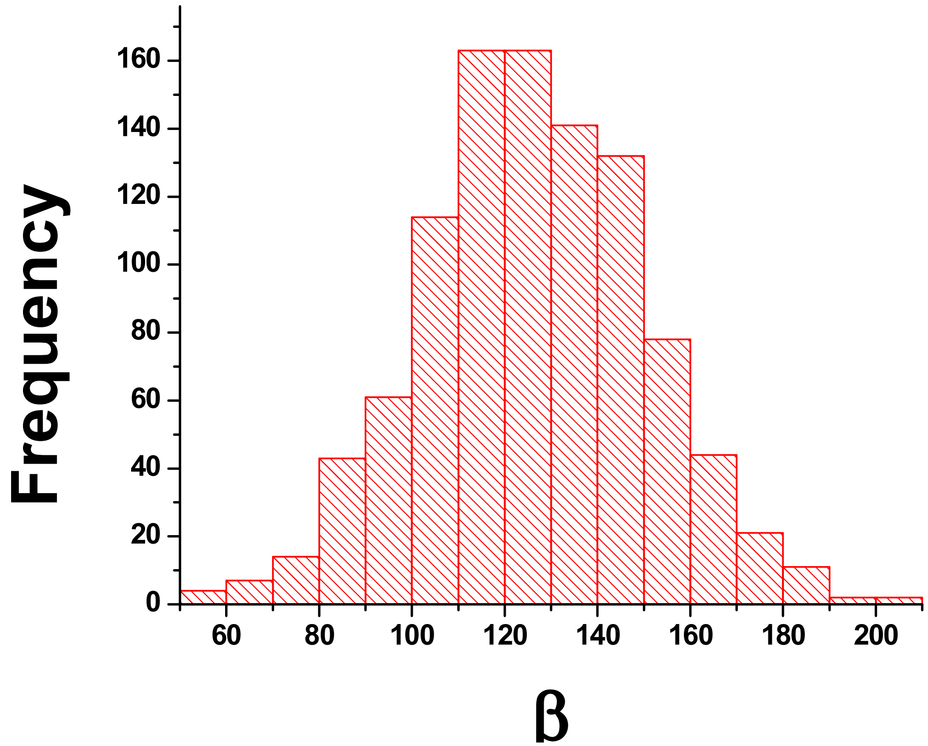
Good Biasing circuit: Bias point is stable against variations in temperature, current gain β, supply voltage etc, power efficient, low cost ….

Variations to watch out for

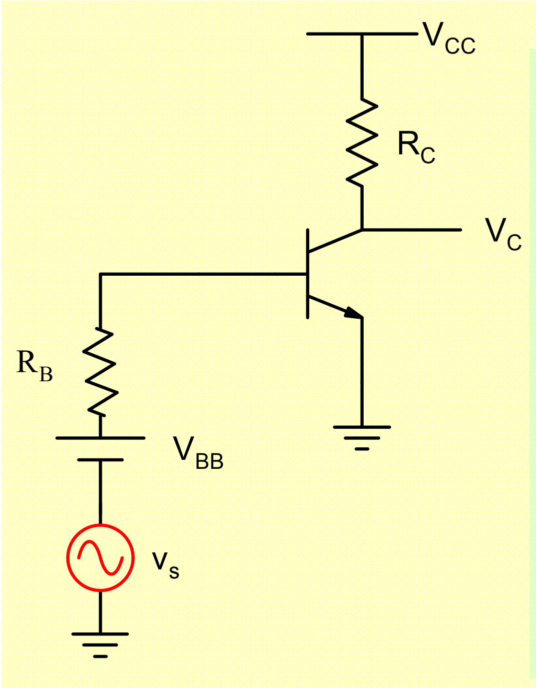


(1) $$\frac{dV_{BE}}{dT} \cong -2mV\,/^{o}\,C$$

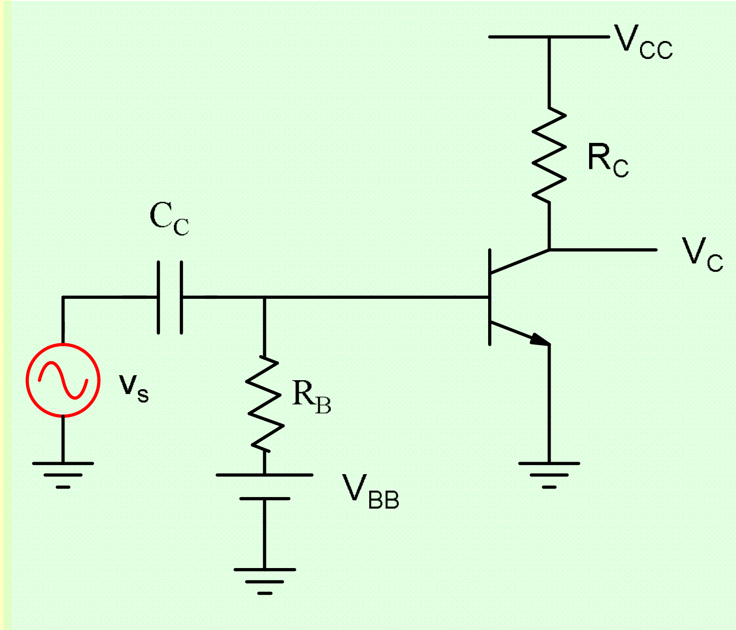
(2)



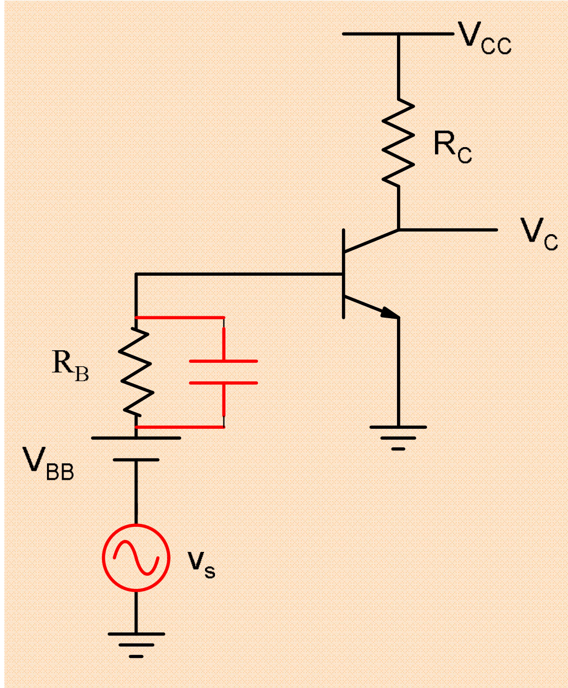
G-Number



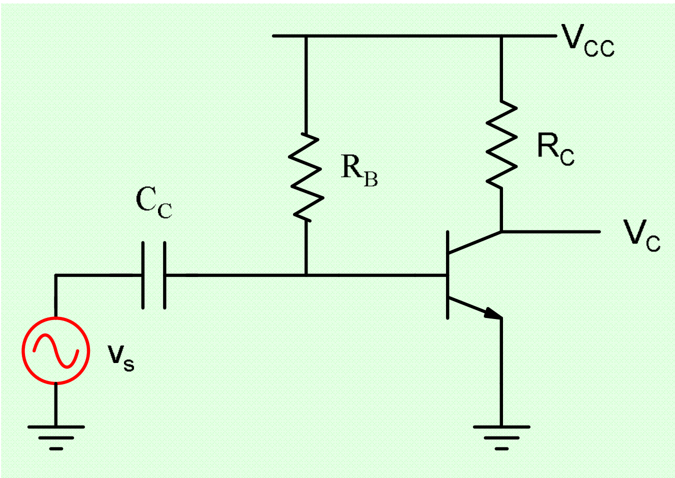
V_{CC}
R_C
V_C
R_B
V_{BB}
v_s



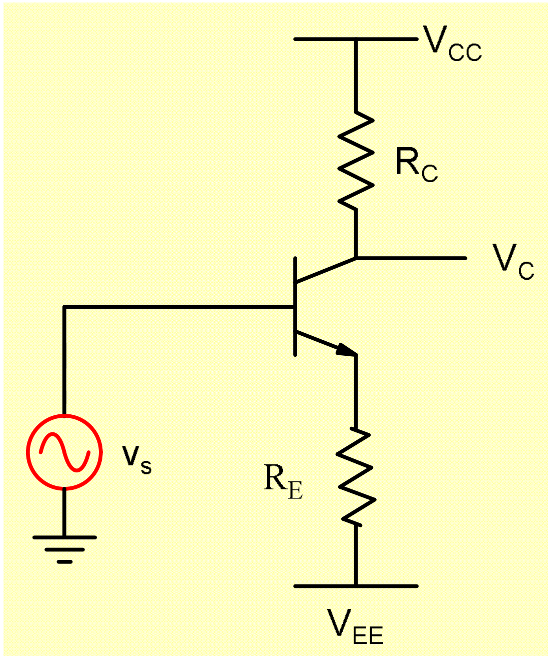
V_{CC}
R_C
C_C
V_C
v_s
R_B
V_{BB}



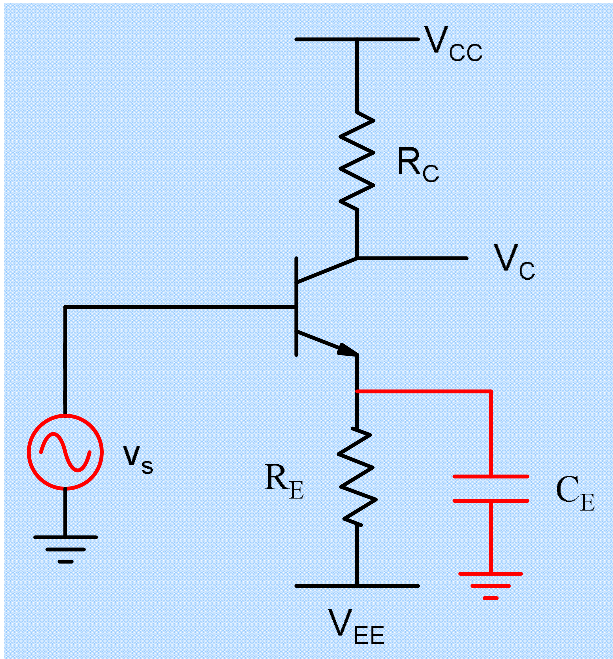
V_{CC}
R_C
V_C
R_B
V_{BB}
v_s



V_{CC}
R_B
R_C
C_C
V_C
v_s



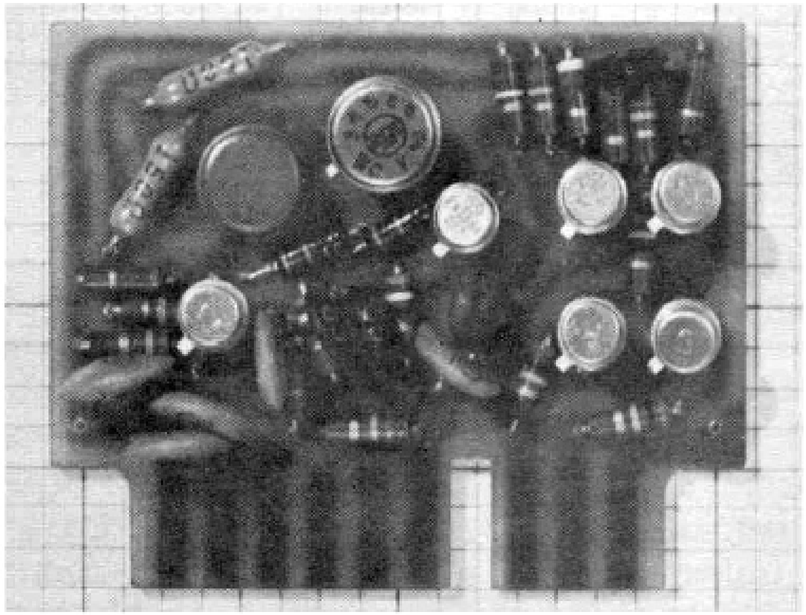
V_{CC}
R_C
V_C
v_s
R_E
V_{EE}

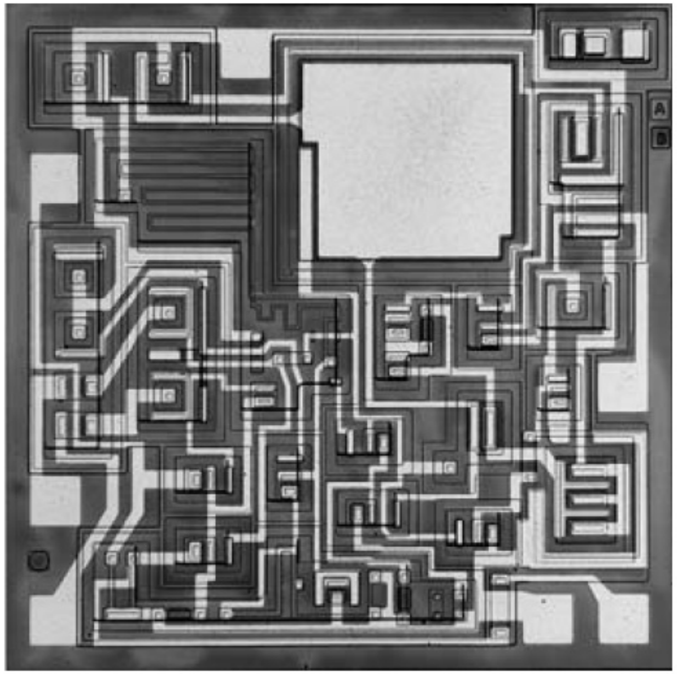


V_{CC}
R_C
V_C
v_s
R_E
C_E
V_{EE}

G-Number

Different biasing circuit for discrete and monolithic (IC) circuit implementation

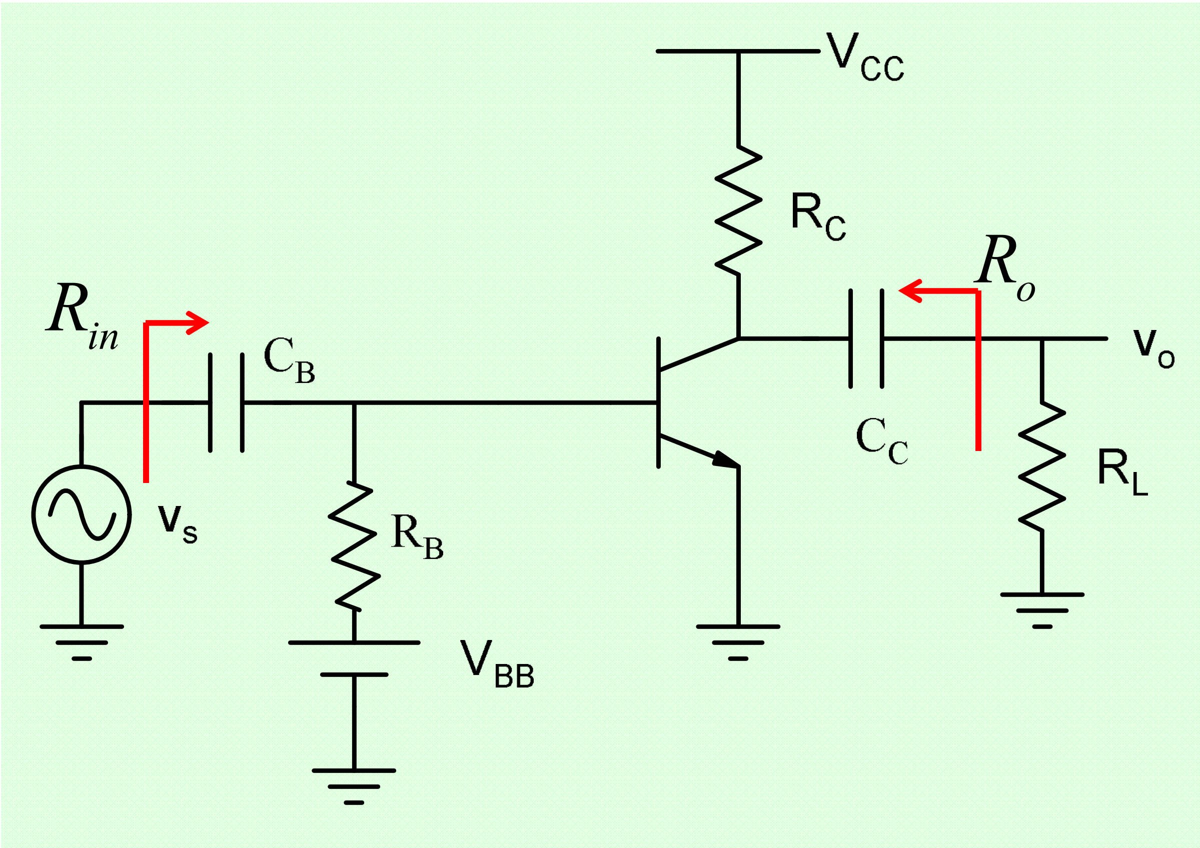




Resistors and capacitors are 'cheap' and transistors are relatively more expensive.

Higher value resistors (MΩ) are expensive and capacitors in pF range only are possible. Passive components are expensive, while transistors are cheap !

Basic Common Emitter Amplifier



$A_V \, , A_{Vo}$

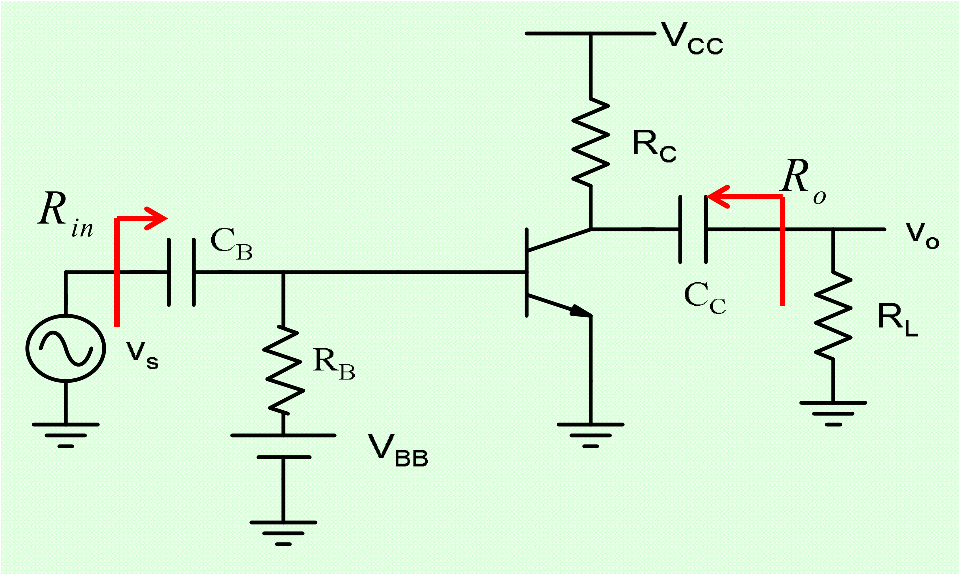
R_{in}, R_o

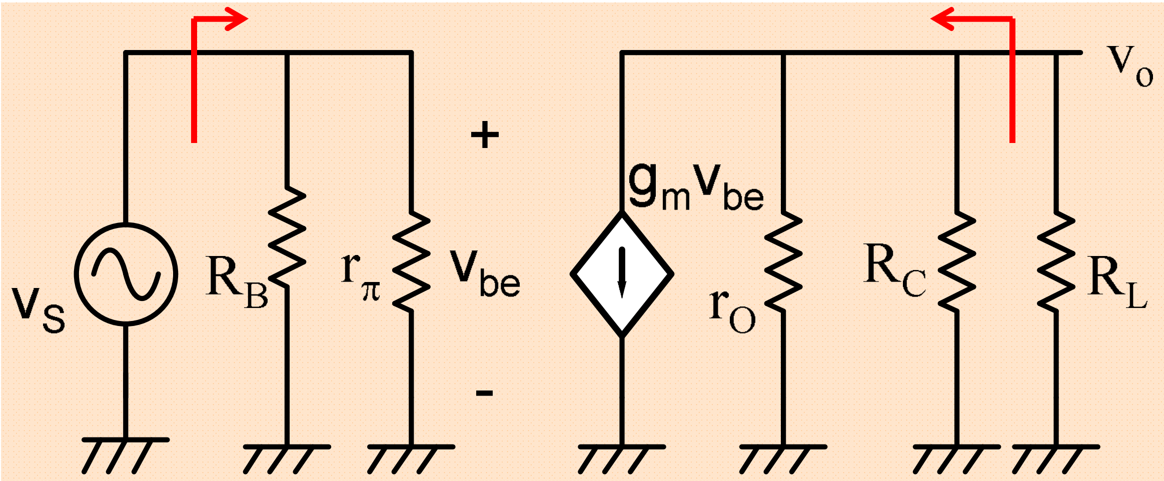
$v_o(\max.)$

f_L, f_H

S_β

Mid-frequency Analysis





$$A_V = -g_m R_C \| R_L$$

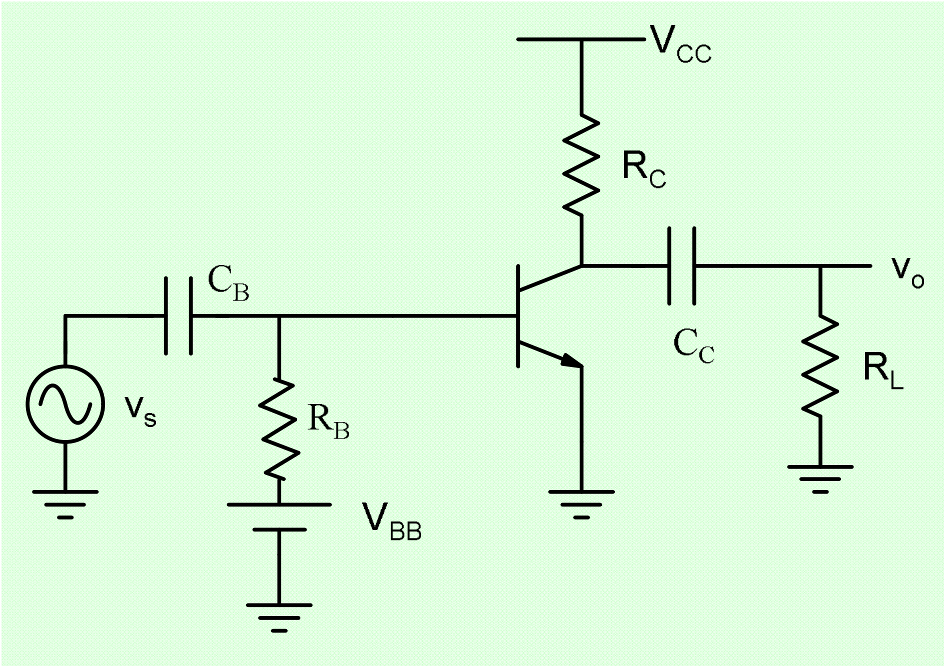
$$A_{VO} = -g_m R_C$$

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

$$R_O = R_C \| r_o$$

Voltage Gain

What is the significance of β ?



$$A_{VO} = -g_m R_C$$

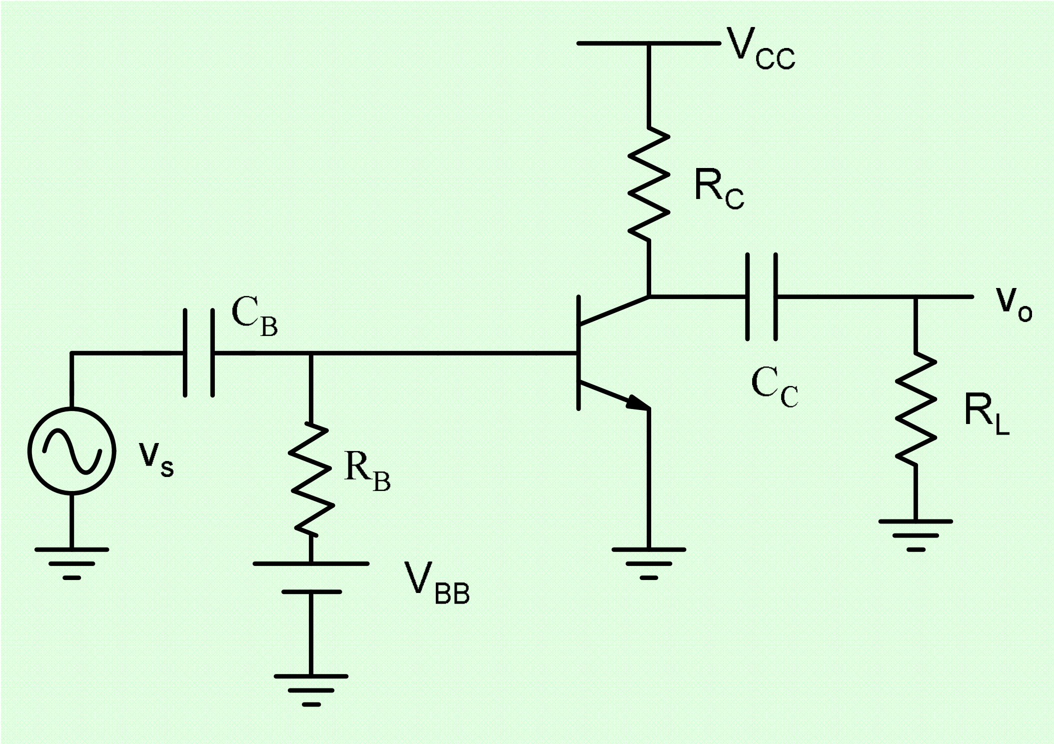
$$A_{VO} = -\frac{I_{CQ} R_C}{V_T}$$

$$I_{CQ} = \beta \times \left(\frac{V_{BB} - V_{BE}}{R_B} \right)$$

$$A_{VO} = -\beta \times \left(\frac{V_{BB} - V_{BE}}{V_T} \right) \times \left(\frac{R_C}{R_B} \right)$$

Two amplifiers of the same design, the one which has a higher value of β will provide a higher value of open circuit voltage gain

Voltage Gain

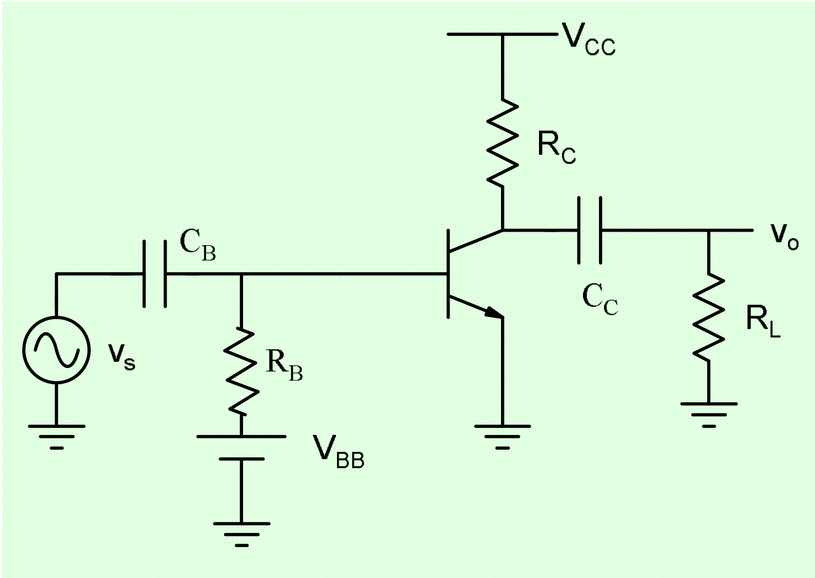


$$A_{VO} = -g_m R_C$$

$$A_{VO} = -\frac{I_{CQ} R_C}{V_T}$$

$$\boxed{A_{VO} = -\left(\frac{V_{CC} - V_{CEQ}}{V_T}\right)}$$

Two amplifiers with BJT biased at the same collector emitter voltage will have the same open circuit voltage gain irrespective of the value of β



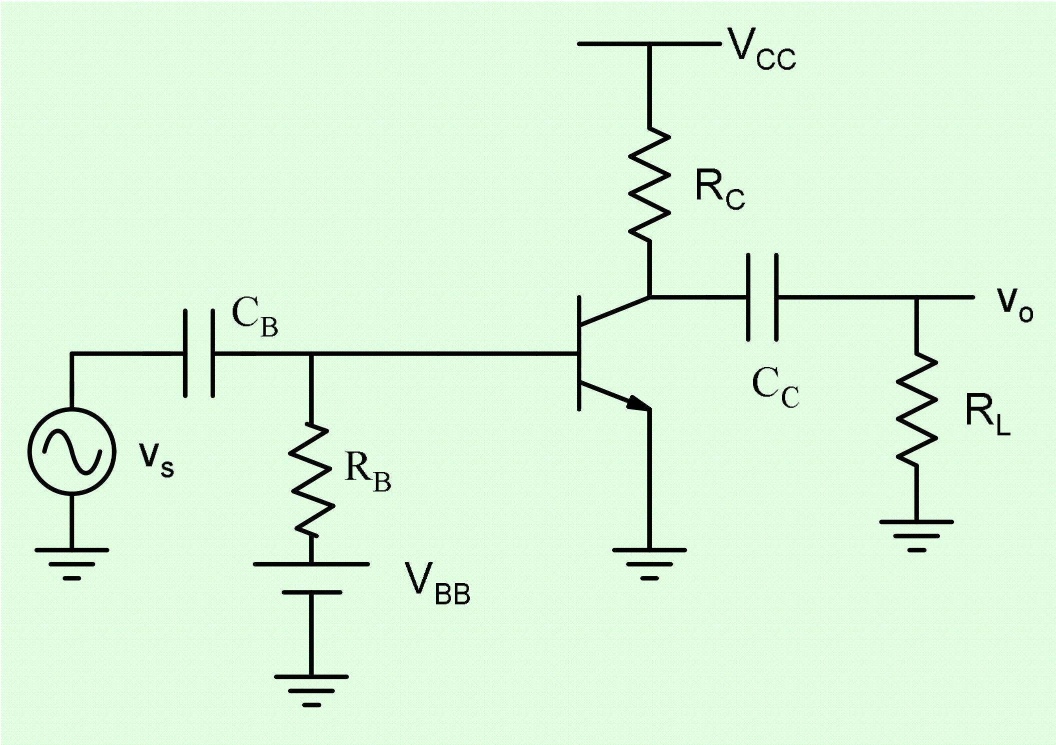
$$A_{VO} = -\beta \times \left(\frac{V_{BB} - V_{BE}}{V_T} \right) \times \left(\frac{R_C}{R_B} \right)$$

$$A_{VO} = -\left(\frac{V_{CC} - V_{CEQ}}{V_T} \right)$$

Two amplifiers of the same design, the one which has a higher value of β will provide a higher value of open circuit voltage gain

Two amplifiers with BJT biased at the same collector emitter voltage will have the same open circuit voltage gain irrespective of the value of β

Voltage Gain



$$A_{VO} = -g_m R_C$$

$$A_{VO} = -\frac{I_{CQ} R_C}{V_T}$$

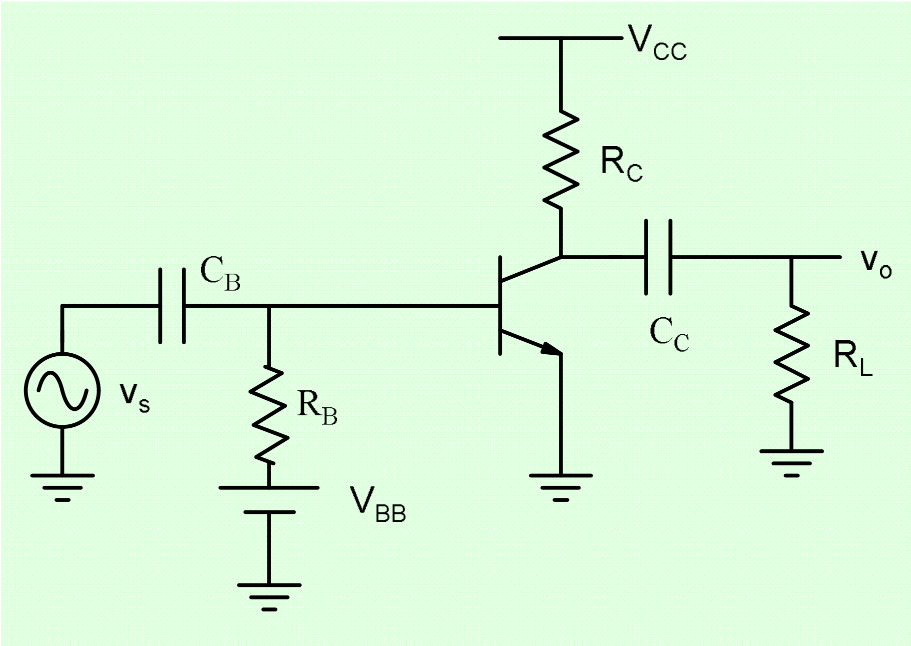
$$A_{VO} = -\left(\frac{V_{CC} - V_{CEQ}}{V_T}\right)$$

$$|A_{VO}| < \frac{V_{CC}}{V_T}$$

The upper limit of gain is limited by supply voltage

For $V_{CC} = 1.5V$ $A_V < 58$

Challenge : How do we obtain large voltage gain at low supply voltages

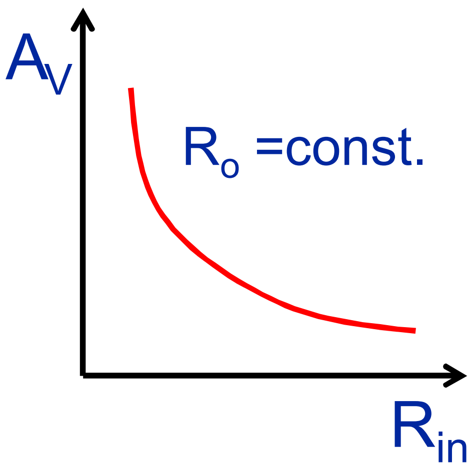


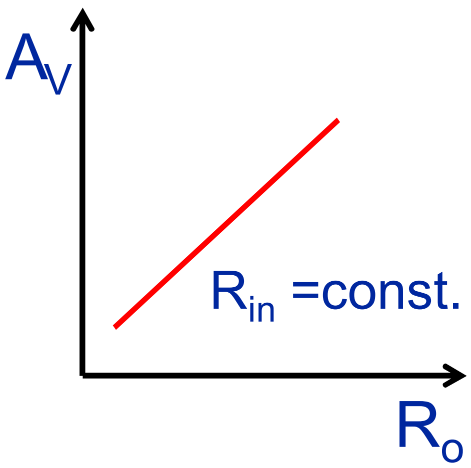
$$A_{VO} = -g_m R_C \Rightarrow |A_{VO}| = \frac{I_{CQ} R_C}{V_T}$$

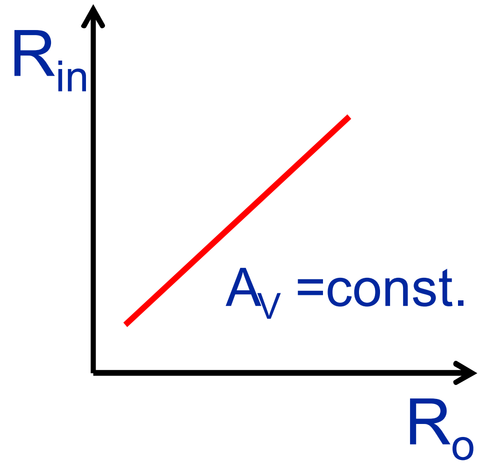
$$R_{in} = R_B \| r_\pi \sim r_\pi = \frac{V_T}{I_{CQ}} \beta$$

$$R_O = R_C \| r_o \sim R_C$$

$$\boxed{\frac{|A_{VO}| \times R_{in}}{R_O} \leq \beta}$$

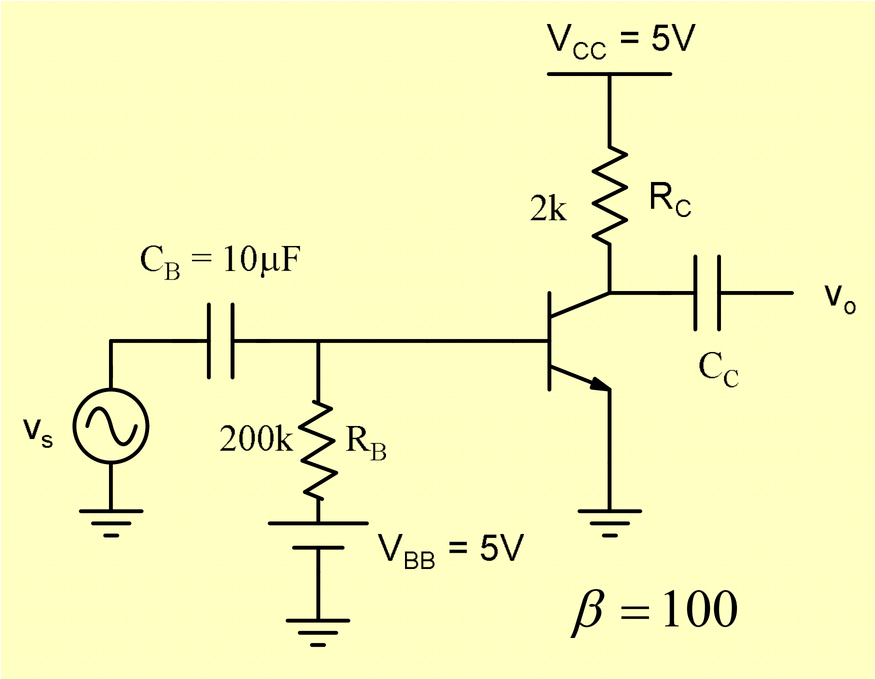






The performance of the BJT voltage amplifier is ultimately limited by β.

CE amplifier: Example-1

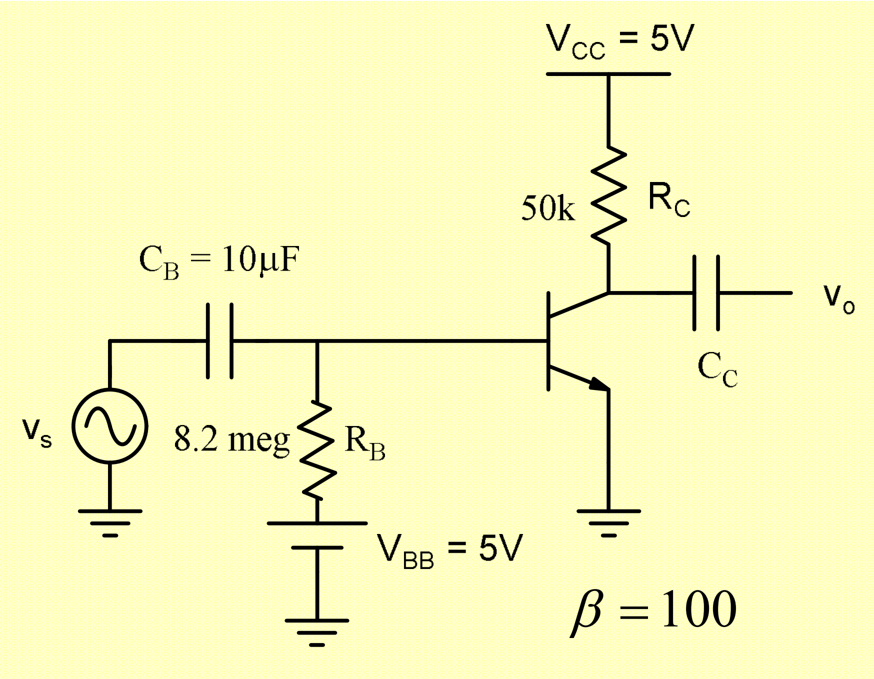


I_{CQ}=2.15mA ; V_{CEQ}=0.7V

A_V=165; R_{in} =1.2K; R_O =1.92K

Parameter	Voltage Gain	Input Resistance	Output Resistance
Value	High	Medium	Medium

CE amplifier: Example-2



$I_{CQ} = 52\mu A$; $V_{CEQ} = 2.4V$

$A_V = 100$; $R_{in} = 50K$; $R_O = 50K$

Parameter	Voltage Gain	Input Resistance	Output Resistance
Value	High	?	?

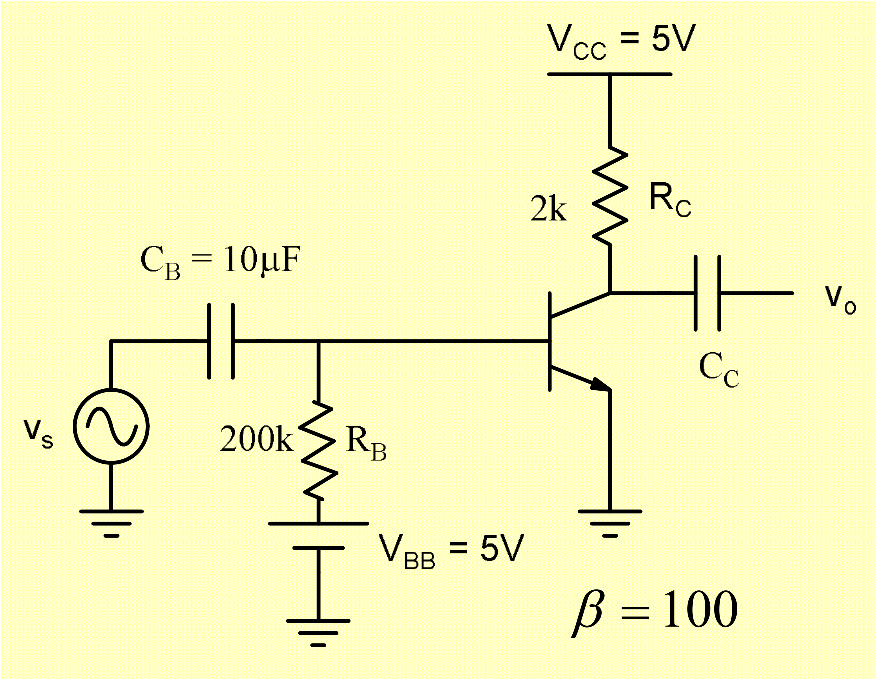
This concludes the analysis of the amplifier proper. Now, we can make the following observations:

1. The input resistance $R_{in} = r_\pi = \beta / g_m$ is moderate to low in value (typically, in the kilohm range). Obviously R_{in} is directly dependent on β and is inversely proportional to the collector bias current I_C. To obtain a higher input resistance, the bias current can be lowered, but this also lowers the gain. This is a significant design trade-off. If a much higher input resistance is desired, then a modification of the CE configuration (to be discussed shortly) or an emitter-follower stage can be employed.
2. The output resistance $R_o \simeq R_C$ is moderate to high in value (typically, in the kilohm range). Reducing R_C to lower R_o is usually not a viable proposition because the voltage gain is also reduced. Alternatively, if a very low output resistance (in the ohms to tens of ohms range) is needed, an emitter-follower stage is called for, as will be discussed in Section 6.6.6.
3. The open-circuit voltage gain A_{vo} can be high, making the CE configuration the workhorse in BJT amplifier design. Unfortunately, however, the bandwidth of the CE amplifier is severely limited. We shall study amplifier frequency response in Chapter 9.

$$\frac{\left|A_{VO}\right| \times R_{in}}{R_O} \leq \beta$$

Sedra and Smith

Class Quiz-3 L 2/2/17



I_{CQ}=2.15mA ; V_{CEQ}=0.7V

A_V=165; R_{in} =1.2K; R_O =1.92K

Suppose I_{CQ} is halved by suitably changing RB while leaving every other component unchanged. What would be the new values of gain, input and output resistance?

G-Number