ESC201T : Introduction to Electronics

Lecture 26: Amplifiers-2

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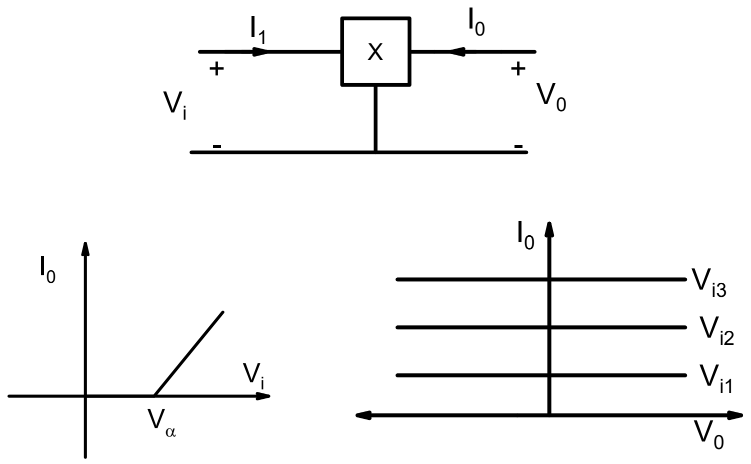
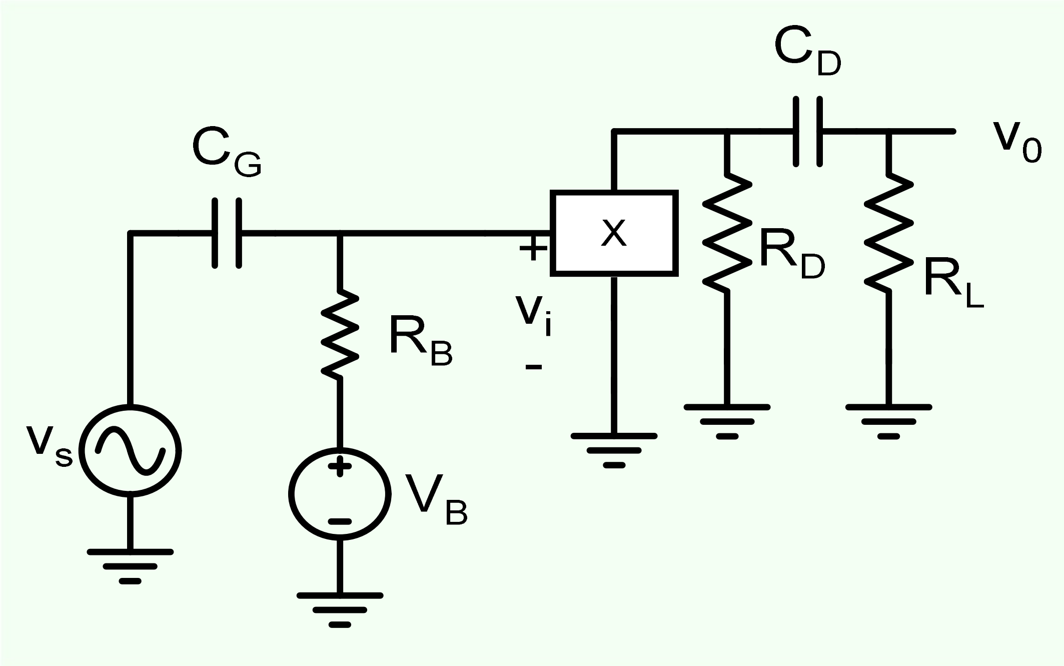
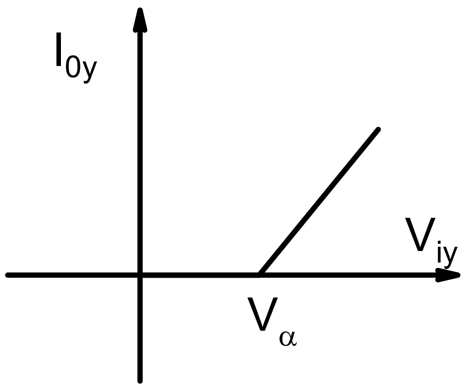
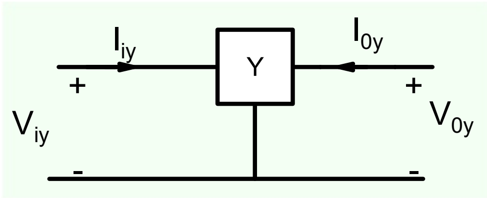
Amplifier Schematic





Device Y



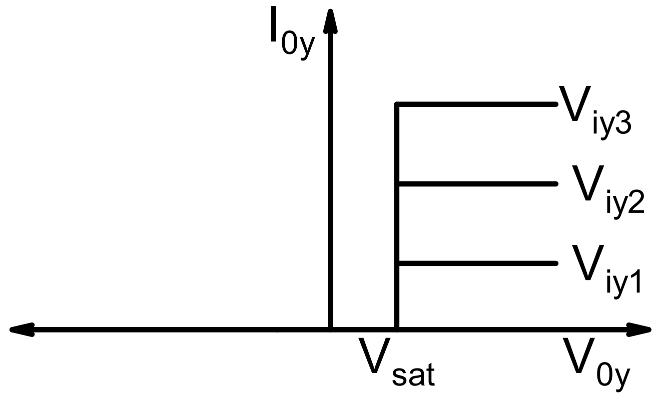


$$I_{oy} = 0 \text{ for } V_{OY} < V_{sat}$$

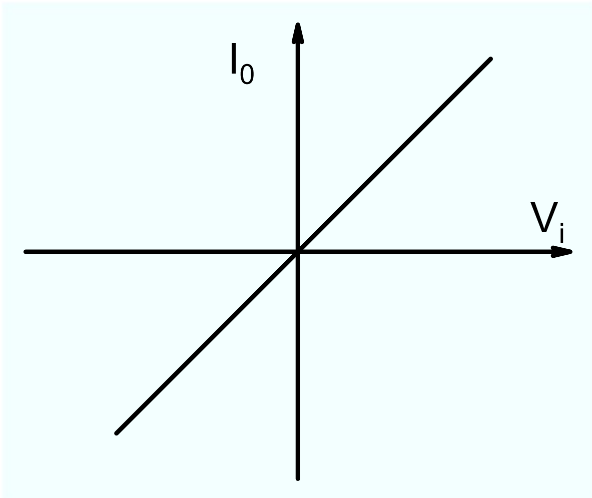
for $V_{OY} \geq V_{sat}$

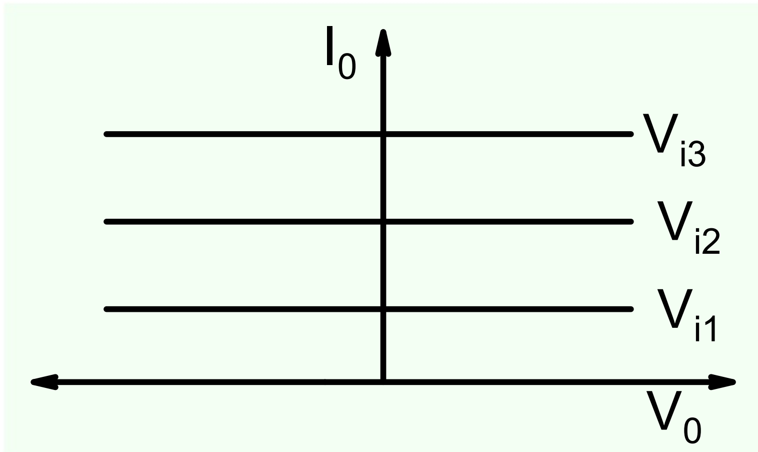
$$I_{oy} = 0 \qquad \text{for } V_{iy} \leq V_{\alpha}$$

$$= g_m \times (V_{iy} - V_{\alpha}) \quad \text{for } V_{iy} > V_{\alpha}$$

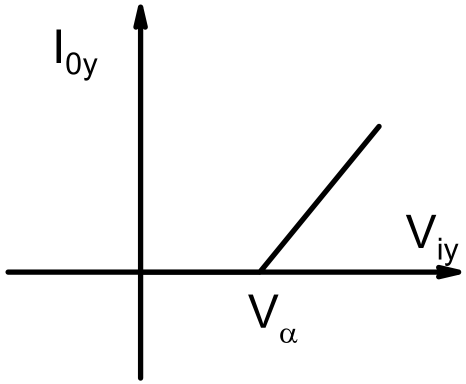


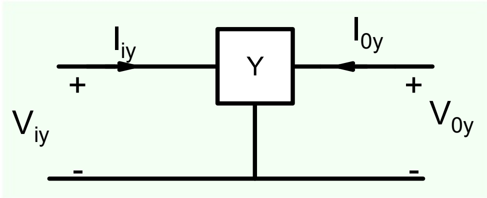
Ideal Characteristics





How do we use device Y to make an amplifier?



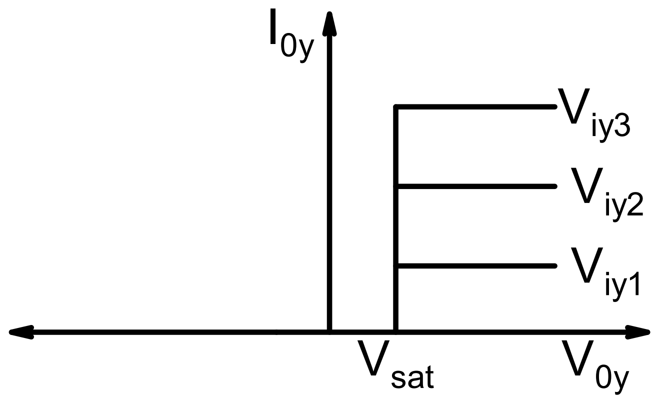


$I_{oy} = 0$ for $V_{OY} < V_{sat}$

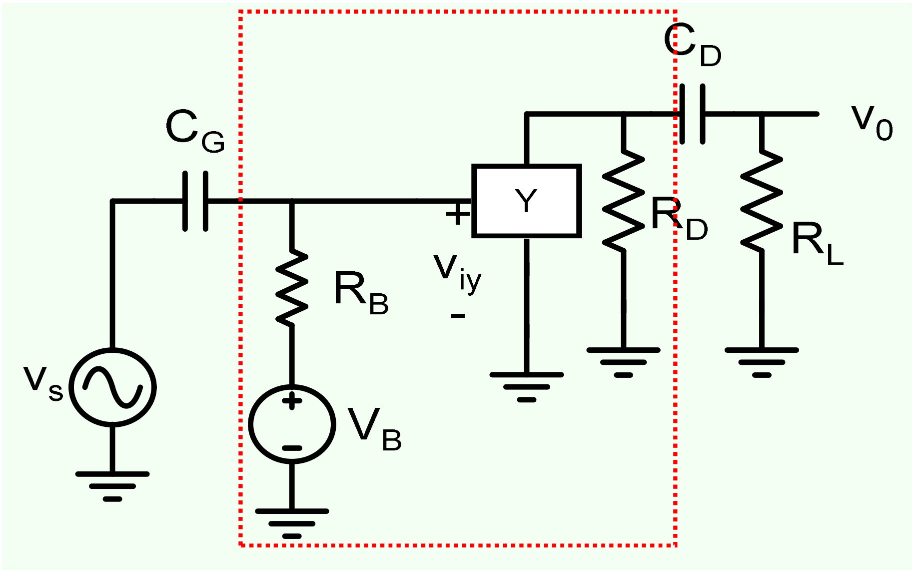
for $V_{OY} \geq V_{sat}$

$I_{oy} = 0$ for $V_{iy} \leq V_\alpha$

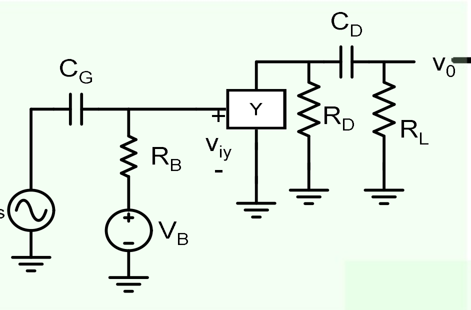
$= g_m \times (V_{iy} - V_\alpha)$ for $V_{iy} > V_\alpha$

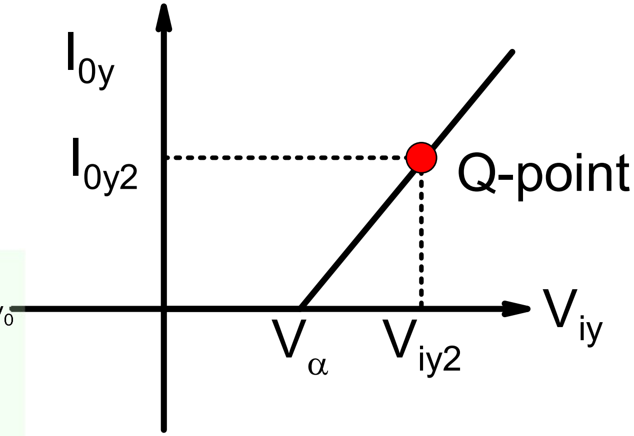


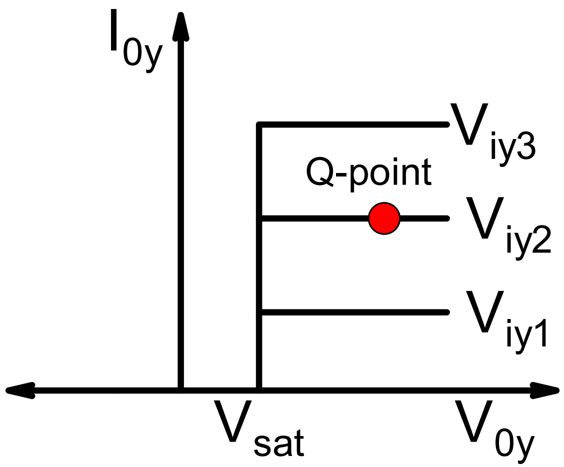
Will the earlier solution work?



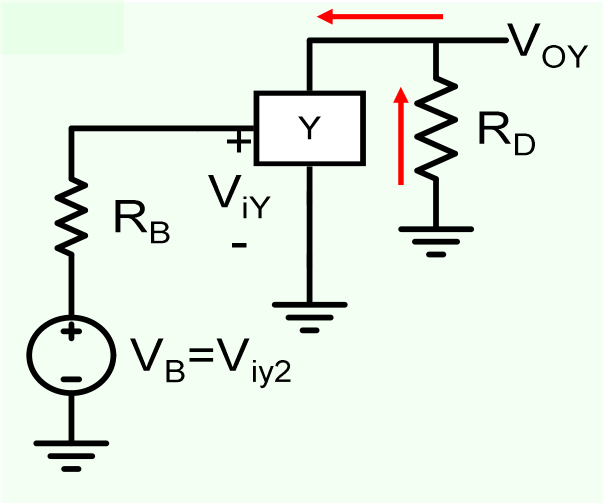
The purpose of biasing network is to operate the device in a region which resembles ideal transistor

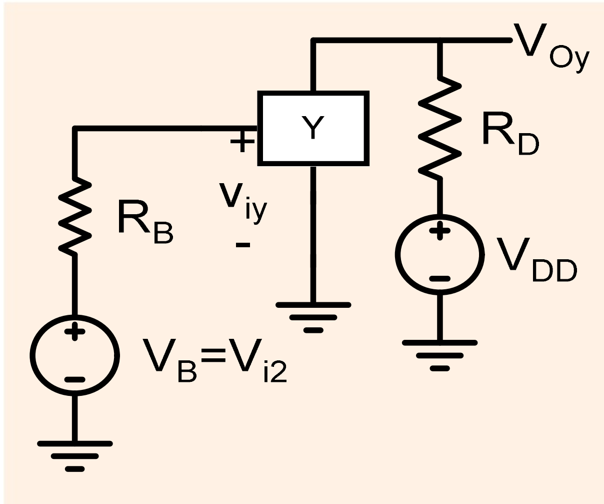




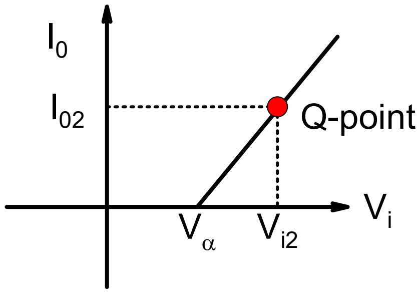


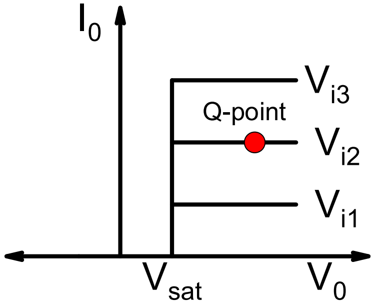
V_{Oy} = -ve which is not possible

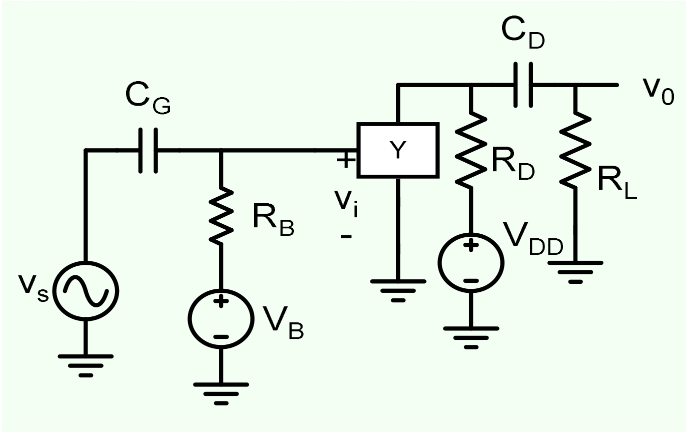


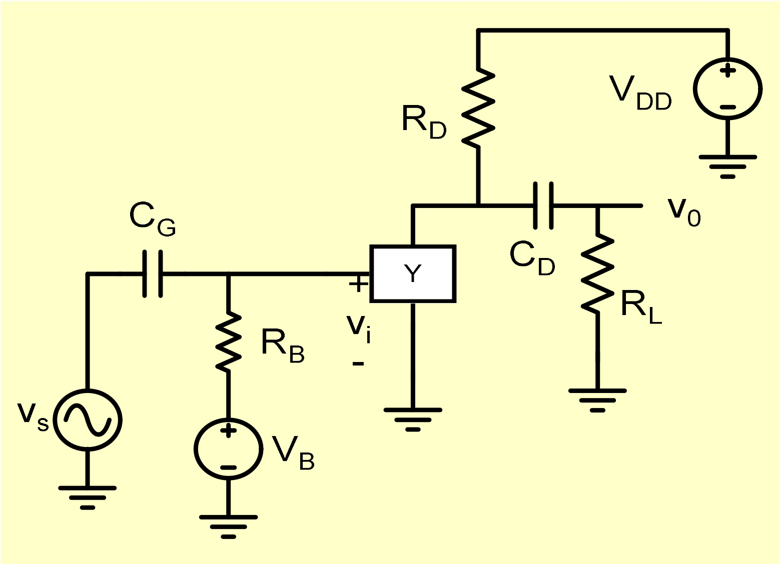


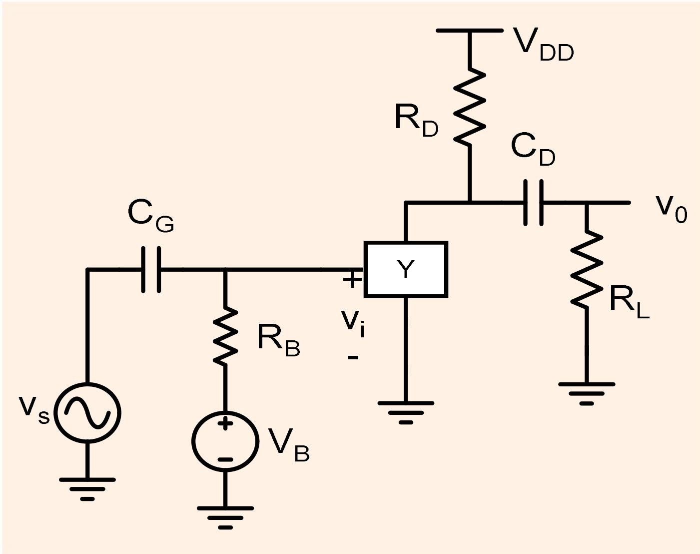
Revised Amplifier Schematic



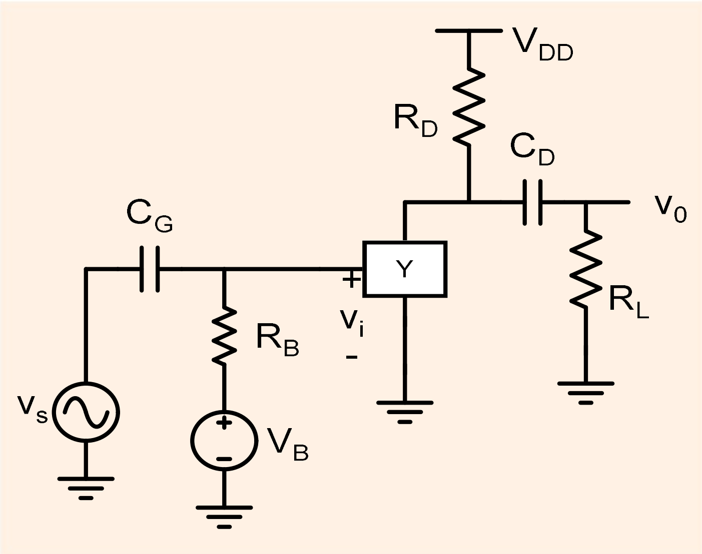


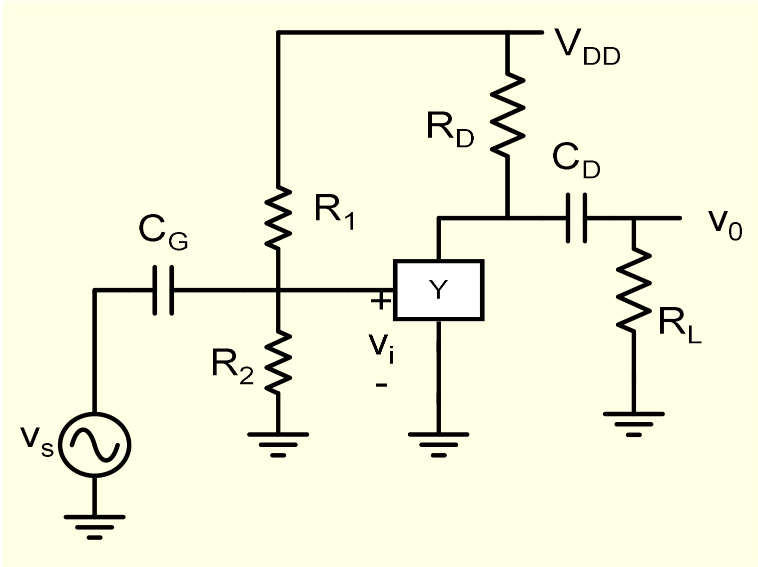




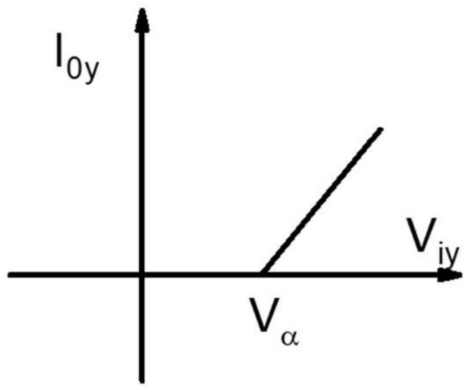


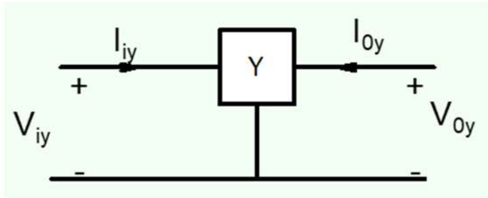
Can we Bias using one dc voltage source only?





$$V_B = V_{DD} \times \frac{R_2}{R_1 + R_2}$$





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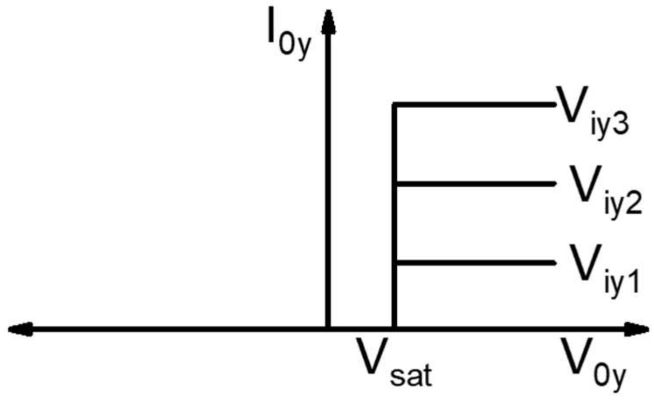
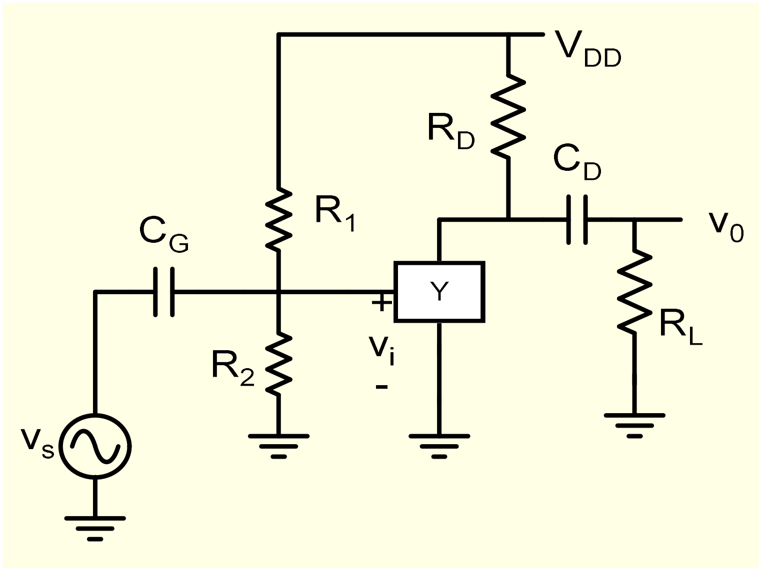
$$\text{for } V_{OY} \geq V_{sat}$$

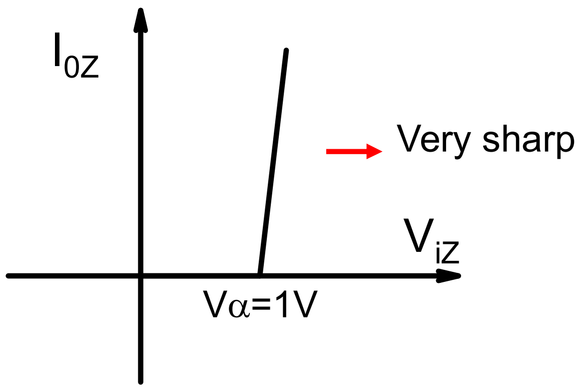
$$I_{oy} = 0 \qquad \text{for } V_{iy} \leq V_{\alpha}$$

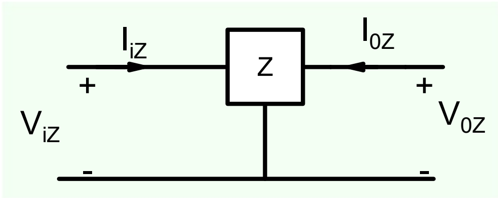
$$= g_m \times (V_{iy} - V_{\alpha}) \text{ for } V_{iy} > V_{\alpha}$$



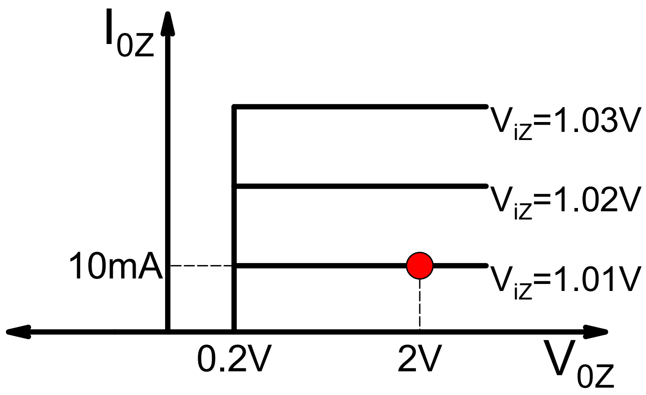


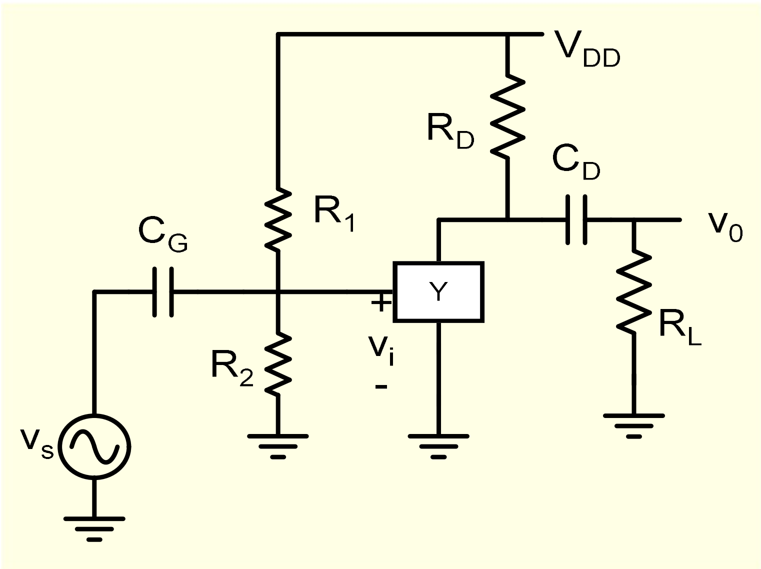
Device Z





$$I_{oz} = 0 \text{ for } V_{OZ} < 0.2V$$
$$\text{for } V_{OZ} \geq 0.2$$
$$I_{oz} = 0 \qquad \text{for } V_{iz} \leq 1V$$
$$= 1\times(V_{iz} - 1V) \ \text{ for } V_{iz} > 1V$$





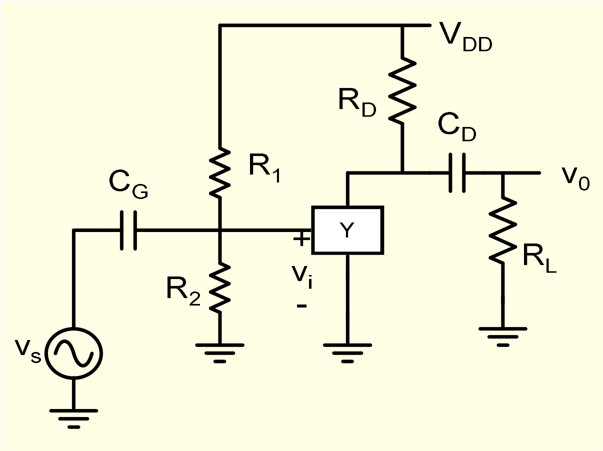
Circuit is very sensitive to variations in resistor values, power supply, device parameters such as $V\alpha$

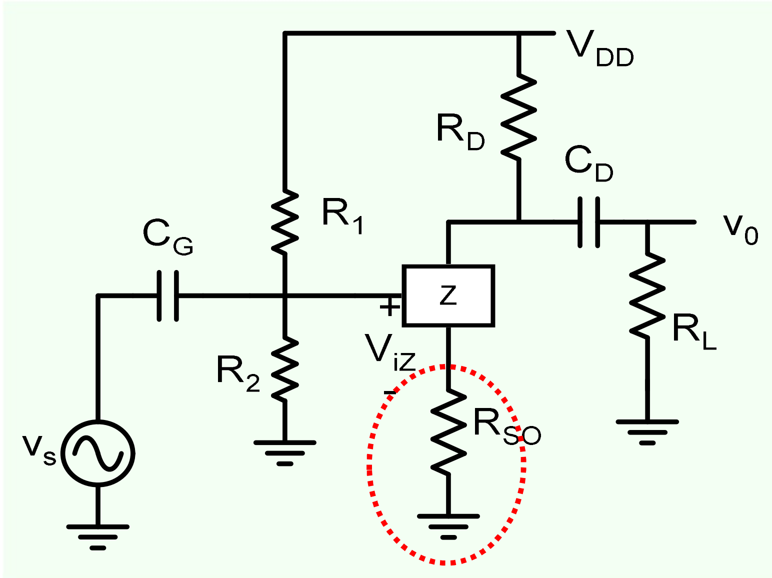
$$V_{DD} = 5V; R_2 = 1K; R_1 = 3.95K$$
$$\Rightarrow V_{iz} = 1.01 \Rightarrow I_{OZ} = 10mA$$

$$V_{DD} = 5V; R_2 = 0.99K; R_1 = 3.95K$$
$$\Rightarrow V_{iz} = 1.002 \Rightarrow I_{OZ} = 1.9mA$$

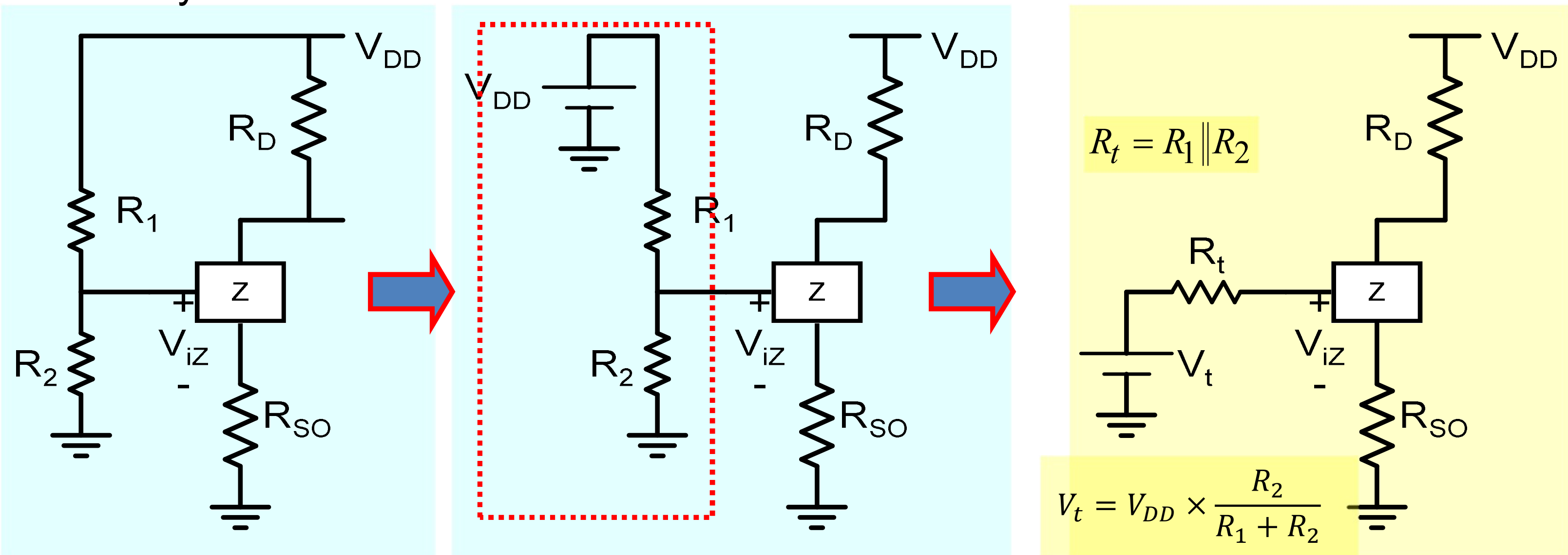
$$V_{DD} = 5V; R_2 = 0.98K; R_1 = 3.95K$$
$$\Rightarrow V_{iz} = 0.994V \Rightarrow I_{OZ} = 0$$

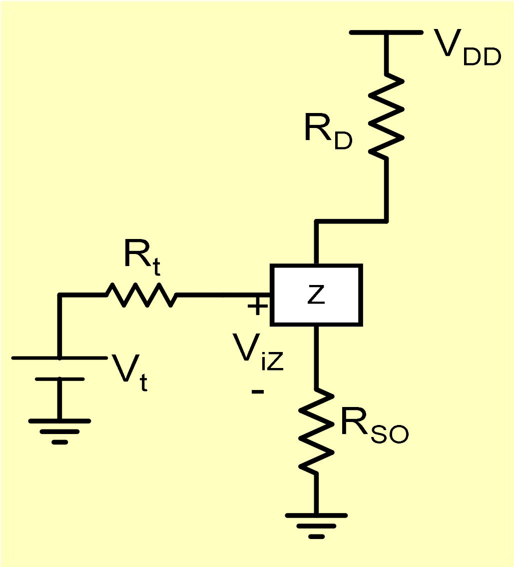
Solution

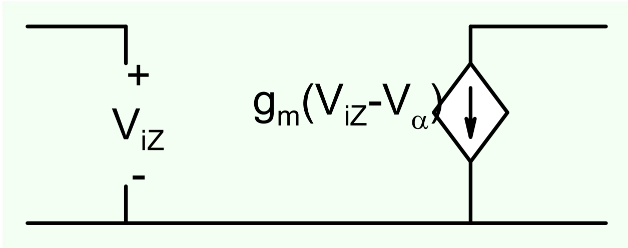


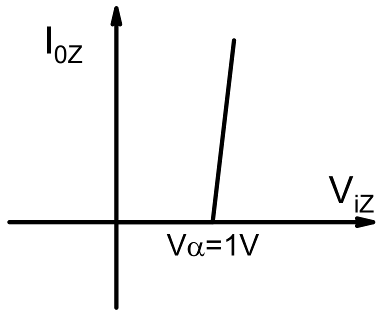


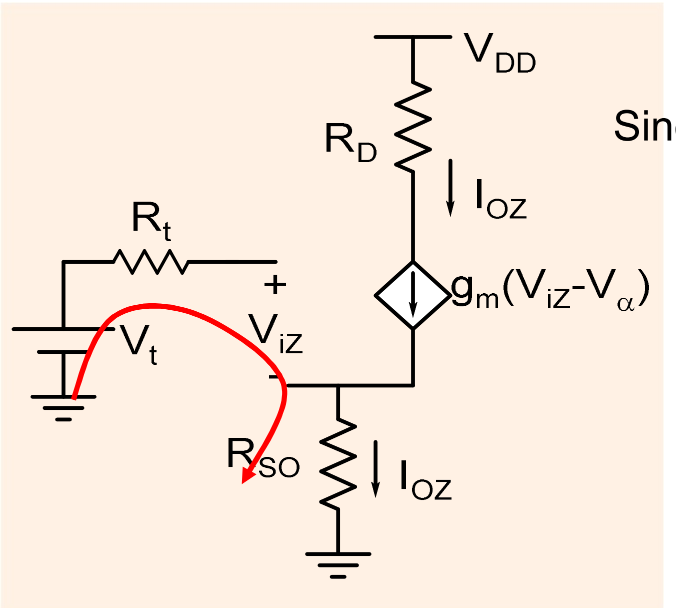
dc Analysis











$$-V_t + 0 \times R_t + V_{iz} + I_{OZ} R_{SO} = 0$$

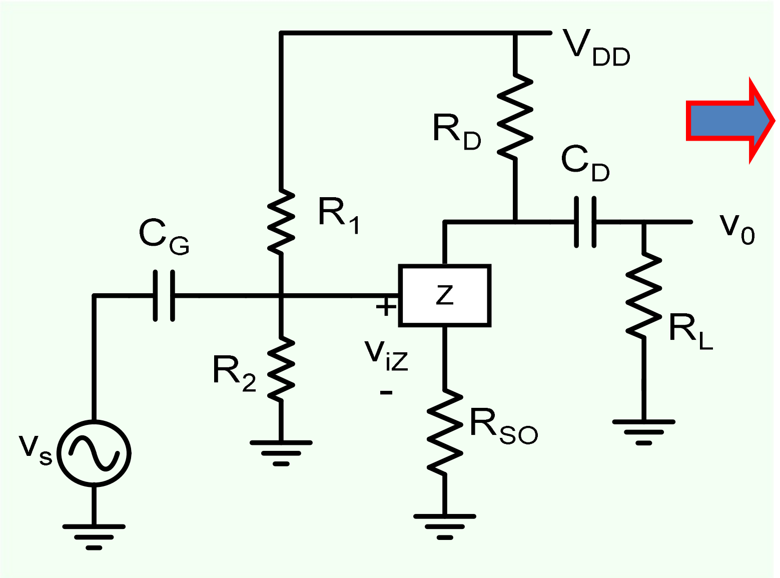
Since I_{oZ} vs. V_{iZ} characteristics is very sharp, $V_{iZ} \sim V_{\alpha} = 1V$

$$I_{OZ} \cong \frac{V_t - V_\alpha}{R_{SO}}$$

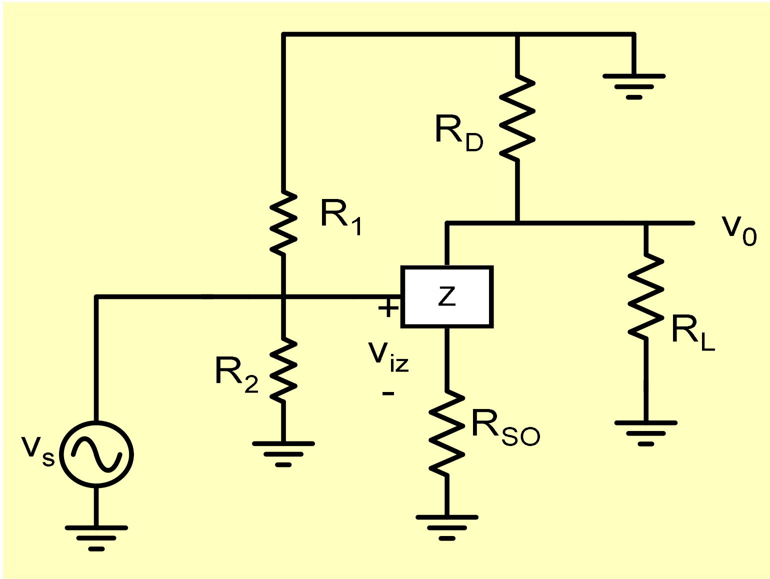
If V_t changes by 1% due to variation in resistor values then the change in output current is proportional.

Circuit is much less sensitive to variations in circuit parameters

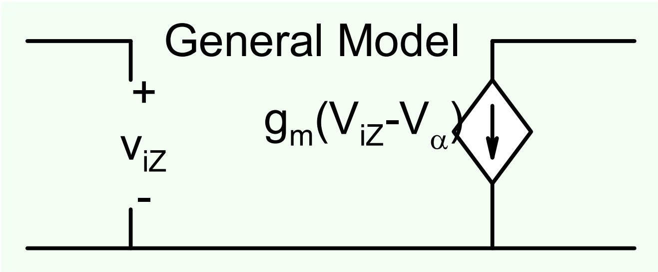
Ac analysis



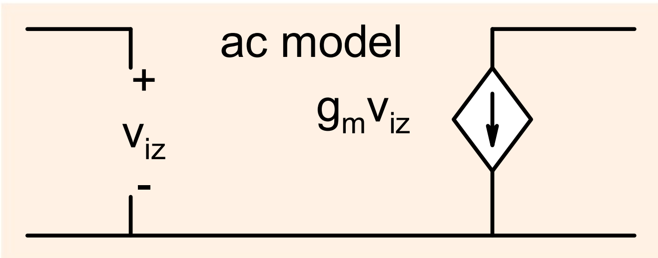
V_{DD}
R_D
C_D
R_1
C_G
v_0
z
+
v_{iZ}
-
R_L
R_2
R_{SO}
v_s



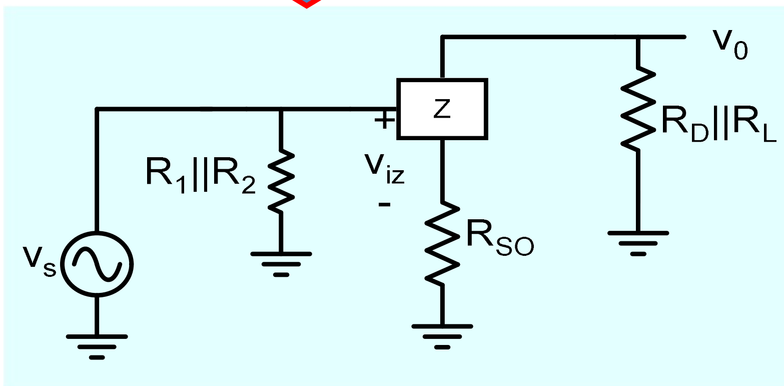
R_D
R_1
v_0
z
+
v_{iz}
-
R_2
R_L
R_{SO}
v_s



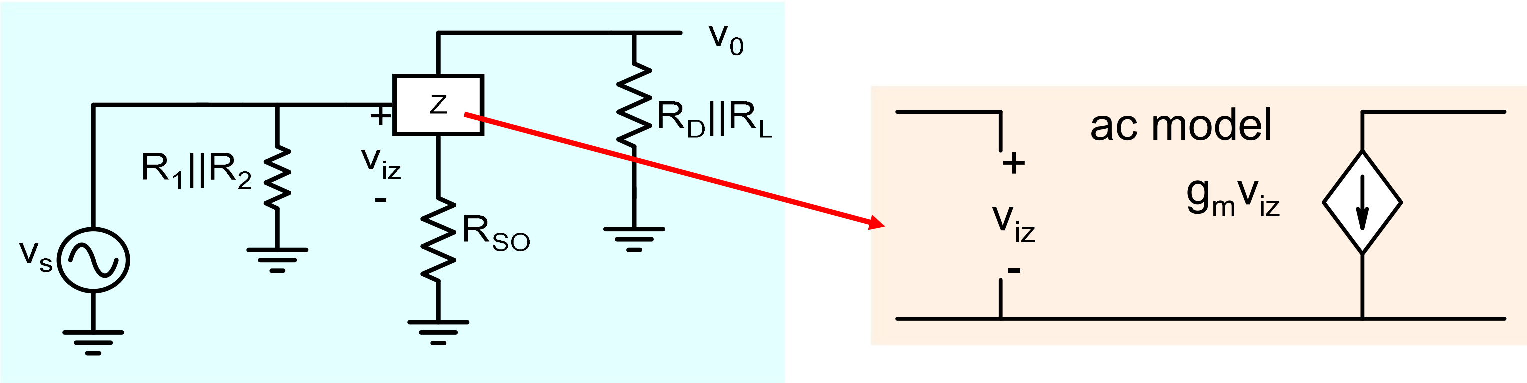
General Model
+
v_{iZ}
-
$g_m(V_{iZ}-V_{\alpha})$

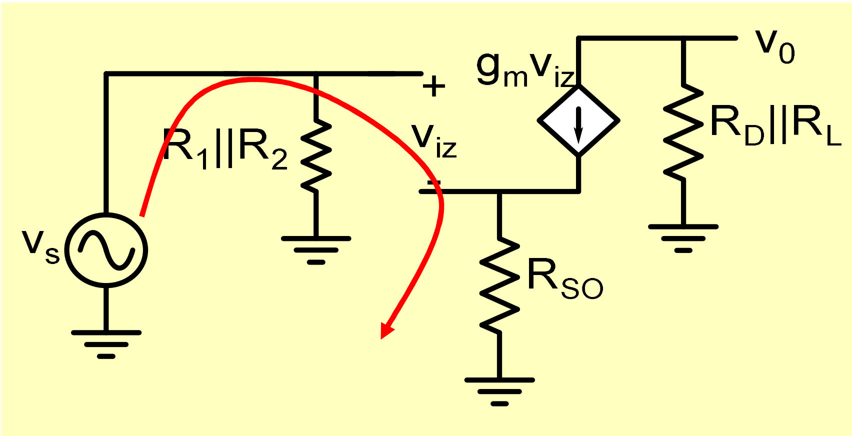


ac model
+
v_{iz}
-
$g_m v_{iz}$



v_0
z
+
$R_D||R_L$
$R_1||R_2$
v_{iz}
-
R_{SO}
v_s

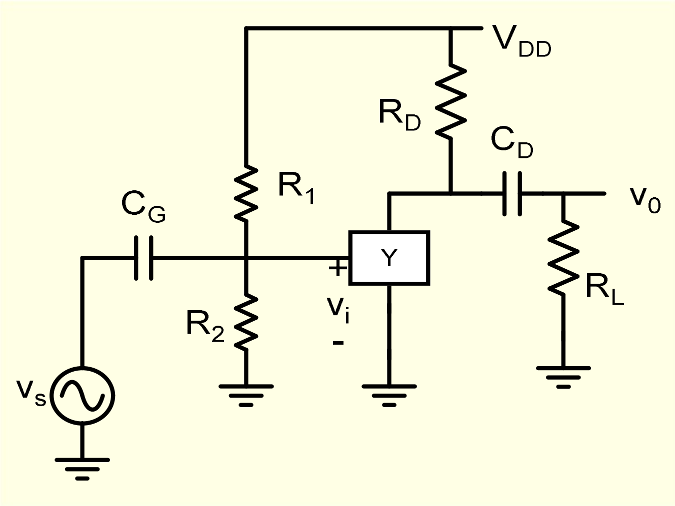




$$v_S = v_{iz} + g_m v_{iz} R_{SO}$$

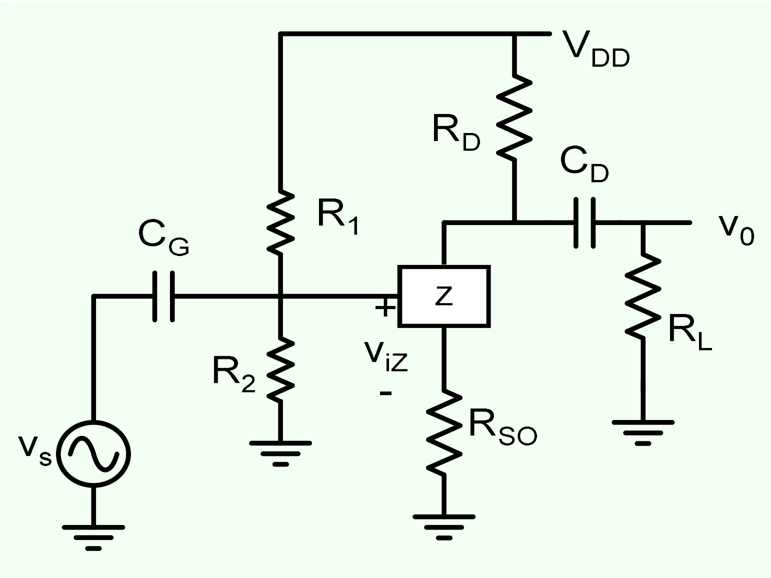
$$v_O = -g_m \times R_D \| R_L$$

$$A_V = \frac{v_o}{v_s} = -\frac{g_m R_D \| R_L}{1 + g_m R_{SO}}$$



Circuit is very sensitive to variations in resistor values, power supply, device parameters such as Vα

$$A_V = \frac{v_o}{v_s} = -g_m R_D \| R_L$$

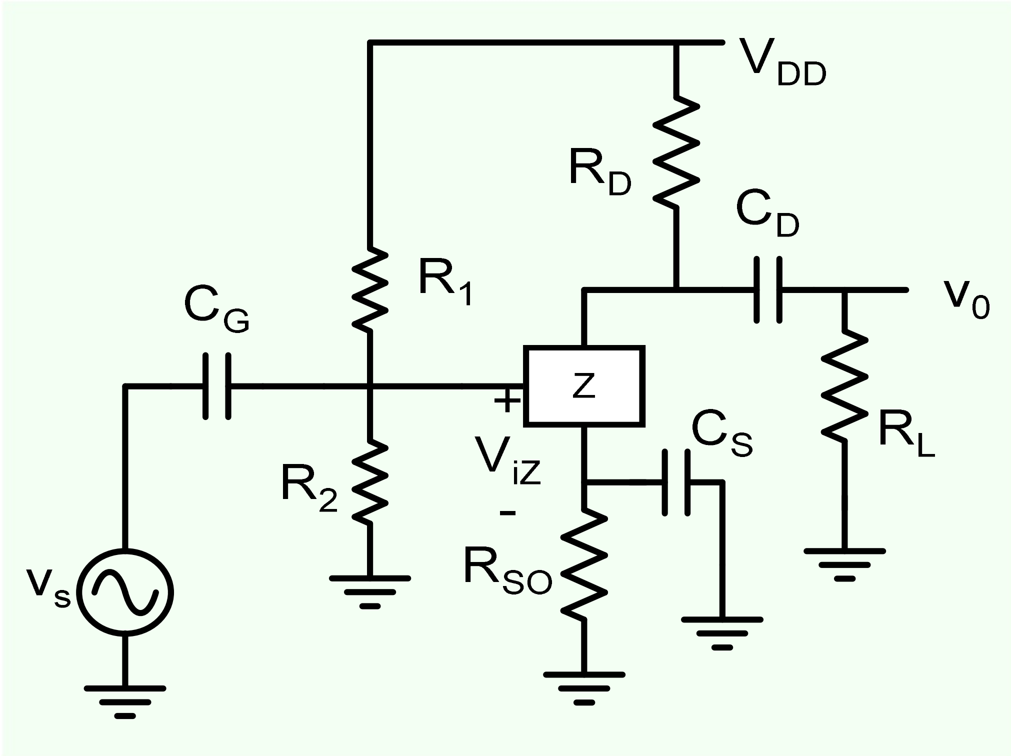


Circuit is much less sensitive to variations in circuit parameters

$$A_V = \frac{v_o}{v_s} = -\frac{g_m R_D \| R_L}{1 + g_m R_{SO}}$$

But gain is smaller

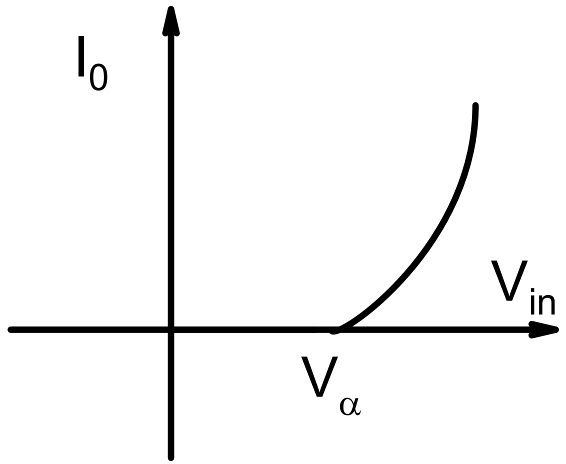
Simple Solution

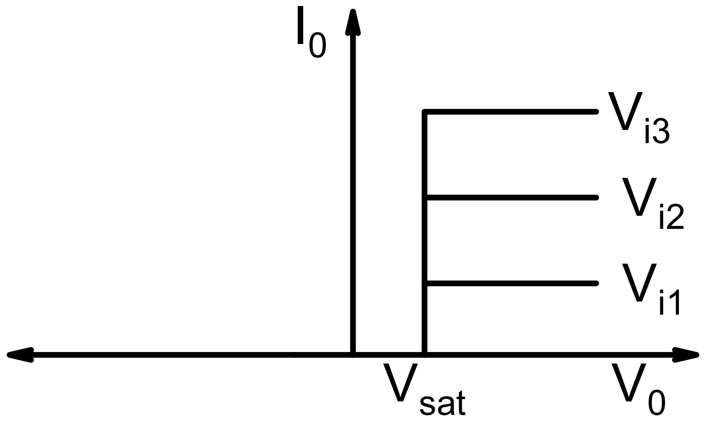


For dc, Capacitor C_S acts as open allowing R_{SO} to reduce variations in current

For ac, Capacitor C_S acts as a short circuit ($1/j\omega C \sim 0$) allowing high voltage gain to be obtained

Device NL:



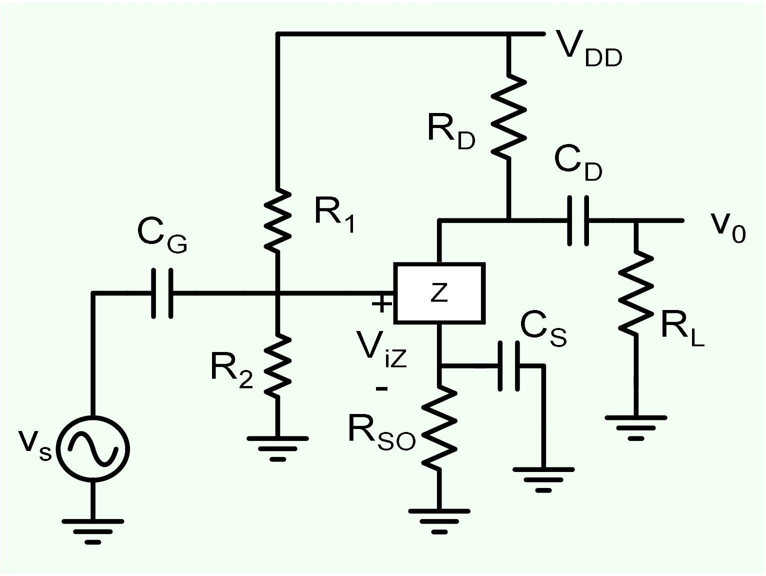


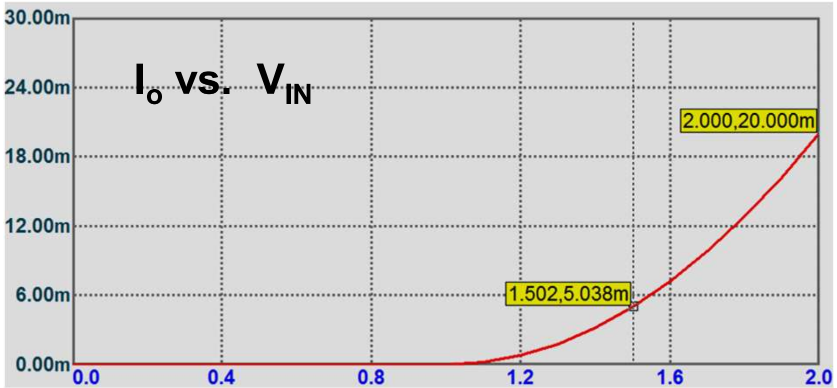
$$I_o = K \times (V_{in} - V_\alpha)^2 \text{ for } V_{in} \geq V_\alpha$$

$$V_\alpha = 1.0V \; ; \; K = 0.02$$

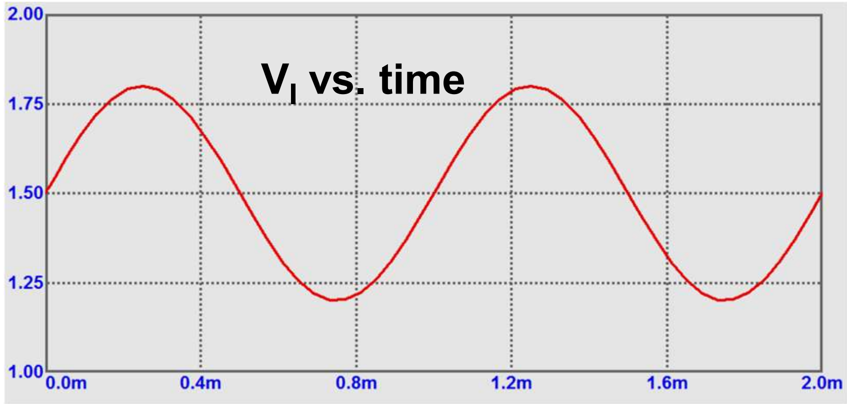
$$V_B = 1.5V$$

$$v_s = 0.3V Sin(\omega t)$$

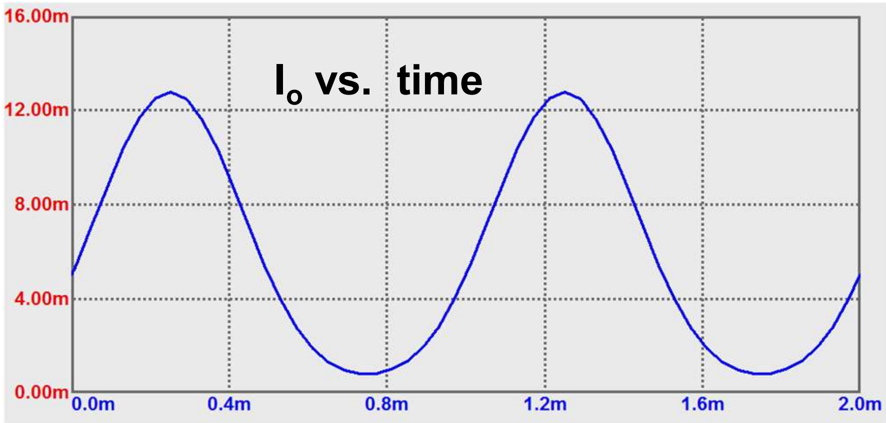




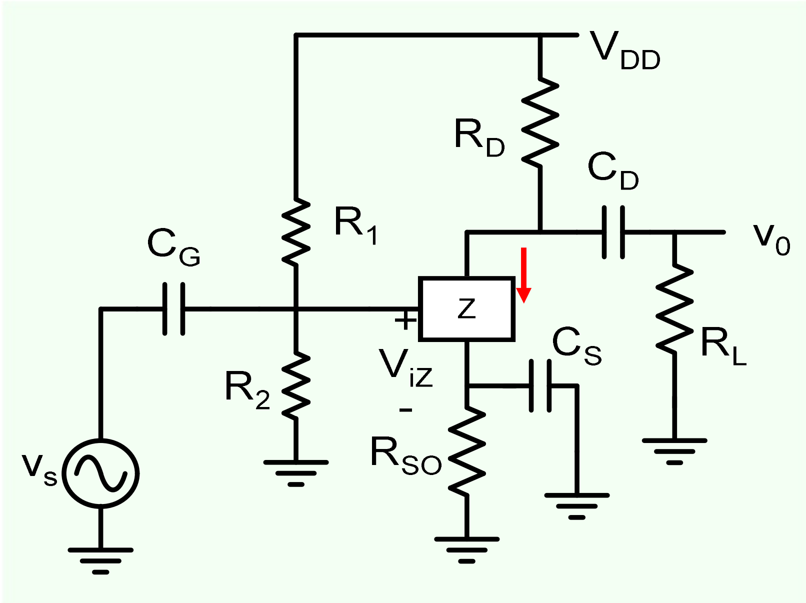
Io vs. VIN
2.000,20.000m
1.502,5.038m
30.00m
24.00m
18.00m
12.00m
6.00m
0.00m
0.0
0.4
0.8
1.2
1.6
2.0



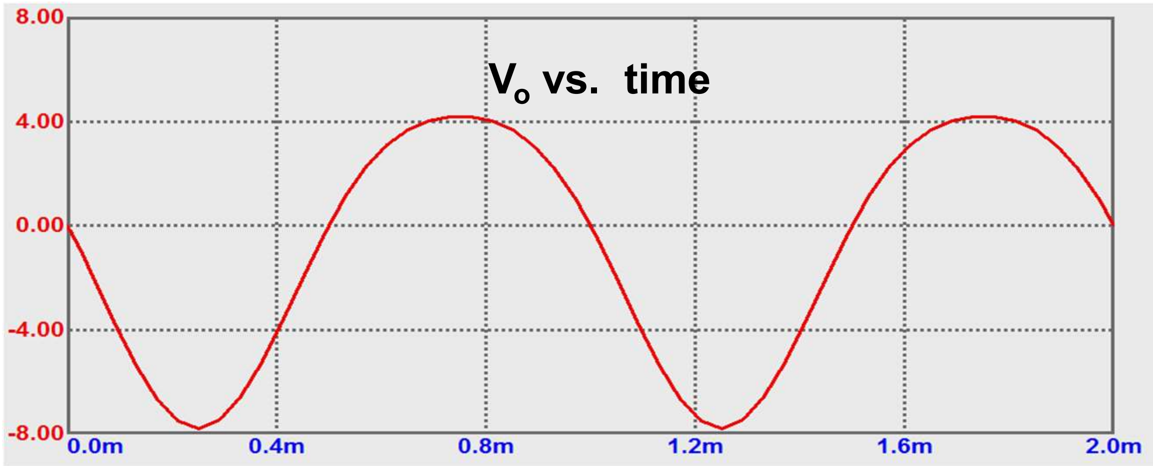
VI vs. time
2.00
1.75
1.50
1.25
1.00
0.0m
0.4m
0.8m
1.2m
1.6m
2.0m

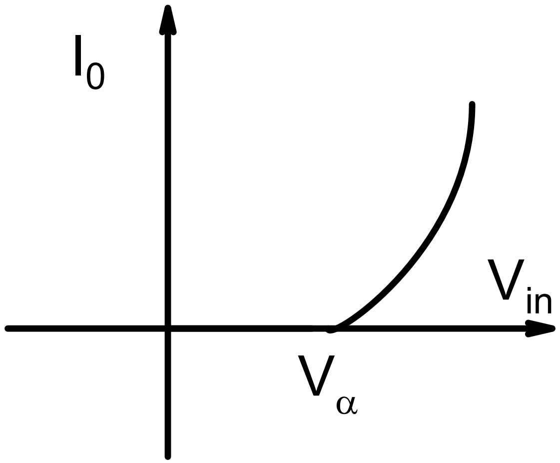


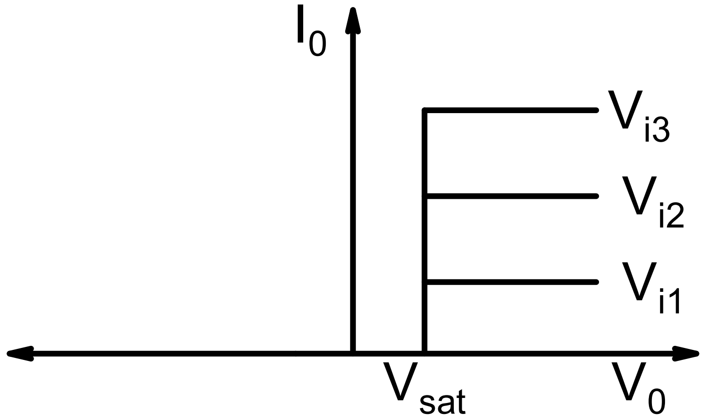
Io vs. time
16.00m
12.00m
8.00m
4.00m
0.00m
0.0m
0.4m
0.8m
1.2m
1.6m
2.0m



VDD
RD
CD
R1
CG
v0
Z
+
ViZ
-
CS
RL
R2
RSO
vs

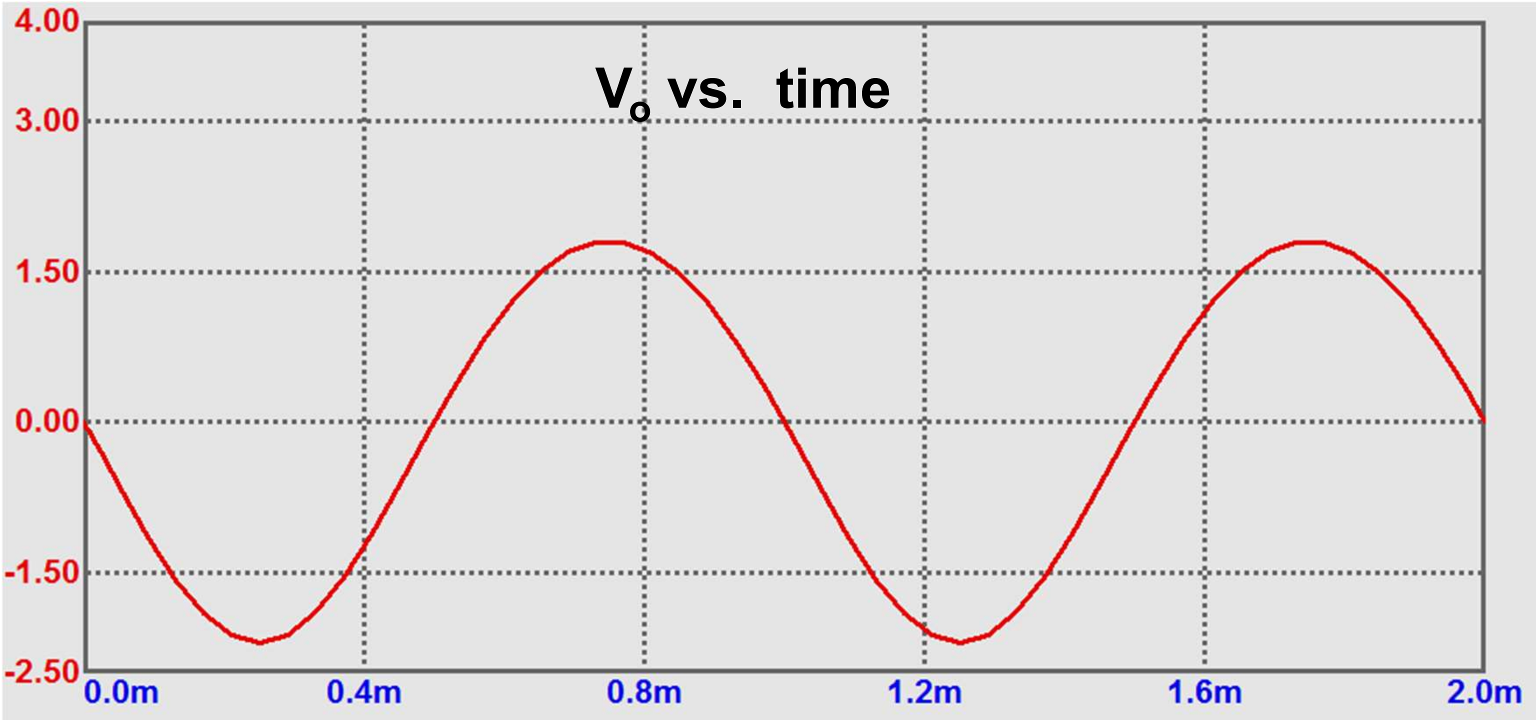






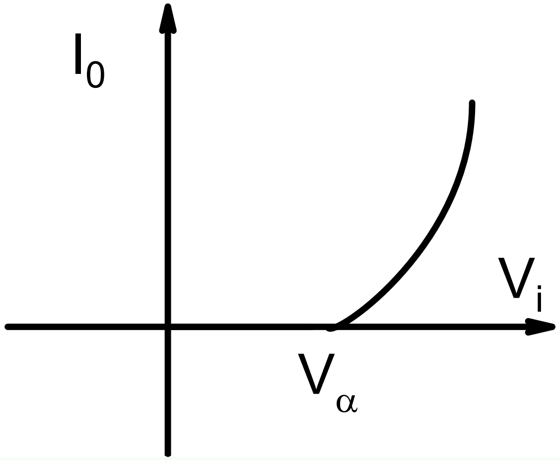
Because of Non-linearity the output waveform is distorted !

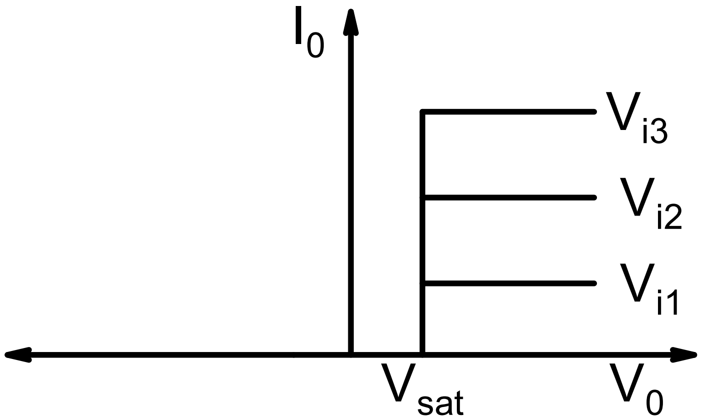
Suppose input is reduced to $v_s = 0.1V\,Sin(\omega t)$

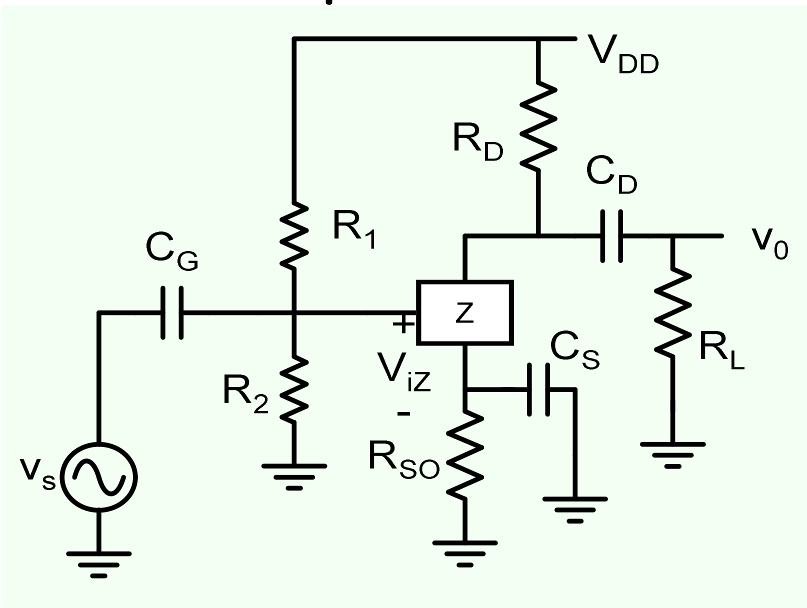


Distortion is much smaller if we restrict input voltage to a small value !

Building Amplifiers with non-linear devices







Amplifier will work properly (with small distortion only if we restrict the amplitude of input signal to small values.

How small depends on the nature of non-linearity. The stronger the non-linearity the lesser the signal amplitude.