

# EE539: Analog Integrated Circuit Design;

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## 1 SOURCE FOLLOWER

### 1.1 Input impedance

Equivalent circuit of the Source Follower to find input impedance is shown in the below figure.

TO FIND INPUT RESISTANCE:

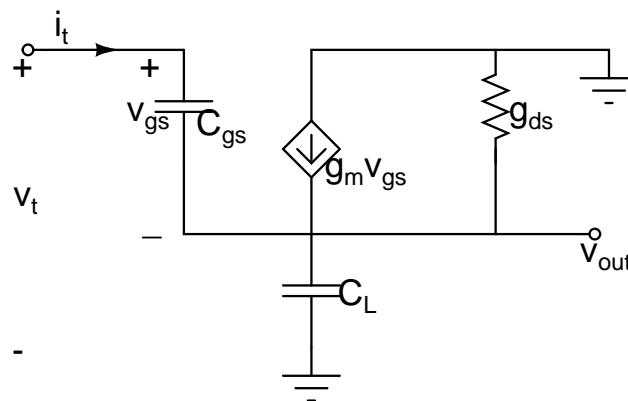


Figure 1: Equivalent circuit of the Source Follower

From the figure ,

$$v_{out} = \left( i_t + \frac{g_m i_t}{sC_{gs}} \right) \left( \frac{1}{sC_L + g_{ds}} \right)$$
$$v_t = \frac{i_t}{sC_{gs}} + v_{out}$$
$$R_{in} = \frac{v_t}{i_t} = \frac{1}{sC_L + g_{ds}} + \frac{1}{sC_{gs}} + \frac{g_m}{sC_{gs}(sC_L + g_{ds})}$$

The equivalent circuit for this input impedance is shown in the below figure,

### 1.2 Output impedance

The equivalent circuit for output impedance derivation is shown below

From the circuit,

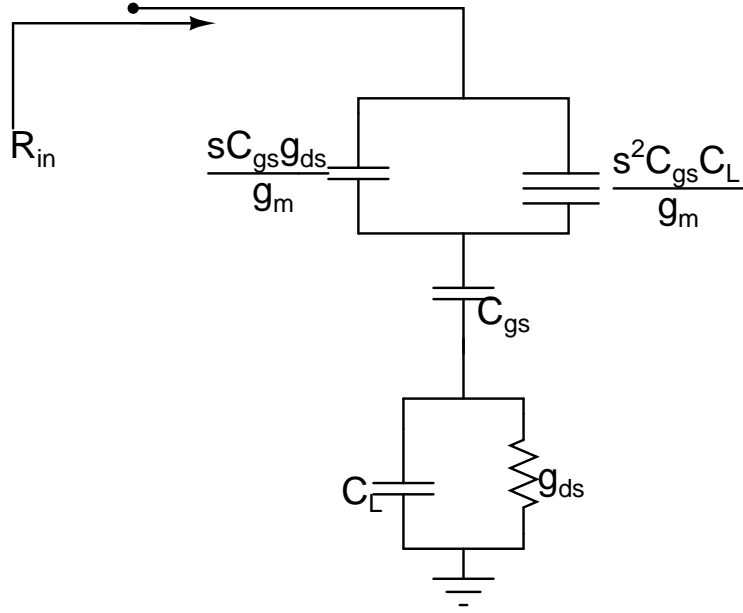


Figure 2: Equivalent circuit for input impedance

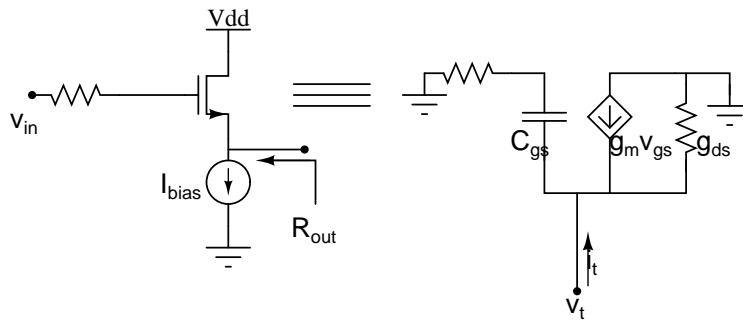


Figure 3: Equivalent circuit for output impedance derivation

$$v_{gs} = \frac{-v_t}{1+sC_{gs}R_s}$$

$$\Rightarrow g_m v_{gs} = \frac{-g_m v_t}{1+sC_{gs}R_s}$$

we can replace the VCCS  $g_m v_{gs}$  by equivalent admittance  $y_{g_m}$ ,

$$y_{g_m} = \frac{g_m}{1+sC_{gs}R_s} = \frac{1}{\frac{1}{g_m} + \frac{sC_{gs}R_s}{g_m}}$$

The Output admittance for the source follower is

$$Y_{out} = \frac{1}{Z_{out}} = \frac{1}{\frac{1}{g_m} + \frac{sC_{gs}R_s}{g_m}} + g_{ds} + \frac{sC_{gs}}{1+sC_{gs}R_s}$$

The equivalent circuit for the output admittance is shown in below figure,

We can also find the output admittance by intuitively from the figures shown below.

Bodeplot for this output admittance is shown below,

## EQUIVALENT CIRCUIT FOR OUTPUT IMPEDANCE:

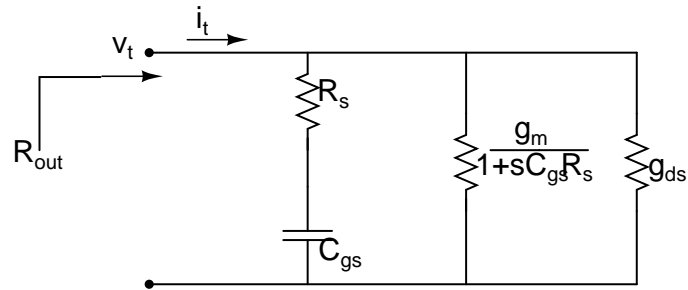


Figure 4: The equivalent circuit for the output admittance

Source follower is supposed to be a good voltage source, since it has low output impedance. But from the Bodeplot, the output impedance increases as frequency increases ( $\Rightarrow$  INDUCTIVE nature), So at higher frequencies it behaves as a worst voltage source.

If we use the source follower in the following circuit configuration, at high frequencies it may tend to oscillate.

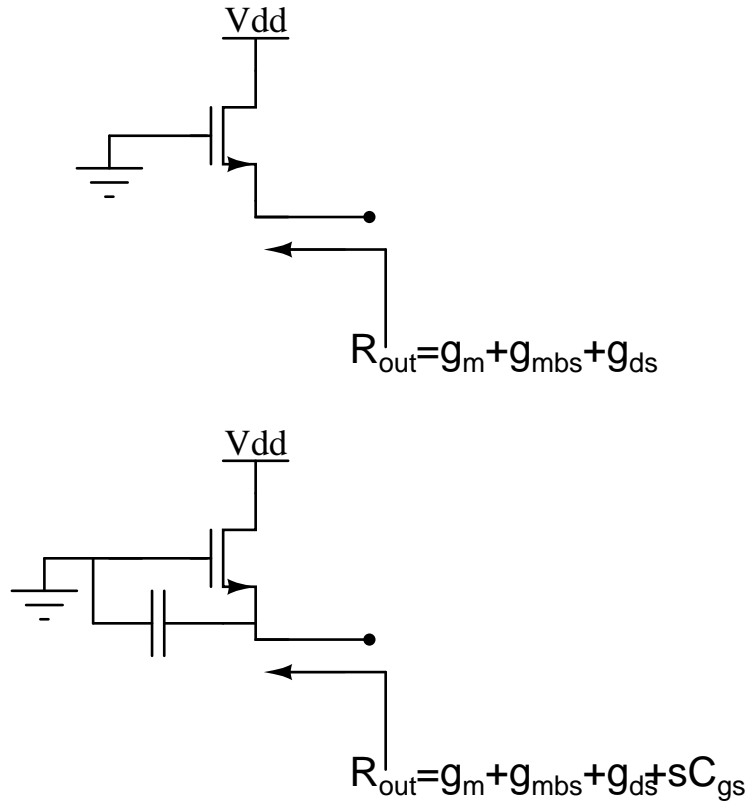


Figure 5: CD amplifier

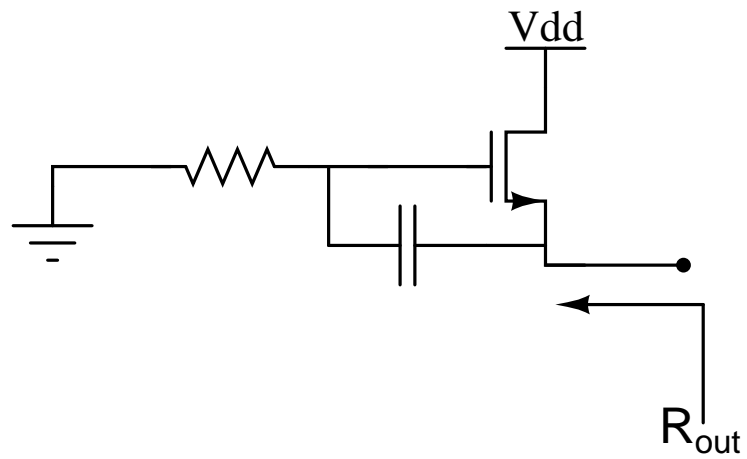


Figure 6: CD amplifier

## ADMITTANCE BODEPLOT:

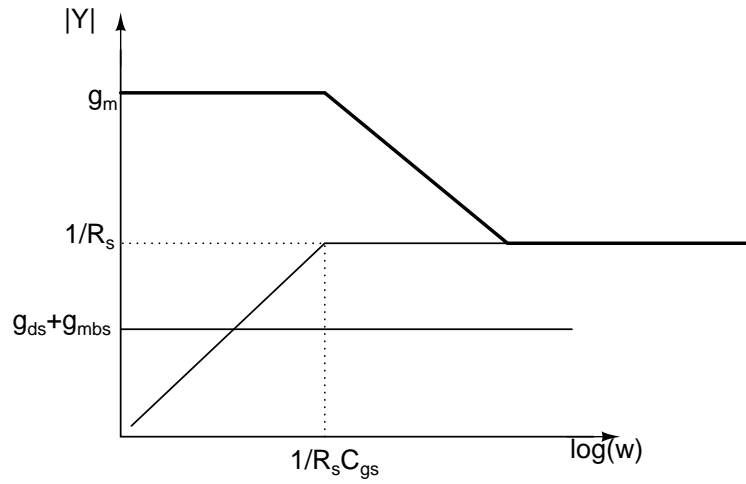


Figure 7: Bodeplot for output admittance

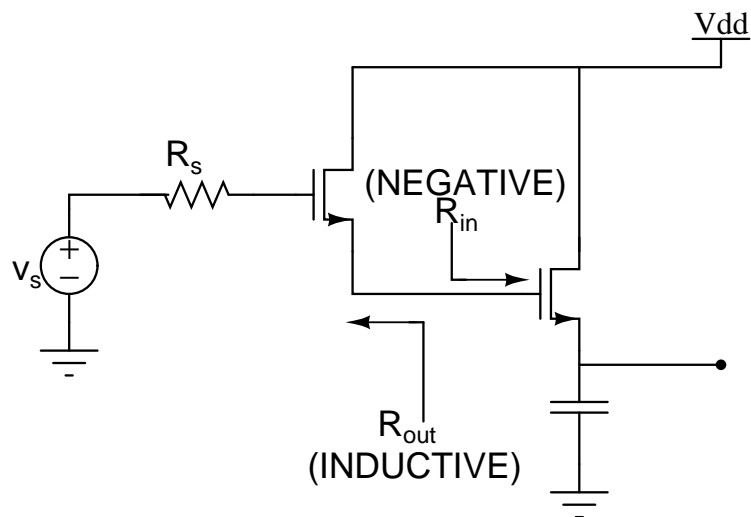


Figure 8: Oscillating circuit

## 2 CG amplifier

Circuit diagrams for CG amplifier with biasing is shown in below figures, DC gain for this CG amplifier

CG AMPLIFIER:

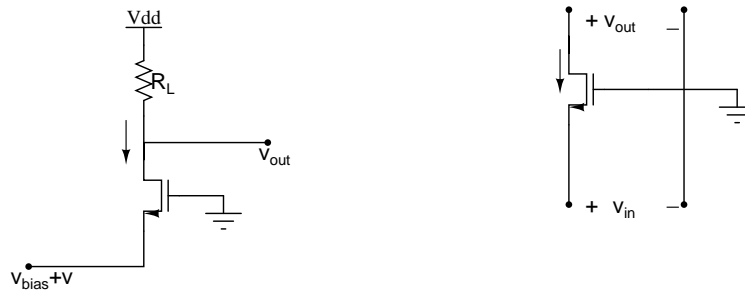


Figure 9: CG AMPLIFIER

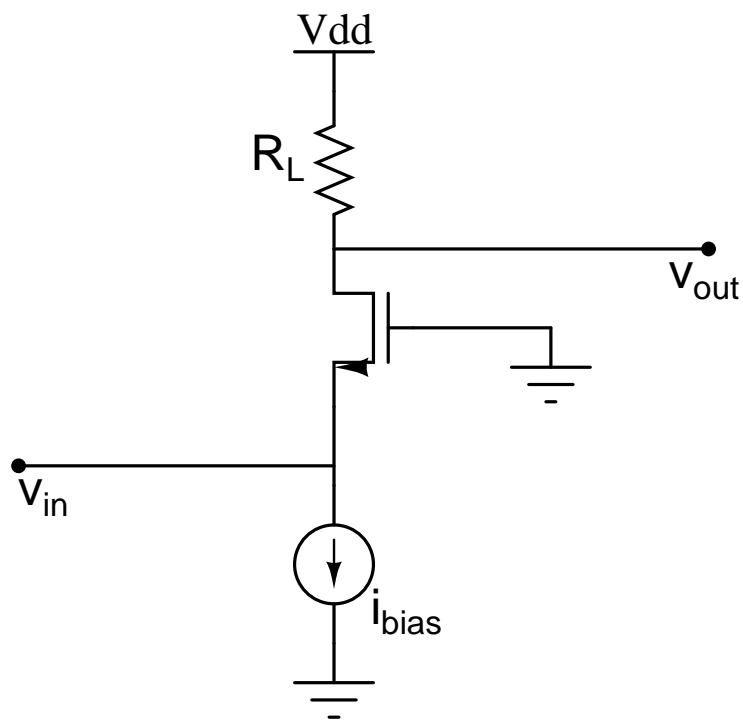


Figure 10: CG AMPLIFIER

configuration is

$$\frac{v_{out}}{v_{in}} = g_m R_L$$

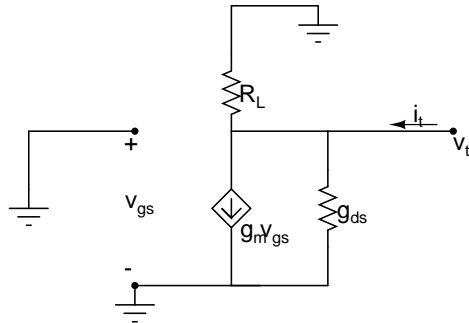


Figure 11: CG amplifier equivalent circuit for output impedance calculations

## 2.1 OUTPUT IMPEDANCE

The output impedance of the CG amplifier is

$$R_o = \frac{1}{g_{ds} + G_L}$$

## 2.2 INPUT IMPEDANCE

The input impedance of the CG amplifier can be calculated from the following figure,

$$R_{in} = \frac{1}{g_m}, \text{ which is very small.}$$

TO FIND INPUT IMPEDANCE:

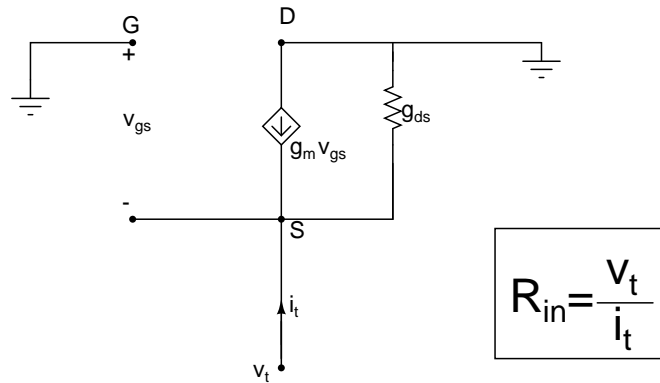


Figure 12: CG amplifier equivalent circuit for input impedance calculations

## 2.3

The small signal equivalent circuit at high frequencies is shown in the below figure. Due to  $C_{gs}$  and  $C_{sb}$ , there is no effect on small signal gain.

$$\frac{v_{out}}{v_{in}} \approx \frac{g_m R_L}{1 + s R_L (C_{db} + C_{gd})}$$

## 2.4 By considering source Resistance

The circuit diagram for the CG amplifier with source Resistance is shown in the below figure, Equivalent circuit for this CG amplifier is shown in the below figure, For this circuit voltage gain is,



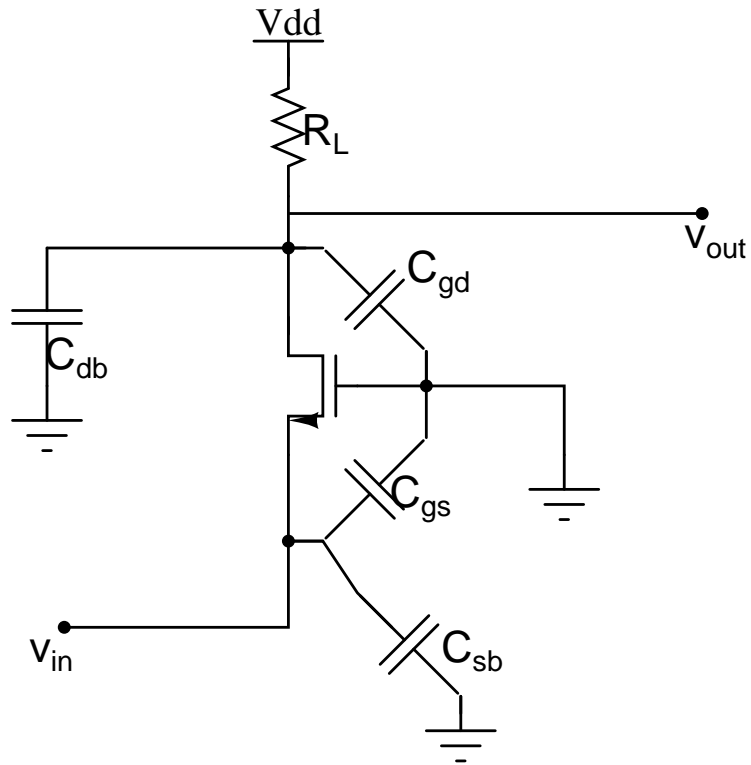


Figure 13: CG amplifier small signal equivalent circuit at high frequencies

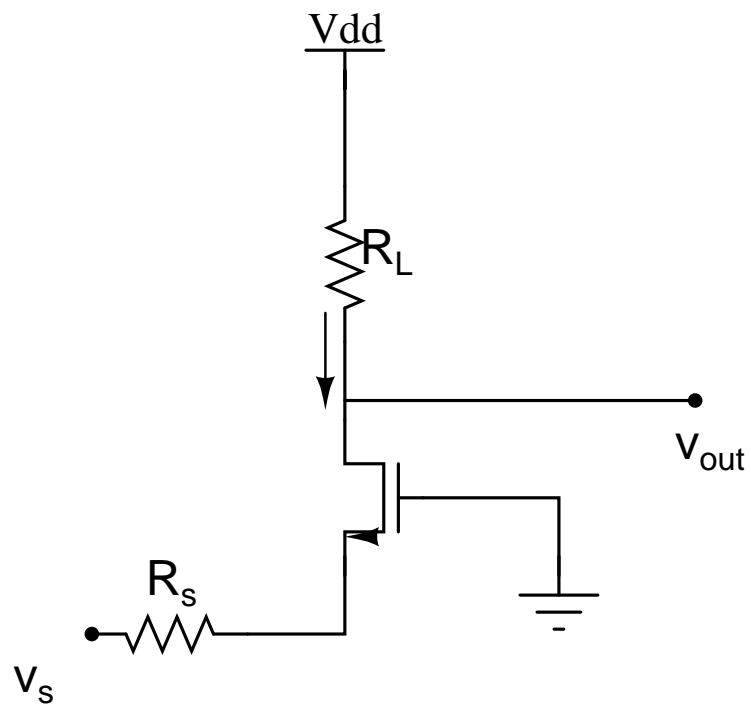


Figure 14: CG amplifier with source Resistance

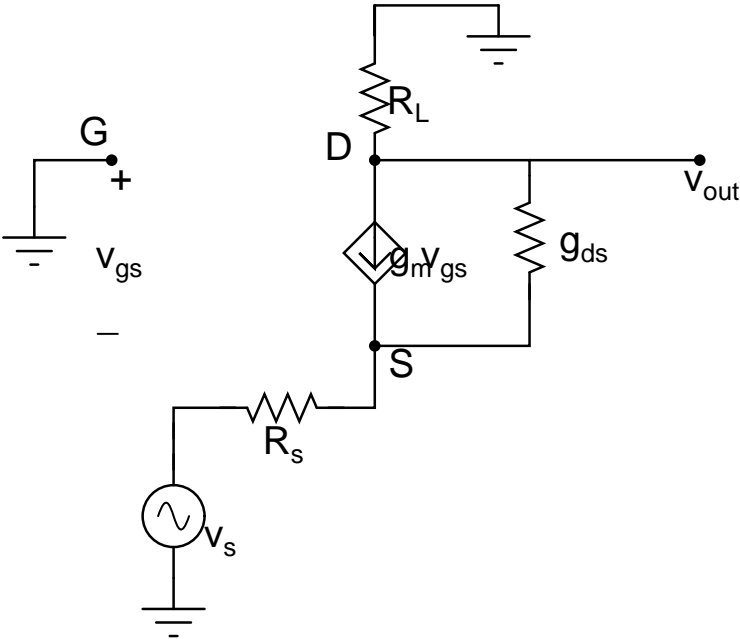


Figure 15: Equivalent circuit for this CG amplifier

$$\frac{v_{out}}{v_s} = \frac{1}{\frac{R_s}{R_L} + \frac{1}{gm} + g_{ds}}$$

If  $g_m$  is very large compared to others (i.e.,  $g_m \gg g_{ds}, \frac{1}{R_L}$ )

$$\frac{v_{out}}{v_s} \approx \frac{R_L}{R_s}$$

For this circuit current gain is always unity.