IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

MICRORLECTRONICS: DEVICES TO CIRCUITS

Internal Cap models and High frequency Modeling

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Outline

- Internal MOS Cap Model
- Junction Capacitances of MOSFET
- The High-frequency MOSFET Model
- The MOSFET Unity-Gain frequency
- Frequency response of CS Amplifier
- High frequency model of CS Amplifier with source resistance
- High frequency model of CG Amplifier
- High frequency model of SF(CD) Amplifier
- Recapitulation

Internal MOS Cap Model

- The gate electrode (polysilicon) forms a parallel –plate capacitor with the channel , with the oxide layer serving as the capacitor.
- The gate capacitive effect can be modeled by the three capacitances C_{gs}, C_{gd}, C_{gb}.

$C_{gs} = C_{gd} = \frac{1}{2} WL C_{OX}$ In triode region

$C_{gs} = \frac{2}{3} WL C_{OX}$ $C_{gd} = 0$ In Saturation region

$C_{gd} = C_{gs} = 0$

$C_{gb} = WL C_{OX}$ In Cutoff Region

$C_{ov} = W L_{ov} C_{oX}$ Overlap capacitance

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Junction Capacitances of MOSFET

- The depletion layer capacitances of the two reverse –biased pn junctions formed between each of the source and the drain diffusion and the body bias.

$$C_{db} = \frac{C_{dbo}}{\sqrt{1 + \frac{V_{DB}}{V_o}}}$$ Drain –body capacitance

$$C_{Sb} = \frac{C_{sbo}}{\sqrt{1 + \frac{V_{SB}}{V_o}}}$$ Source-body capacitance

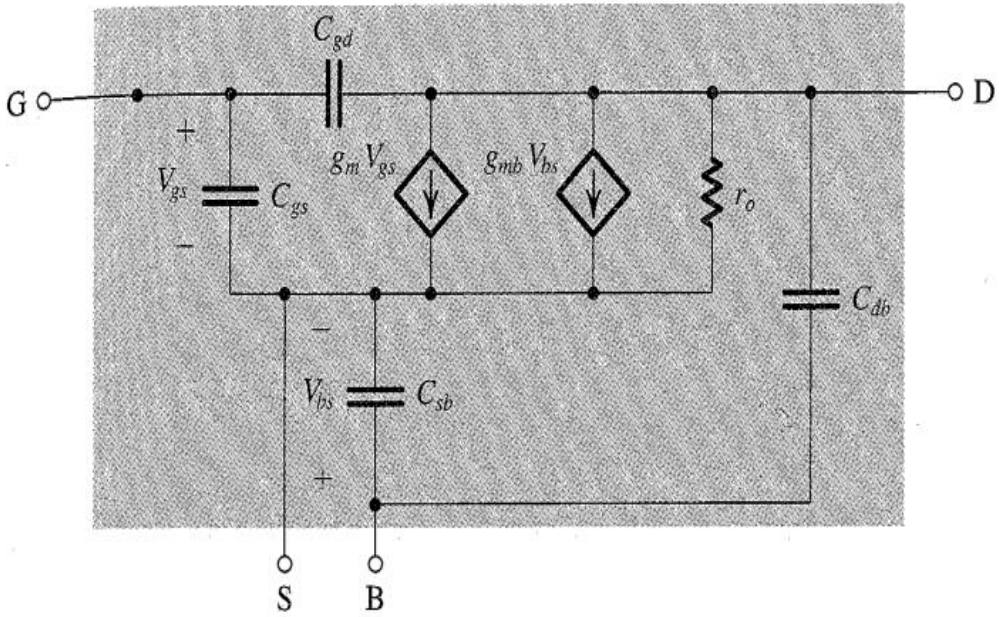
Assuming grading coefficient for both junction is

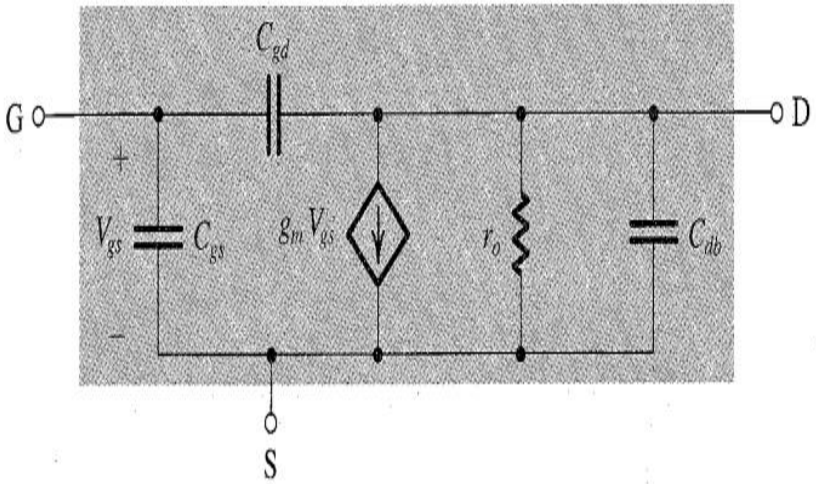
m=1/2

Where C_{Sbo} Source-body capacitance with zero body bias

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

The High-frequency MOSFET Model

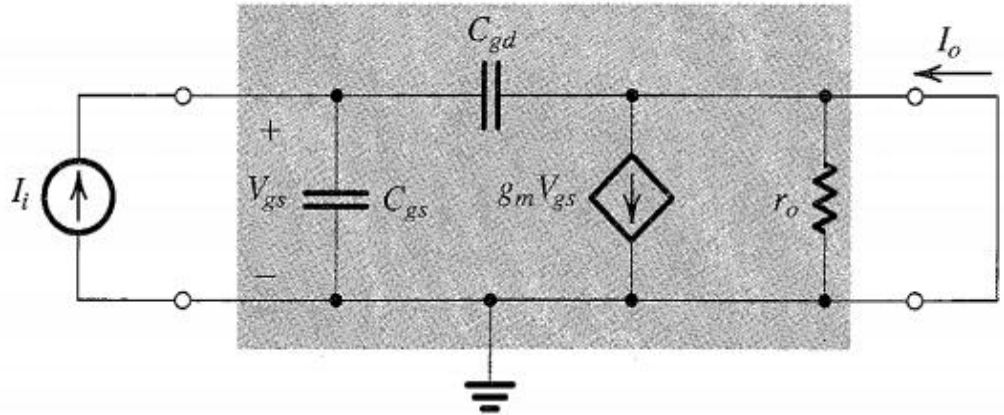




Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

The MOSFET Unity-Gain frequency

- A figure of merit for the high –frequency operation of the MOSFET as an amplifier is the unity gain frequency.
- This is defined as the frequency at which the short circuit current gain of common-source configuration becomes unity.



Short circuit gain= $\frac{I_o}{I_i}$

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

$$I_o = g_m V_{gs} - sC_{gd} V_{gs}$$

$$I_o = g_m V_{gs}$$ If gate to drain capacitance is small

$$V_{gs} = \frac{I_i}{s(C_{gs} + C_{gd})}$$

$$f_T = \frac{g_m}{2\pi(C_{gs} + C_{gd})}$$

$$\frac{I_o}{I_i} = \frac{g_m}{s(C_{gs} + C_{gd})}$$

$$w_T = \frac{g_m}{(C_{gs} + C_{gd})}$$

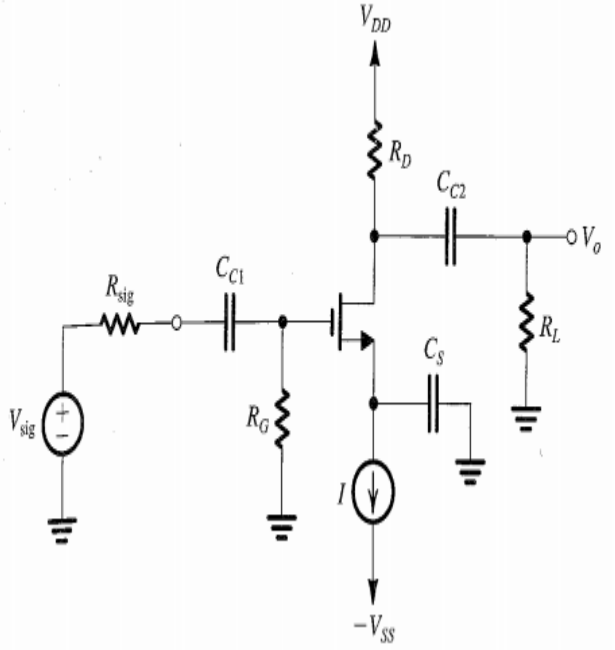
$$f_T = \frac{w_T}{2\pi}$$

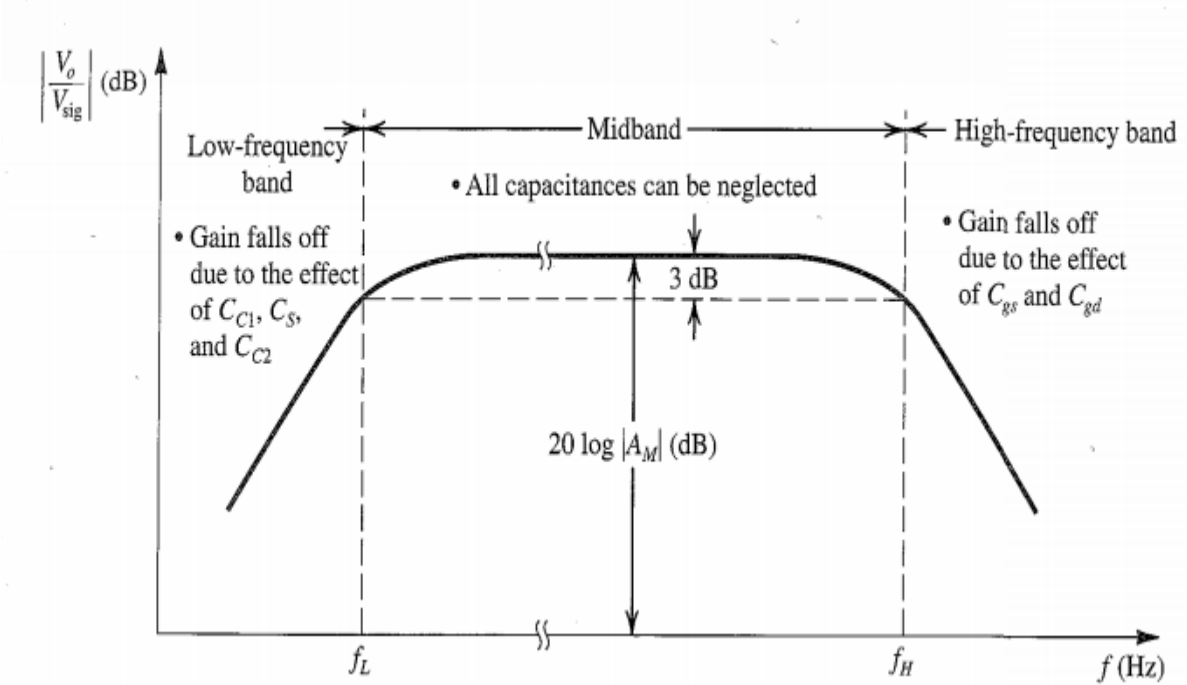
$$S = jw$$

The higher the value of f_T, the more effective the FET becomes as an amplifier.

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Frequency response of CS Amplifier





Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

- The gain is almost constant over a wide frequency band called the **midband**.

Midband gain $A_M = \frac{V_o}{V_{sig}} = -\frac{R_G}{R_G + R_{sig}} g_m \left(g_m \| R_D \| R_L\right)$

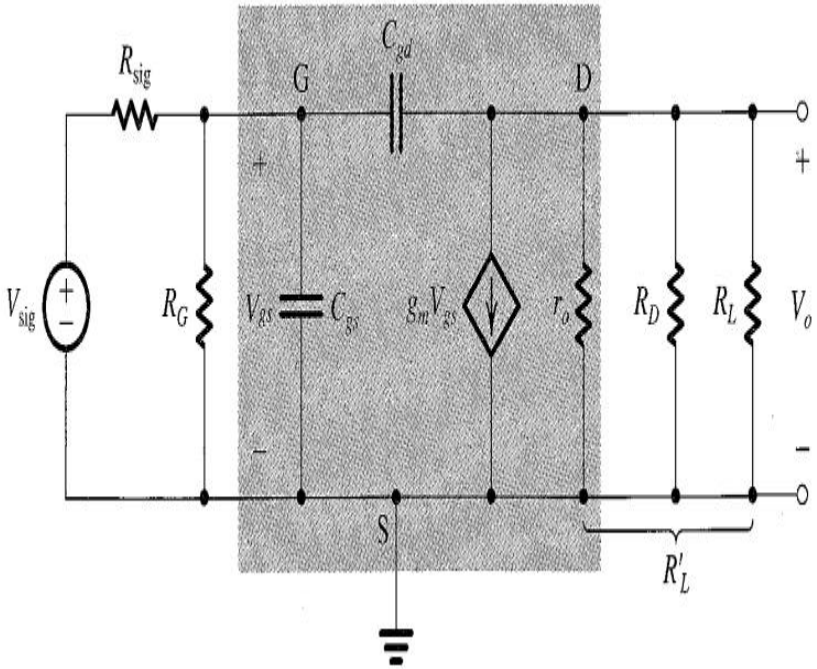
3dB bandwidth is $BW = f_H - f_L$

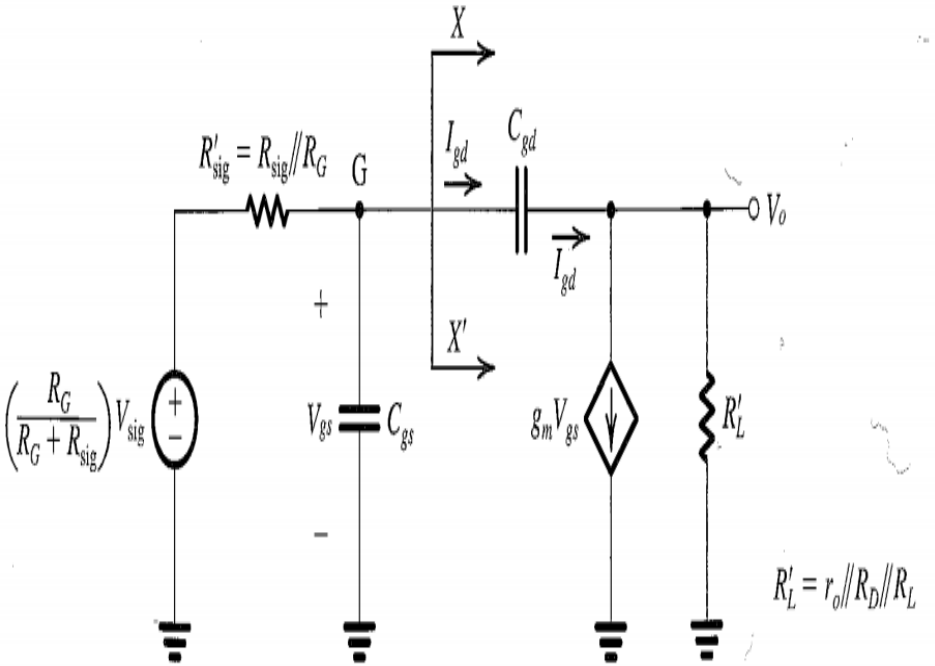
If $f_H >> f_L$ Than bandwidth $BW = f_H$

- A figure of merit for the amplifier is its gain –bandwidth product .

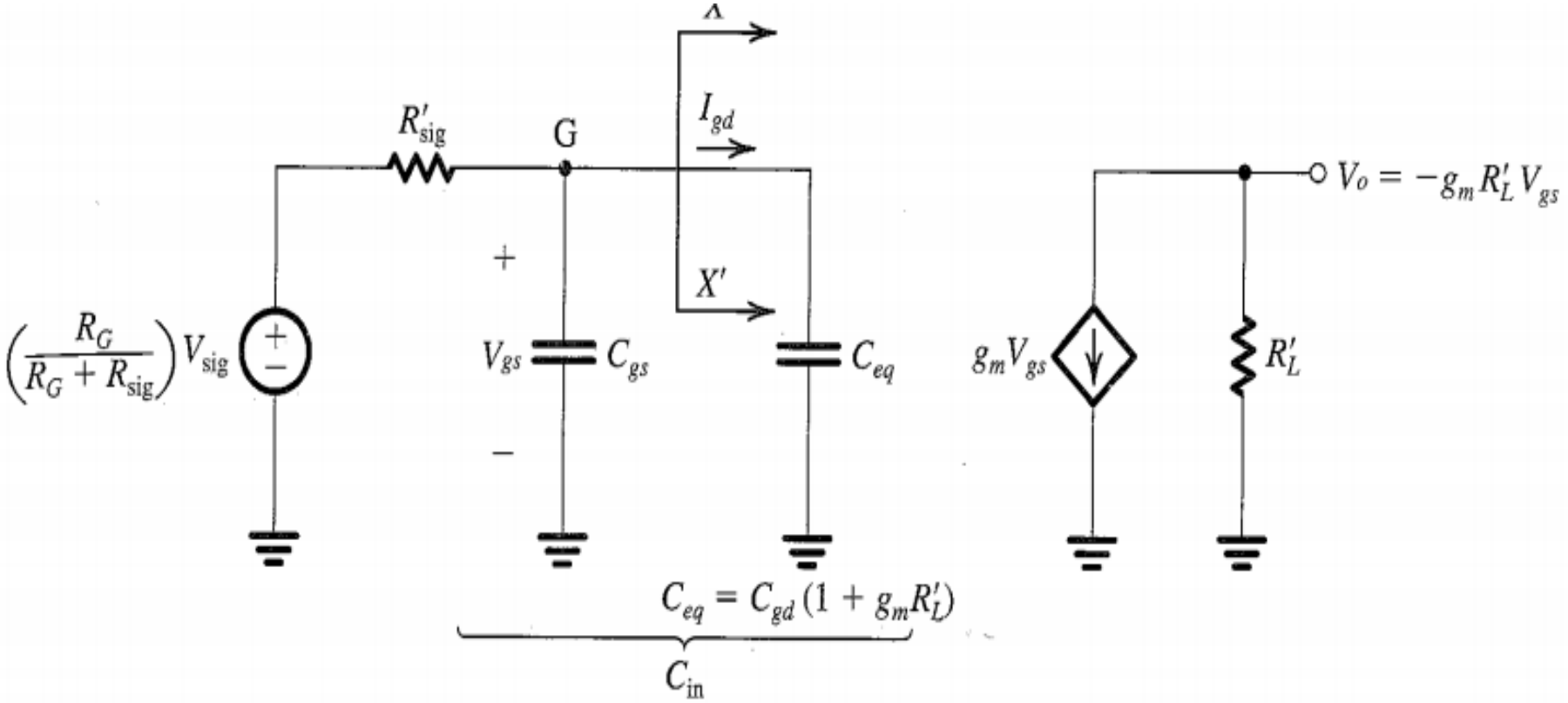
$$GB = \left|A_M\right| BW$$

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

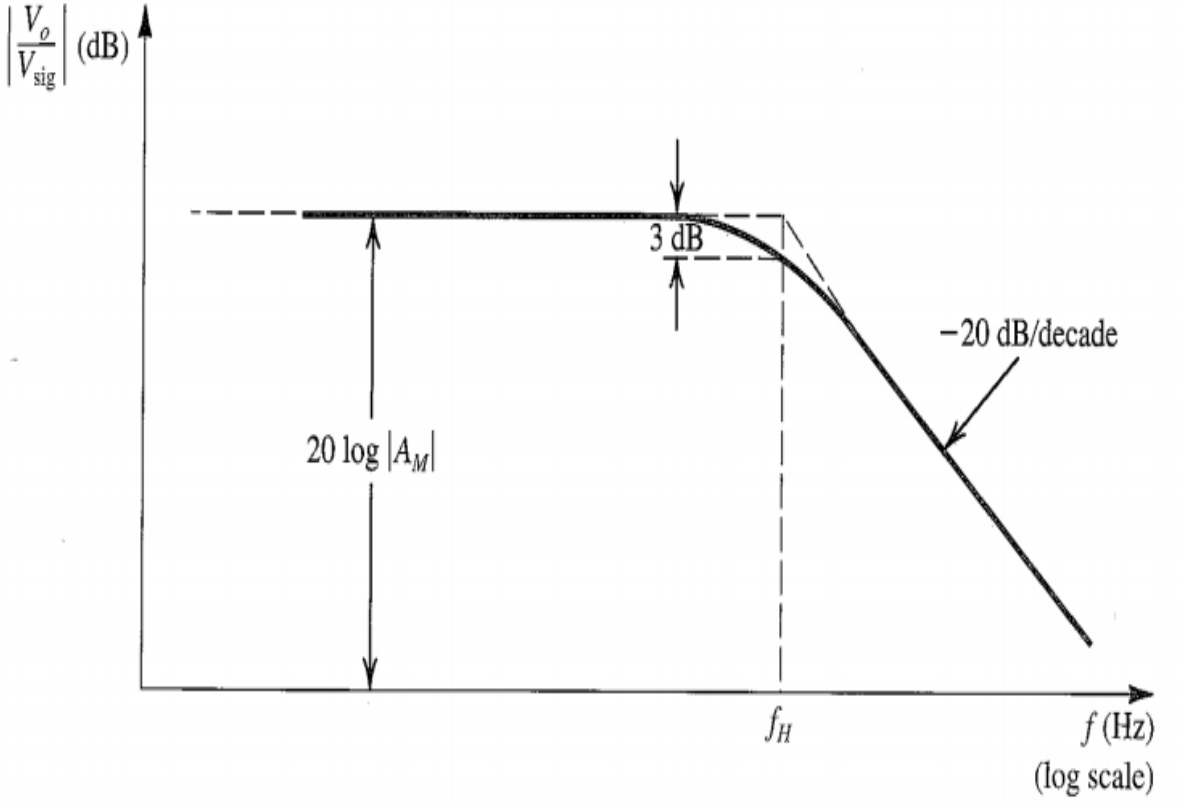




Source: Microelectronics Circuits, Sedra and Smith, Fifth edition



Source: Microelectronics Circuits, Sedra and Smith, Fifth edition



$$\frac{V_o}{V_{sig}} = \frac{A_M}{1 + \frac{s}{\omega_H}}$$

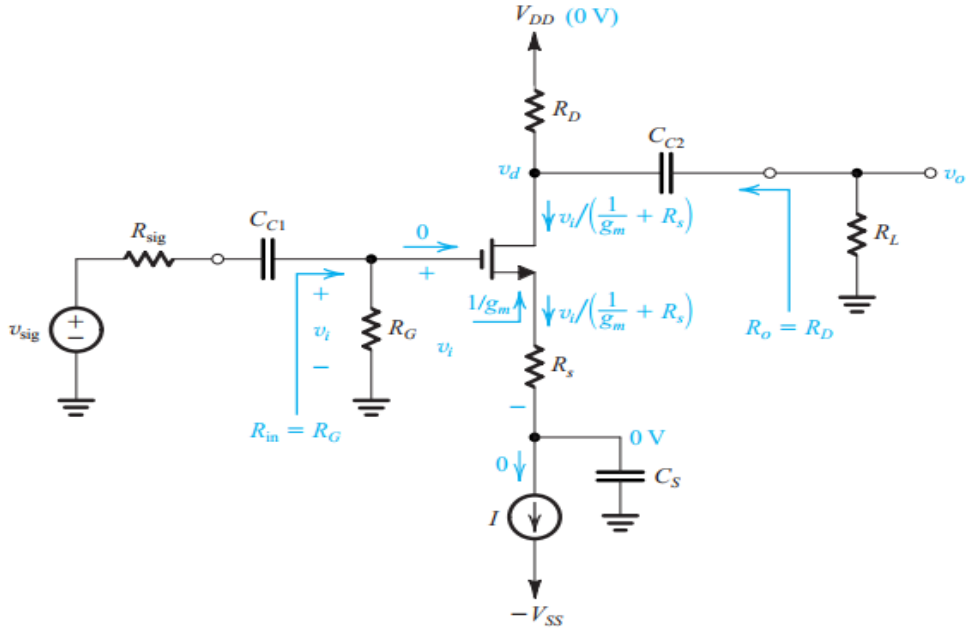
$$f_H = \frac{1}{2\pi C_{in} R'_{sig}}$$

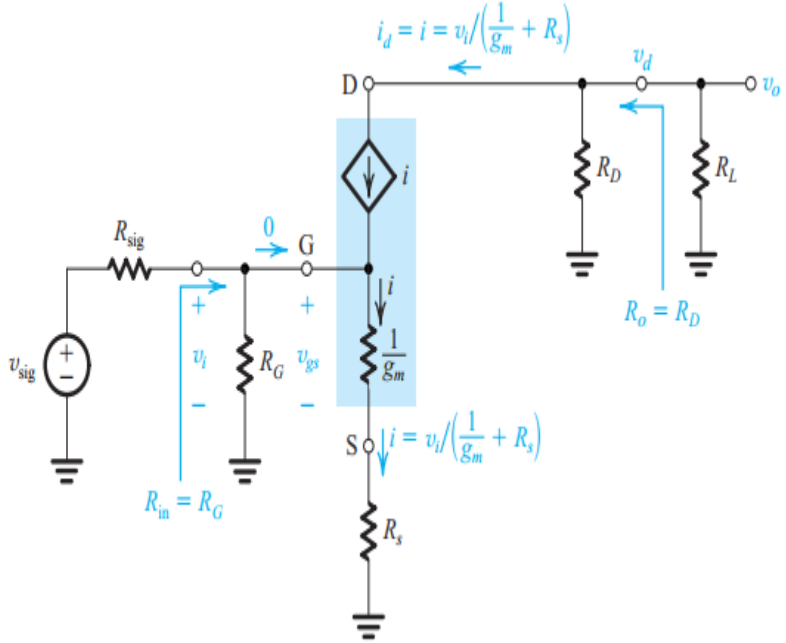
$$C_{in} = C_{gs} + C_{gd}\left(1 + g_m R'_L\right)$$

$$R'_{sig} = R_{sig} \parallel R_G$$

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

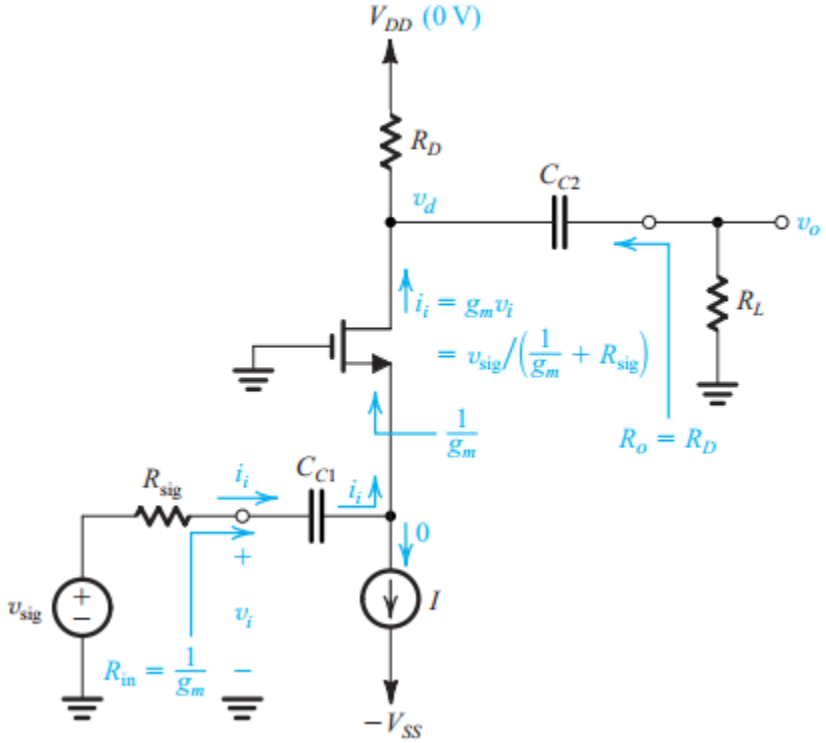
High frequency model of CS Amplifier with source resistance

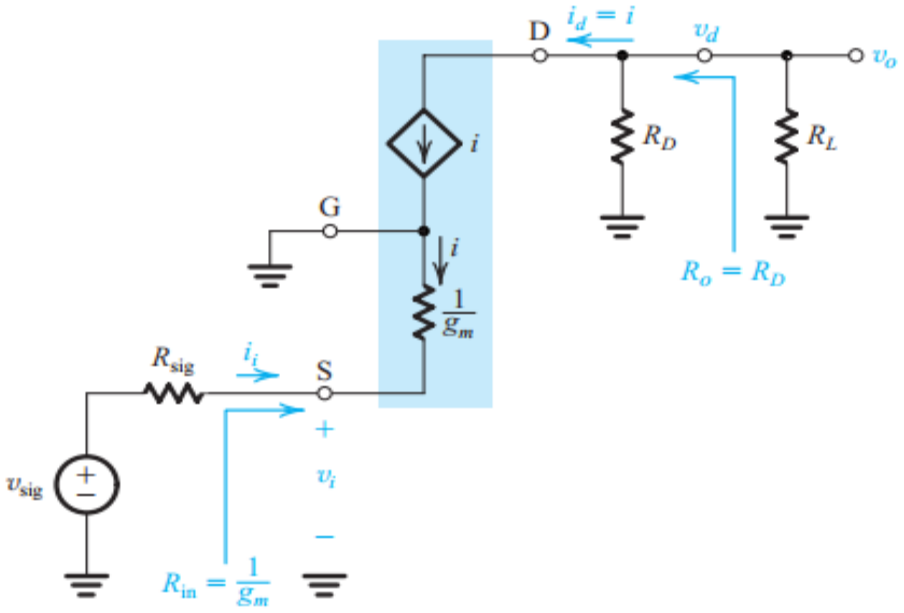




Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

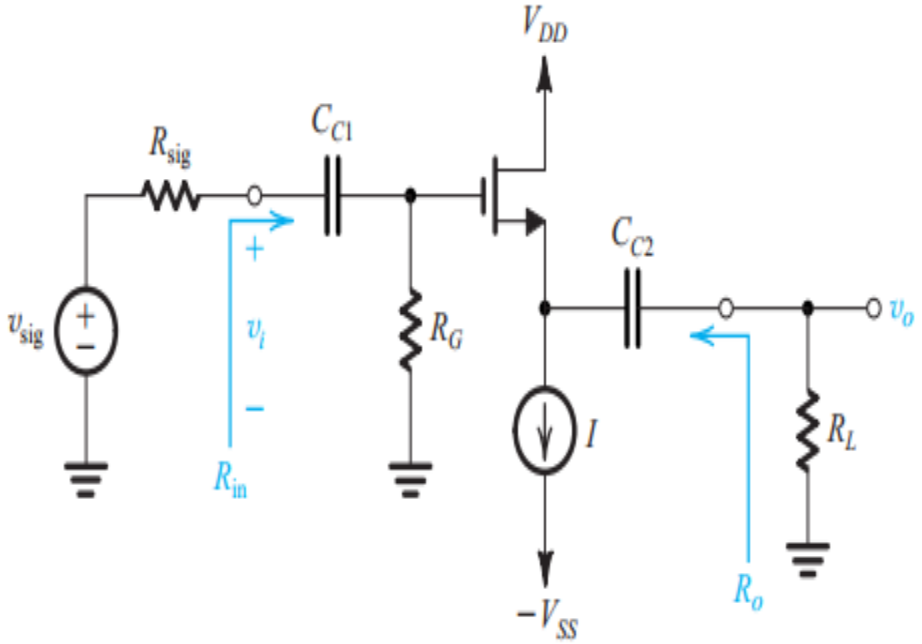
High frequency model of CG Amplifier

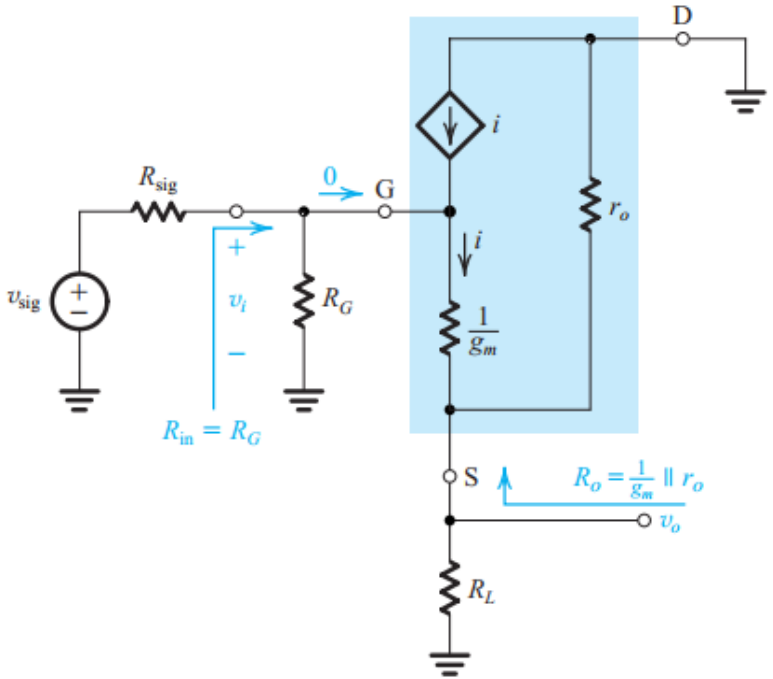




Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

High frequency model of SF(CD) Amplifier





Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Recapitulation

- A figure of merit for the high –frequency operation of the MOSFET as an amplifier is the unity gain frequency f_T.
- f_T is proportional to g_m and inversely proportional to the FET internal capacitance.
- The higher the value of f_T, the more effective the FET becomes as an amplifier.
- Miller –effect occur due to gate to drain capacitance.
- The midband is the useful frequency band of the amplifier.
- f_H and f_L are the frequencies at which the gain drops by 3dB below its value at midband.

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Thank You