Analog Electronic Circuits (UEC301)

By

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THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
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Subject: Analog Electronic Circuits (UEC301)

Faculty names: Dr. Mayank Kumar Rai (Associate Professor & Course Coordinator)

Topic of today's Lecture : Small Signal Models and Operation of Enhancement Mode NMOS

Key points

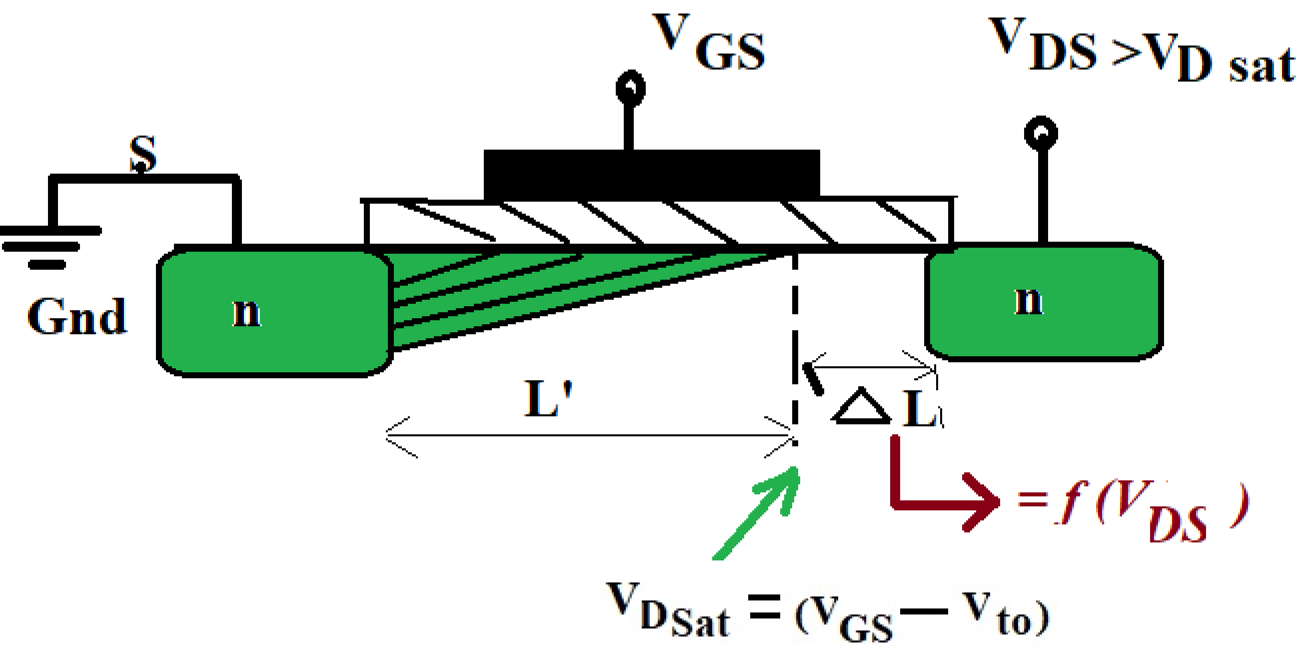
- **Second Order Effects**
- **Small Signal Low Frequency Models of Enhancement Mode NMOS**
- **Small Signal high frequency model of Enhancement Mode NMOS**
- **Small Signal Parameters**
- **Types of Single Stage Amplifier**
- **Low Frequency Small Signal operation of Single Stage Common Source Amplifier**

Contents of this lecture are based on the following books:

- *Jacob Milman & and C.C.Halkias, **"Integrated Electronics Analog and Digital Circuit and Systems"**Second Edition.*
- *Adel S. Sedra & K. C. Smith, **"MicroElectronic Circuits Theory and Application"** Fifth Edition.*
- *Robert L. Boylestad & L. Nashelsky, **"Electronic Devices and Circuit Theory"** Eleventh Edition.*

Second Order Effects

(i) Channel length Modulation(Lambda effect)

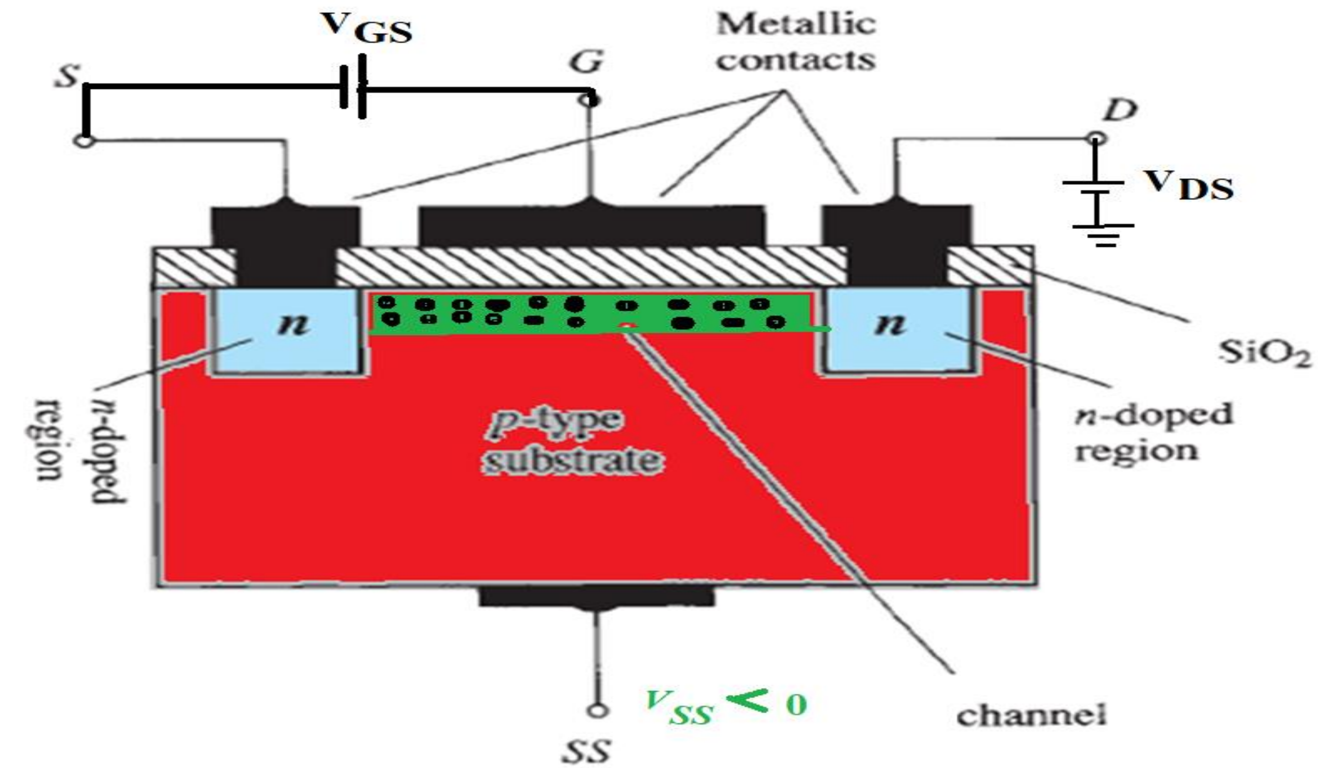


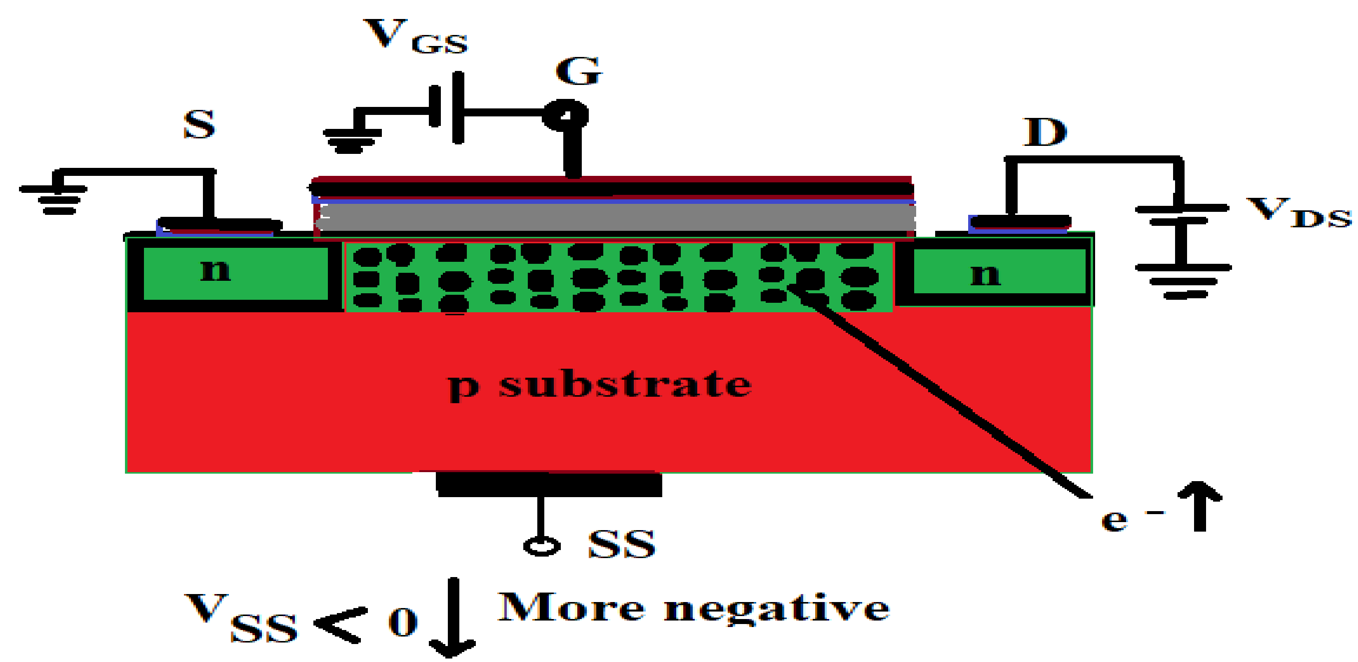
As V_{DS} increases ($V_{DS} > V_{DS\ at}$),the channel gradually moves toward the source end i.e. The channel length decreases(L) with increase in V_{DS}

⇩

Channel length modulation

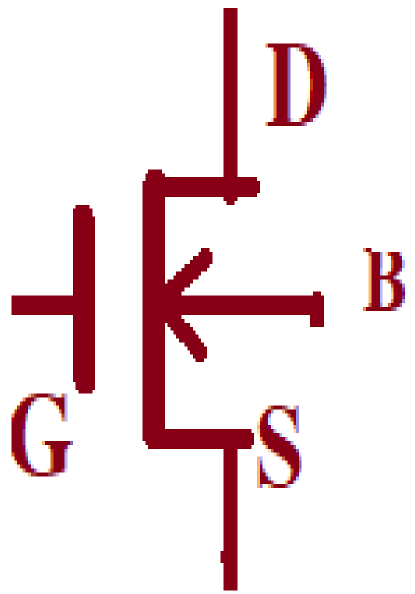
(ii) Body Effect(γ effect)





$e^- \uparrow \Rightarrow Q_c \uparrow \Rightarrow V_{to} \uparrow$

Small Signal Low Frequency Models of Enhancement Mode NMOS



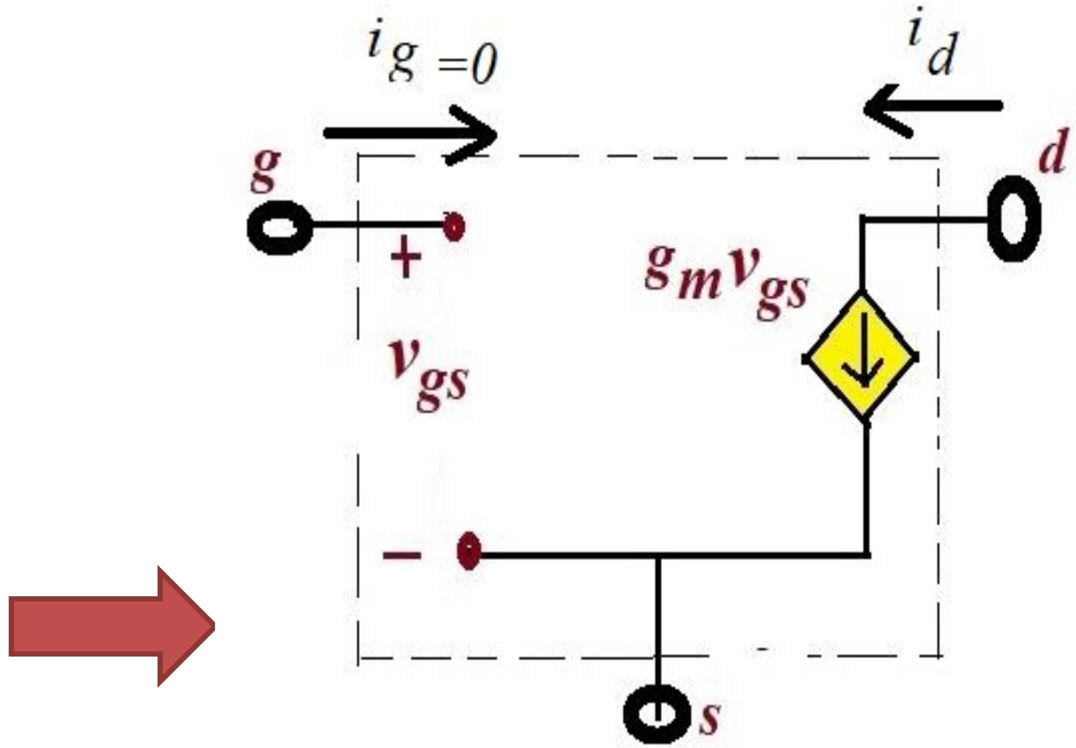


Figure 1 : The small signal π model without channel length and body effect.

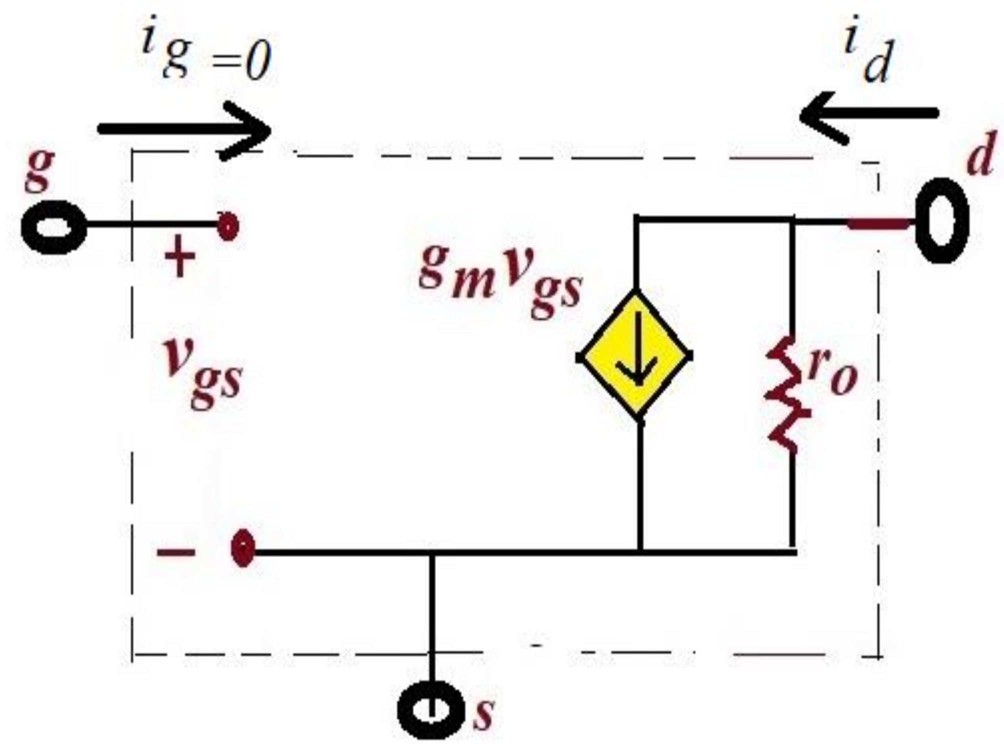
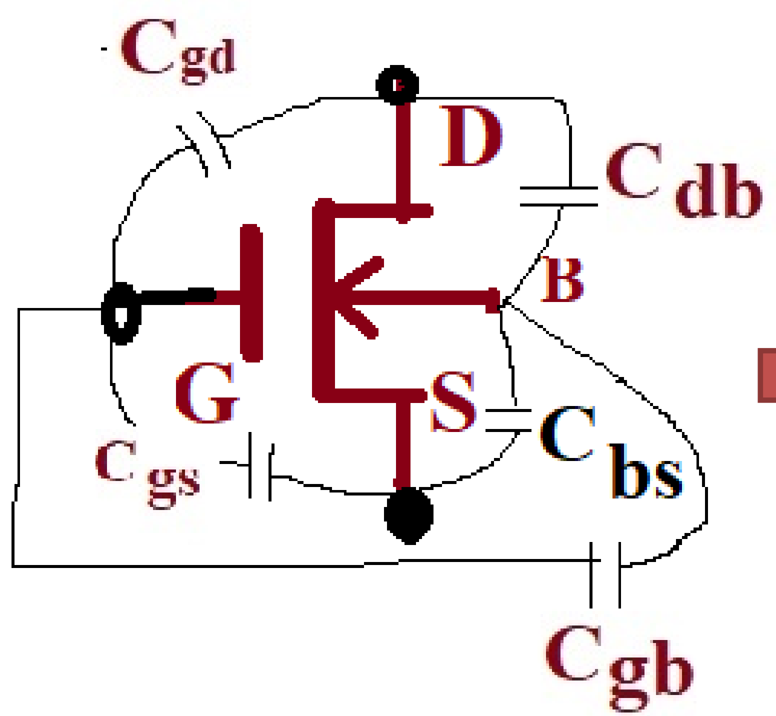


Figure 2 : The small signal π model with channel length modulation and without body effect $(\gamma) = 0$.

Small Signal High Frequency Model of Enhancement Mode NMOS



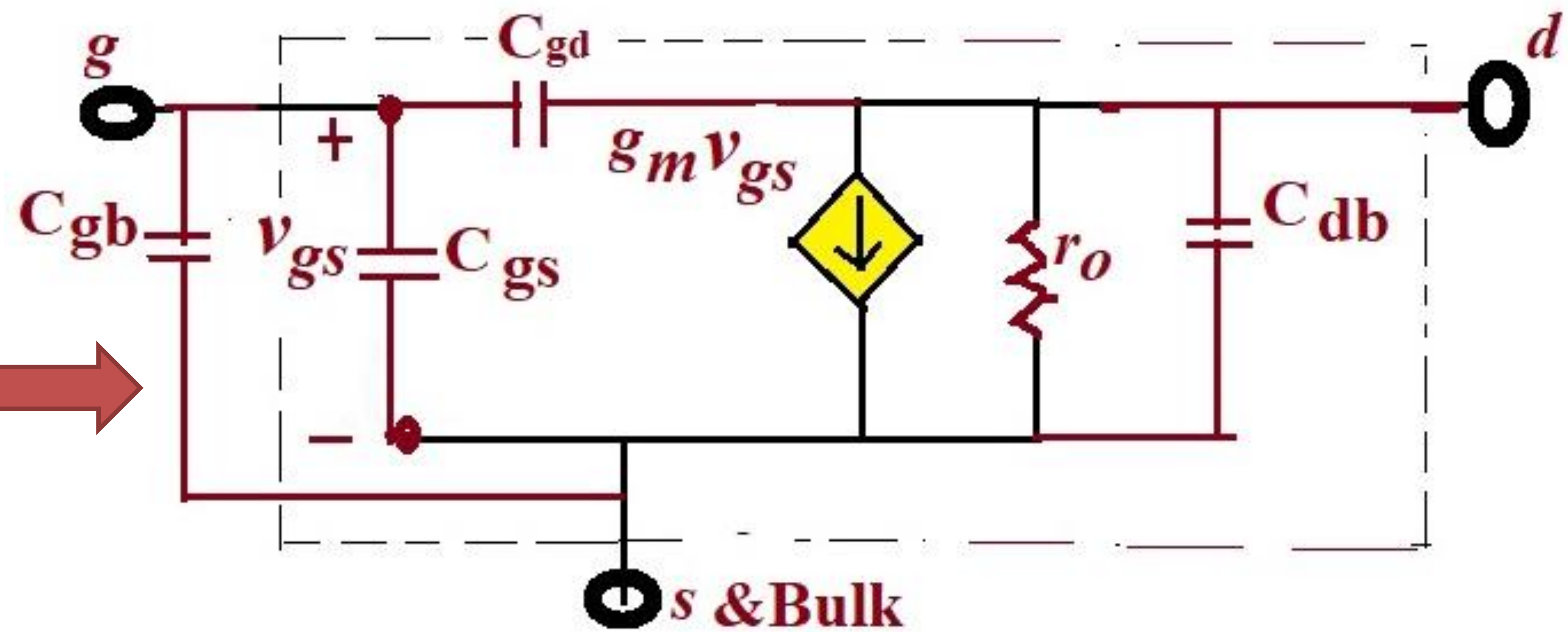


Figure 3: High frequency π model of enhancement mode NMOS with no body effect.

Small signal parameters

$$i_D = \frac{1}{2}\mu_n C_{OX}\frac{W}{L}(v_{GS} - V_{to})^2 \text{ ....(1),}$$

$$i_D = \frac{1}{2}\mu_n C_{OX}\frac{W}{L}\left(V_{GS} + v_{gs} - V_{to}\right)^2 \text{.......(2),}$$

$$i_D = \frac{1}{2}\mu_n C_{OX}\frac{W}{L}(V_{GS} - V_{to})^2 + \mu_n C_{OX}\frac{W}{L}(V_{GS} - V_{to})v_{gs} + \frac{1}{2}\mu_n C_{OX}\frac{W}{L}{v_{gs}}^2 \ldots..(3),$$

$$\frac{1}{2}\mu_n C_{OX}\frac{W}{L}{v_{gs}}^2 \ll \mu_n C_{OX}\frac{W}{L}(V_{GS} - V_{to})v_{gs} \text{......(4),}$$

resulting in

$$v_{gs} \ll 2(V_{GS} - V_{to}) \text{......(5),}$$

$$V_{OV} = (V_{GS} - V_{to}) \text{......(6),}$$

$$i_D = I_D + i_d \text{ ....(7),}$$

$$i_d = \mu_n C_{OX}\frac{W}{L}(V_{GS} - V_{to})v_{gs} \text{ ...(8),}$$

$$g_m = \frac{i_d}{v_{gs}} = \mu_n C_{OX} \frac{W}{L} (V_{GS} - V_{to}) \text{.......(9)},$$

from graphical interpretation

$$g_m = \frac{\partial i_D}{\partial v_{GS}} \quad at\ const\ V_{DS} \text{............(10)},$$

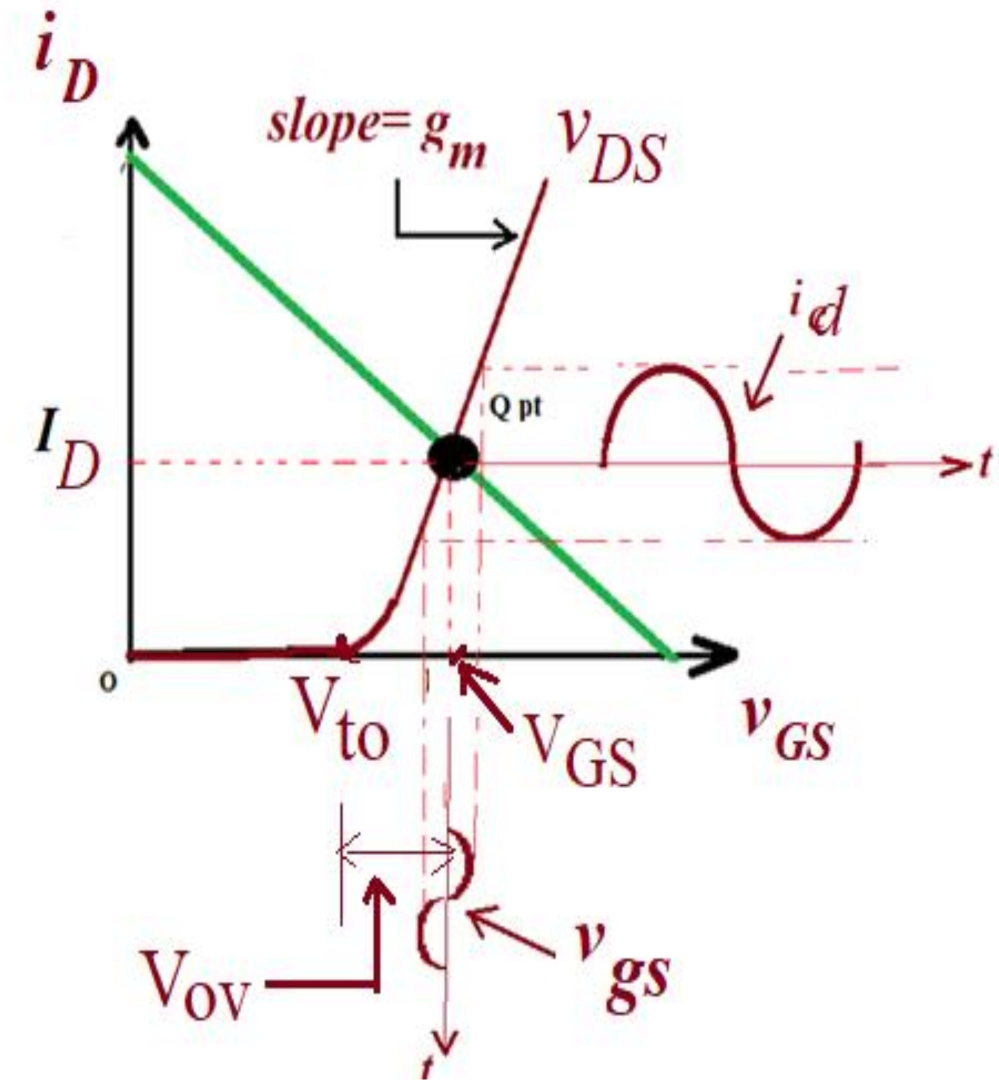


Figure 4 : i_D- v_{GS} characteristic at the bias point.

$$r_o = \frac{\partial V_{DS}}{\partial I_D} \quad \text{..........................(11)},$$

$$I_D \approx \frac{1}{2} \mu_n C_{OX} \frac{W}{L} (V_{GS} - V_{to})^2 (1 + \lambda V_{DS}) \quad \text{........(12)},$$

$$r_o = \frac{1}{\frac{\partial I_D}{\partial V_{DS}}} = \frac{1}{\frac{1}{2} \mu_n C_{OX} \frac{W}{L} (V_{GS} - V_{to})^2 . \lambda} \quad \text{...(13)},$$

$$r_o = \frac{1}{I_D . \lambda} \quad \text{...(14)},$$

$$\text{where} \lambda = \frac{1}{V_A}$$

Types of Single Stage Amplifier

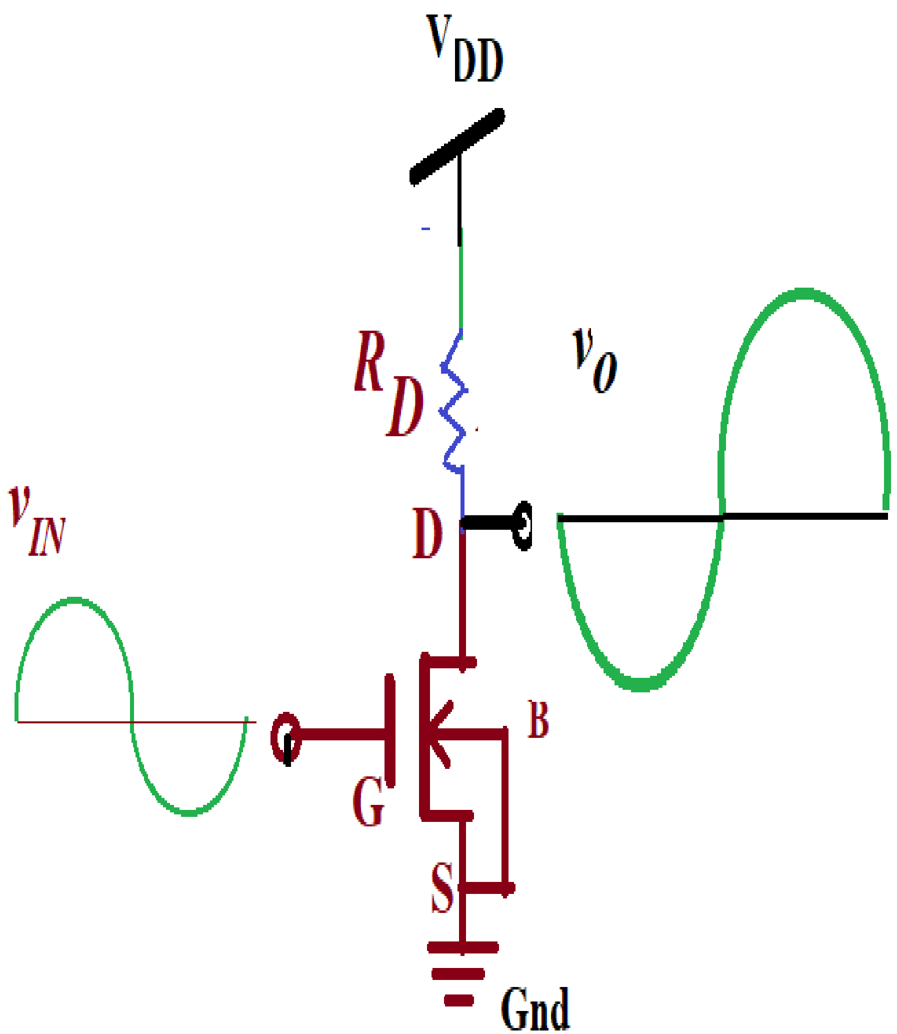


Figure 5: The Common source stage.

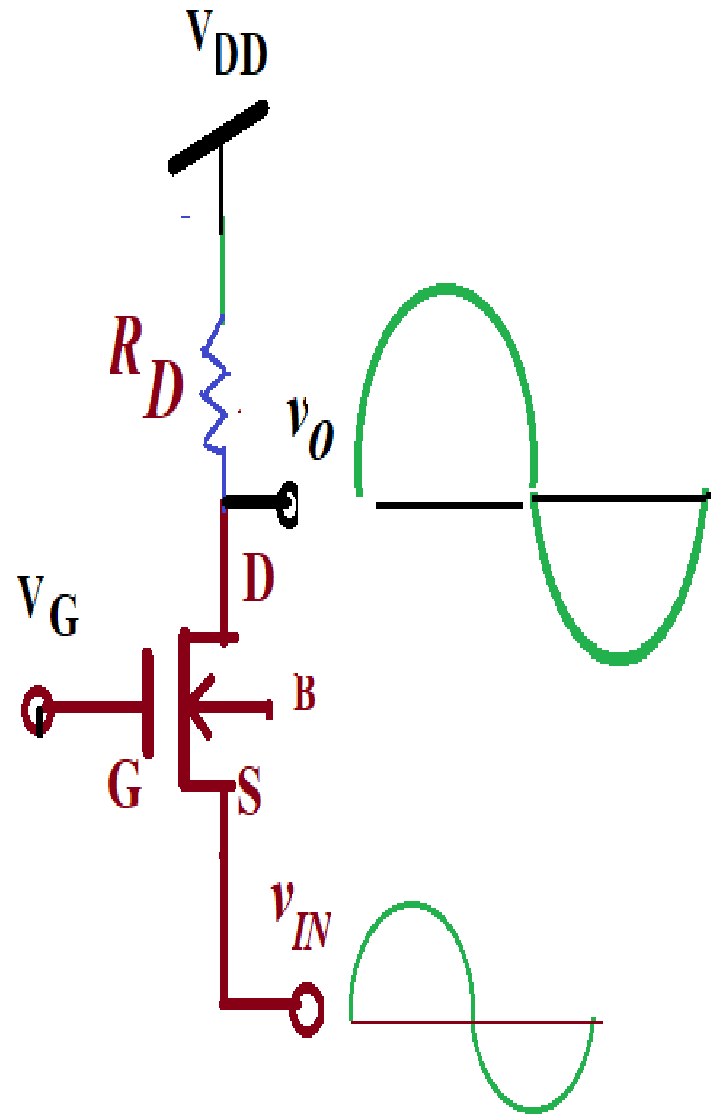


Figure 6: The Common gate stage.

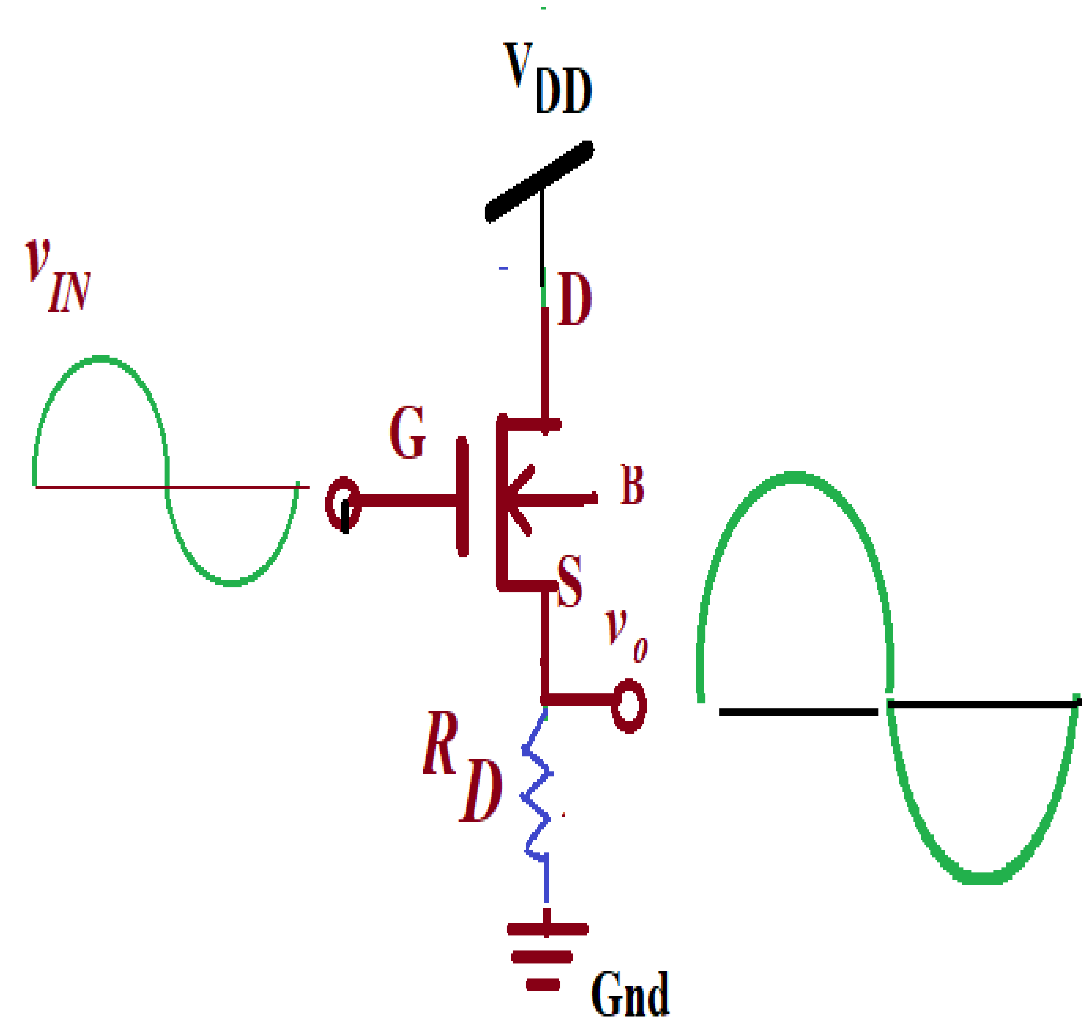


Figure 7: The Common drain stage.

Low Frequency Small Signal operation of Single Stage Common Source Amplifier

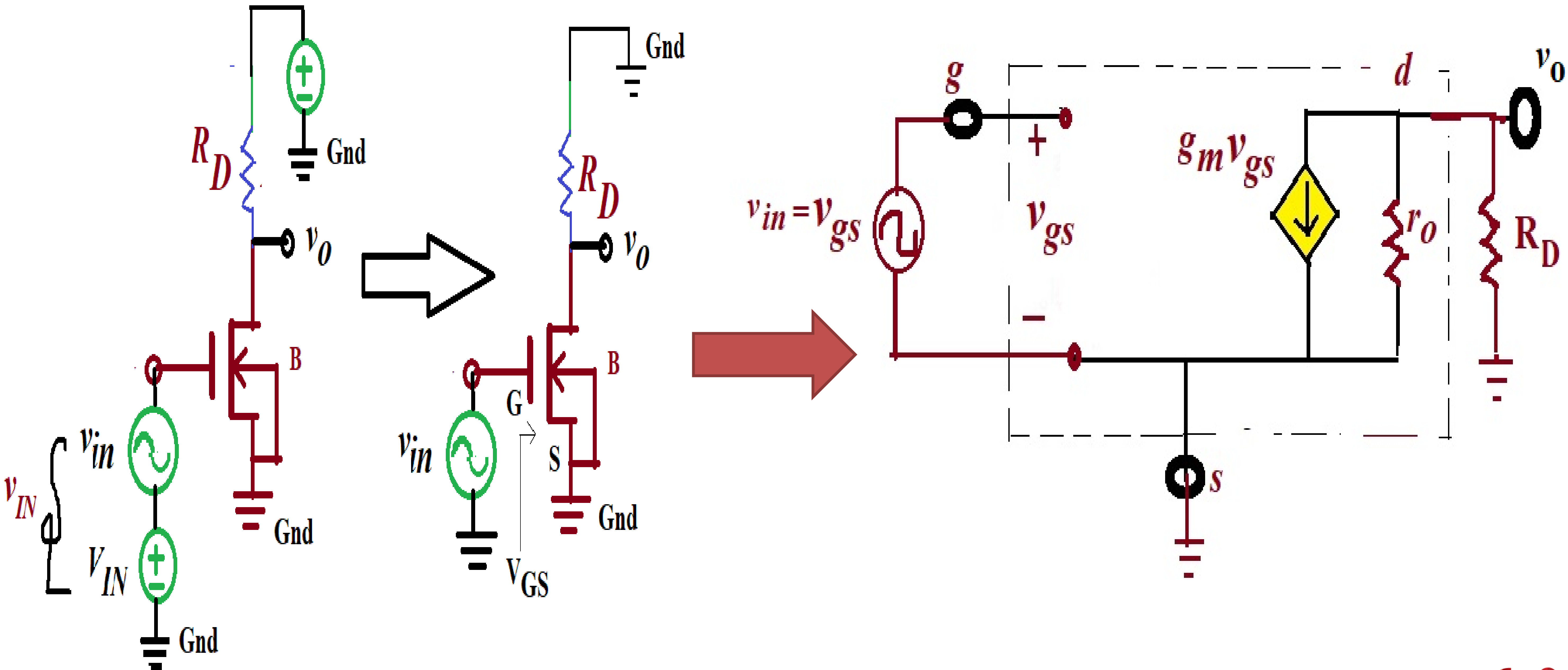


Figure 8: Small signal equivalent π model based single stage common source amplifier circuit with no body effect.

Small Signal operation..........

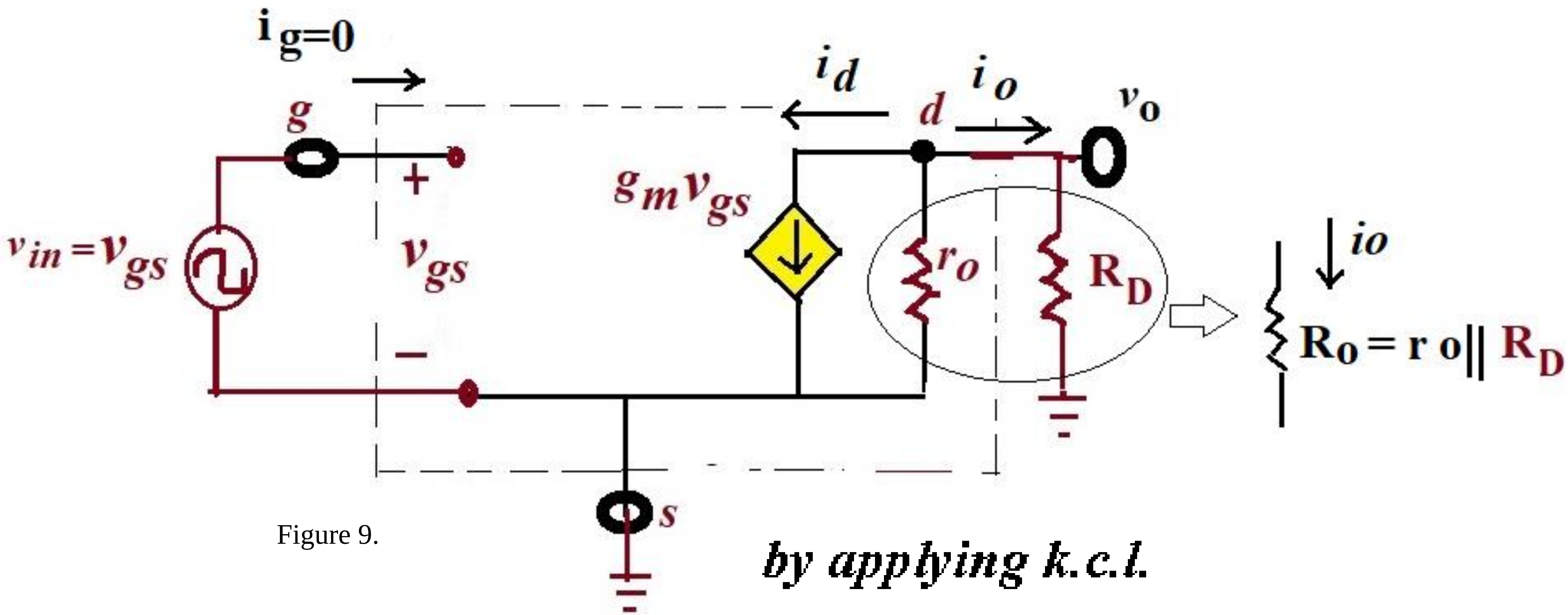


Figure 9.

by applying k.c.l.

$$i_0 + i_d = 0 \text{ ....(15)}$$

$$v_0 = i_0 R_o = -i_d R_o = -g_m v_{GS} R_o \text{ .....(16)}$$

$$A_v = \frac{v_0}{v_{in}=v_{GS}} = -g_m R_o \text{ ....(17)}$$

$$R_o = r_o \| R_D \text{ ....(18)}$$

Thank You