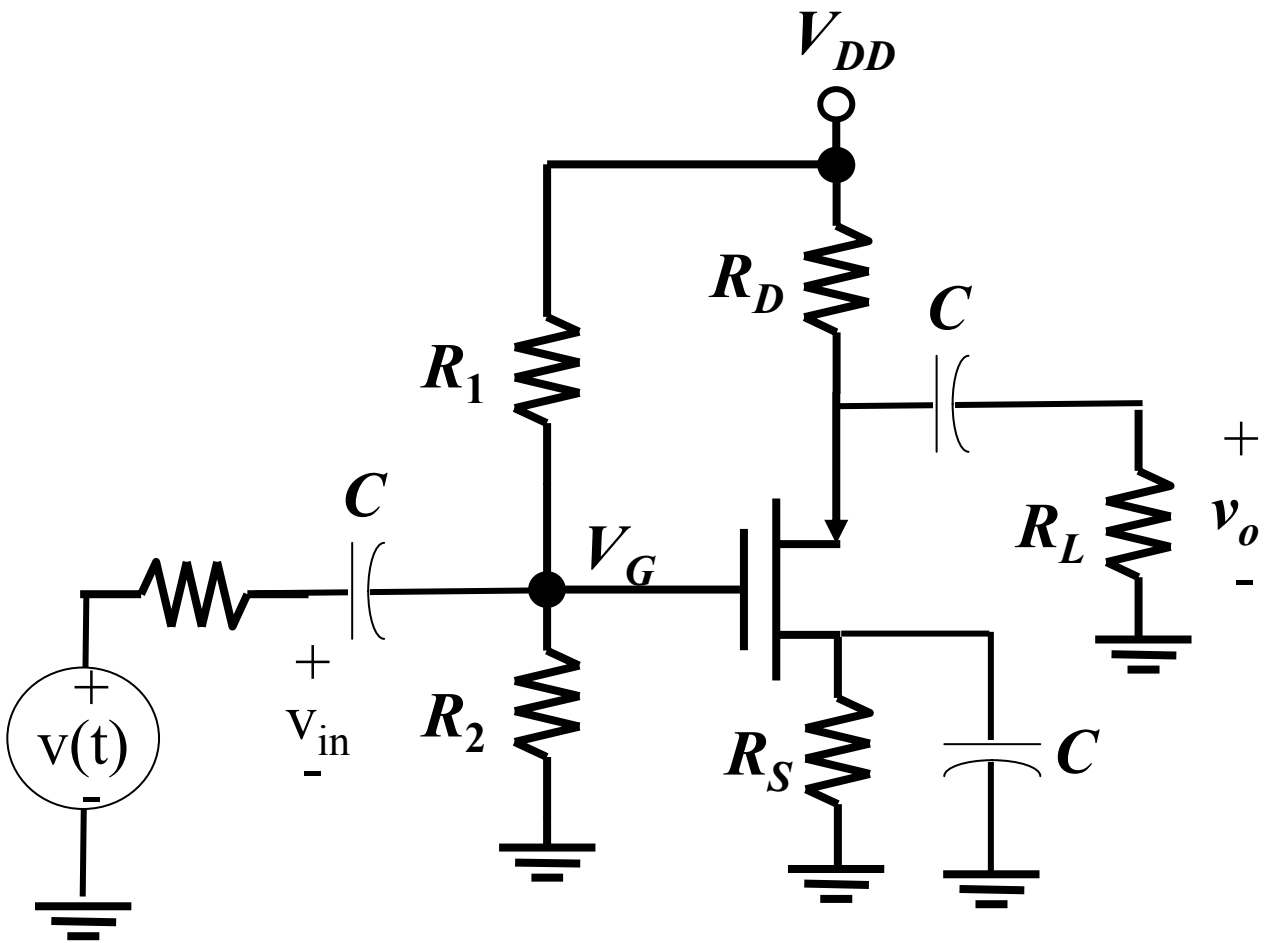
Common Source Amplifier

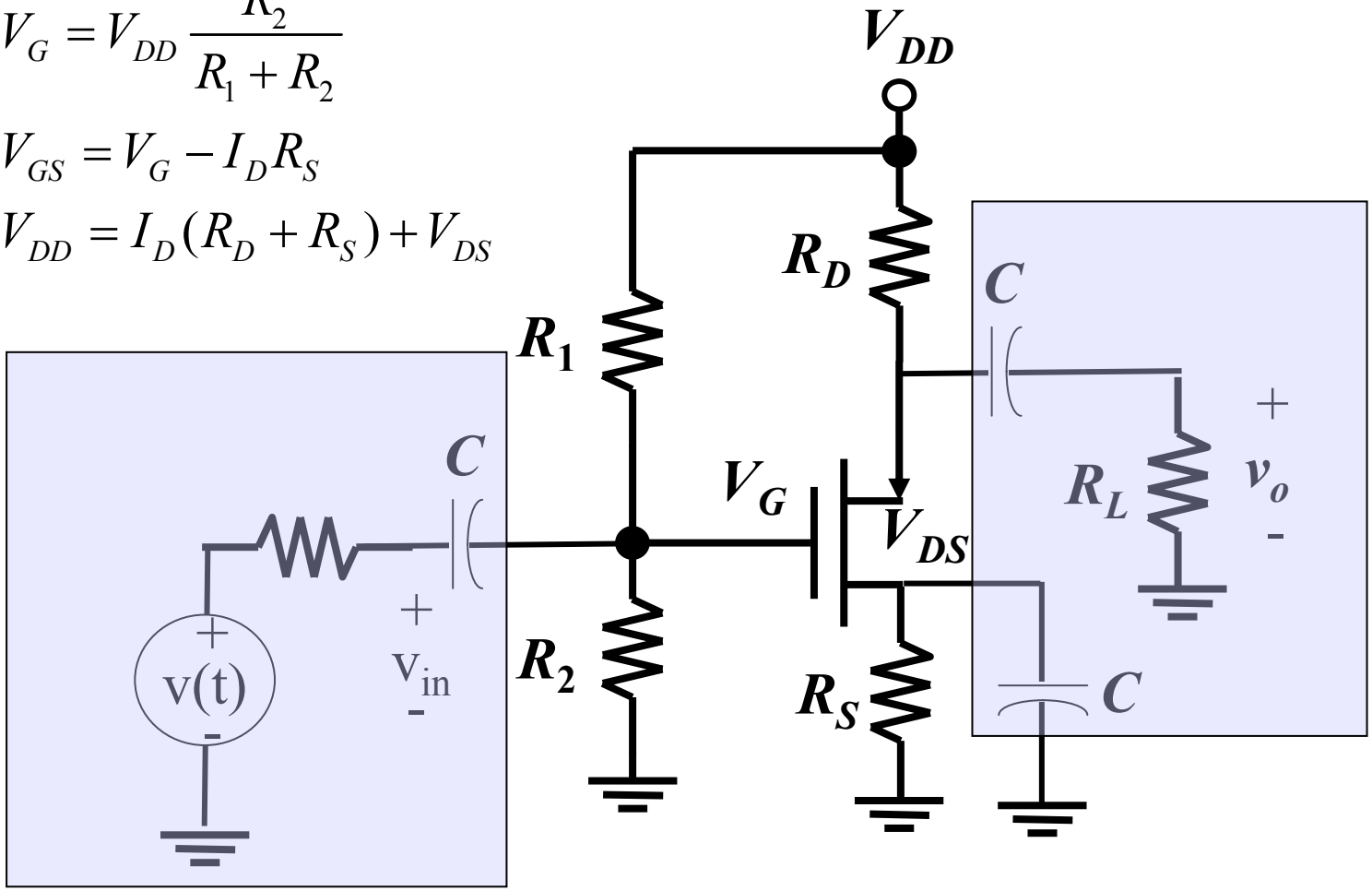


Step 1: find Q point

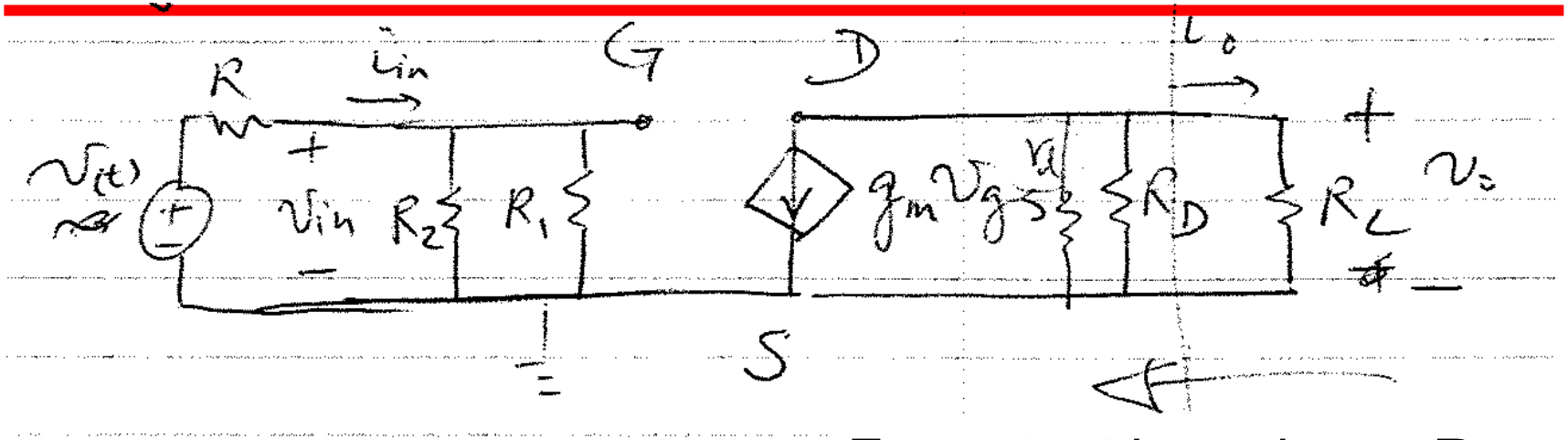
$$V_G = V_{DD}\frac{R_2}{R_1 + R_2}$$

$$V_{GS} = V_G - I_D R_S$$

$$V_{DD} = I_D(R_D + R_S) + V_{DS}$$



Small Signal Model



$$v_g = v_{in}, v_s = 0 \rightarrow v_{gs} = v_{in}$$

$$v_o = \frac{R_L R_D}{R_L + R_D}(-g_m v_{gs})$$

$$A_v = \frac{v_o}{v_{in}} = -g_m \frac{R_L R_D}{R_L + R_D}$$

$$R_{in} = \frac{v_{in}}{i_{in}} = \frac{R_1 R_2}{R_1 + R_2}$$

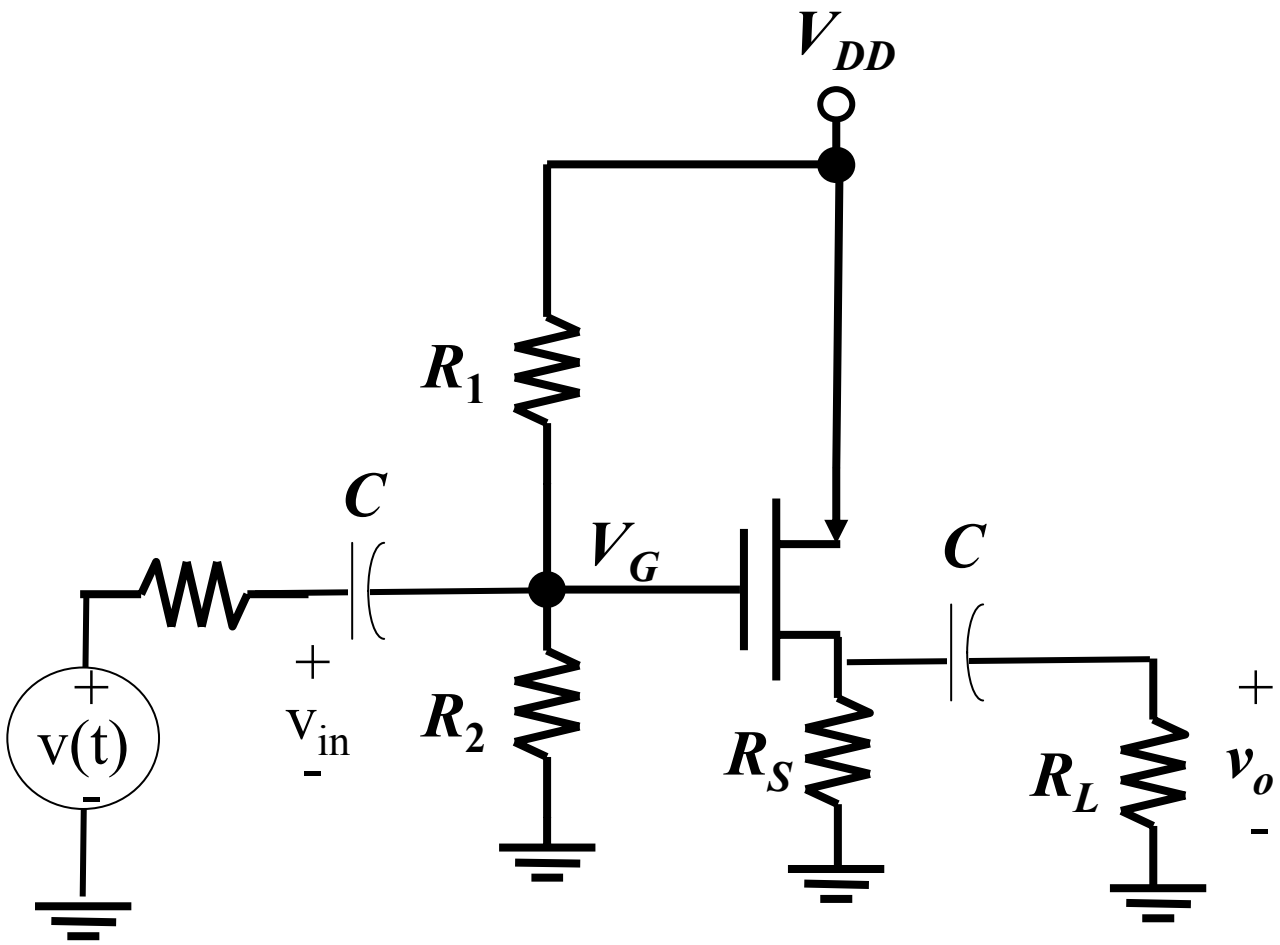
For output impedance R_{out}:

1. Turn off all independent sources.
2. Take away load impedance R_L

$$v_{in} = 0, v_{gs} = 0, g_m v_{gs} = 0$$

$$R_{out} = \frac{r_d R_D}{r_d + R_D}$$

Source Follower

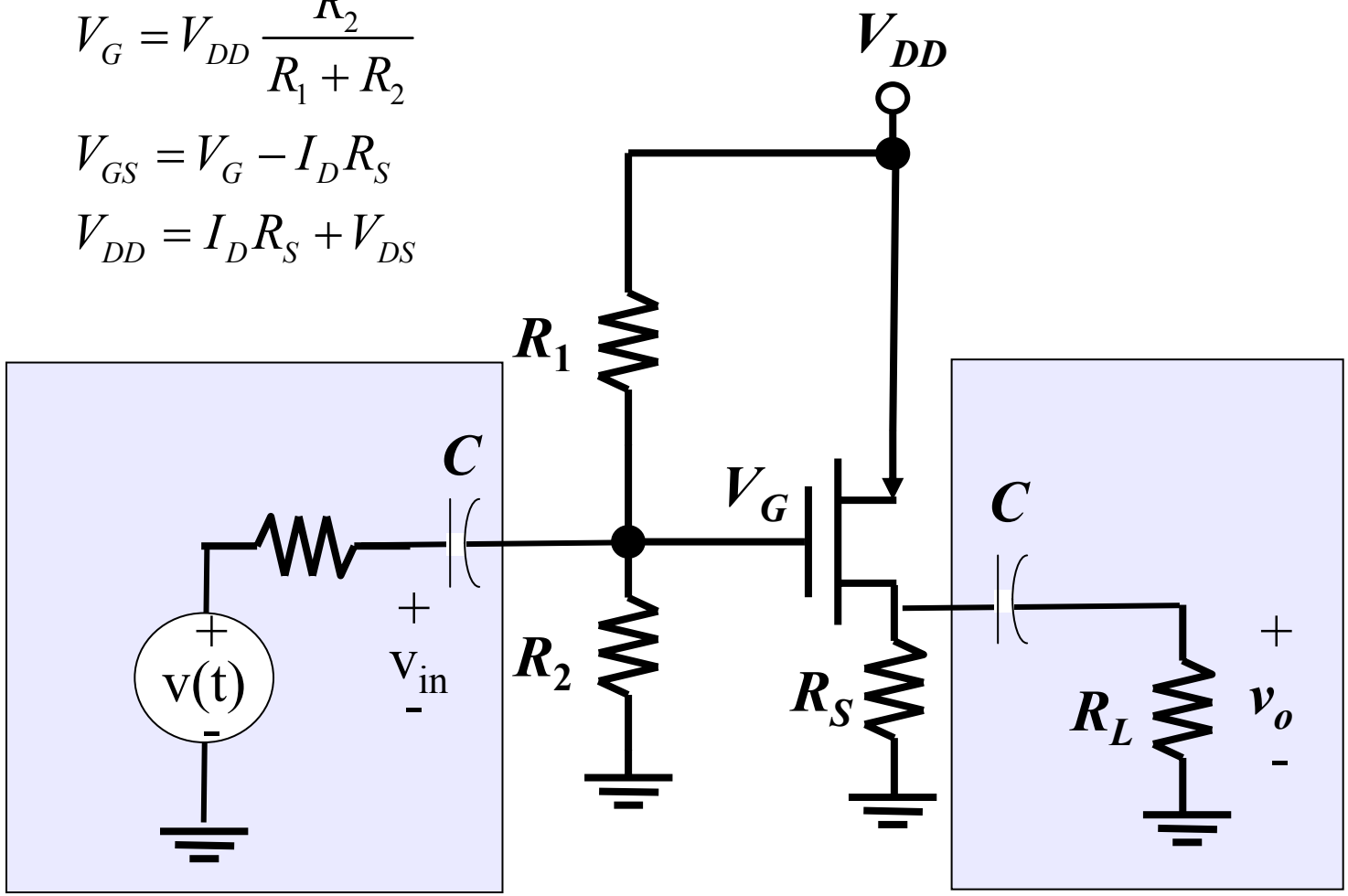


Step 1: find Q point

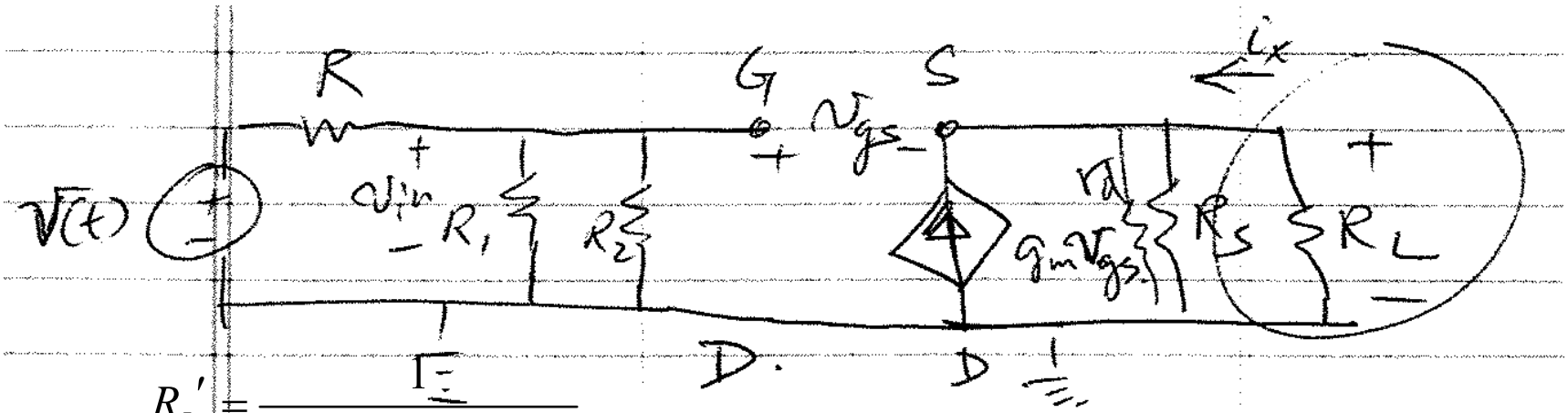
$$V_G = V_{DD}\frac{R_2}{R_1 + R_2}$$

$$V_{GS} = V_G - I_D R_S$$

$$V_{DD} = I_D R_S + V_{DS}$$



Small Signal Model



$$R_L' = \frac{1}{r_d^{-1} + R_S^{-1} + R_L^{-1}}$$

$$v_{gs} = v_{in} - v_o$$

$$v_o = g_m v_{gs} R_L'$$

$$v_{in} = v_{gs}(1 + g_m R_L')$$

$$A_v = \frac{v_o}{v_{in}} = \frac{g_m R_L'}{1 + g_m R_L'}$$

$$R_{in} = \frac{v_{in}}{i_{in}} = \frac{R_1 R_2}{R_1 + R_2}$$

For output impedance R_{out}:

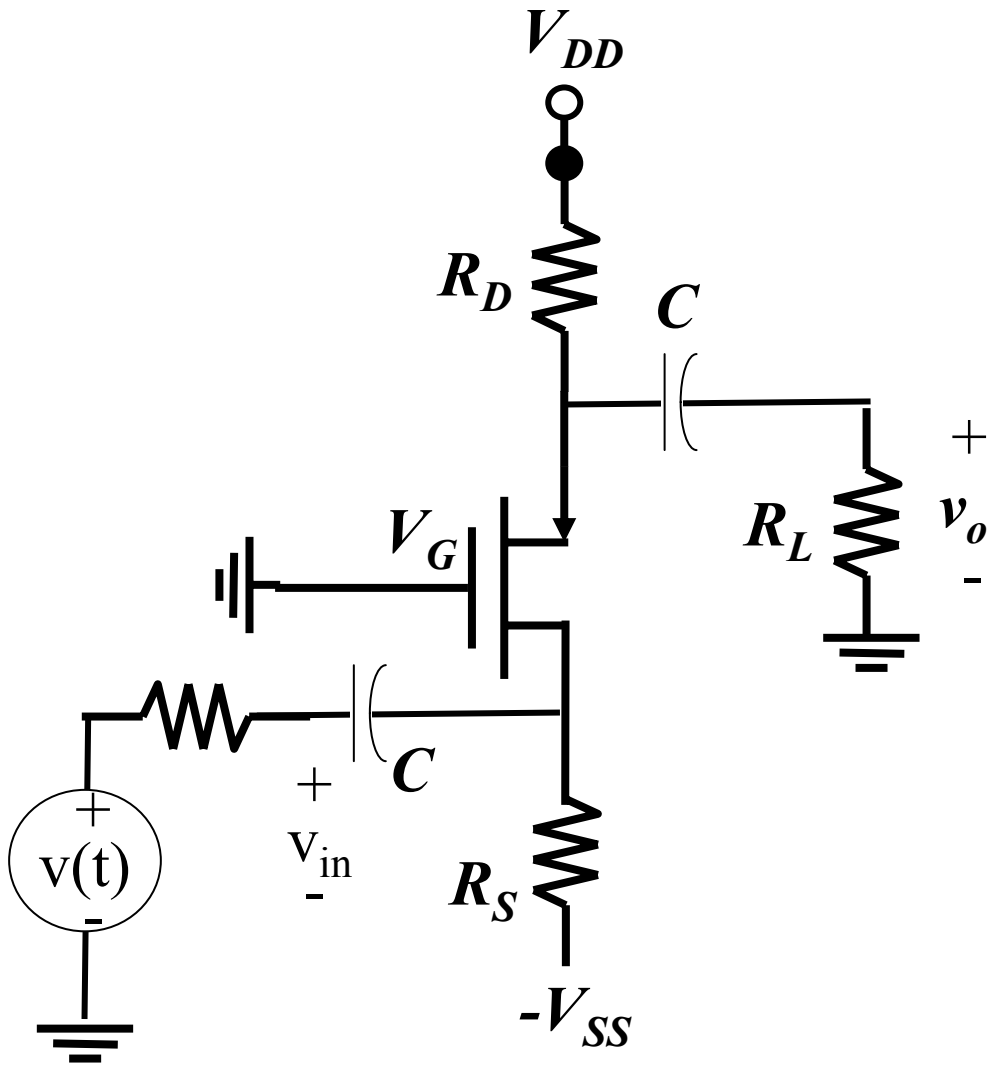
1. Turn off all independent sources.
2. Take away R_L
3. Add V_x and find i_x

$$v_x = v_s, v_g = 0, v_{gs} = -v_x$$

$$R_s' = \frac{r_d R_s}{r_d + R_s}, i_x = \frac{v_x}{R_s'} - g_m(-v_x) = v_x\left(R_s'^{-1} + g_m\right)$$

$$R_{out} = \frac{1}{g_m + r_d^{-1} + R_s^{-1}}$$

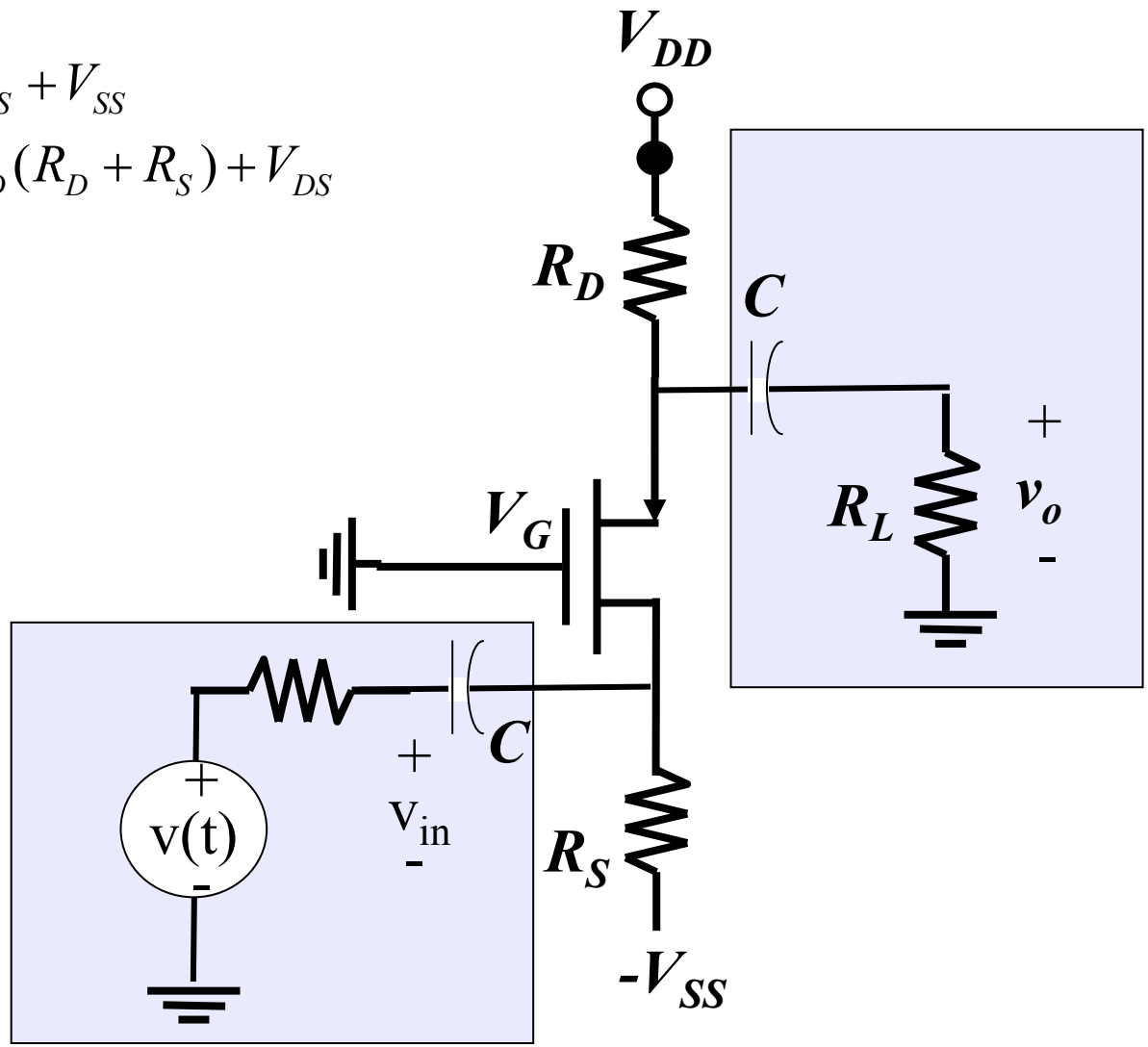
Common Gate Amplifier



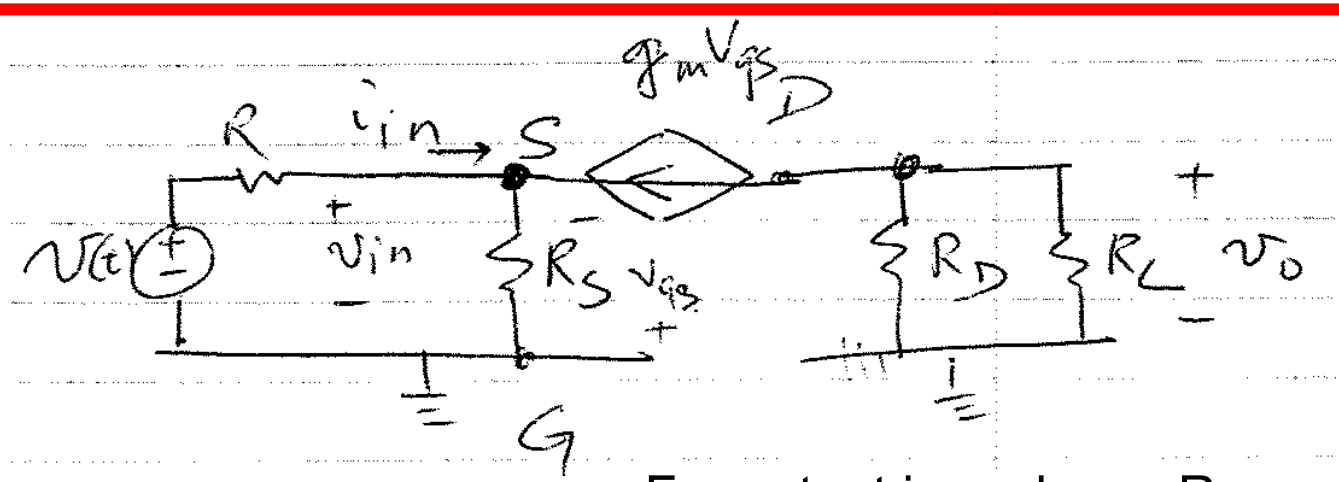
Step 1: find Q point

$$V_{GS} = 0 - I_D R_S + V_{SS}$$

$$V_{DD} + V_{SS} = I_D (R_D + R_S) + V_{DS}$$



Small Signal Model



$$R_L' = \frac{1}{R_L^{-1} + R_D^{-1}}$$

$$v_{gs} = -v_{in}$$

$$v_o = -g_m v_{gs} R_L'$$

$$A_v = \frac{v_o}{v_{in}} = g_m R_L'$$

$$i_{in} = -(g_m v_{gs} + \frac{v_{gs}}{R_s})$$

$$R_{in} = \frac{v_{in}}{i_{in}} = \frac{1}{g_m + R_s^{-1}}$$

For output impedance R_{out}:

1. Turn off all independent sources.
2. Take away R_L
3. Add V_x and find i_x

$$R' = \frac{RR_s}{R + R_s}$$

$$i_x = \frac{v_x}{R_D} + g_m v_{gs}$$

$$v_{gs} = -g_m v_{gs} R', \ \ but \ \ g_m R' \neq 1 \therefore v_{gs} = 0$$

$$R_{out} = R_D$$