Coupling and Bypass Capacitors

Coupling capacitors (or dc blocking capacitors) are use to decouple ac and dc signals so as not to disturb the quiescent point of the circuit when ac signals are injected at the input.

Bypass capacitors are used to force signal currents around elements by providing a low impedance path at the frequency.

Circuit Analysis - dc & ac Equivalent Circuits

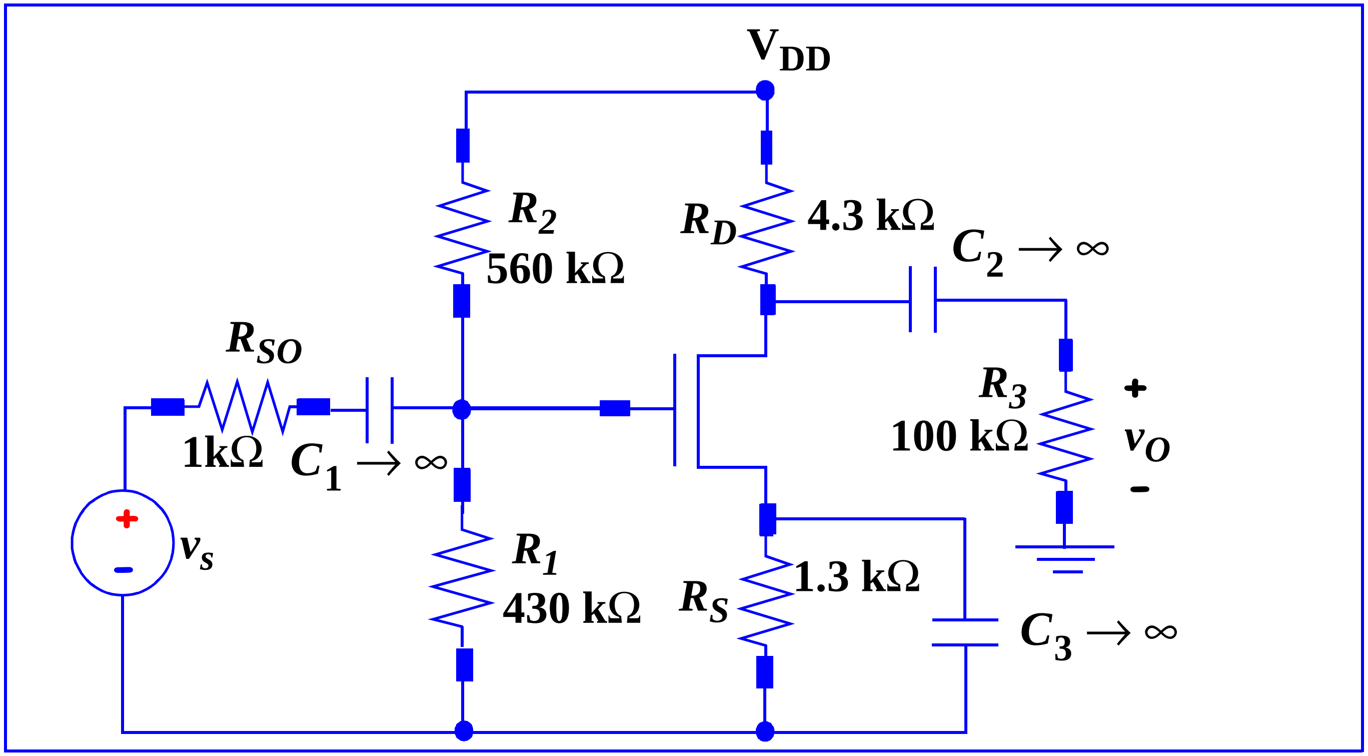
DC Analysis

1. Find dc equivalent circuit. C's replaced by open circuits and L's replaced by short circuits.
2. Find Q-point from dc equivalent circuit using appropriate large-signal model for transistor.

AC Analysis

3. Find ac equivalent circuit. C's replaced by short circuits and L's replaced by open circuits. DC voltage sources are replaced by ground connections and dc current sources by open circuits in ac equivalent circuit.
4. Replace transistor by small-signal model.
5. Analyze ac characteristics from small-signal ac equivalent circuit.
6. Combine results from #2 and #5 to get total voltages and currents in complete network.

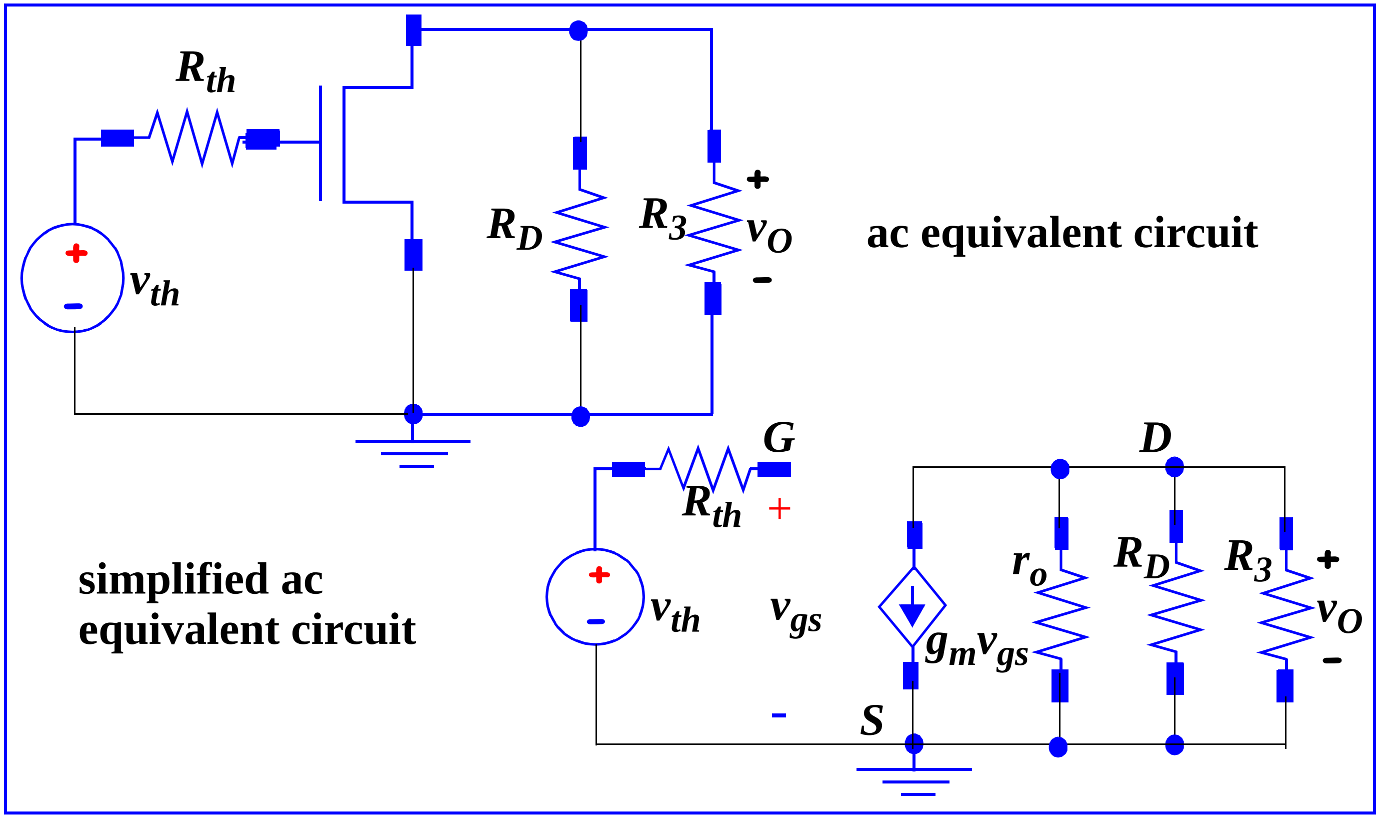
The Common-Source Amplifier



DC Analysis

for VDD=12.0 v, Kn=0.5 mA/V2, VTN=1.0v find the Q-point?

AC Analysis



$$R_G = R_1 \| R_2;\ R_{th} = R_{SO} \| R_G;\ v_{th} = \frac{R_G}{R_{SO} + R_G} v_s = v_{gs}$$

The load resistance is $R_L = r_o \| R_D \| R_3$

Voltage Gain $A_{V,\,th} = \dfrac{v_o}{v_{th}} = \dfrac{-g_m v_{gs} R_L}{v_{gs}} = -g_m R_L$

Voltage Gain $A_V = \frac{v_o}{v_s} = -g_m v_{gs} R_L \bullet \left\{\frac{1}{v_{gs}} \cdot \frac{R_G}{R_{SO} + R_G}\right\}$.

Since $R_G \gg R_{SO}$, then $A_V = -g_m R_L = -g_m(r_o \| R_D \| R_3)$

Rule-of-Thumb for the Common-Source Amplifier

Generally $r_o \gg R_3$ and $R_3 \gg R_D$, so $(r_o \| R_D \| R_3) \approx R_D$.

Therefore, $A_V \approx -g_m R_D$ or $A_V \approx -\frac{I_D}{(V_{GS} - V_{TN})/2} R_D$.

Assuming that $I_D R_D = \frac{V_{DD}}{2}$, $(V_{GS} - V_{TN}) = 1\text{V}$, then

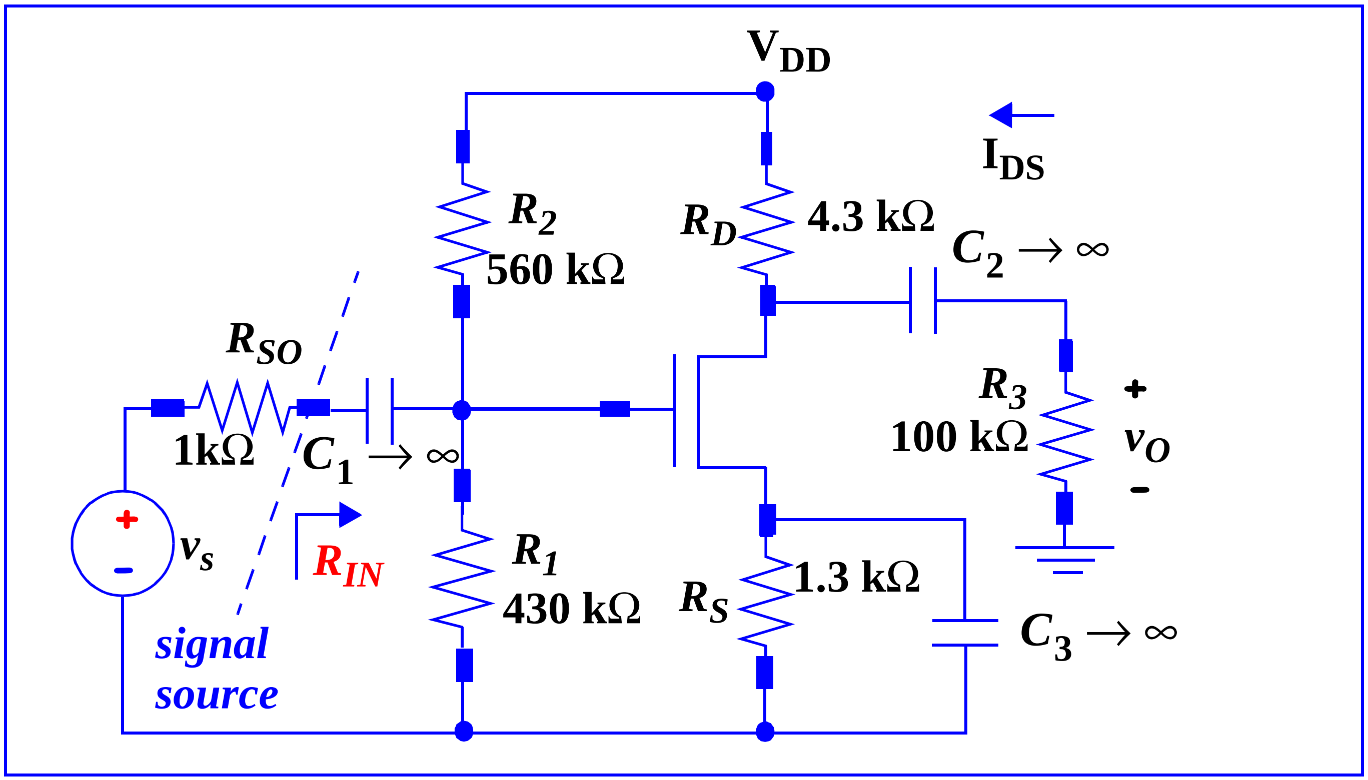
$$A_V \approx -\frac{V_{DD}/2}{(V_{GS} - V_{TN})/2} \approx -V_{DD}$$.

CS Voltage Gain - Upper Bound

If $R_D \| R_3 \gg r_o$ and letting $R_3, R_D \to \infty$, then $A_V \approx -g_m r_o = -\mu_f$

Voltage gain of CS stage cannot exceed the amplification factor of the transistor itself.

Input Resistance of CS Amplifier



$v_x = i_x R_G$

$R_{IN} = R_G$

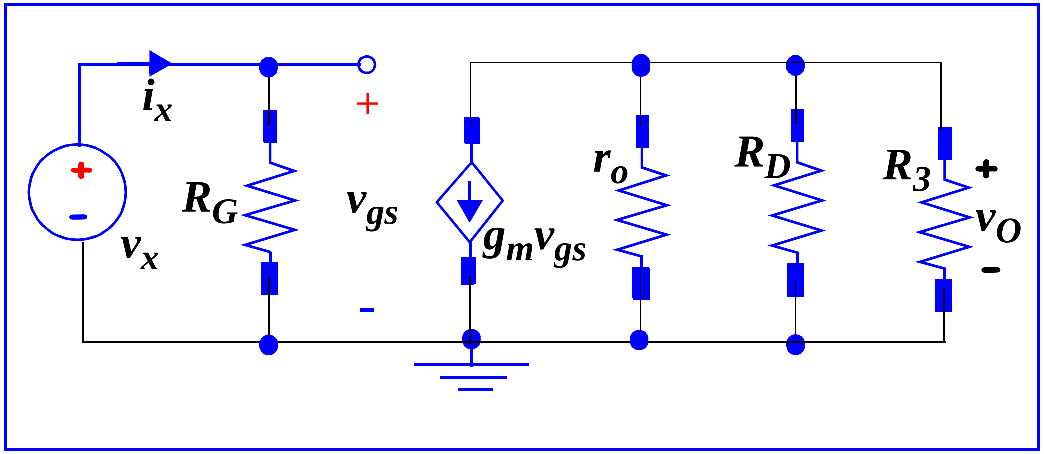
$R_G = R_1 \| R_2$

$R_G = 243k\Omega$

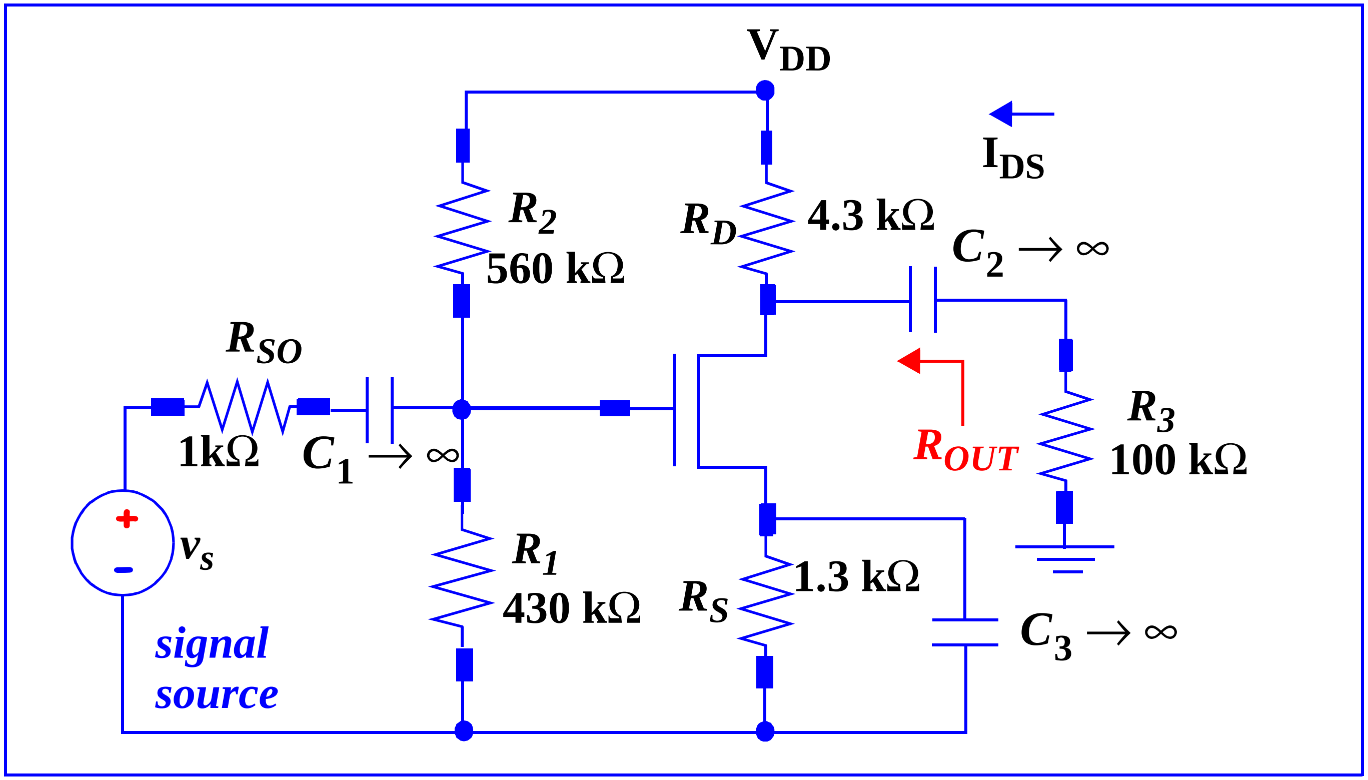
$R_{IN} = 243k\Omega$

Input Resistance

$$\boxed{R_{IN} = R_G}.$$



Output Resistance of CS Amplifier (p. 625)



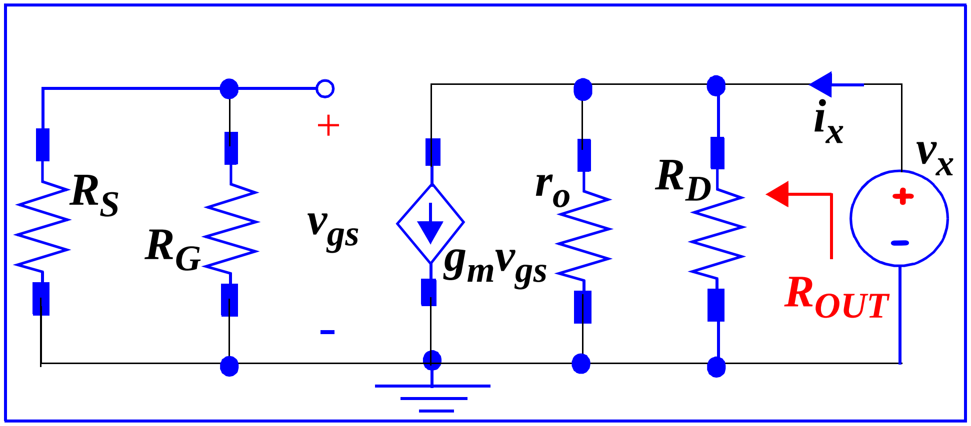
$$v_x = i_x R_{OUT}$$

$$R_{OUT} = R_D \| r_o$$

$$I_D r_o = I_D \frac{1 + \lambda V_{DS}}{\lambda I_D}$$

$I_D r_o \approx \frac{1}{\lambda}$ and

$$I_D R_D \approx \frac{V_{DD}}{2}$$



Output resistance $R_{OUT} = (R_D \| r_o) \approx R_D$ since $R_D \ll r_o$.

Verify Results in PSpice!