Low Freq Cutoff

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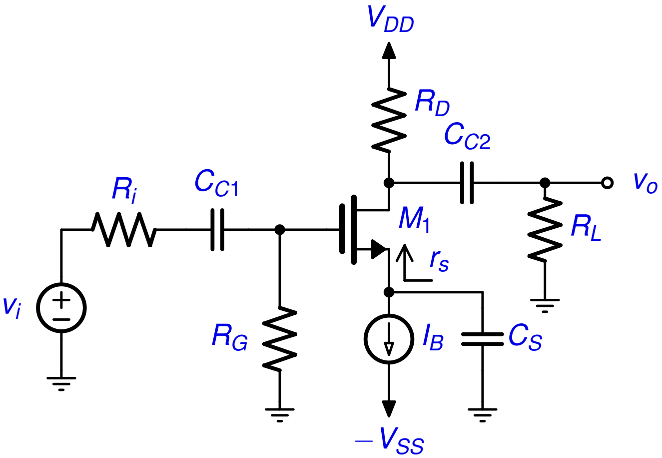
Low Frequency Cutoff

- The low frequency cutoff is generally due to coupling and bypass capacitors
- Coupling and bypass capacitors are intentionally added to the circuit
- Coupling Caps
  - Added in series with the signal so that the dc bias conditions can be different for different parts of the amplifier
  - Or to filter out low freq signals/noise
- Bypass Caps
  - Added across an element (often a current source) so that the element is a high impedance at low freq and a low impedance at high frequencies
  - Makes biasing easier
  - Also filters out low freq signals/noise

Low Frequency Cutoff



Low Frequency Cutoff

- Assume $r_o \to \infty$
  - Impedance looking into M_1 drain is ∞
  - Impedance looking into M_1 source is $r_s = 1/g_m$
- Include r_{oB} for current source
- Coupling Caps
  - C_{C1} and C_{C2}
- Bypass Cap
  - C_S
  - To bypass current source so v_x looks like ground at midband and high freq
- There are 3 LF (low freq) poles
  - Due to C_{C1}, C_{C2} and C_S
- There are 2 zeros at dc, one finite zero
  - dc zeros due to C_{C1}, C_{C2}; finite zero due to C_S

Low Frequency Cutoff

- 3 LF poles

$$C_{C1} \quad \Rightarrow \quad \omega_{p1} = \frac{1}{C_{C1}(R_i + R_G)} \tag{1}$$

$$C_{C2} \quad \Rightarrow \quad \omega_{p2} = \frac{1}{C_{C2}(R_D + R_L)} \tag{2}$$

$$C_S \quad \Rightarrow \quad \omega_{p3} = \frac{1}{C_S(r_s || r_{oB})} \tag{3}$$

- Finite zero due to C_S

$$H(s) = \frac{-(R_D||R_L)}{r_s + (r_{oB}||(1/sC_S))} \tag{4}$$

$$H(s) = -(R_D||R_L) \times \frac{1 + sC_S r_{oB}}{(r_s + r_{oB}) + sC_S r_s r_{oB}} \tag{5}$$

$\omega_{z3} = 1/(C_S r_{oB}) < \omega_{p3}$

  – Could have found zero by finding where C_S and r_{oB} go to infinite impedance

Low Frequency Cutoff

- Example
  - $R_i = 100\text{k}\Omega$; $R_G = 4.7\text{M}\Omega$; $R_D = 15\text{k}\Omega$; $R_L = 15\text{k}\Omega$; $r_{oB} \to \infty$
  - $g_m = 1\text{mA/V} \Rightarrow r_s = 1/g_m = 1\text{k}\Omega$
  - Select C_{C1}, C_{C2}, and C_S so $f_L \approx 100\text{Hz}$ by having 1 pole at 100Hz and 2 poles each at 10Hz.
    Also, minimize the total capacitance size.

- Solution
  - $\omega_{p1} = \frac{1}{C_{C1}(R_i+R_G)}$ $\quad \omega_{p2} = \frac{1}{C_{C2}(R_D+R_L)}$ $\quad \omega_{p3} = \frac{1}{C_S r_s}$
  - Since $r_s < (R_D + R_L) < (R_i + R_G)$, to minimize capacitance, make ω_{p3} be the largest pole at 100Hz
  - $C_s = \frac{1}{\omega_{p3} r_s} = \frac{1}{(2\pi \times 100)(1k)} = 1.6\mu\text{F}$
  - Now let $\omega_{p1} = \omega_{p2} = 2\pi \times (10\text{Hz})$
  - $C_{C1} = \frac{1}{\omega_{p1}(R_i+R_G)} = 3.3\text{nF}$
  - $C_{C2} = \frac{1}{\omega_{p2}(R_D+R_L)} = 0.53\mu\text{F}$

Topics Covered

- Low freq cutoff
- Due to added coupling or bypass capacitors
  - Added to simplify design or to filter dc signals