Noise and Feedback

- Ideal feedback:
  - No increase of input referred noise
  - No decrease of SNR at output

- Practical feedback: increased noise
  - Noise from feedback network
  - Noise gain from elements outside feedback loop

Real Feedback

- Conceptually identical to standard two port calculations
- Use $R_s = 0$ to find $v_{in}^2$
- Use $R_s = \infty$ to find $i_{in}^2$

- Calculations get tedious...

Practical Feedback Analysis

- Quick approximation method:
  - Consider loading of feedback network on the input
  - Add a noise source associated with this element.
  - Example: shunt feedback
  - Loading at input is $R_f \rightarrow i_s^2 = i_n^2 + 4kT \Delta f / R_f$

Example #2: Series-Shunt Feedback

- Loading is $R_f || R_E$
- So, noise voltage becomes:
  - $v_n^2 = v_s^2 + 4kT(R_f || R_E) \Delta f$
Implications: Non-Inverting Amp

- Minimum power from feedback \( \rightarrow \) large \( R_1+R_2 \)
- Example:
  - \( A_v = 10, R_2 = 100k\Omega, R_1 = R_2(A_v-1) = 900k\Omega \)
  - \( v_{nfb}^2 = 40nV/\sqrt{\text{Hz}} \) (very high)
  - Only way to lower noise is increase power...

Example (cont.)

- Calculate noise TF to amplifier output:
  \[
  v_o = \frac{1}{C_z} \left( C_z F_z + s C_z F_z \right) v_i = g_m v_i + i_{r_2}
  \]
  \[
  v_o = 0, v_i = \frac{g_m v_i + g_m v_i + i_{r_2} = 0}
  \]
  \[
  v_o = \frac{v_i}{F = \frac{C_z}{C_z + C_m}}
  \]

Example: Inverting Amplifier

- Ignoring noise from \( R_1, R_2 \):
  \[
  v_o = s \left( R_2 + R_1 \right) v_i = g_m v_i + i_{r_2}
  \]
  \[
  v_o = 0, v_i = s C_z v_i + g_m v_i + i_{r_2} = 0
  \]
  \[
  v_o = \frac{v_i}{F = \frac{C_z}{C_z + C_m}}
  \]

Example (cont.)

- Low frequency:
  - \( i_{r_2} \) doesn't reach output
- High frequency:
  - \( C_z \) acts as a short

“Complete” Noise Example

- Effect of cascode device noise on common-source feedback amplifier

Example (cont.)

- Total noise:
  \[
  v_o^2 = \frac{1}{C_m} \left( \frac{a}{[F]_{m_i}} \right)(4fT)g_m
  \]
  \[
  v_o^2 = \frac{1}{F_{m_i}} \left( g_m (C_z + F_z) \right) \left( C_z + F_z \right)
  \]
  \[
  v_o^2 = \frac{4fT}{C_z + F_z} \left[ C_z + F_z \right]
  \]