Continued...

\[ V_{in} \]

\[ \frac{V_{in}}{V_{in}} \]

\[ R_{11} \]

\[ R_{22} \]

\[ \frac{V_{o}}{V_{in}} \]

\[ R_{3} \]

\[ R_{21} \]

\[ \frac{V_{1}}{V_{in}} \]

\[ \frac{V_{2}}{V_{1}} \]

\[ - \text{recognize as Common Source Amplifier with source degeneration resistor } R_{11} \]

\[ \Rightarrow \frac{V_{1}}{V_{in}} = \frac{-g_{m1}R_{11}}{1 + g_{m1}R_{11}} \]

\[ \text{Second stage: } \frac{V_{2}}{V_{1}} \]

\[ - \text{recognize as Common Gate Amplifier} \]

\[ \Rightarrow \frac{V_{2}}{V_{1}} = -g_{m2}R_{21} \]

\[ \text{Third stage: } \frac{I_{o}}{V_{2}} \text{ (since we want current output)} \]

\[ - \text{again C.S. with source degeneration} \]

\[ \Rightarrow \frac{I_{o}}{V_{2}} = \frac{g_{m2}}{1 + g_{m2}R_{22}} \]

\[ \text{Total gain: } A = \frac{I_{o}}{V_{in}} = \frac{V_{1}}{V_{in}} \frac{V_{2}}{V_{1}} \frac{I_{o}}{V_{2}} = \frac{g_{m1}g_{m2}R_{11}R_{22}}{1 + g_{m1}R_{11}X(1 + g_{m2}R_{22})} \]

\[ \beta = \frac{V_{2}}{V_{1}} = \frac{R_{11}}{R_{21} + R_{22} + R_{F}} \]

\[ \text{New: from before } \]

\[ \Rightarrow A_{f} = \frac{A}{1 + A \beta} \]
As transistors get smaller, integration levels and operating speeds increase, and traditionally analog circuit functions are taken over by digital circuitry. But analog circuits will never disappear entirely - all real world signals are inherently analog, so at the very least we will always need ADCs and DACs.

**Example:** Software defined radio receiver

**Basic Concepts:**

- Taking an analog signal into the digital domain involves 2 steps:
  1. Sampling mixes the continuous time, continuous value analog signal to a discrete time, continuous value signal.

  ![Sample Levels](image)

  Sampling instance

- Commonly done using a sample & hold circuit:

  - $V(s(k))$ tracks $V(t(k))$ when switch is closed.
  - Switch is opened at sampling instant and capacitor holds $V(s(k))$ until next sampling.

  ![Sample & Hold Circuit](image)