Now, given that we care about the effects of the signal component:

\[ G \rightarrow \text{only signal component} \rightarrow D \leftarrow \text{id. (only signal component)} \]

open circuit
since no low
freq. current
caused

- In analyzing a circuit like this, for \( V_{gs} = V_{gs} + V_{gs} \),
  - the bias component \( V_{gs} \) is used to calculate the component values for the small signal model, which is often used for analyzing how the signal propagates through the system.
  - to find \( V_{d} \) we must use \( I_{d} \) expression which takes channel length modulation into account:

\[
V_{d} = \left[ \frac{\partial I_{d}}{\partial V_{gs}} \right]^{-1} \quad \text{(evaluated at } V_{gs} \text{ bias point)}.
\]

\[ = \frac{1}{2wLd} \quad \text{bias level of drain current} \]

- Single Stage Mos Amplifier:
  - Common-Source:
  - most commonly used
  - good for getting gain

- Common-Gate:
  - useful for having a constant input impedance across frequency
  - useful characteristics for wideband amplifier

- Common-Drain (Sane-Follows):
  - often used as an output stage due to low output impedance
  - no voltage gain, but can provide current gain
Let's analyze one of these cases:

- General Form of CS amplifier (pg 307 in text):

- $C_1, C_2, C_s$ are coupling capacitors since they allow the signal to pass.
- It is assumed that the source is AC coupling to appear as shorts at the signal frequency and open at DC.
- For a capacitor $Z = \frac{1}{j\omega C}$, $Z \to 0$ as $\omega \to \infty$.
- Also called "blocking" capacitors, on the block, dc signal cd allows the bias conditions to be met.

- $R_s$ is output impedance of the drove source (not part of amplifier).
- $R_b$ is a large resistance included to set DC level of the gate for driving.
- Often not necessary, eq if being driven by another transistor.
- $R_b$ acts as a local resistor to provide a voltage output based on the drain current ($I_D$) induced by the input voltage swing.
- $R_i$ is the input impedance of another thermal amplifier it's driving (not part of the amplifier).

To analyze:

1. Examine bias conditions to determine the values of the small signal parameters ($g_m$ & $r_o$).
   - Simple here, because biasing is provided by a current source.
   - Need to check $V_{ds}$ to ensure that $M_1$ is operating in the SAT. region:
     - Assume SAT. region, calculate $V_{ds}$ using $I_D = \mu C_W \frac{V_{gs} - V_T}{2}$
     - Now, $V_{ds} = (V_{dd} - I_B R_b) - (-V_{ds})$
     - As long as $V_{ds} > V_{ds} - V_T$, device will be in SAT. region.

   - Use $g_m = \sqrt{2} \mu C_W \frac{V_{ds}}{I_D}$ and $r_o = \frac{1}{g_m}$ constant.

2. Replace transistor with small signal model, replace coupling capacitors with shorts, dc current sources with open circuits, dc voltage sources with small signal grounds:

   ![Small Signal Model Diagram]
Perform standard circuit analysis techniques (KCL or KVL) to determine the gain, etc. (e.g. input impedance, output impedance).

- By inspection, \( V_{gs} = \frac{V_{gs}}{R_{g} + R_{o}} \approx V_{gs} \) if \( R_{o} \gg R_{g} \).

\[ V_{at} = -g_{m} \cdot V_{gs} \cdot (\frac{1}{R_{o} || R_{L}}) \]

\[ V_{o} \text{ voltage gain} = A_{v} = -g_{m} \cdot (\frac{1}{R_{o} || R_{L}}) \]

- Also define open-circuit voltage gain. \( A_{vo} \approx -g_{m} \cdot R_{o} \)

If \( R_{o} \gg R_{d} \) (often the case), \( A_{vo} \approx -g_{m} \cdot R_{o} \).

This straightforward set of steps can be applied to any of the amplifier configurations to confirm their properties that were mentioned.

- With experience you will know what to reflect and be able to analyze without drawing at the S.S. model each time.

BJT Review

- BJT is similar to MOSFET in that it is used as a voltage-controlled current source.

struct: NPN:

- Several modes of operation, depending on whether each pn junction is forward or reverse biased.

- Most important is "Active" region, where BE is forward biased, BC is reverse biased.

- Current flows in forward biased BE junction - mostly electrons due to doping levels.

- Base is thin so electrons reach BC junction and are swept across by E-field of reverse biased junction.

- Results in a small "leak" leading to a base current which then leads to a much larger collector current.

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