Problems for Amplifier Section

Lecture notes: Sec. 6
Exercise 1: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

- This is a common collector amplifier (emitter follower).
  - Input at the base, output at the emitter.
- It has an emitter-degeneration bias with a voltage divider.
Exercise 1: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

\[ R_B = 22 \, k \parallel 18 \, k = 9.90 \, k \]
\[ V_{BB} = \frac{22 \, k}{22 \, k + 18 \, k} \times 9 = 4.95 \, V \]
Exercise 1: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

### Bias Calculations

- $R_B = 9.9 \, k\Omega \quad V_{BB} = 4.95 \, V$

Assume BJT is in Active:

- $V_{BE} = 0.7 \, V$, $I_C > 0$ and $V_{CE} \geq 0.7 \, V$

**BE-KVL:**

$$4.95 = I_B R_B + V_{BE} + I_E R_E$$

$$4.95 = 9.9 \times 10^3 I_E / (\beta + 1) + 0.7 + 10^3 I_E$$

$$I_E = 4.05 \, mA \approx I_C$$

$$I_B = I_C / \beta = 20.3 \, \mu A$$

**CE-KVL:**

$$9 = V_{CE} + I_E R_E$$

$$9 = V_{CE} + 4 \times 10^{-3} \times 10^3$$

$$V_{CE} = 5 \, V > V_{D0} = 0.7 \, V$$

### Thevenin form of the Voltage divider

- $g_m = \frac{I_C}{V_T} = \frac{4.05 \times 10^{-3}}{26 \times 10^{-3}} = 156 \, mA/V$
- $r_o \approx \frac{V_A}{I_C} = \frac{150}{4 \times 10^{-3}} = 37.0 \, k\Omega$
- $r_a = \frac{V_T}{I_B} = \frac{\beta}{g_m} = 1.28 \, k\Omega$
Exercise 1: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).
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Amplifier Parameters
This is a common collector amplifier (emitter follower)

$$A_v = \frac{v_o}{v_i} = \frac{g_m (r_o \parallel R_E \parallel R_L)}{1 + g_m (r_o \parallel R_E \parallel R_L)}$$

$$g_m (r_o \parallel R_E \parallel R_L) = 156 \times 10^{-3} (38.8k \parallel 1k \parallel 100k) = 151$$

$$A_v = \frac{151}{1+151} \approx 1$$

$$g_m = 156 \text{ mA/V}$$

$$r_o = 38.8 \text{ k}$$

$$r_\pi = 1.28 \text{ k}$$

$$R_i = R_B \parallel [r_\pi + (1+\beta)(r_o \parallel R_E \parallel R_L)]$$

$$R_i = 9.9k \parallel [1.3k + 194k] \approx 9.9k$$

$$R_o = r_o \parallel \frac{r_\pi + R_B}{\beta} \parallel R_{sig} = r_o \parallel \frac{r_\pi}{\beta} = 6.4 \Omega$$
Exercise 1: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

Amplifier Parameters 
(Cut-off frequency)

$$f_{p1} = \frac{1}{2\pi (R_i + R_{sig})C_{c1}}$$

$$f_{p1} = \frac{1}{2\pi (9.9 \times 10^3 + 0) \times 0.47 \times 10^{-6}} = 34.2 \text{ Hz}$$

$$f_{p2} = \frac{1}{2\pi (R_o + R_L)C_{c2}}$$

$$f_{p2} = \frac{1}{2\pi (6.4 + 100 \times 10^3) \times 0.47 \times 10^{-6}} = 3.39 \text{ Hz}$$

$$f_p \approx f_{p1} + f_{p2} = 34.2 + 3.4 = 37.6 \text{ Hz}$$

$g_m = 156 \text{ mA/V}$

$r_o = 38.8 \text{ k}$

$r_\pi = 1.28 \text{ k}$

$R_i = 9.9 \text{ k}$

$R_o = 13 \Omega$
Exercise 2: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

- This is a common emitter amplifier with $R_E$.
  - Input at the base, output at the collector.
- It has a emitter-degeneration bias with a voltage divider.
Exercise 2: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

\[ R_B = 34\,k \parallel 5.9\,k = 5.0\,k \]
\[ V_{BB} = \frac{5.9\,k}{34\,k + 5.9\,k} \times 15 = 2.22\,V \]

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Exercise 2: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

**Bias calculations**

\[ R_B = 5.0 \text{ k} \quad V_{BB} = 2.22 \text{ V} \]

Assume BJT is in Active:
\[ V_{BE} = 0.7 \text{ V}, \quad I_C > 0 \quad \text{and} \quad V_{CE} \geq 0.7 \text{ V} \]

BE - KVL: \[ 2.22 = I_B R_B + V_{BE} + I_E R_E \]
\[ 2.22 = 5.0 \times 10^3 I_E / (\beta + 1) + 0.7 + 510 I_E \]
\[ I_E = 2.84 \text{ mA} \approx I_C \]
\[ I_B = I_C / \beta = 14.2 \mu\text{A} \]

CE - KVL: \[ 15 = I_C R_C + V_{CE} + I_E R_E \]
\[ 15 = V_{CE} + 2.84 \times 10^{-3} \times (10^3 + 510) \]
\[ V_{CE} = 10.5 \text{ V} \quad > V_{D0} = 0.7 \text{ V} \]

**Thevenin form of the Voltage divider**

\[ g_m = \frac{I_C}{V_T} = \frac{2.84 \times 10^{-3}}{26 \times 10^{-3}} = 10.9 \text{ mA/V} \]
\[ r_0 \approx \frac{V_A}{I_C} = \frac{150}{2.84 \times 10^{-3}} = 52.8 \text{ k} \]
\[ r_\pi = \frac{V_T}{I_B} = \frac{\beta}{g_m} = 1.83 \text{ k} \]
Exercise 2: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).
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Amplifier Parameters
This is a CE amplifier with $R_E$

$$v_o \approx -\frac{g_m (R_C \parallel R_L)}{1 + g_m R_E + (R_C \parallel R_L) / r_o}$$

$$R_C \parallel R_L = 1 \text{k} \parallel 100 \text{k} = 0.990 \text{k}$$

$$v_o = -\frac{10.9 \times 10^{-3} \times 990}{1 + 10.9 \times 10^{-3} \times 510 + 0.990 / 52.8} = -1.64$$

$$R_i \approx R_B \parallel \left[ r_\pi + (1 + \beta) R_E \right]$$

$$R_i = 5.0 \text{k} \parallel \left[ 1.83 \text{k} + 201 \times 0.51 \text{k} \right] = 4.8 \text{k}$$

$$R_o \approx R_C \parallel \left[ r_o \left( 1 + \frac{\beta R_E}{r_\pi + R_E + R_B \parallel R_{\text{sig}}} \right) \right]$$

$$R_o \approx R_C = 1.0 \text{k}$$

$g_m = 10.9 \text{ mA/V}$

$$r_o = 52.8 \text{ k} \quad r_\pi = 1.83 \text{ k}$$

$$A_v = \frac{v_o}{v_{\text{sig}}} = \frac{R_i}{R_i + R_{\text{sig}}} \times \frac{v_o}{v_i}$$

$$A_v = \frac{4,800}{4,800 + 100} \times (-1.64) = -1.59$$
Exercise 2: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

Amplifier Cut-off frequency
(2 caps: 2 poles)

\[
\begin{align*}
f_{p1} &= \frac{1}{2\pi (R_i + R_{\text{sig}})C_{c1}} \\
&= \frac{1}{2\pi (4.8 \times 10^3 + 100) \times 4.7 \times 10^{-6}} = 6.91 \text{ Hz}
\end{align*}
\]

\[
\begin{align*}
f_{p2} &= \frac{1}{2\pi (R_o + R_L)C_{c2}} \\
&= \frac{1}{2\pi (10^3 + 100 \times 10^3) \times 100 \times 10^{-9}} = 15.8 \text{ Hz}
\end{align*}
\]

\[
f_p \approx f_{p1} + f_{p2} = 6.9 + 15.8 = 22.7 \text{ Hz}
\]
Exercise 3: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

- This is a PNP common emitter amplifier (no $R_E$).
  - Input at the base, output at the collector ($R_E$ is shorted out by a cap)
- It has a emitter-degeneration bias with two voltage sources.
Exercise 3: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

Assume BJT is in Active:

$V_{EB} = 0.7$ V, $I_C > 0$ and $V_{EC} \geq 0.7$ V

BE – KVL: $3 = 2.3 \times 10^3 I_E + V_{EB}$

$I_E = 1.0$ mA $\approx I_C$

$I_B = I_C / \beta = 5.0$ $\mu$A

CE – KVL: $3 = 2.3 \times 10^3 I_E + V_{EC} + 2.3 \times 10^3 I_C - 3$

$V_{EC} = 6 - 4.6 \times 10^{-3} \times 10^3$

$V_{EC} = 1.4$ V $> V_{D0} = 0.7$ V

$g_m = \frac{I_C}{V_T} = \frac{10^{-3}}{26 \times 10^{-3}} = 38.5$ mA/V

$r_o \approx \frac{V_A}{I_C} = \frac{150}{10^{-3}} = 150$ k

$r_\pi = \frac{V_T}{I_B} = \frac{\beta}{g_m} = 5.26$ k
Exercise 3: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

Real circuit

Signal circuit

Amplifier Parameters

This is a CE amplifier with no $R_E$

\[
\frac{v_o}{v_i} = -g_m (r_o \parallel R_C \parallel R_L)
\]

\[
\frac{v_o}{v_i} = -38.5 \times 10^{-3} (150 \text{ k} \parallel 2.3 \text{ k} \parallel 100 \text{ k}) = -85.3
\]

\[
A_v = \frac{R_i}{R_i + R_{\text{sig}}} \times \frac{v_o}{v_i} = \frac{v_o}{v_i} = -85.3
\]

\[
R_i = R_B \parallel r_\pi = r_\pi = 5.26 \text{ k}
\]

\[
R_o = R_C \parallel r_o
\]

\[
R_o = 150 \text{ k} \parallel 2.3 \text{ k} = 2.27 \text{ k}
\]

\[
g_m = 38.5 \text{ mA/V}
\]

\[
r_o = 150 \text{ k} \quad r_\pi = 5.26 \text{ k}
\]

* Show \[f_p \approx f_{p1} + f_{p2} = 67 + 16 = 82 \text{ Hz}\]
Exercise 4: Find the bias point and the amplifier parameters of this circuit. 
\( \mu_n C_{ox} = 100 \ \mu A/V^2, (W/L) = 6/0.1, \ V_t = 0.5 \ \text{V}, \ \lambda = 0.1 \ \text{V}^{-1} \). Assume capacitors are large and ignore channel width modulation in biasing.

- This is a MOS common source amplifier (no \( R_S \)).
  - Input at the gate, output at the drain (\( R_S \) is shorted out by a cap)
- It has a source-degeneration bias with voltage divider.
Exercise 4: Find the bias point and the amplifier parameters of this circuit. 
($\mu n C_{ox} = 100 \, \mu A/V^2$, $(W/L) = 6/0.1$, $V_t = 0.5 \, V$, $\lambda = 0.1 \, V^{-1}$. Assume capacitors are large and ignore channel width modulation in biasing. )

**Bias (capacitors are open circuit):**

$I_G = 0 \Rightarrow V_G = \frac{100k}{33k + 100k} \cdot 1.8 = 1.353 \, V$

Assume Saturation

$I_D = 0.5 \mu n C_{ox} \frac{W}{L} V_{OV}^2 = 3 \times 10^{-3} V_{OV}^2$

**GS-KVL:**

$V_G = V_{GS} + R_S I_D = V_{OV} + V_t + R_S I_D$

$1.353 = V_{OV} + 0.5 + 2 \times 10^3 \times 3 \times 10^{-3} V_{OV}^2$

$6V_{OV}^2 + V_{OV} - 0.853 = 0$

$V_{OV} = 0.303 \, V$

$V_{GS} = V_{OV} + V_t = 0.803 \, V$

$I_D = 3 \times 10^{-3} V_{OV}^2 = 0.275 \, mA$

$V_S = V_G - V_{GS} = 0.550 \, V$

$V_D = 1.8 - R_D I_D = 1.249 \, V$

$V_{DS} = V_D - V_S = 0.699 \, V$

$V_{DS} > V_{OV} \Rightarrow \text{Saturation}$
Exercise 4: Find the bias point and the amplifier parameters of this circuit. 
($\mu_nC_{ox} = 100 \, \mu A/V^2$, $(W/L) = 6/0.1$, $V_t = 0.5 \, V$, $\lambda = 0.1 \, V^{-1}$. Assume capacitors are large and ignore channel width modulation in biasing.)

Amplifier Parameters
This is a CS amplifier with no $R_S$

\[
\frac{v_o}{v_i} = -g_m (r_o \parallel R_D \parallel R_L)
\]

\[
\frac{v_o}{v_i} = -1.82 \times 10^{-3} (36.3 \, k \parallel 2 \, k \parallel \infty) = -3.45
\]

\[
A_v = \frac{R_i}{R_i + R_{sig}} \times \frac{v_o}{v_i} = \frac{v_o}{v_i} = -3.45
\]

$R_G = 100k \parallel 33k = 24.8 \, k$

$g_m = \frac{2I_D}{V_{OV}} = 2 \times 0.275 \times 10^{-3} \times \frac{1}{0.303} = 1.82 \, mA/V$

$r_o = \frac{V_A}{I_D} = \frac{10}{0.275 \times 10^{-3}} = 36.3 \, k$

$R_i = R_G = 24.8 \, k$

$R_o = r_o \parallel R_D$

$R_o = 36.3 \, k \parallel 2 \, k = 1.90 \, k$
Exercise 5: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

- This is a common collector amplifier (emitter follower).
  - Input at the base, output at the emitter.
- It is biased with a current source!
Exercise 5: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

Real circuit

Bias circuit

Assume BJT is in Active:

$V_{BE} = 0.7$ V, $I_C > 0$ and $V_{CE} \geq 0.7$ V

$I_E = 4.3$ mA $\approx I_C$

$I_B = I_C / \beta = 21.5$ $\mu$A

$V_{BE} = 0 - V_E$

$V_E = -0.7$ V

$V_{CE} = 4 - V_E = 4.7$ V $> V_{D0} = 0.7$ V

$g_m = \frac{I_C}{V_T} = \frac{4.3 \times 10^{-3}}{26 \times 10^{-3}} = 16.5$ mA/V

$r_o \approx \frac{V_A}{I_C} = \frac{150}{4.3 \times 10^{-3}} = 34.9$ k

$r_\pi = \frac{V_T}{I_B} = \frac{\beta}{g_m} = 1.21$ k
Exercise 5: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

Real circuit

Signal circuit

Amplifier Parameters

This is an emitter follower ($R_E = \infty$)

$$v_o = \frac{g_m (r_o \parallel R_E \parallel R_L)}{1 + g_m (r_o \parallel R_E \parallel R_L)}$$

$$r_o \parallel R_E \parallel R_L = 34.9k \parallel \infty \parallel 100k = 25.9k$$

$$g_m (r_o \parallel R_E \parallel R_L) = 427$$

$$A_v = \frac{v_o}{v_i} = \frac{427}{1 + 427} \approx 1$$

$$R_i = R_B \parallel [r_\pi + (1 + \beta)(r_o \parallel R_E \parallel R_L)]$$

$$R_i = 1.2k + 201 \times 25.9k = 5.2 \text{ M}$$

$$R_o \approx R_E \parallel \frac{r_\pi + R_B \parallel R_{sig}}{1 + \beta} \approx \frac{r_\pi}{\beta} = 60.6 \text{ } \Omega$$

$g_m = 16.5 \text{ mA/V}$

$r_o = 34.9 \text{ k}$

$r_\pi = 1.21 \text{ k}$
Exercise 5: Find the bias point and the amplifier parameters of the circuit below. (Si BJT with $\beta = 200$, $V_A = 150$ V, ignore Early effect in bias calculations).

Signal circuit

Cut-off frequency

\[ f_p = \frac{1}{2\pi (R_L + R_o) C_{c2}} \]

\[ f_p = \frac{1}{2\pi (100 \times 10^3 + 61) \times 0.47 \times 10^{-6}} = 3.34 \text{ Hz} \]

\[ g_m = 16.5 \text{ mA/V} \]

\[ r_o = 34.9 \text{ k} \]

\[ r_\pi = 1.21 \text{ k} \]
Exercise 6: Find the bias point and the amplifier parameters of the circuit below. \( \mu_p C_{ox} (W/L) = 400 \ \mu \text{A/V}^2, \ V_{tp} = -4 \ \text{V}, \ \lambda = 0.01 \ \text{V}^{-1}. \) Ignore channel width modulation in biasing).

- This is a PMOS common drain amplifier.
  - Input at the gate, output at the source.
- It has a source-degeneration bias with two voltage sources.
Exercise 6: Find the bias point and the amplifier parameters of the circuit below. \( \mu p C_{ox} (W/L) = 400 \, \mu A/V^2 \), \( V_{tp} = -4 \, V \), \( \lambda = 0.01 \, V^{-1} \). Ignore channel width modulation in biasing.

Assume Saturation

\[
I_D = 0.5 \mu p C_{ox} \frac{W}{L} V_{OV}^2
\]

GS-KVL:

\[
13 = 10^4 \times I_D + V_{SG} = 10^4 \times I_D + V_{OV} + |V_{tp}|
\]

\[
10^4 \times 0.5 \times 400 \times 10^{-6} V_{OV}^2 + V_{OV} - 9 = 0
\]

\[
2V_{OV}^2 + V_{OV} - 9 = 0
\]

\[
V_{OV} = 1.9 \, V
\]

\[
I_D = 0.5 \times 400 \times 10^{-6} V_{OV}^2 = 0.71 \, mA
\]

\[
V_{SG} = V_{OV} + I_D = 5.9 \, V
\]

\[
V_{SG} = V_S - 0 \rightarrow V_S = 5.9 \, V
\]

\[
V_{SD} = V_S - (-5) = 10.9 \, V
\]

\[
V_{DS} > V_{OV} \Rightarrow \text{Saturation}
\]

\[
g_m = \frac{2I_D}{V_{OV}} = \frac{2 \times 0.71 \times 10^{-3}}{0.303} = 0.747 \, mA/V
\]

\[
r_o = \frac{1}{\lambda I_D} = \frac{1}{0.01 \times 0.71 \times 10^{-3}} = 141 \, k
\]
Exercise 6: Find the bias point and the amplifier parameters of the circuit below. \( \mu p C_{ox} (W/L) = 400 \ \mu A/V^2, \ \ V_{tp} = -4 \ \text{V}, \ \lambda = 0.01 \ \text{V}^{-1}. \) Ignore channel width modulation in biasing).

**Real circuit**

- 13V
- 10k
- 0.47\( \mu \)F
- \(-5\) V

**Signal circuit**

- 10k
- 0.47\( \mu \)F
- 100k

**Amplifier Parameters**

This is a common collector Amp.

\[ A_v = \frac{g_m (r_o \parallel R_S \parallel R_L)}{1 + g_m (r_o \parallel R_S \parallel R_L)} = 0.88 \]

\[ R_i = R_G = \infty \]

\[ R_o = R_S \parallel \frac{1}{g_m} = 10 \ \text{k} \parallel 1.34 \ \text{k} = 1.2 \ \text{k} \]

**Cut-off frequency**

\[ f_p = \frac{1}{2\pi [R_L + R_o]C_c} \]

\[ f_p = \frac{1}{2\pi (100 \times 10^3 + 1.2 \times 10^3) \times 0.47 \times 10^{-6}} = 3.39 \ \text{Hz} \]
Exercise 7: Find the bias point and the amplifier parameters of the circuit below. \( \mu_n C_{ox} \frac{W}{L} = 800 \, \mu A/V^2, \, V_t = 1 \, V, \, \lambda = 0.01 \, V^{-1}. \) Ignore channel width modulation in biasing.

- This is a NMOS common gate amplifier.
  - Input at the source, output at the drain.
- It has a source-degeneration bias with voltage divider.
Exercise 7: Find the bias point and the amplifier parameters of the circuit below. \( \mu_n C_{ox} (W/L) = 800 \mu A/V^2, V_t = 1 \text{ V}, \lambda = 0.01 \text{ V}^{-1}. \) Ignore channel width modulation in biasing).

Assume Saturation

\[
I_D = 0.5\mu_n C_{ox} \frac{W}{L} V_{OV}^2
\]

GS-KVL:

\[
V_G = 6 = V_{GS} + 10^4 \times I_D = V_{OV} + V_t + 10^4 \times I_D
\]

\[
10^4 \times 0.5 \times 800 \times 10^{-6} V_{OV}^2 + V_{OV} - 5 = 0
\]

\[
4V_{OV}^2 + V_{OV} - 5 = 0
\]

\[
V_{OV} = 1.0 \text{ V}
\]

\[
I_D = 0.5 \times 800 \times 10^{-6} V_{OV}^2 = 0.40 \text{ mA}
\]

\[
V_{GS} = V_{OV} + V_t = 2.0 \text{ V}
\]

DS-KVL:

\[
15 = 10^4 \times I_D + V_{DS} + 10^4 \times I_D
\]

\[
V_{DS} = 15 - 4 - 4 = 7 \text{ V}
\]

\[
V_{DS} > V_{OV} \Rightarrow \text{ Saturation}
\]
Exercise 7: Find the bias point and the amplifier parameters of the circuit below. \( (\mu_n C_{ox} (W/L) = 800 \ \mu A/V^2, \ V_t = 1 \ \text{V}, \ \lambda = 0.01 \ \text{V}^{-1}. \) Ignore channel width modulation in biasing).

Amplifier Parameters
This is a common gate Amp.

\[ A_v = g_m (r_o \parallel R_S \parallel R_L) \]
\[ A_v = 0.8 \times 10^{-3} (250 \ \text{k} \parallel 10 \ \text{k} \parallel \infty) = 7.7 \]

\[ R_i = R_S \parallel \left[ \frac{1+(R_D \parallel R_L)/r_o}{g_m} \right] = 1.1 \ \text{k} \]

\[ R_o = R_D \parallel [r_o (1+g_m(R_S \parallel R_{sig})] \approx 10 \ \text{k} \]

\[ g_m = \frac{2I_D}{V_{OV}} = \frac{2 \times 0.4 \times 10^{-3}}{1} = 0.8 \ \text{mA/V} \]

\[ r_o = \frac{1}{\lambda I_D} = \frac{1}{0.01 \times 0.4 \times 10^{-3}} = 250 \ \text{k} \]

Cut-off frequency
\[ f_{p1} = \frac{1}{2\pi [R_i + R_{sig}]C_{c1}} \quad f_{p2} = \frac{1}{2\pi [R_L + R_o]C_{c2}} \]
\[ f_p = f_{p1} + f_{p2} = 1.45 \ \text{kHz} + 22 \ \text{Hz} = 1.47 \ \text{kHz} \]
Exercise 8: Find the bias point and the amplifier parameters of the circuit below. ($\mu_nC_{ox} (W/L) = 400 \ \mu\text{A}/\text{V}^2$, $V_t = 3 \ \text{V}$, $\lambda = 0.01 \ \text{V}^{-1}$. Ignore channel width modulation in biasing).

- This is a NMOS common drain amplifier.
  - Input at the gate, output at the source.
- It is biased with a current source.
Exercise 8: Find the bias point and the amplifier parameters of the circuit below. \( \mu_n C_{ox} (W/L) = 400 \ \mu A/V^2, \ V_t = 3 \ \text{V}, \ \lambda = 0.01 \ \text{V}^{-1}. \) Ignore channel width modulation in biasing.

**Bias circuit**

\[ V_{OV} = 1.0 \ \text{V} \]

\[ V_{GS} = V_{OV} + V_t = 4.0 \ \text{V} \]

\[ V_{GS} = V_G - V_S \quad \rightarrow \quad V_S = 0 - V_{GS} = -4.0 \ \text{V} \]

\[ V_{DS} = V_D - V_S = 5 - (-4) = 9 \ \text{V} \]

\[ V_{DS} > V_{OV} \quad \Rightarrow \quad \text{Saturation} \]

\[ I_D = 0.71 \ \text{mA} \]

Assume Saturation

\[ I_D = 0.5 \mu_n C_{ox} \frac{W}{L} V_{OV}^2 = 0.71 \times 10^{-3} \]
Exercise 8: Find the bias point and the amplifier parameters of the circuit below. \( \mu n C_{ox} (W/L) = 400 \, \mu A/V^2, \, V_t = 3 \, V, \, \lambda = 0.01 \, V^{-1}. \) Ignore channel width modulation in biasing.

**Real circuit**

**Signal circuit**

**Amplifier Parameters**

This is a common collector Amp.

\[
A_v = \frac{g_m (r_o \parallel R_S \parallel R_L)}{1 + g_m (r_o \parallel R_S \parallel R_L)} = 0.99
\]

\[
R_i = R_G = \infty
\]

\[
R_o = R_S \parallel \frac{1}{g_m} = \infty \parallel 704 = 704 \, \Omega
\]

\[
g_m = \frac{2I_D}{V_{OV}} = \frac{2 \times 0.71 \times 10^{-3}}{1} = 1.42 \, mA/V
\]

\[
r_o = \frac{1}{\lambda I_D} = \frac{1}{0.01 \times 0.71 \times 10^{-3}} = 141 \, k
\]

**Cut-off frequency**

\[
f_p = \frac{1}{2\pi [R_L + R_o] C_{c2}}
\]

\[
f_p = \frac{1}{2\pi (100 \times 10^3 + 704) \times 0.47 \times 10^{-6}} = 3.36 \, Hz
\]