

Experiment 3



भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

Bachelor of Technology

Department of Electrical Engineering

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1 Objective

Now that small-signal analysis of diode, MOS, and BJT devices is done, design and simulate the following amplifier circuits:

1. MOSFET

- (a) Common Source
- (b) Common Drain
- (c) Common Gate

2. BJT

- (a) Common Emitter
- (b) Common Collector
- (c) Common Base

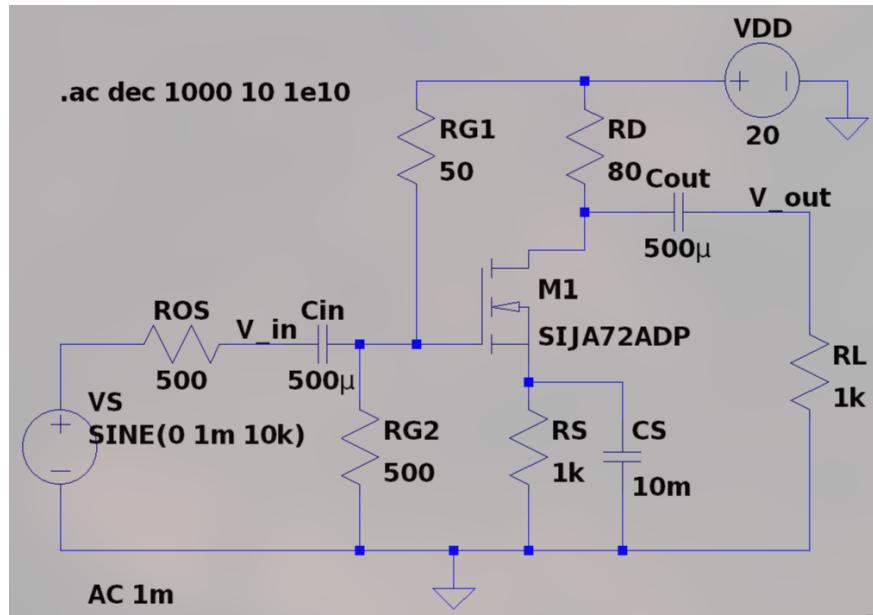
For each amplifier,

1. Draw the circuit schematic with proper biasing.
2. Show the DC operating point (bias currents and voltages).
3. Simulate mid-band gain, input resistance, and output resistance.
4. Plot frequency response (gain vs frequency) and identify bandwidth.
5. Show a transient simulation with a sinusoidal input to verify linear amplification.

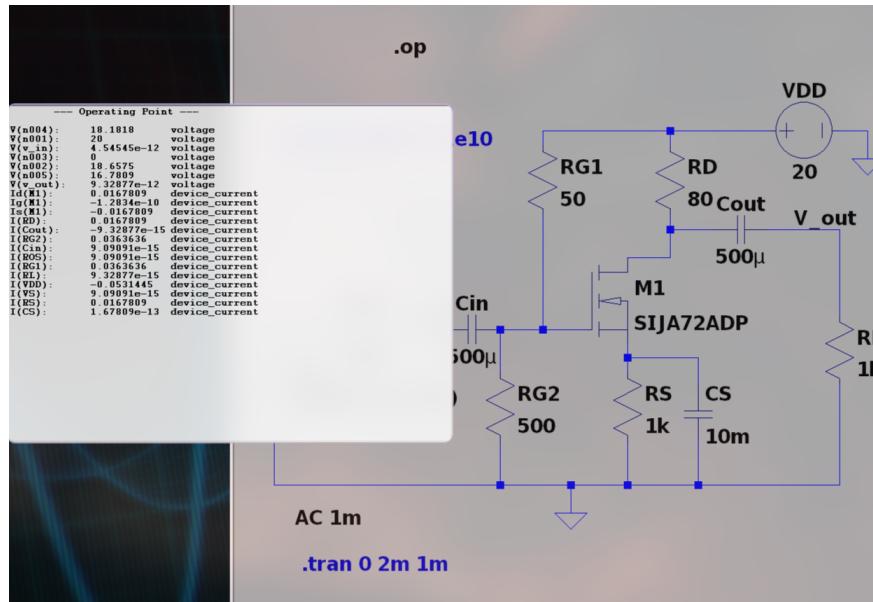
2 MOSFET

2.1 Common Source

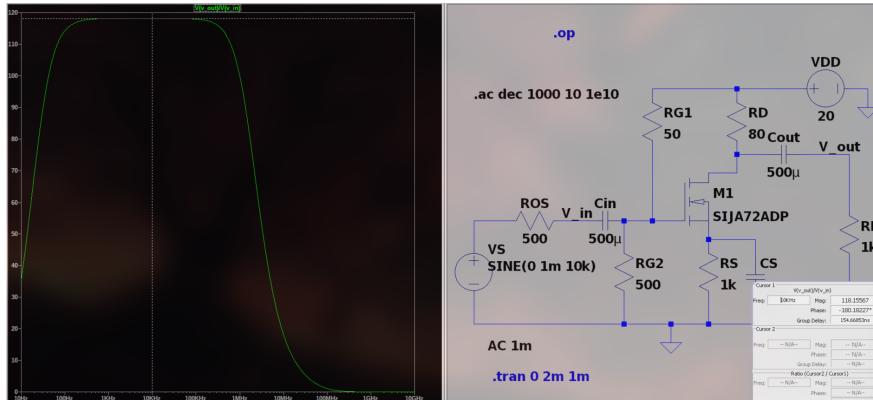
2.1.1 Circuit



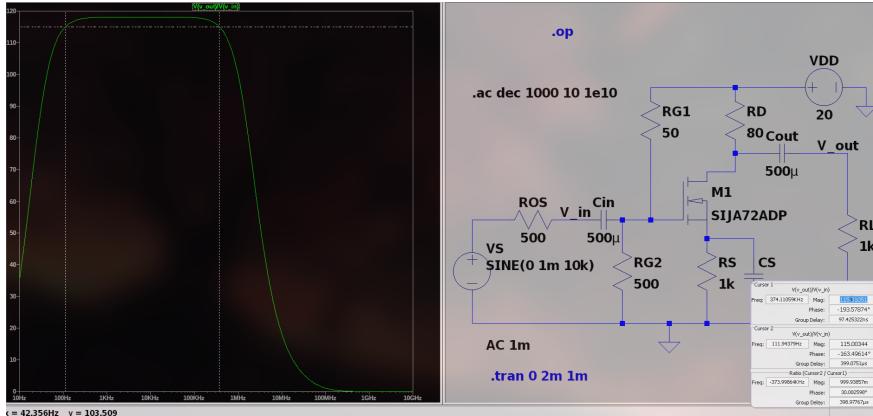
2.1.2 DC Operating Point



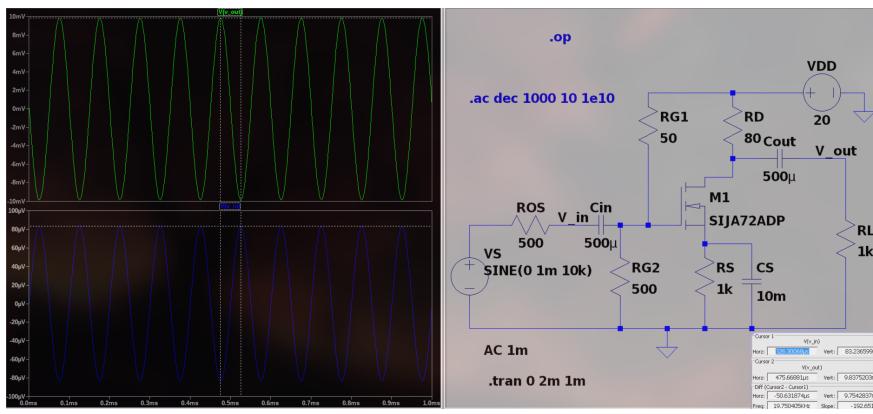
2.1.3 Midband Gain



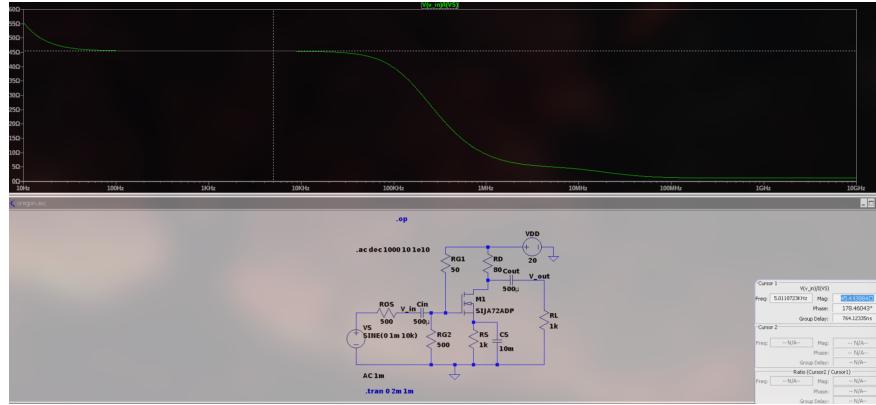
2.1.4 Bandwidth



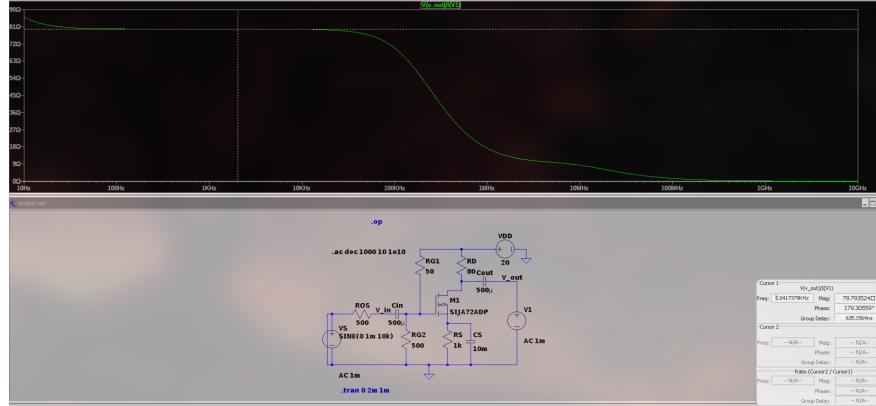
2.1.5 Transient



2.1.6 Input Resistance



2.1.7 Output Resistance



2.1.8 Theory

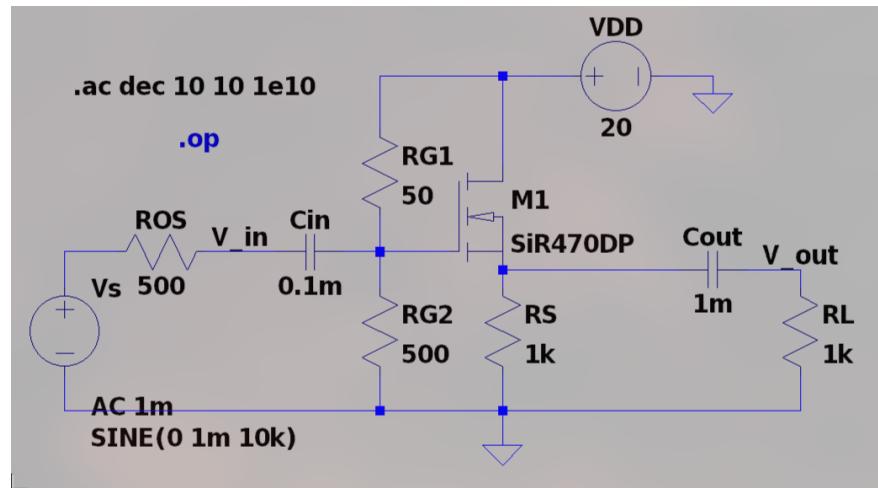
- Transconductance $g_m = \frac{2I_d}{V_{GS} - V_{TO}}$
- $V_{TO} = 1.38V$ (Specific to MOSFET model)
- Input Resistance $R_i = R_{G1} \parallel R_{G2}$
- Output Resistance $R_o = R_D$
- Voltage gain $A = \frac{V_{in}}{V_{out}} = g_m R_o$

2.2 Data

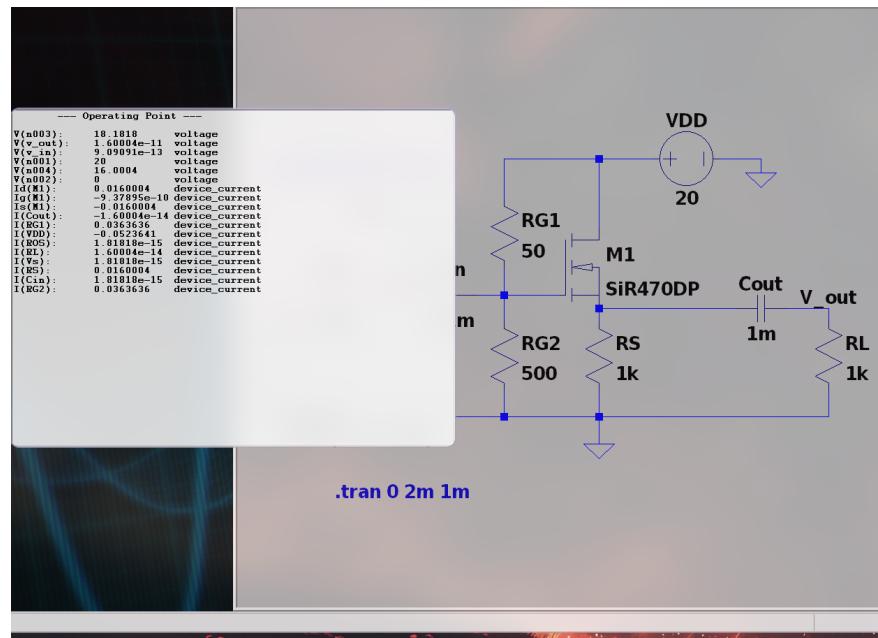
| Midband gain (graph) | Midband gain (theory) | R_i (graph) | R_i (theory) | R_o (graph) | R_o (theory) | Bandwidth |
|----------------------|-----------------------|---------------|----------------|---------------|----------------|--------------|
| 118.15567 | 123.155 | 45.443984Ω | 45.4545Ω | 79.793524Ω | 80Ω | 373.9986 KHz |

2.3 Common Drain

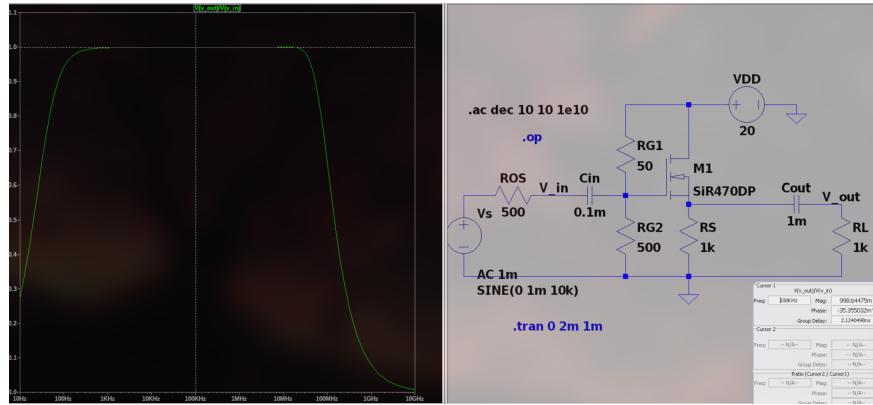
2.3.1 Circuit



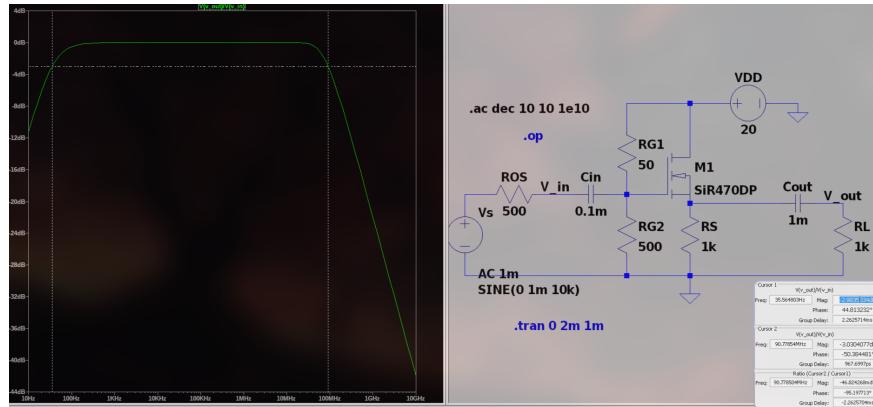
2.3.2 DC Operating Point



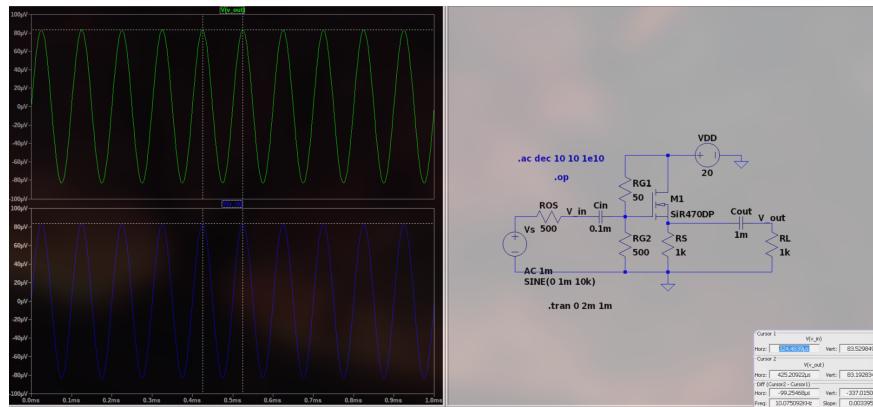
2.3.3 Midband Gain



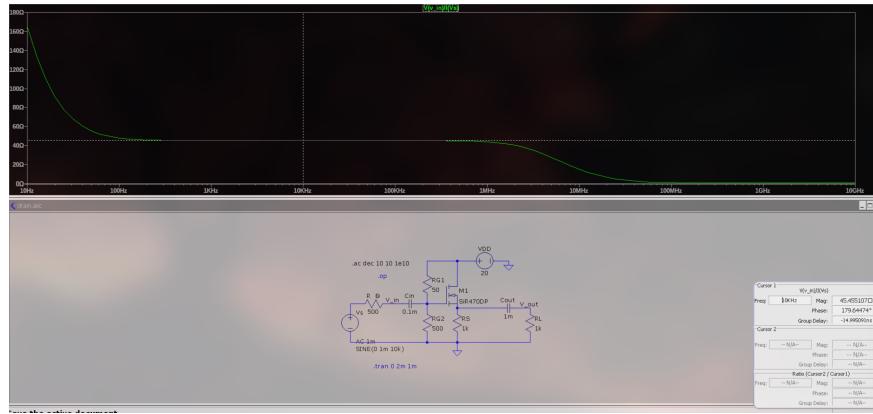
2.3.4 Bandwidth



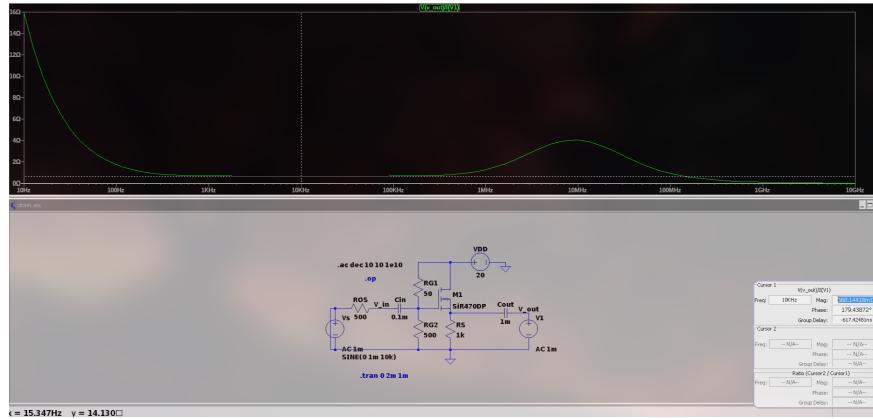
2.3.5 Transient



2.3.6 Input Resistance



2.3.7 Output Resistance



2.3.8 Theory

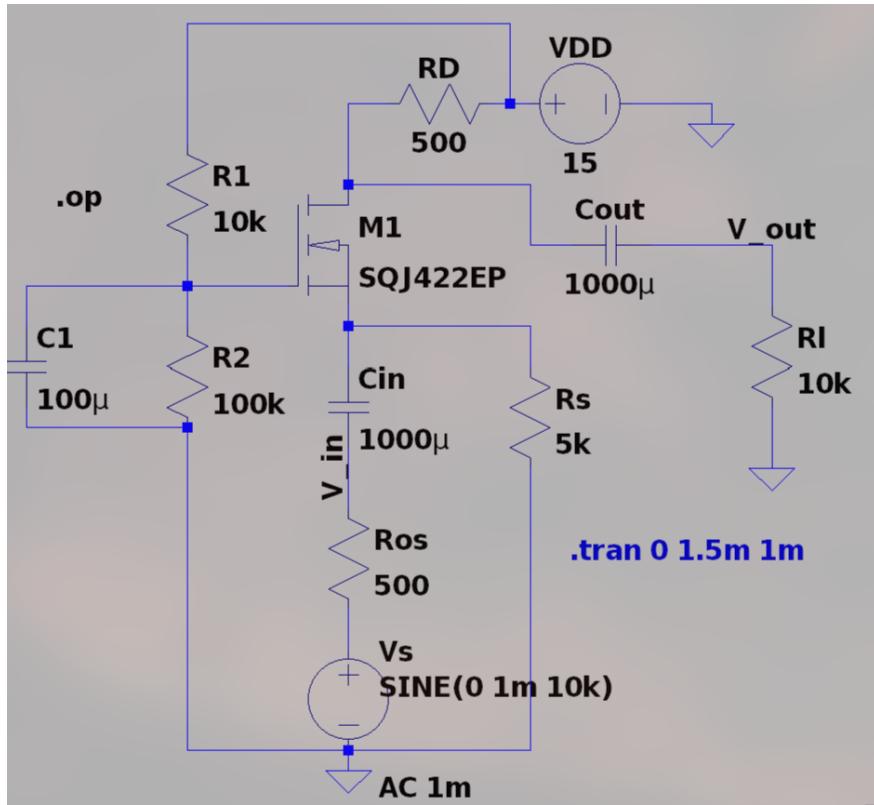
- Transconductance $g_m = \frac{2I_d}{V_{GS} - V_{TO}}$
- $V_{TO} = 2.16V$ (Specific to MOSFET model)
- Input Resistance $R_i = R_{G1} \parallel R_{G2}$
- Output Resistance $R_o = R_s \parallel \frac{1}{g_m}$
- Voltage gain $A = \frac{V_{in}}{V_{out}} = \frac{g_m(R_s \parallel R_L)}{1 + g_m(R_s \parallel R_L)}$

2.3.9 Data

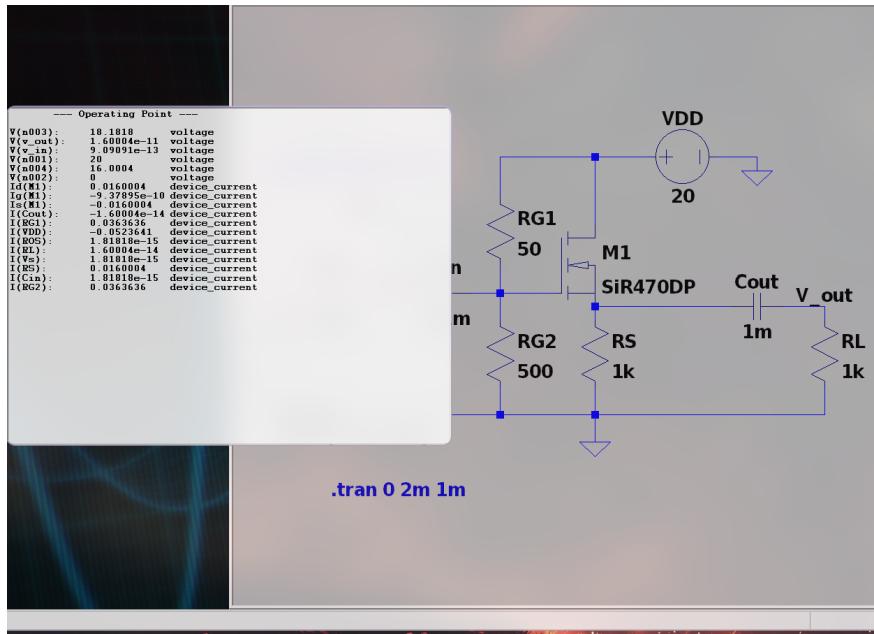
| Midband gain (graph) | Midband gain (theory) | R_i (graph) | R_i (theory) | R_o (graph) | R_o (theory) | Bandwidth |
|-------------------------|--------------------------|------------------|-------------------|------------------|-------------------|------------|
| 0.99864 | 0.998638 | 45.45510Ω | 45.4545Ω | 0.668144Ω | 0.68134Ω | 90.7785MHz |

2.4 Common Gate

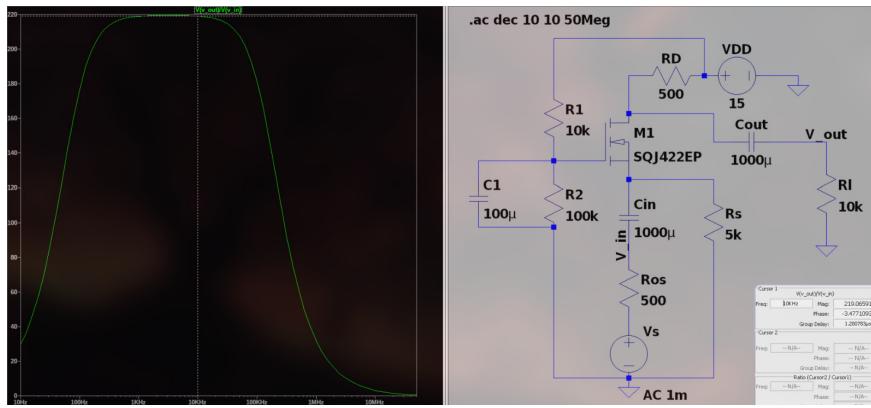
2.4.1 Circuit



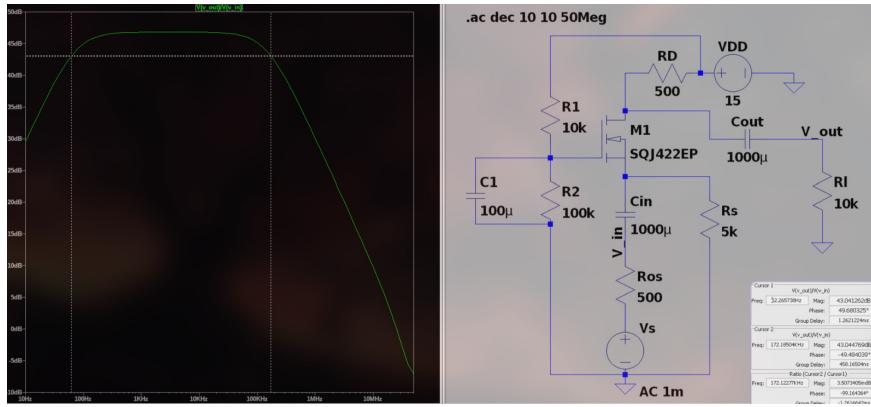
2.4.2 DC Operating Point



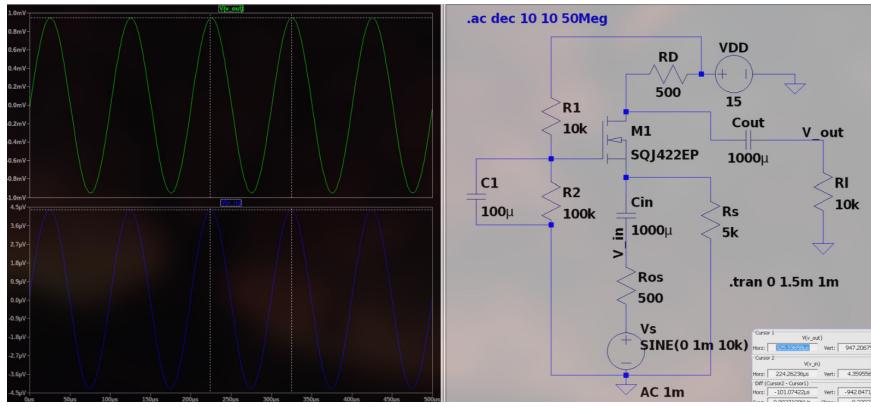
2.4.3 Midband Gain



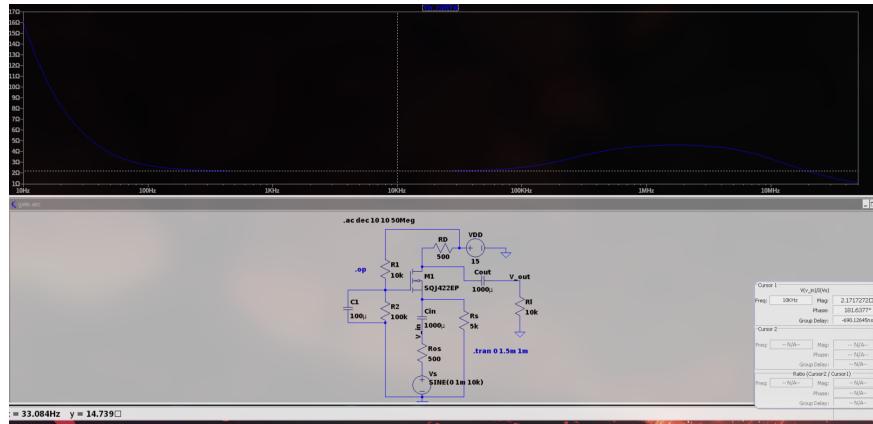
2.4.4 Bandwidth



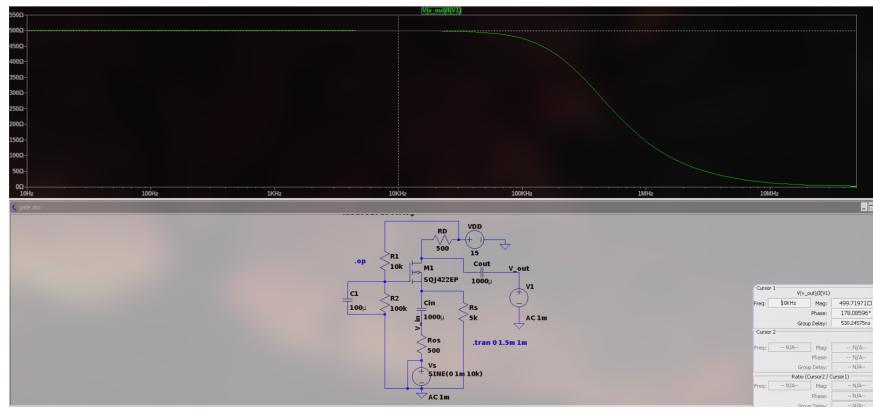
2.4.5 Transient



2.4.6 Input Resistance



2.4.7 Output Resistance



2.4.8 Theory

1. Transconductance $g_m = \frac{2I_d}{V_{GS} - V_{TO}}$
2. $V_{TO} = 2.16V$ (Specific to MOSFET model)
3. Input Resistance $R_i = R_S \parallel \frac{1}{g_m}$
4. Output Resistance $R_o = R_D$
5. Voltage gain $A = \frac{V_{in}}{V_{out}} = g_m (R_D \parallel R_L)$

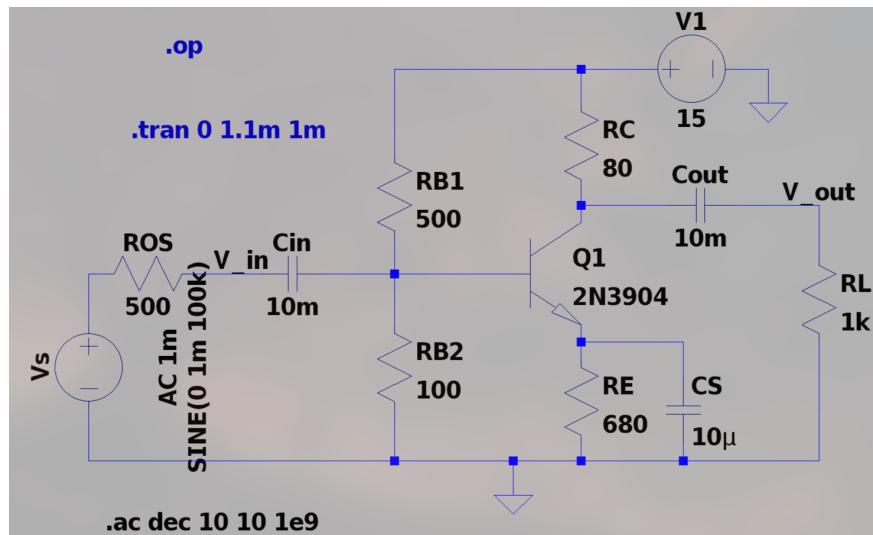
2.4.9 Data

| Midband gain (graph) | Midband gain (theory) | R_i (graph) | R_i (theory) | R_o (graph) | R_o (theory) | Bandwidth |
|-------------------------|--------------------------|------------------|-------------------|------------------|-------------------|---------------|
| 219.065 | 212.020 | 2.171727Ω | 2.244Ω | 499.71971Ω | 500Ω | 172.132775KHz |

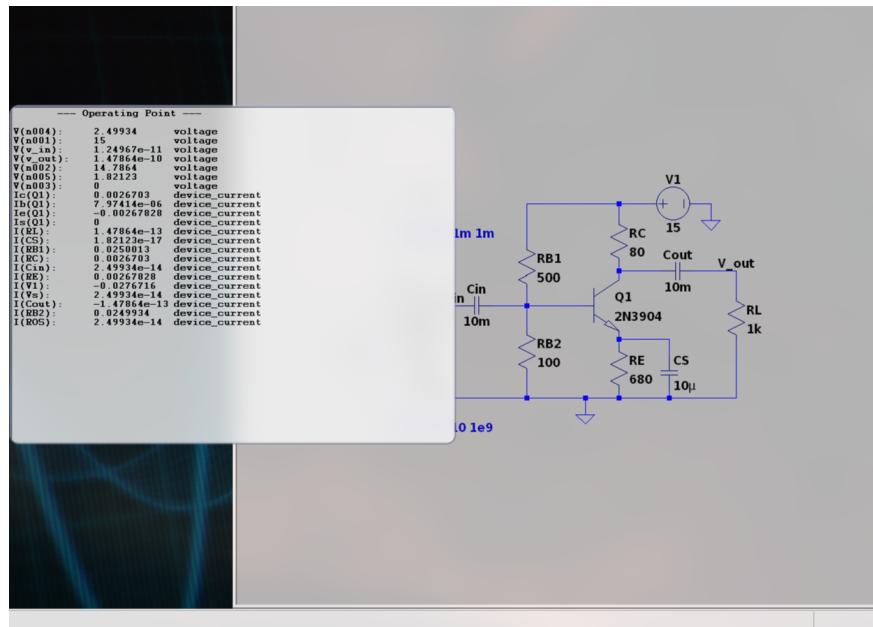
3 BJT

3.1 Common Emitter

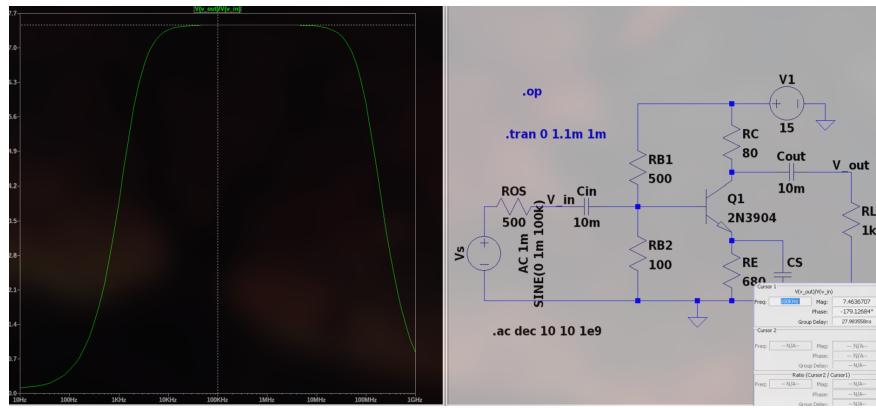
3.1.1 Circuit



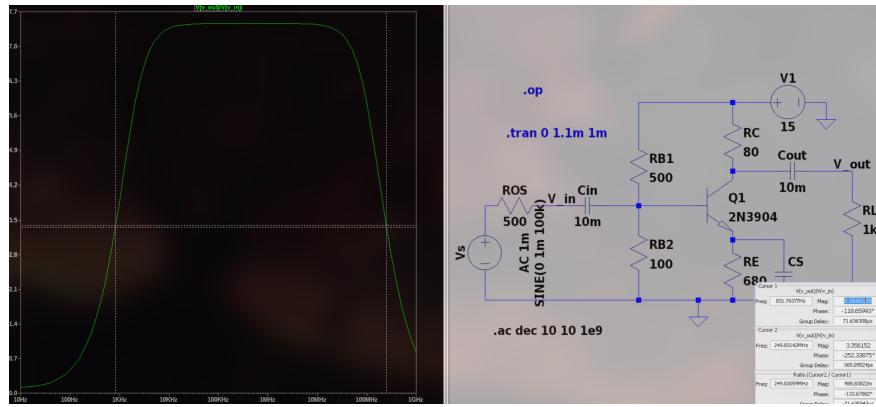
3.1.2 DC Operating Point



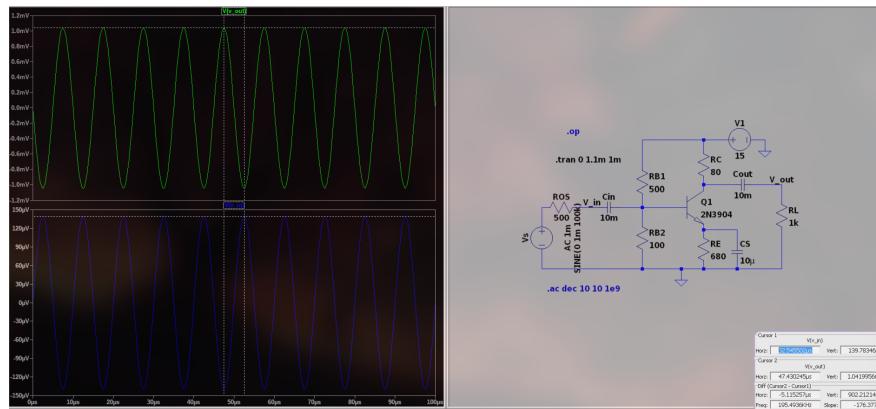
3.1.3 Midband Gain



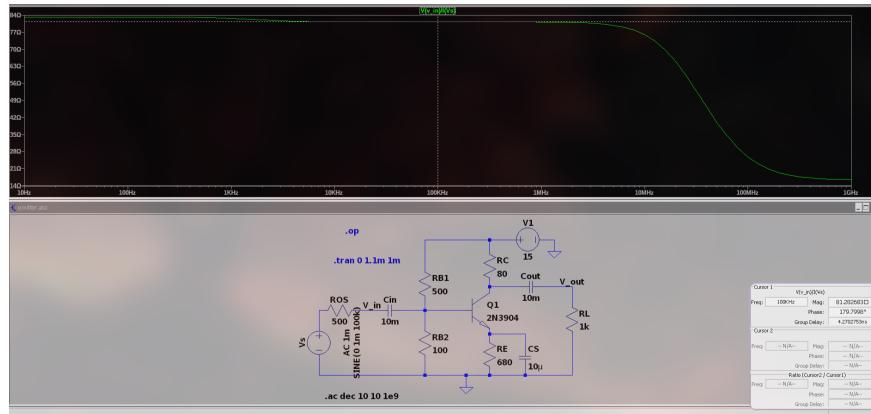
3.1.4 Bandwidth



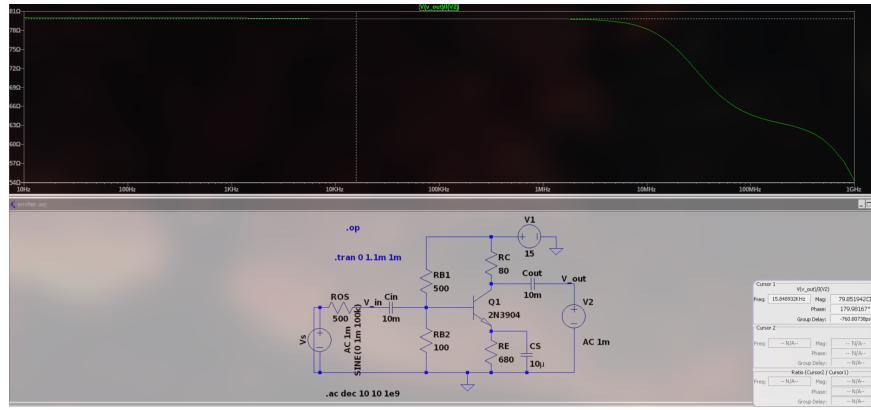
3.1.5 Transient



3.1.6 Input Resistance



3.1.7 Output Resistance



3.1.8 Theory

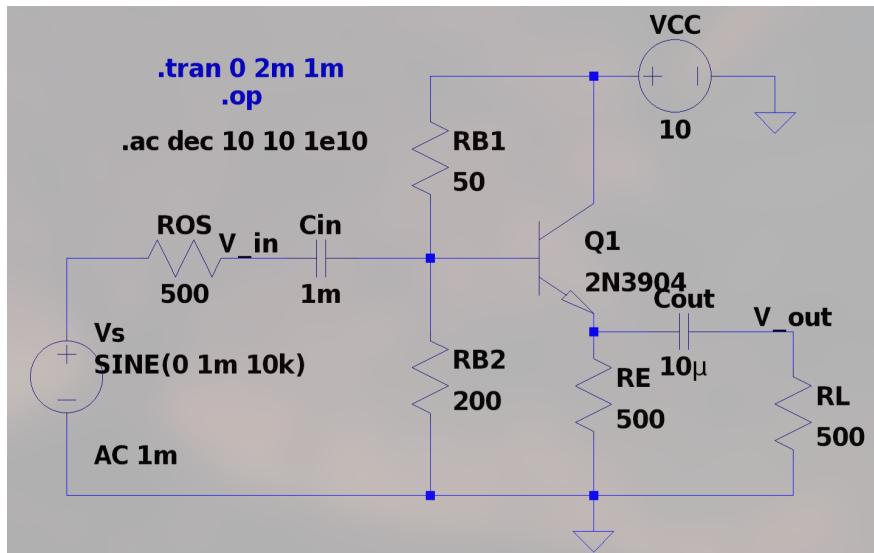
1. Transconductance $g_m = \frac{I_C}{V_T}$ (where $V_T = \frac{kT}{q}$)
2. Input Resistance $R_i = R_{B1} \parallel R_{B2} \parallel r_\pi$
3. $r_\pi = \frac{\beta}{g_m}$
4. $\beta = \frac{I_C}{I_B}$
5. Output Resistance $R_o = R_C$
6. Voltage gain $A = \frac{V_{in}}{V_{out}} = g_m (R_C \parallel R_L)$

3.1.9 Data

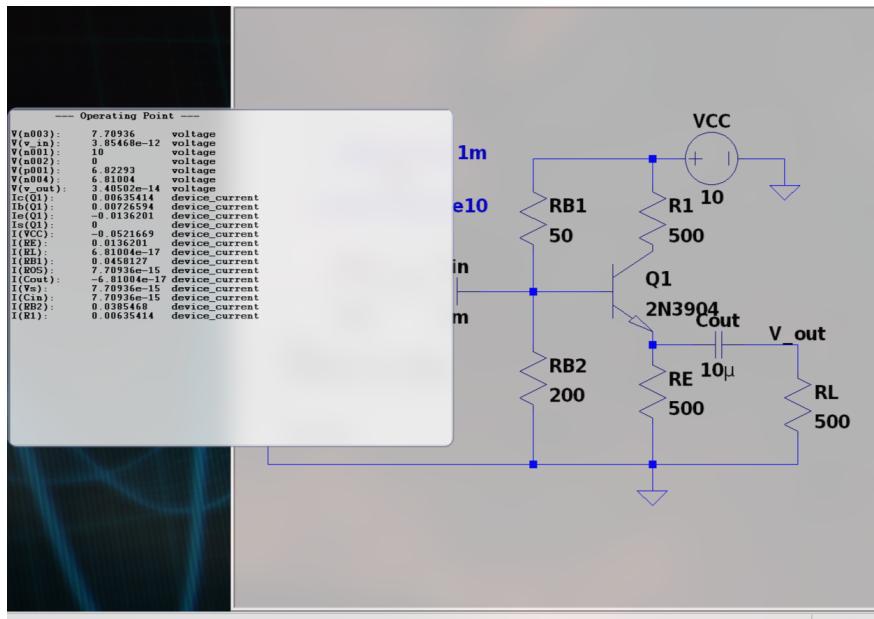
| Midband gain (graph) | Midband gain (theory) | R_i (graph) | R_i (theory) | R_o (graph) | R_o (theory) | Bandwidth |
|-------------------------|--------------------------|------------------|-------------------|------------------|-------------------|-------------|
| 7.4636707 | 7.6435 | 81.282683Ω | 81.24784Ω | 79.85194Ω | 74.074074Ω | 249.8305MHz |

3.2 Common Collector

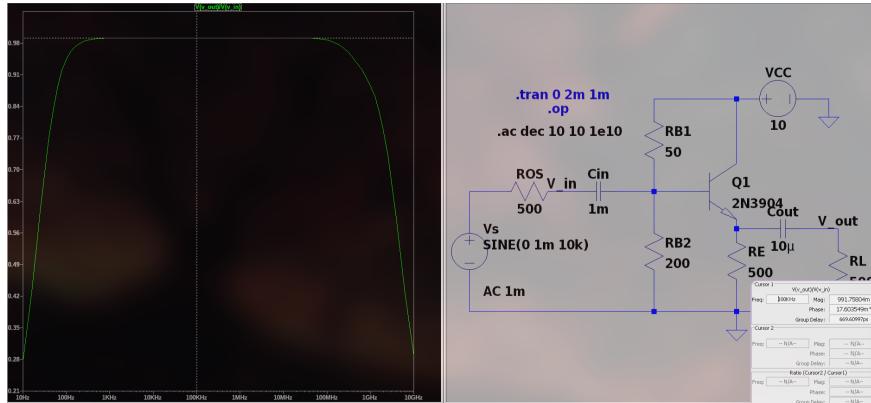
3.2.1 Circuit



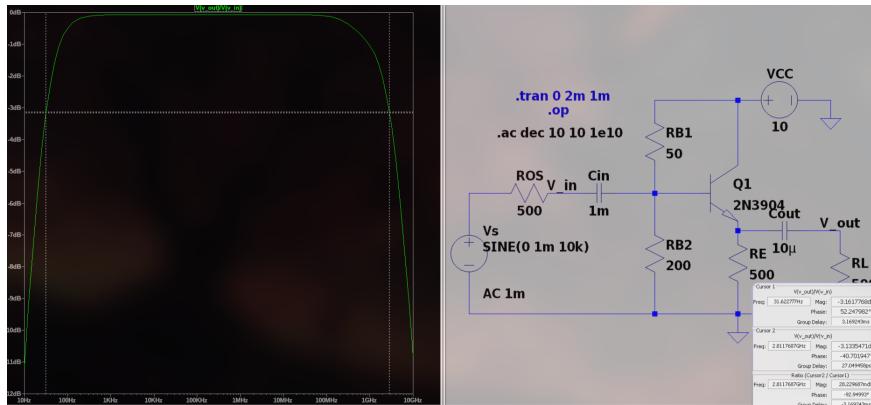
3.2.2 DC Operating Point



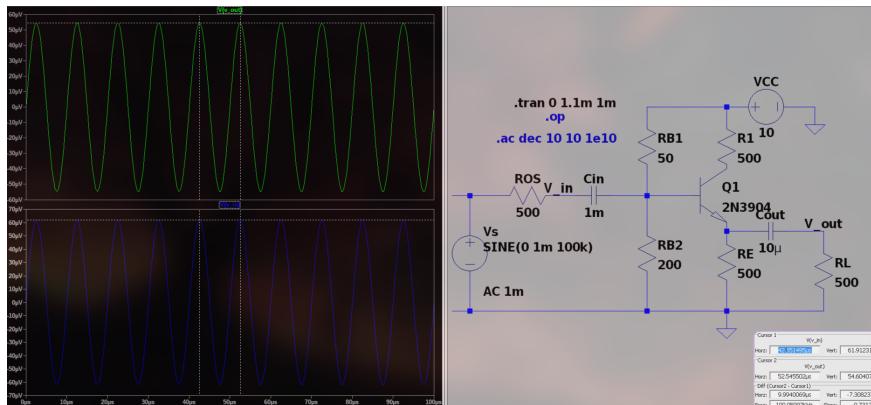
3.2.3 Midband Gain



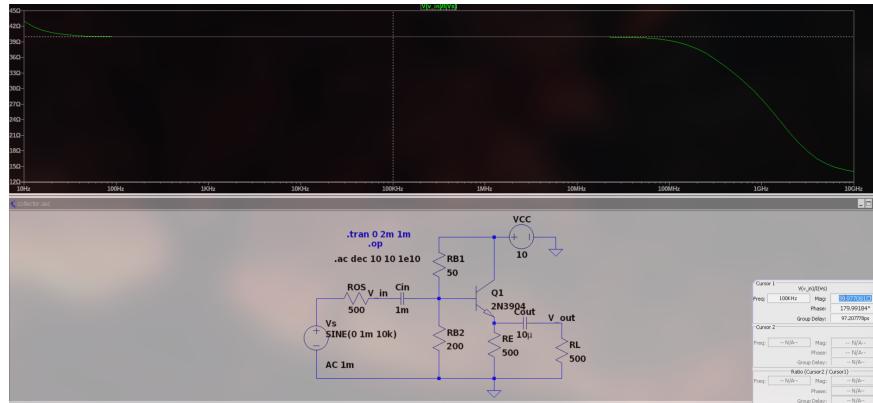
3.2.4 Bandwidth



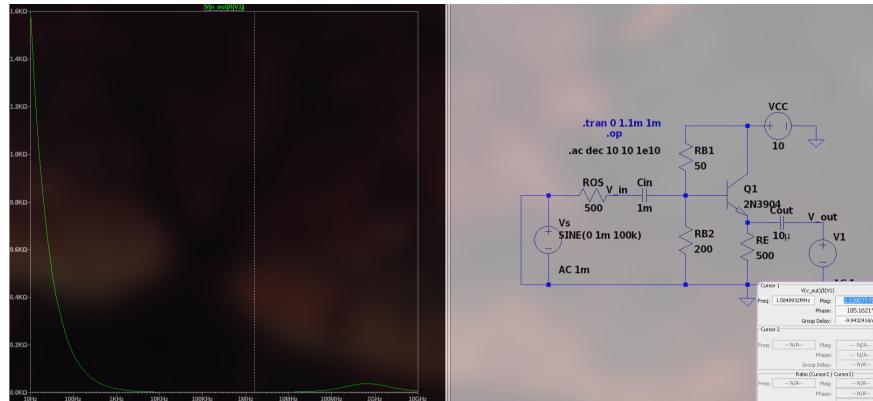
3.2.5 Transient



3.2.6 Input Resistance



3.2.7 Output Resistance



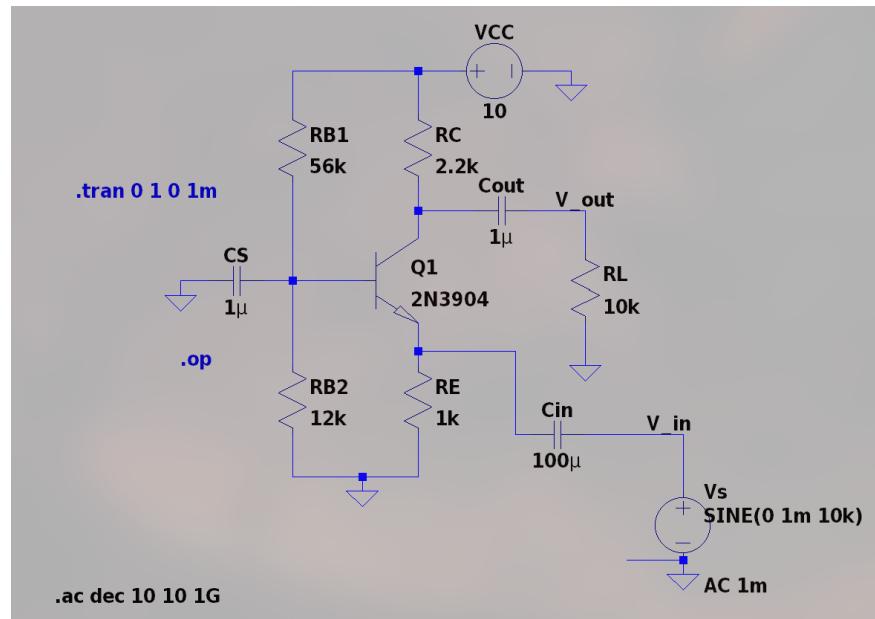
3.2.8 Theory

1. $r'_e = \frac{V_T}{I_E}$ (where $V_T = \frac{kT}{q}$)
2. Input Resistance $R_i = R_{B1} \parallel R_{B2} \parallel \beta(R_E \parallel R_L)$
3. Output Resistance $R_o = r'_e \parallel R_E \parallel R_L$
4. Voltage gain $A = \frac{V_{in}}{V_{out}} = \frac{R_E}{R_E + r'_e}$

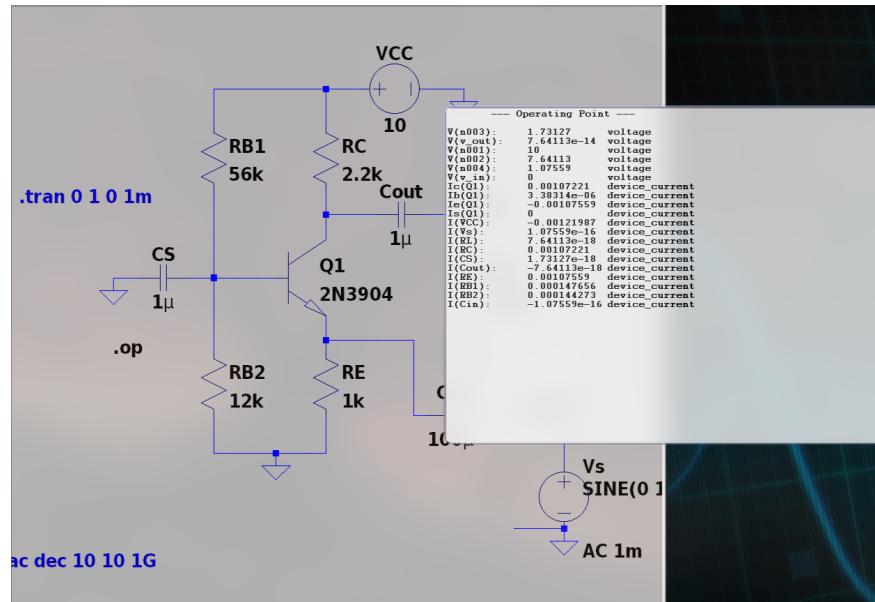
| Midband gain (graph) | Midband gain (theory) | R_i (graph) | R_i (theory) | R_o (graph) | R_o (theory) | Bandwidth |
|----------------------|-----------------------|-------------------|-------------------|------------------|------------------|-------------|
| 0.991758 | 0.99293 | 39.977081Ω | 39.978354Ω | 2.139077Ω | 1.766766Ω | $2.8117GHz$ |

3.3 Common Base

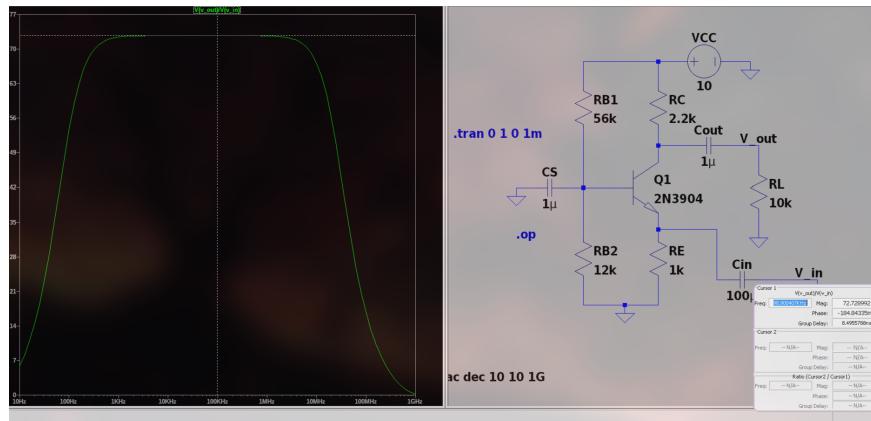
3.3.1 Circuit



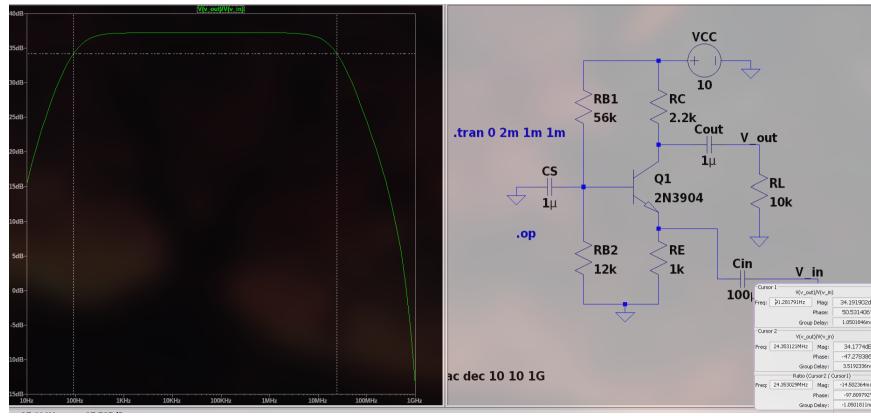
3.3.2 DC Operating Point



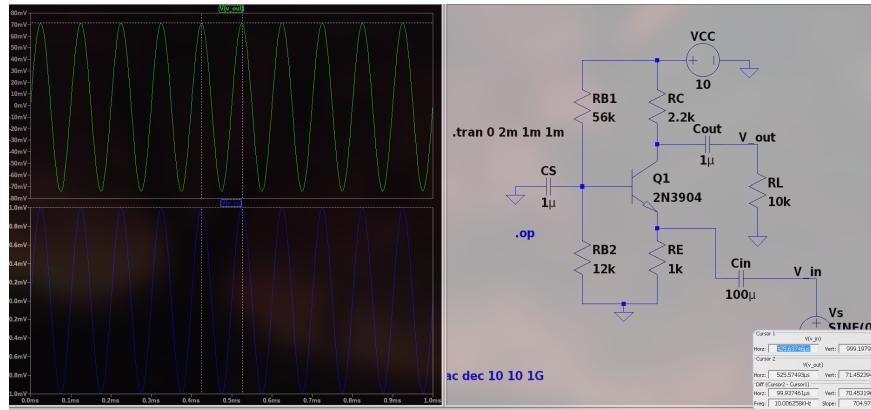
3.3.3 Midband Gain



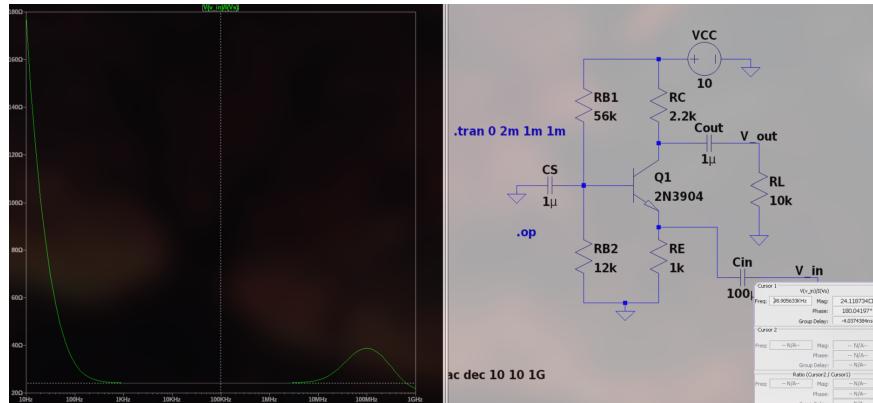
3.3.4 Bandwidth



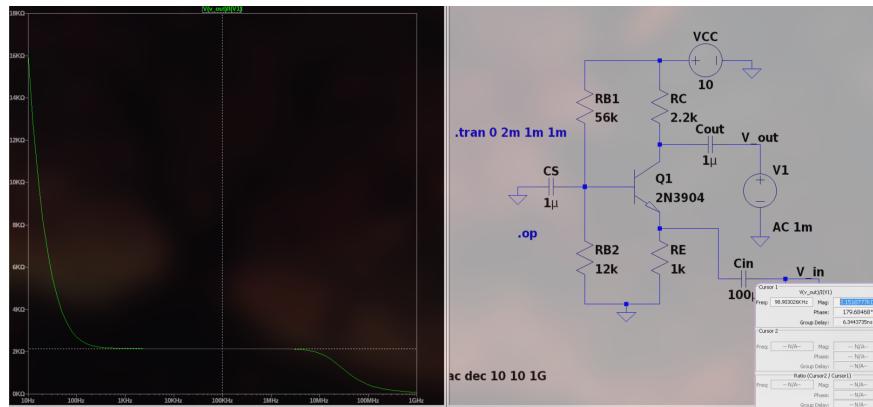
3.3.5 Transient



3.3.6 Input Resistance



3.3.7 Output Resistance



3.3.8 Theory

1. $r'_e = \frac{V_T}{I_E}$ (where $V_T = \frac{kT}{q}$)
2. Input Resistance $R_i = r'_e \parallel R_E$
3. Output Resistance $R_o = R_C$
4. Voltage gain $A = \frac{V_{in}}{V_{out}} = \frac{R_C \parallel R_L}{r'_e}$

3.3.9 Data

| Midband gain (graph) | Midband gain (theory) | R_i (graph) | R_i (theory) | R_o (graph) | R_o (theory) | Bandwidth |
|-------------------------|--------------------------|-------------------|---------------------|---------------------|-------------------|-----------|
| 72.728992 | 74.95367 | 24.11873 Ω | 24.0585774 Ω | 2.1518777 $k\Omega$ | 2.2 $k\Omega$ | 24.353MHz |