Swagat Panda 2017B5A30983P

Analog Electronics Lab 1 – CE Amplifier

Objectives

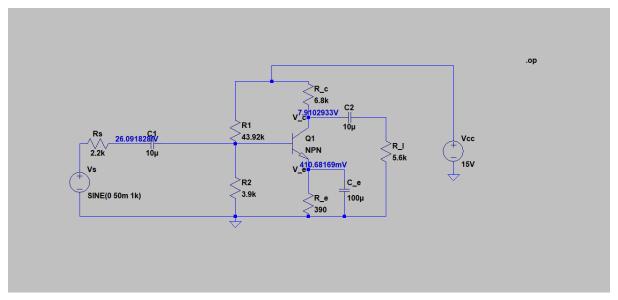
Design the provided circuit on LT Spice and calculate the following parameters with and without the emitter capacitor:

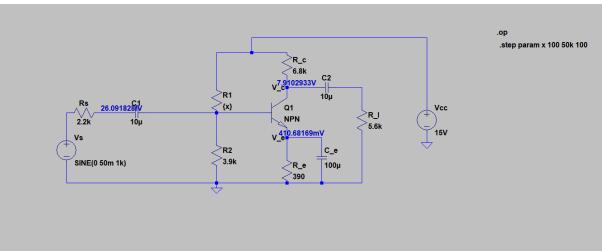
- A. Voltage gain
- B. Input Resistance
- C. Output Resistance
- D. Show input and output waveform

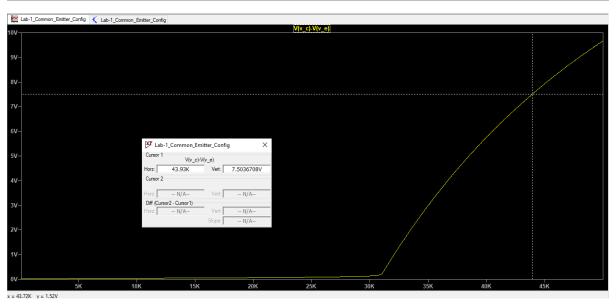
Components

- DC Voltage source 15 V
- Resistances of values 6.8 k Ω , 390 Ω , 2.2 k Ω , 3.9 k Ω and 5.6 k Ω
- One variable Resistance
- Capacitors of values 10 μF , 10 μF and 100 μF
- AC voltage source (50mV, 1kHz)

Determination of the Variable Resistance for the desired Q point







DC Analysis using .op – $\underline{R_1}$ comes out to be 43.92 k Ω , for $V_{CE}=7.5V$.

.ac Analysis to find the gain at 1 kHz

Gain with $C_F: -123.43392$

| AC Analysis | | | | | |
|----------------|------|---------------------|-----------|-----------------|--|
| frequency: | 1000 | Hz | | | |
| V(v_c): | mag: | 2.47203 phase: | -177.446° | v oltage | |
| V(n003): | mag: | 0.0200167 phase: | -1.06345° | voltage | |
| V(v_e): | mag: | 0.00129394 phase: | -87.1233° | voltage | |
| V(n001): | mag: | 0 phase: | 0° | voltage | |
| $V(v_{out})$: | mag: | 2.47202 phase: | -177.284° | voltage | |
| $V(v_{in}):$ | mag: | 0.0200262 phase: | -1.6837° | voltage | |
| V(n002): | mag: | 0.05 phase: | 0° | voltage | |
| Ic(Q1): | mag: | 0.000804966 phase: | 2.64288° | device current | |
| Ib (Q1): | mag: | 8.04966e-006 phase: | 2.64288° | device current | |
| Ie(Q1): | mag: | 0.000813016 phase: | -177.357° | device current | |
| I(C e): | mag: | 0.000813009 phase: | 2.87669° | device current | |
| I(C2): | mag: | 0.000441433 phase: | -177.284° | device current | |
| I(C1): | mag: | 1.3631e-005 phase: | -178.876° | device current | |
| I (Rs) : | mag: | 1.3631e-005 phase: | -178.876° | device current | |
| I(R 1): | mag: | 0.000441433 phase: | -177.284° | device current | |
| I(R e): | mag: | 3.31781e-006 phase: | -87.1233° | device current | |
| I (R2): | mag: | 5.1325e-006 phase: | -1.06345° | device current | |
| I(R1): | mag: | 4.55754e-007 phase: | 178.937° | device current | |
| I(R c): | mag: | 0.000363534 phase: | 2.55358° | device current | |
| I (Vcc) : | mag: | 0.000363079 phase: | -177.442° | device current | |
| | maσ: | 1.3631e-005 phase: | -178.876° | device current | |

Gain without C_E : -7.334278

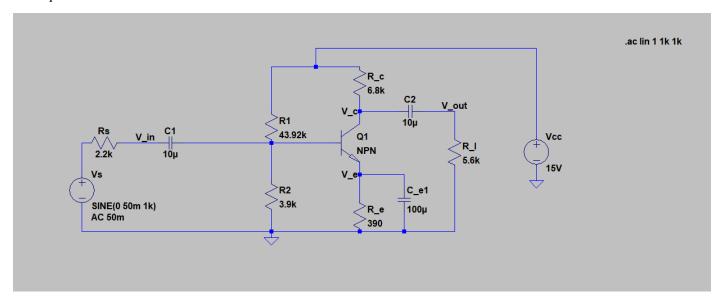
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```
--- AC Analysis ---
              1000
frequency:
                             Ηz
V(v c):
              mag:
                    0.220022 phase:
                                       -179.923°
                                                          voltage
V(n003):
              mag:
                    0.0299986 phase:
                                       0.165808°
                                                          voltage
                    0.0282212 phase:
                                       0.165808°
V(v_e):
              mag:
                                                          voltage
V(n001):
                            0 phase:
                                             o°
              mag:
                                                          voltage
                     0.220021 phase:
                                       -179.761°
V(v_out):
                                                          voltage
              mag:
V(v in):
              mag:
                     0.029999 phase:
                                       -0.110549°
                         0.05 phase:
                                              0°
V(n002):
                                                          voltage
              mag:
Ic(Q1):
              mag: 7.16457e-005 phase:
                                         0.165808°
                                                          device_current
              mag: 7.16457e-007 phase:
Ib (Q1):
                                         0.165808°
                                                          device current
              mag: 7.23621e-005 phase:
                                         -179.834°
Ie(Q1):
                                                          device current
I(C2):
              mag: 3.92895e-005 phase:
                                         -179.761°
                                                          device_current
              mag: 9.09144e-006 phase:
I(C1):
                                         -179.834°
                                                          device_current
I(Rs):
              mag: 9.09144e-006 phase:
                                         -179.834°
                                                          device_current
              mag: 3.92895e-005 phase:
                                         -179.761°
I(R 1):
                                                          device current
              mag: 7.23621e-005 phase:
I(R e):
                                         0.165808°
                                                          device_current
              mag: 7.69195e-006 phase:
                                         0.165808°
I(R2):
                                                          device current
              mag: 6.83029e-007 phase:
I(R1):
                                         -179.834°
                                                          device current
I(R c):
              mag: 3.23562e-005 phase: 0.0765106°
                                                          device current
              mag: 3.16732e-005 phase:
I(Vcc):
                                         -179.925°
                                                          device_current
I(Vs):
              mag: 9.09144e-006 phase:
                                         -179.834°
                                                          device_current
```

Input Resistance - R_{in} with C_E

DC Input Resistance - Infinity

AC Input Resistance:



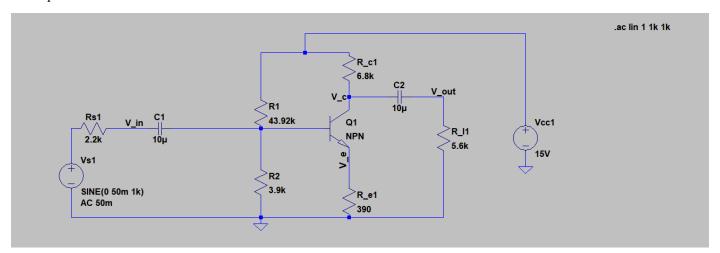
```
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                                                                                ×
       --- AC Analysis ---
               1000
frequency:
                              Ηz
                       2.47203 phase:
                                         -177.446°
                                                            voltage
V(v_c):
               mag:
               mag: 0.0200167 phase:
V(n003):
                                         -1.06345°
                                                            voltage
                                         -87.1233°
∇(v_e):
               mag: 0.00129394 phase:
                                                            voltage
V(n001):
               mag:
                             0 phase:
                                                            voltage
                       2.47202 phase:
                                         -177.284°
               mag:
                                                            voltage
V(v out):
                     0.0200262 phase:
                                          -1.6837°
V(v in):
               mag:
                                                            voltage
V(n002):
               mag:
                          0.05 phase:
                                                0°
                                                            voltage
               mag: 0.000804966 phase:
Ic(Q1):
                                           2.64288°
                                                            device_current
                                            2.64288°
               mag: 8.04966e-006 phase:
Ib(Q1):
                                                            device_current
Ie(Q1):
               mag: 0.000813016 phase:
                                          -177.357°
                                                            device current
I(C e):
               mag: 0.000813009 phase:
                                          2.87669°
                                                            device current
               mag: 0.000441433 phase:
I(C2):
                                          -177.284°
                                                            device_current
I(C1):
               mag: 1.3631e-005 phase:
                                          -178.876°
                                                            device current
               mag: 1.3631e-005 phase:
I(Rs):
                                          -178.876°
                                                            device current
I(R_1):
               mag: 0.000441433 phase:
                                          -177.284°
                                                            device_current
I(R_e):
               mag: 3.31781e-006 phase:
                                           -87.1233°
                                                            device_current
I(R2):
               mag: 5.1325e-006 phase:
                                          -1.06345°
                                                            device current
               mag: 4.55754e-007 phase:
                                            178.937°
I(R1):
                                                            device_current
I(R_c):
               mag: 0.000363534 phase:
                                           2.55358°
                                                            device current
              mag: 0.000363079 phase:
I(Vcc):
                                          -177.442°
                                                            device current
I(Vs):
               mag: 1.3631e-005 phase:
                                          -178.876°
                                                            device_current
```

$$R_{in} = \frac{V_{in}}{I_{in}} = \frac{0.0200262}{1.3631 \times 10^{-5}} = 1.46916 \text{ k}\Omega$$

Input Resistance - R_{in} without C_E

DC Input Resistance - Infinity

AC Input Resistance:



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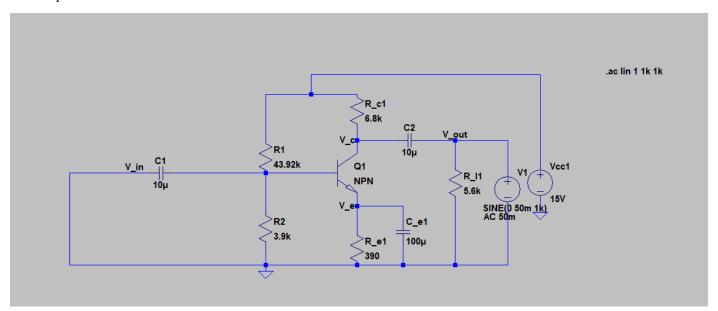
```
--- AC Analysis ---
frequency:
               1000
                              Ηz
V(v c):
               mag:
                      0.220022 phase:
                                         -179.923°
                                                            voltage
V(n003):
                     0.0299986 phase:
                                         0.165808°
               mag:
                                                            voltage
V(v e):
               mag:
                     0.0282212 phase:
                                         0.165808°
                                                            voltage
V(n001):
               mag:
                             0 phase:
                                                            voltage
                      0.220021 phase:
V(v out):
                                         -179.761°
                                                            voltage
               mag:
                      0.029999 phase:
V(v in):
                                        -0.110549°
               mag:
                                                            voltage
V(n002):
                          0.05 phase:
                                                o°
                                                            voltage
               mag:
               mag: 7.16457e-005 phase:
Ic(Q1):
                                           0.165808°
                                                            device current
               mag: 7.16457e-007 phase:
Ib(Q1):
                                           0.165808°
                                                            device_current
               mag: 7.23621e-005 phase:
Ie(Q1):
                                           -179.834°
                                                            device current
               mag: 3.92895e-005 phase:
                                           -179.761°
I(C2):
                                                            device current
              mag: 9.09144e-006 phase:
                                           -179.834°
I(C1):
                                                            device current
              mag: 9.09144e-006 phase:
I(Rs1):
                                           -179.834°
                                                            device current
I(R 11):
              mag: 3.92895e-005 phase:
                                           -179.761°
                                                            device current
              mag: 7.23621e-005 phase:
I(R e1):
                                           0.165808°
                                                            device current
              mag: 7.69195e-006 phase:
I(R2):
                                           0.165808°
                                                            device current
               mag: 6.83029e-007 phase:
I(R1):
                                           -179.834°
                                                            device current
I(R c1):
               mag: 3.23562e-005 phase:
                                          0.0765106°
                                                            device_current
I(Vcc1):
              mag: 3.16732e-005 phase:
                                           -179.925°
                                                            device_current
              mag: 9.09144e-006 phase:
I(Vs1):
                                           -179.834°
                                                            device current
```

$$R_{in} = \frac{V_{in}}{I_{in}} = \frac{0.029999}{9.09144 \times 10^{-6}} = 3.2997 \text{ k}\Omega$$

Output Resistance - R_{out} of the complete circuit (including R_L) with C_E

DC Output Resistance – $5.6 \text{ k}\Omega$

AC Output Resistance:



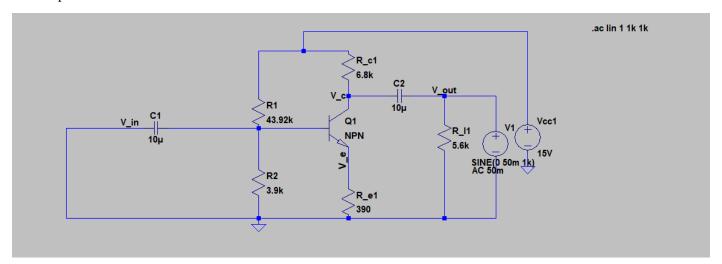
```
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                                                                                  X
       --- AC Analysis ---
frequency:
               1000
                              Ηz
                     0.0499999 phase:
                                          0.134101°
V(v_c):
               mag:
                                                             voltage
V(n002):
               mag: 7.95397e-013 phase:
                                            -89.2457°
                                                             voltage
V(v e):
               mag: 5.14169e-014 phase:
                                            -175.306°
                                                             voltage
                                                 0°
V(n001):
               mag:
                              0 phase:
                                                             voltage
V(v_out):
                           0.05 phase:
                                                 0°
               mag:
                                                             voltage
Ic(Q1):
               mag: 6.1355e-014 phase:
                                           -31.1881°
                                                             device_current
Ib(Q1):
               mag: 4.99767e-014 phase:
                                             -179.5°
                                                             device current
                                             94.4607°
Ie(Q1):
               mag: 3.23065e-014 phase:
                                                             device_current
               mag: 3.23062e-014 phase:
                                            -85.3055°
I(C_e1):
                                                             device_current
I(C2):
               mag: 7.35292e-006 phase:
                                            -179.866°
                                                             device_current
                                            \textbf{0.754348}^{\circ}
               mag: 4.99763e-014 phase:
                                                             device_current
I(C1):
               mag: 8.92857e-006 phase:
I(R 11):
                                                             device current
               mag: 1.31838e-016 phase:
I(R e1):
                                            -175.306°
                                                             device_current
I(R2):
               mag: 2.03948e-016 phase:
                                            -89.2457°
                                                             device_current
I(R1):
               mag: 1.81101e-017 phase:
                                             90.7543°
                                                             device current
I(R c1):
               mag: 7.35292e-006 phase:
                                            -179.866°
                                                             device current
I(V1):
               mag: 1.62815e-005 phase:
                                            -179.939°
                                                             device current
               mag: 7.35292e-006 phase:
                                            0.134101°
I (Vcc1):
                                                             device_current
```

$$R_{out\,with\,load\,resistance} = \frac{V_{out}}{I_{out}} = \frac{0.05}{1.62815\times10^{-5}} = R_c ||R_L = 3.070\;k\Omega$$

Output Resistance - Rout of the complete circuit (including RL) without CE

DC Output Resistance – $5.6 \text{ k}\Omega$

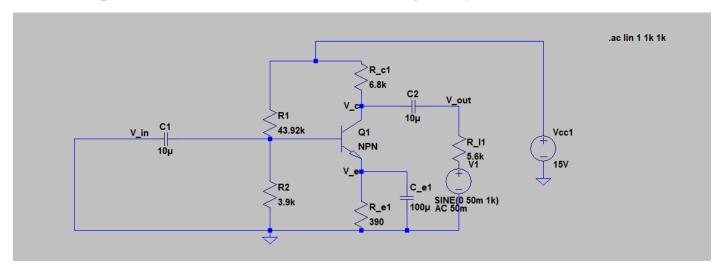
AC Output Resistance:



```
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                                                                                ×
       --- AC Analysis ---
              1000
frequency:
                              Ηz
              mag: 0.0499999 phase:
V(v_c):
                                         0.134101°
                                                            voltage
              mag: 7.95397e-013 phase:
V(n002):
                                          -89.2457°
                                                            voltage
V(v e):
              mag: 5.14169e-014 phase:
                                           -175.306°
                                                            voltage
V(n001):
                                                0°
              mag:
                             0 phase:
                                                            voltage
                                                o°
V(v out):
                          0.05 phase:
              mag:
                                                            voltage
              mag: 6.1355e-014 phase:
                                          -31.1881°
Ic(Q1):
                                                            device_current
Ib (Q1):
              mag: 4.99767e-014 phase:
                                            -179.5°
                                                            device_current
                                            94.4607°
Ie(Q1):
              mag: 3.23065e-014 phase:
                                                            device_current
I(C_e1):
              mag: 3.23062e-014 phase:
                                           -85.3055°
                                                            device current
I(C2):
              mag: 7.35292e-006 phase:
                                           -179.866°
                                                            device current
              mag: 4.99763e-014 phase:
                                           0.754348^{\circ}
I(C1):
                                                            device_current
              maq: 8.92857e-006 phase:
I(R 11):
                                                            device current
              mag: 1.31838e-016 phase:
                                           -175.306°
I(R e1):
                                                            device current
              mag: 2.03948e-016 phase:
                                           -89.2457°
I(R2):
                                                            device_current
I(R1):
              mag: 1.81101e-017 phase:
                                           90.7543°
                                                            device current
              mag: 7.35292e-006 phase:
I(R_c1):
                                           -179.866°
                                                            device_current
I(V1):
              mag: 1.62815e-005 phase:
                                           -179.939°
                                                            device current
              mag: 7.35292e-006 phase:
                                           0.134101°
                                                            device_current
I (Vcc1):
```

$$R_{out\,with\,load\,resistance} = \frac{V_{out}}{I_{out}} = \frac{0.05}{1.62815\times 10^{-5}} = R_c ||R_L = 3.070\;k\Omega$$

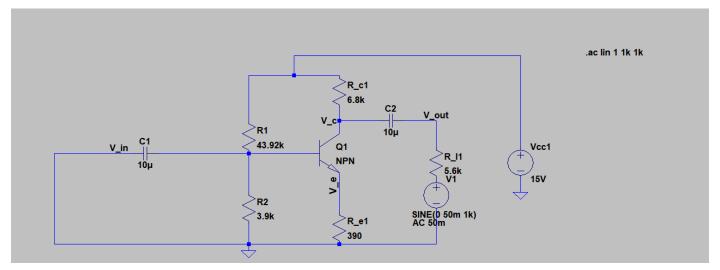
Output Resistance - Rout of the CE stage only (before RL) with CE



```
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                                                                                 X
       --- AC Analysis ---
               1000
frequency:
                              Ηz
               mag: 0.0274193 phase: 0.0735396°
V(v c):
                                                             voltage
V(n002):
               mag: 4.36186e-013 phase:
                                            -89.3062°
                                                             voltage
V(v_e):
               mag: 2.81964e-014 phase:
                                            -175.366°
                                                             voltage
V(n\overline{0}01):
                             0 phase:
                                                             voltage
               mag:
                    0.0274194 phase: -0.0605617°
V(v_out):
               mag:
                                                             voltage
                                                 o°
V(p001):
                          0.05 phase:
               mag:
                                                             voltage
               mag: 3.36464e-014 phase:
                                            -31.2487°
Ic(Q1):
                                                             device_current
                                           -179.561°
Ib(Q1):
               mag: 2.74067e-014 phase:
                                                             device_current
               mag: 1.77165e-014 phase:
                                             94.4001°
Ie(Q1):
                                                             device_current
               mag: 1.77163e-014 phase:
                                           -85.3661°
I(C e1):
                                                             device current
I(C2):
               mag: 4.03225e-006 phase:
                                           -179.926°
                                                             device_current
               mag: 2.74064e-014 phase:
I(C1):
                                           0.693786°
                                                             device_current
I(R_11):
               mag: 4.03225e-006 phase:
                                           -179.926°
                                                             device_current
               mag: 7.22986e-017 phase:
                                           -175.366°
I(R_e1):
                                                             device current
I(R2):
               mag: 1.11843e-016 phase:
                                           -89.3062°
                                                             device current
I(R1):
               mag: 9.93138e-018 phase:
                                             90.6938°
                                                             device current
               mag: 4.03225e-006 phase:
I(R c1):
                                           -179.926°
                                                             device_current
I(V1):
               mag: 4.03225e-006 phase:
                                           -179.926°
                                                             device_current
I (Vcc1):
               mag: 4.03225e-006 phase:
                                          0.0735396°
                                                             device current
```

$$R_{out \text{ of CE stage}} = \frac{V_{out}}{I_{out}} = \frac{0.0274194}{4.03225 \times 10^{-6}} = R_c = 6.8 \text{ k}\Omega$$

Output Resistance - Rout of the CE stage only (before RL) without CE

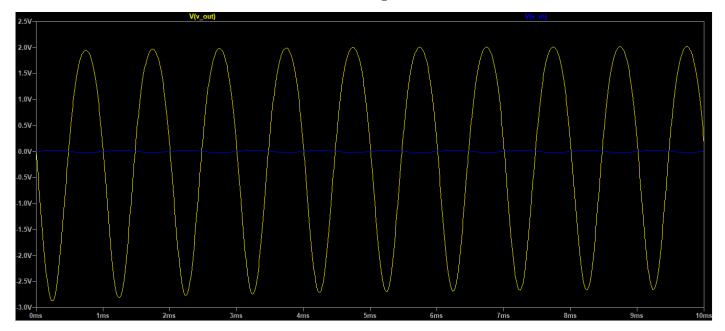


```
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                                                                               X
       --- AC Analysis ---
              1000
frequency:
                              Ηz
              mag: 0.0274193 phase: 0.0735396°
V(v_c):
                                                            voltage
V(n002):
              mag: 4.36186e-013 phase:
                                          -89.3062°
                                                            voltage
              mag: 2.81964e-014 phase:
V(v e):
                                           -175.366°
                                                            voltage
                                                ٥°
V(n001):
                             0 phase:
                                                            voltage
              mag:
                    0.0274194 phase: -0.0605617°
V(v_out):
                                                            voltage
V(p001):
              mag:
                         0.05 phase:
                                                            voltage
              mag: 3.36464e-014 phase:
                                           -31.2487°
Ic(Q1):
                                                            device_current
              mag: 2.74067e-014 phase:
Ib(Q1):
                                          -179.561°
                                                            device current
              mag: 1.77165e-014 phase:
                                            94.4001°
Ie(Q1):
                                                            device current
              mag: 1.77163e-014 phase:
I(C e1):
                                           -85.3661°
                                                            device_current
I(C2):
              mag: 4.03225e-006 phase:
                                           -179.926°
                                                            device_current
I(C1):
              mag: 2.74064e-014 phase:
                                           0.693786°
                                                            device current
              mag: 4.03225e-006 phase:
                                          -179.926°
I(R_11):
                                                            device_current
              mag: 7.22986e-017 phase:
I(R_e1):
                                          -175.366°
                                                            device current
I(R2):
              mag: 1.11843e-016 phase:
                                          -89.3062°
                                                            device current
I(R1):
              mag: 9.93138e-018 phase:
                                           90.6938°
                                                            device_current
I(R_c1):
              mag: 4.03225e-006 phase:
                                           -179.926°
                                                            device_current
I(V1):
              mag: 4.03225e-006 phase:
                                           -179.926°
                                                            device current
              mag: 4.03225e-006 phase:
                                         0.0735396°
I (Vcc1):
                                                            device_current
```

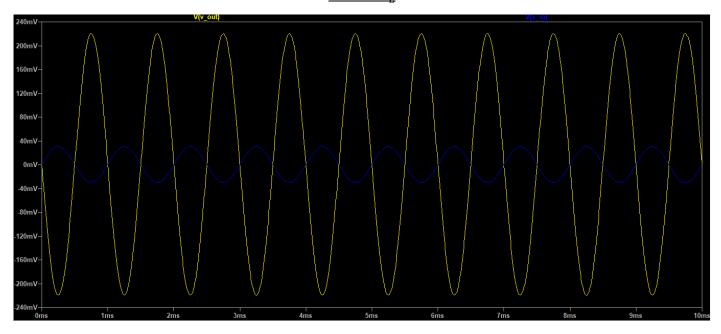
$$R_{out \text{ of CE stage}} = \frac{V_{out}}{I_{out}} = \frac{0.0274194}{4.03225 \times 10^{-6}} = R_c = 6.8 \text{ k}\Omega$$

Input and Output Waveforms

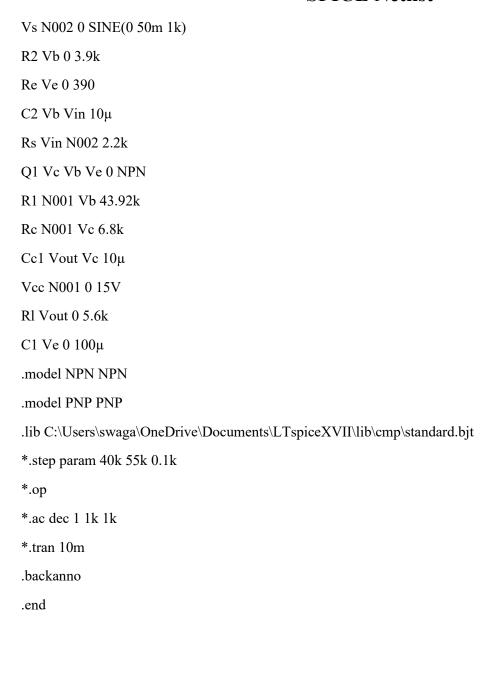
With C_E



Without C_E



SPICE Netlist



Observations & Conclusions:

- Common emitter circuit uses "Voltage Divider Biasing", hence bias at V supply /2, at the Q-point. It gives the best stability.
- BJT in CE configuration, behaves as an inverting amplifier.