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

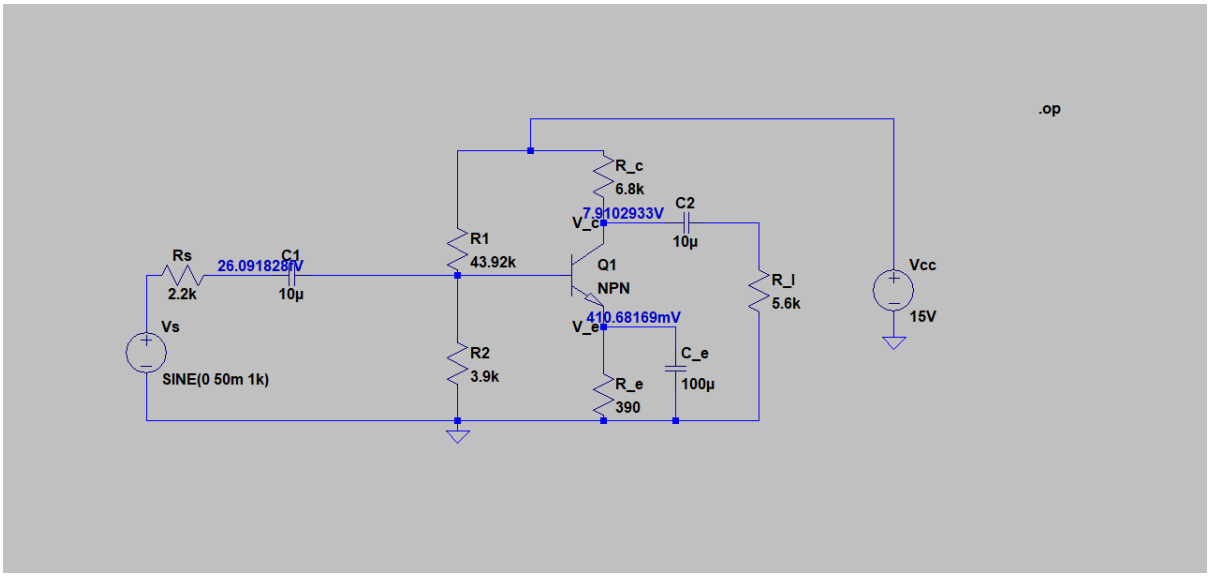
C. Output Resistance

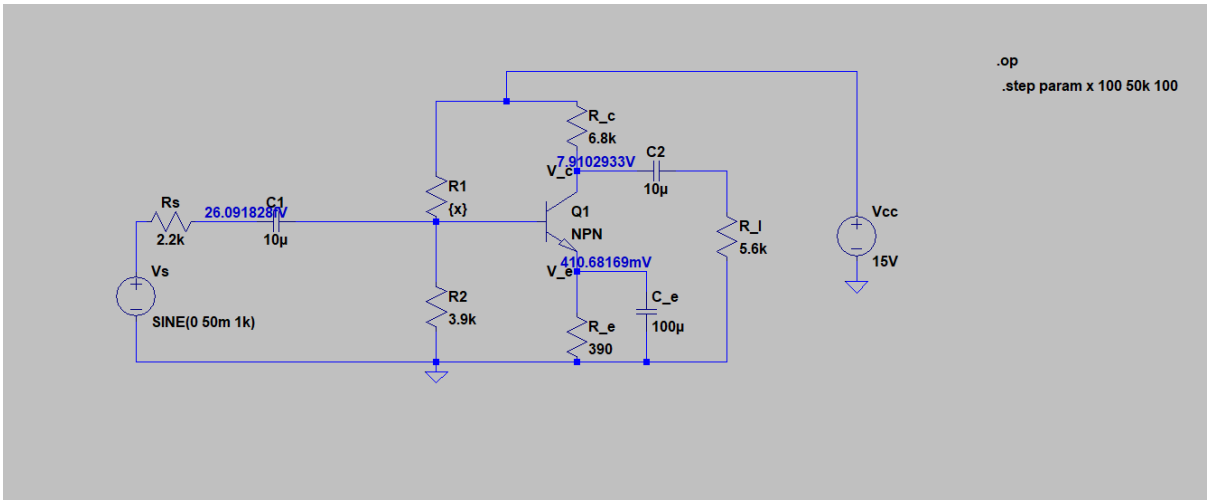
D. Show input and output waveform

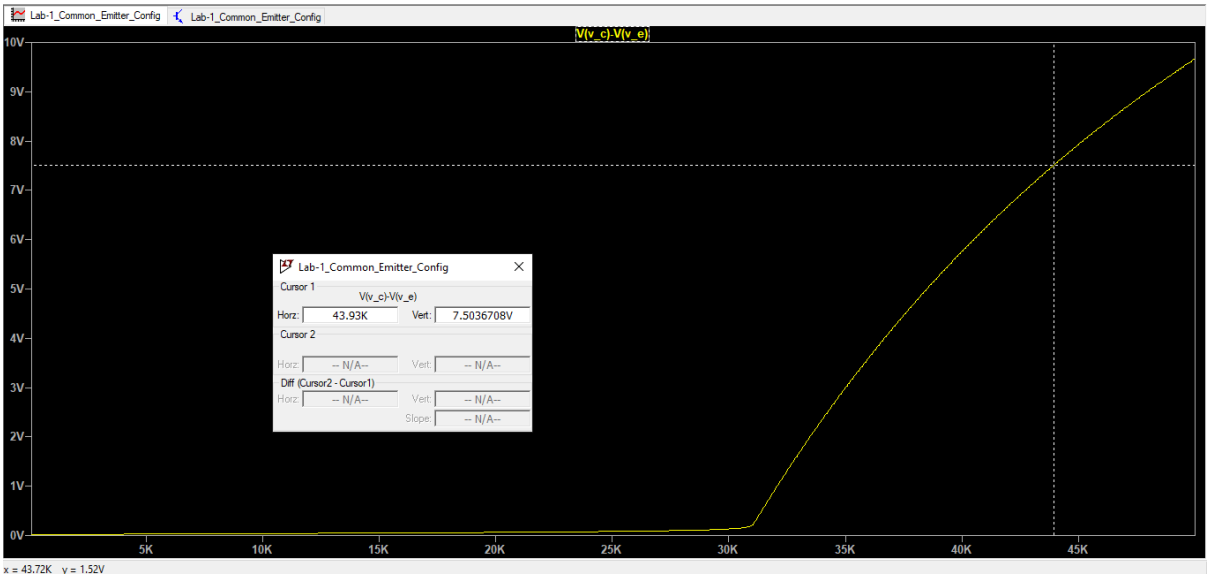
Components

- DC Voltage source 15 V
- Resistances of values 6.8 kΩ, 390 Ω, 2.2 kΩ, 3.9 kΩ and 5.6 kΩ
- 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



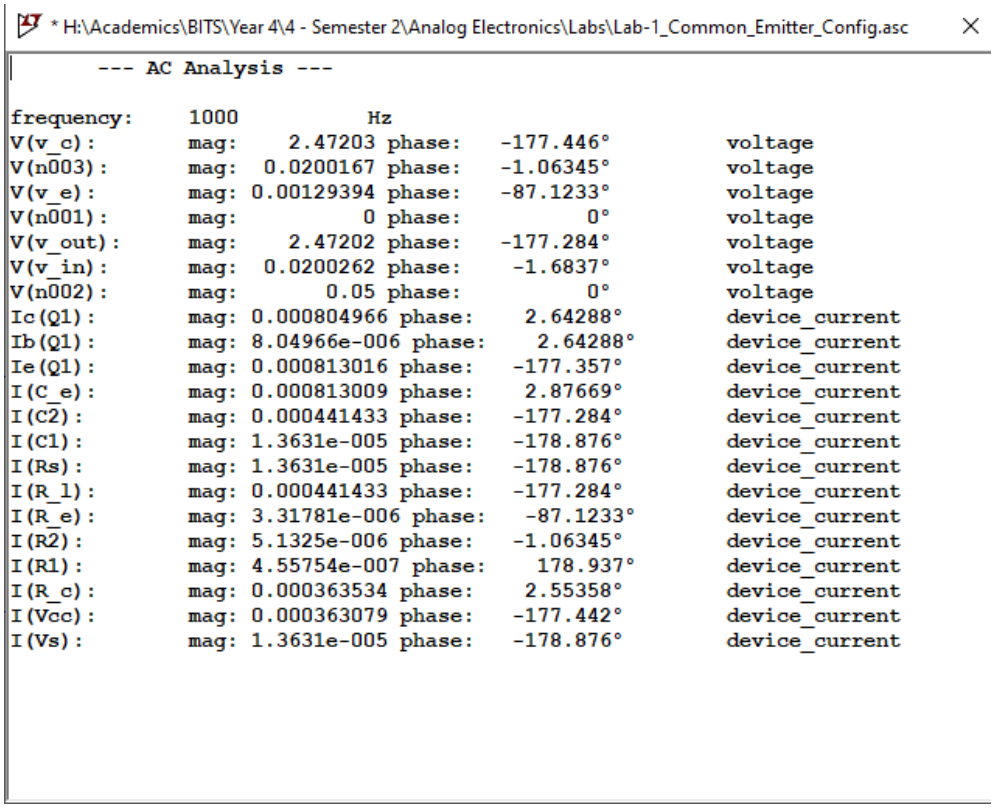




DC Analysis using .op – $\underline{R_1}$ comes out to be 43.92 kΩ, for $V_{CE} = 7.5V$.

.ac Analysis to find the gain at 1 kHz

Gain with C_E: – 123.43392



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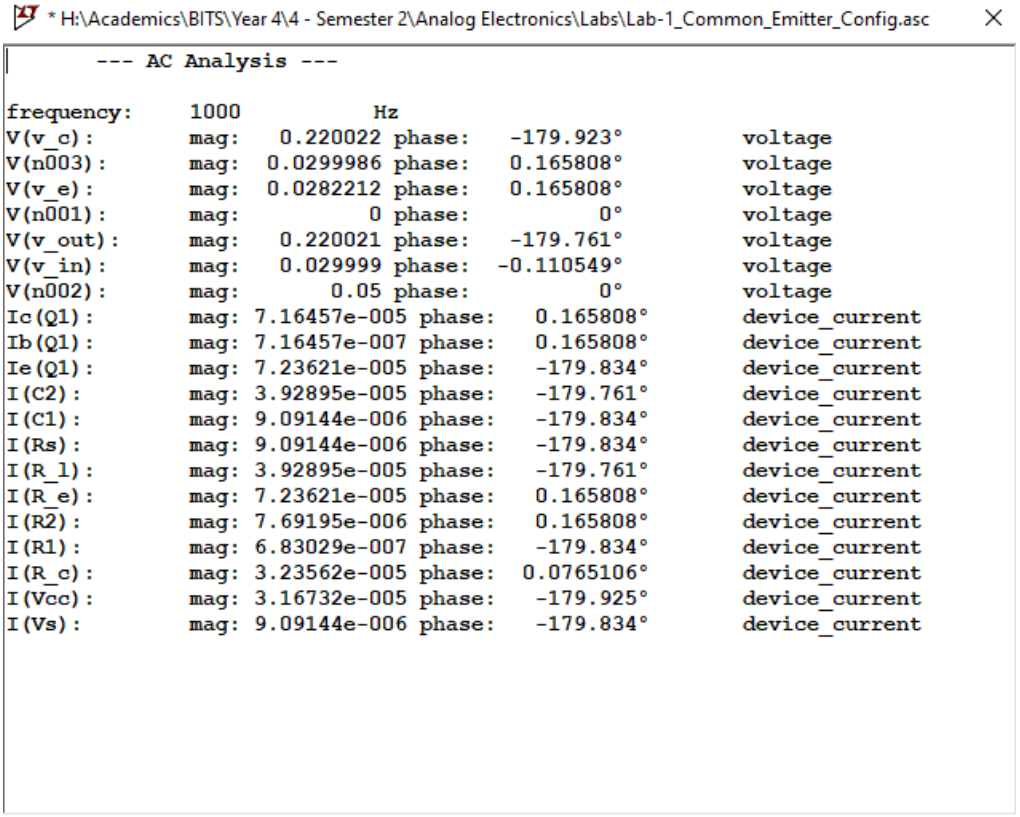
```
      --- AC Analysis ---

frequency:     1000          Hz
V(v_c):        mag:     2.47203 phase:    -177.446°          voltage
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_l):        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
I(Vs):         mag: 1.3631e-005 phase:    -178.876°          device_current
```

Gain without C_E: – 7.334278



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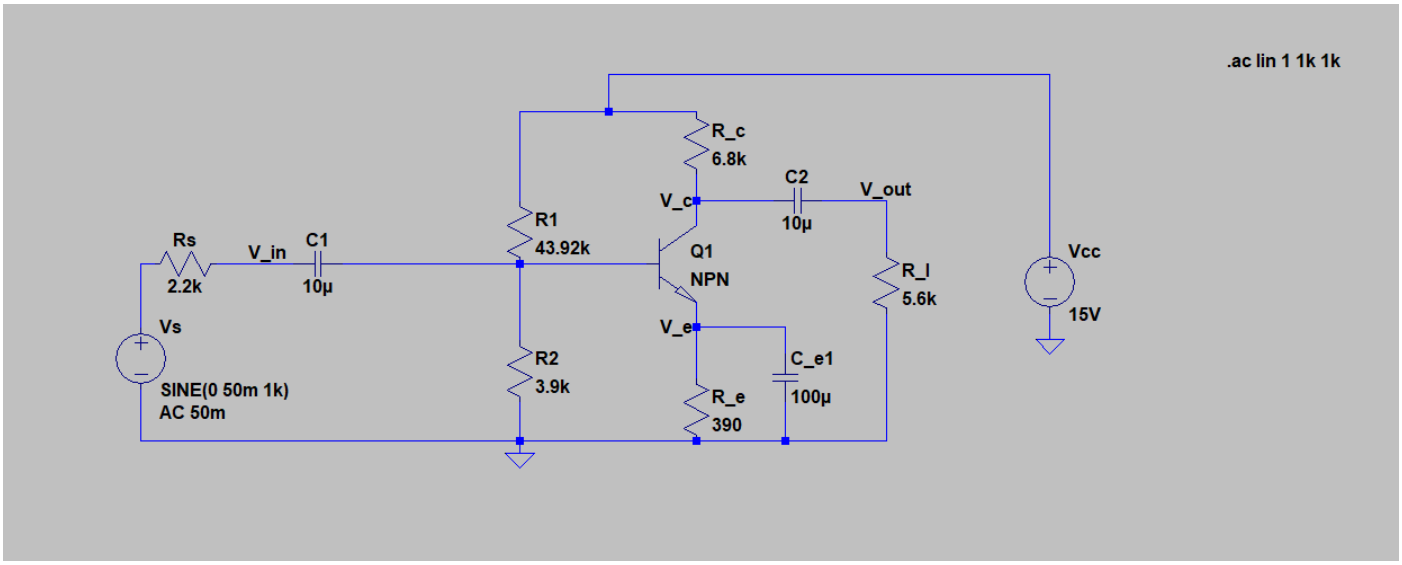
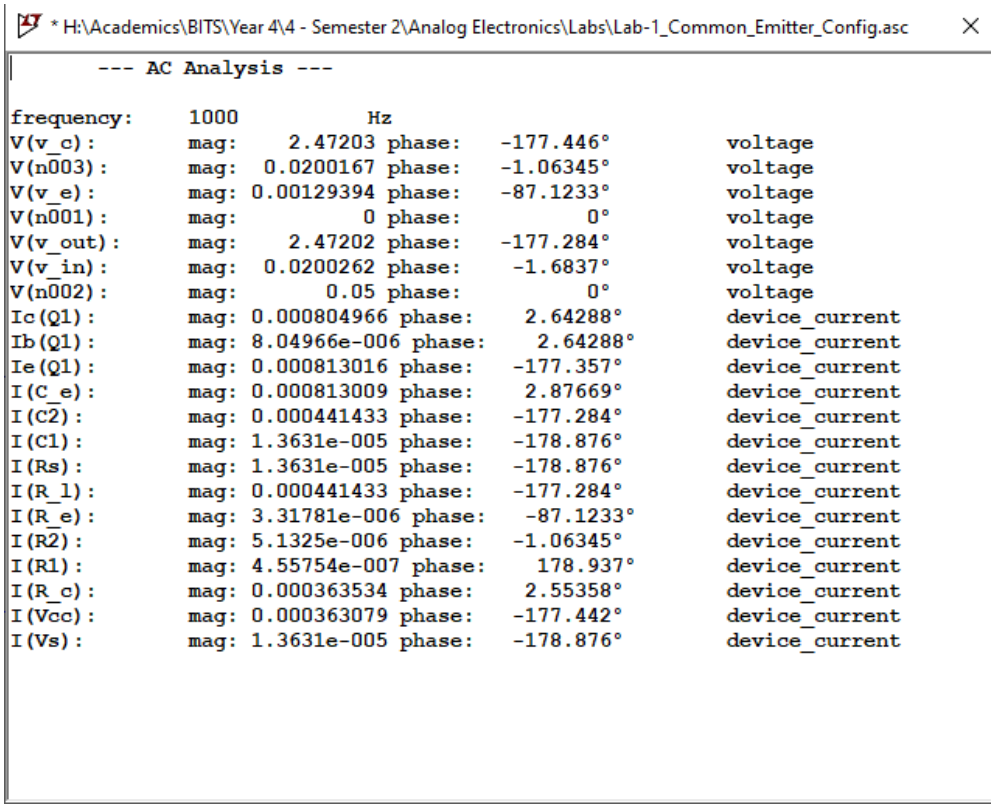
```
      --- AC Analysis ---

frequency:     1000          Hz
V(v_c):        mag:    0.220022 phase:    -179.923°          voltage
V(n003):       mag:   0.0299986 phase:    0.165808°          voltage
V(v_e):        mag:   0.0282212 phase:    0.165808°          voltage
V(n001):       mag:           0 phase:           0°          voltage
V(v_out):      mag:    0.220021 phase:    -179.761°          voltage
V(v_in):       mag:    0.029999 phase:   -0.110549°          voltage
V(n002):       mag:        0.05 phase:           0°          voltage
Ic(Q1):        mag: 7.16457e-005 phase:    0.165808°          device_current
Ib(Q1):        mag: 7.16457e-007 phase:    0.165808°          device_current
Ie(Q1):        mag: 7.23621e-005 phase:    -179.834°          device_current
I(C2):         mag: 3.92895e-005 phase:    -179.761°          device_current
I(C1):         mag: 9.09144e-006 phase:    -179.834°          device_current
I(Rs):         mag: 9.09144e-006 phase:    -179.834°          device_current
I(R_l):        mag: 3.92895e-005 phase:    -179.761°          device_current
I(R_e):        mag: 7.23621e-005 phase:    0.165808°          device_current
I(R2):         mag: 7.69195e-006 phase:    0.165808°          device_current
I(R1):         mag: 6.83029e-007 phase:    -179.834°          device_current
I(R_c):        mag: 3.23562e-005 phase:   0.0765106°          device_current
I(Vcc):        mag: 3.16732e-005 phase:    -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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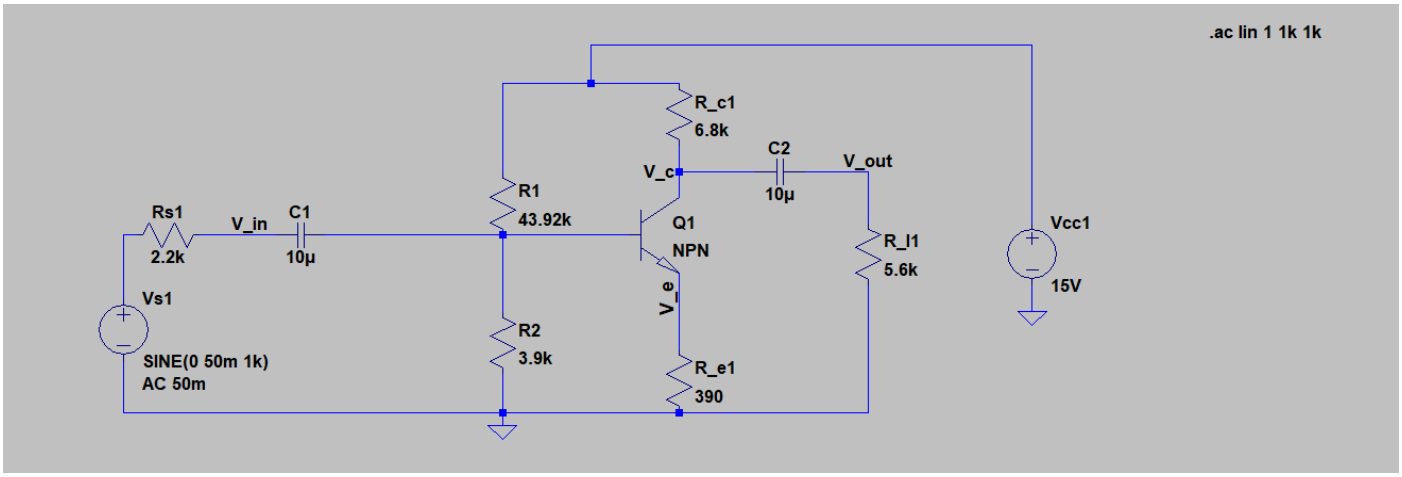
```
      --- AC Analysis ---

frequency:     1000          Hz
V(v_c):        mag:    2.47203 phase:   -177.446°        voltage
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_l):        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
I(Vs):         mag: 1.3631e-005 phase:   -178.876°        device_current
```

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

Input Resistance - R_{in} without C_E

DC Input Resistance – Infinity

AC Input Resistance:



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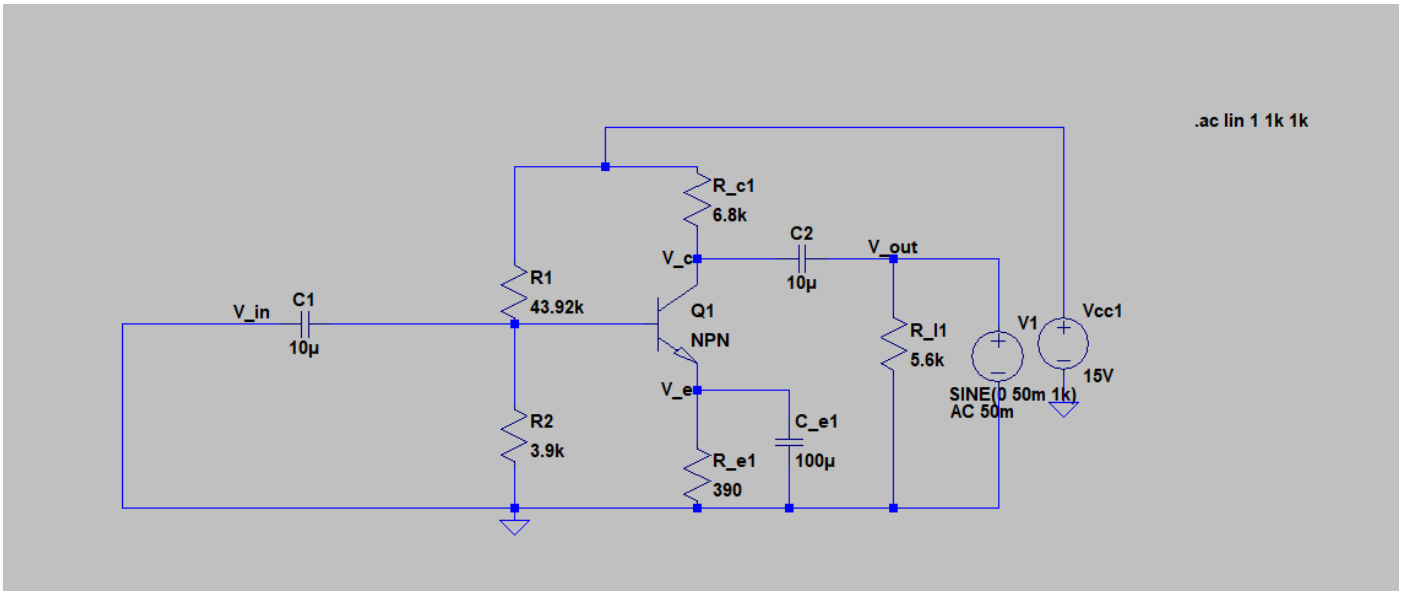
```
        --- AC Analysis ---

frequency:      1000          Hz
V(v_c):         mag:    0.220022 phase:    -179.923°          voltage
V(n003):        mag:   0.0299986 phase:    0.165808°          voltage
V(v_e):         mag:   0.0282212 phase:    0.165808°          voltage
V(n001):        mag:           0 phase:           0°          voltage
V(v_out):       mag:    0.220021 phase:    -179.761°          voltage
V(v_in):        mag:    0.029999 phase:   -0.110549°          voltage
V(n002):        mag:        0.05 phase:           0°          voltage
Ic(Q1):         mag: 7.16457e-005 phase:    0.165808°          device_current
Ib(Q1):         mag: 7.16457e-007 phase:    0.165808°          device_current
Ie(Q1):         mag: 7.23621e-005 phase:    -179.834°          device_current
I(C2):          mag: 3.92895e-005 phase:    -179.761°          device_current
I(C1):          mag: 9.09144e-006 phase:    -179.834°          device_current
I(Rs1):         mag: 9.09144e-006 phase:    -179.834°          device_current
I(R_l1):        mag: 3.92895e-005 phase:    -179.761°          device_current
I(R_e1):        mag: 7.23621e-005 phase:    0.165808°          device_current
I(R2):          mag: 7.69195e-006 phase:    0.165808°          device_current
I(R1):          mag: 6.83029e-007 phase:    -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
I(Vs1):         mag: 9.09144e-006 phase:    -179.834°          device_current
```

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

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

DC Output Resistance – 5.6 kΩ

AC Output Resistance:



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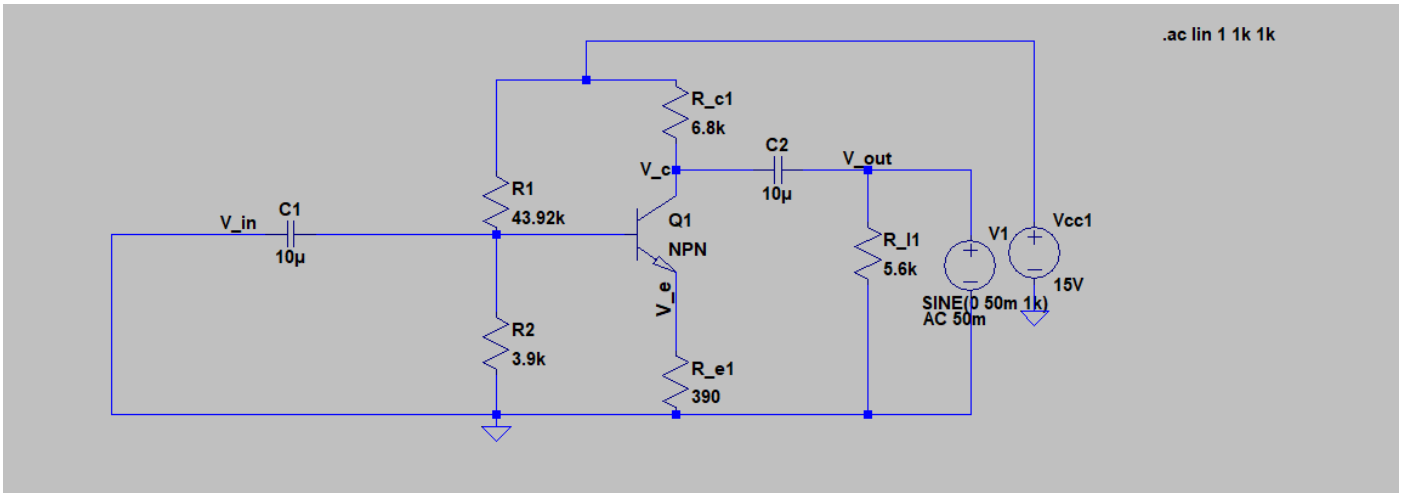
```
      --- AC Analysis ---

frequency:     1000           Hz
V(v_c):        mag:  0.0499999 phase:   0.134101°        voltage
V(n002):       mag: 7.95397e-013 phase:   -89.2457°      voltage
V(v_e):        mag: 5.14169e-014 phase:   -175.306°      voltage
V(n001):       mag:          0 phase:         0°        voltage
V(v_out):      mag:       0.05 phase:         0°        voltage
Ic(Q1):        mag: 6.1355e-014 phase:   -31.1881°       device_current
Ib(Q1):        mag: 4.99767e-014 phase:     -179.5°      device_current
Ie(Q1):        mag: 3.23065e-014 phase:    94.4607°      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
I(C1):         mag: 4.99763e-014 phase:   0.754348°      device_current
I(R_l1):       mag: 8.92857e-006 phase:         0°       device_current
I(R_e1):       mag: 1.31838e-016 phase:   -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
I(Vcc1):       mag: 7.35292e-006 phase:   0.134101°      device_current
```

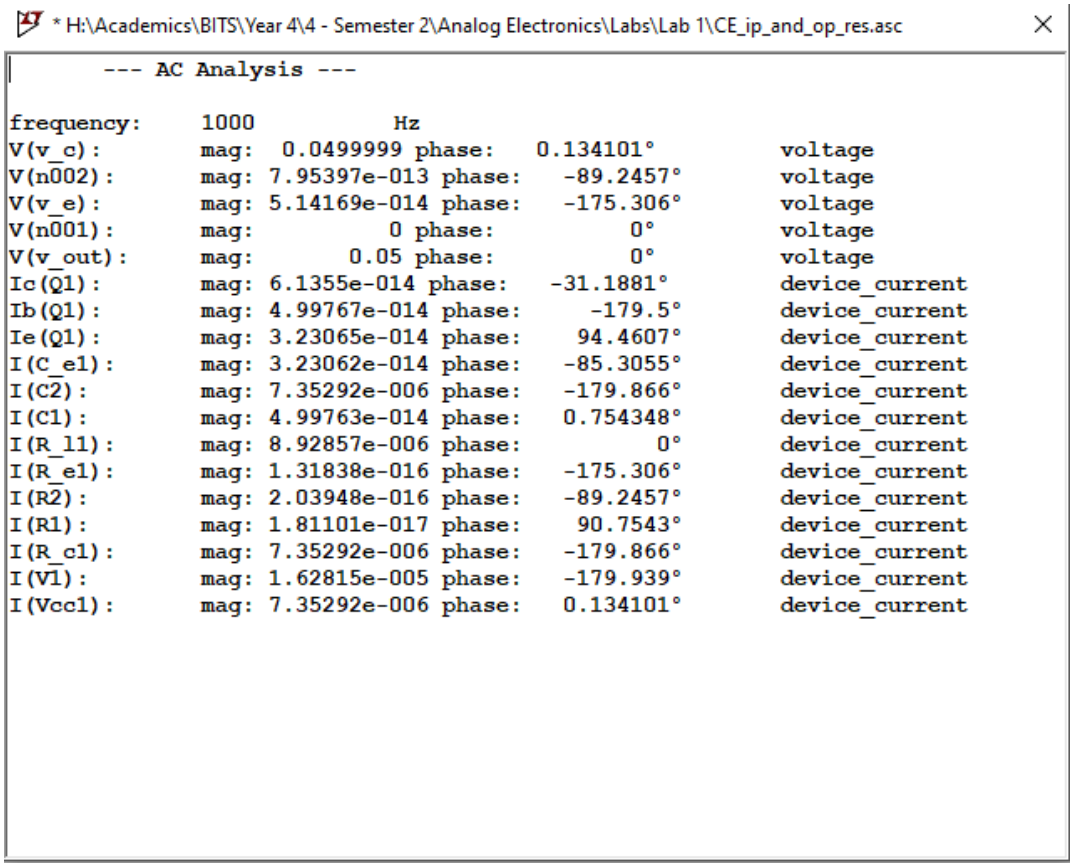
$$R_{\text{out with load resistance}} = \frac{V_{out}}{I_{out}} = \frac{0.05}{1.62815 \times 10^{-5}} = R_c || R_L = 3.070\ \text{k}\Omega$$

Output Resistance - R_{out} of the complete circuit (including R_L) without C_E

DC Output Resistance – 5.6 kΩ

AC Output Resistance:





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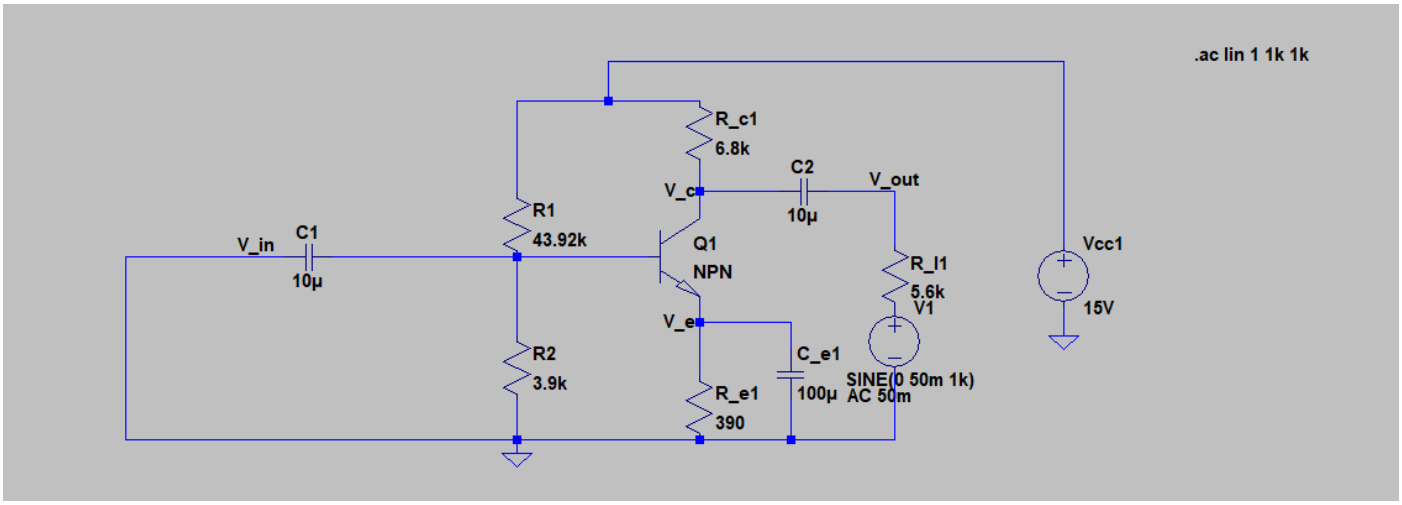
```
        --- AC Analysis ---

frequency:     1000          Hz
V(v_c):        mag:  0.0499999 phase:   0.134101°        voltage
V(n002):       mag: 7.95397e-013 phase:   -89.2457°      voltage
V(v_e):        mag: 5.14169e-014 phase:   -175.306°      voltage
V(n001):       mag:          0 phase:         0°        voltage
V(v_out):      mag:       0.05 phase:         0°        voltage
Ic(Q1):        mag: 6.1355e-014 phase:   -31.1881°       device_current
Ib(Q1):        mag: 4.99767e-014 phase:     -179.5°      device_current
Ie(Q1):        mag: 3.23065e-014 phase:    94.4607°      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
I(C1):         mag: 4.99763e-014 phase:   0.754348°      device_current
I(R_l1):       mag: 8.92857e-006 phase:          0°      device_current
I(R_e1):       mag: 1.31838e-016 phase:   -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
I(Vcc1):       mag: 7.35292e-006 phase:   0.134101°      device_current
```

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

Output Resistance - R_{out} of the CE stage only (before R_L) with C_E



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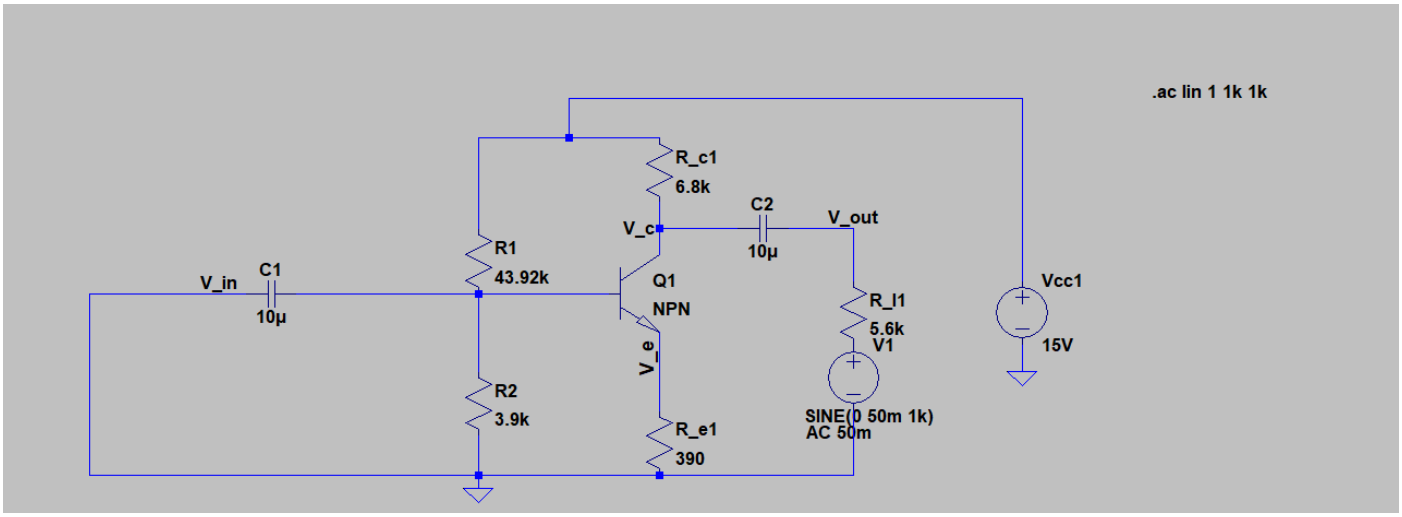
```
      --- AC Analysis ---

frequency:     1000          Hz
V(v_c):        mag:  0.0274193 phase:  0.0735396°        voltage
V(n002):       mag: 4.36186e-013 phase:   -89.3062°      voltage
V(v_e):        mag: 2.81964e-014 phase:   -175.366°      voltage
V(n001):       mag:          0 phase:          0°        voltage
V(v_out):      mag:  0.0274194 phase: -0.0605617°        voltage
V(p001):       mag:       0.05 phase:          0°        voltage
Ic(Q1):        mag: 3.36464e-014 phase:   -31.2487°      device_current
Ib(Q1):        mag: 2.74067e-014 phase:   -179.561°      device_current
Ie(Q1):        mag: 1.77165e-014 phase:    94.4001°      device_current
I(C_e1):       mag: 1.77163e-014 phase:   -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
I(R_l1):       mag: 4.03225e-006 phase:   -179.926°      device_current
I(R_e1):       mag: 7.22986e-017 phase:   -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
I(Vcc1):       mag: 4.03225e-006 phase:  0.0735396°      device_current
```

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

Output Resistance - R_{out} of the CE stage only (before R_L) without C_E



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```
      --- AC Analysis ---

frequency:     1000          Hz
V(v_c):        mag:  0.0274193 phase:  0.0735396°        voltage
V(n002):       mag: 4.36186e-013 phase:   -89.3062°      voltage
V(v_e):        mag: 2.81964e-014 phase:   -175.366°      voltage
V(n001):       mag:          0 phase:          0°        voltage
V(v_out):      mag:  0.0274194 phase: -0.0605617°        voltage
V(p001):       mag:       0.05 phase:          0°        voltage
Ic(Q1):        mag: 3.36464e-014 phase:   -31.2487°      device_current
Ib(Q1):        mag: 2.74067e-014 phase:   -179.561°      device_current
Ie(Q1):        mag: 1.77165e-014 phase:    94.4001°      device_current
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I(C2):         mag: 4.03225e-006 phase:   -179.926°      device_current
I(C1):         mag: 2.74064e-014 phase:   0.693786°      device_current
I(R_l1):       mag: 4.03225e-006 phase:   -179.926°      device_current
I(R_e1):       mag: 7.22986e-017 phase:   -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
I(Vcc1):       mag: 4.03225e-006 phase:  0.0735396°      device_current
```
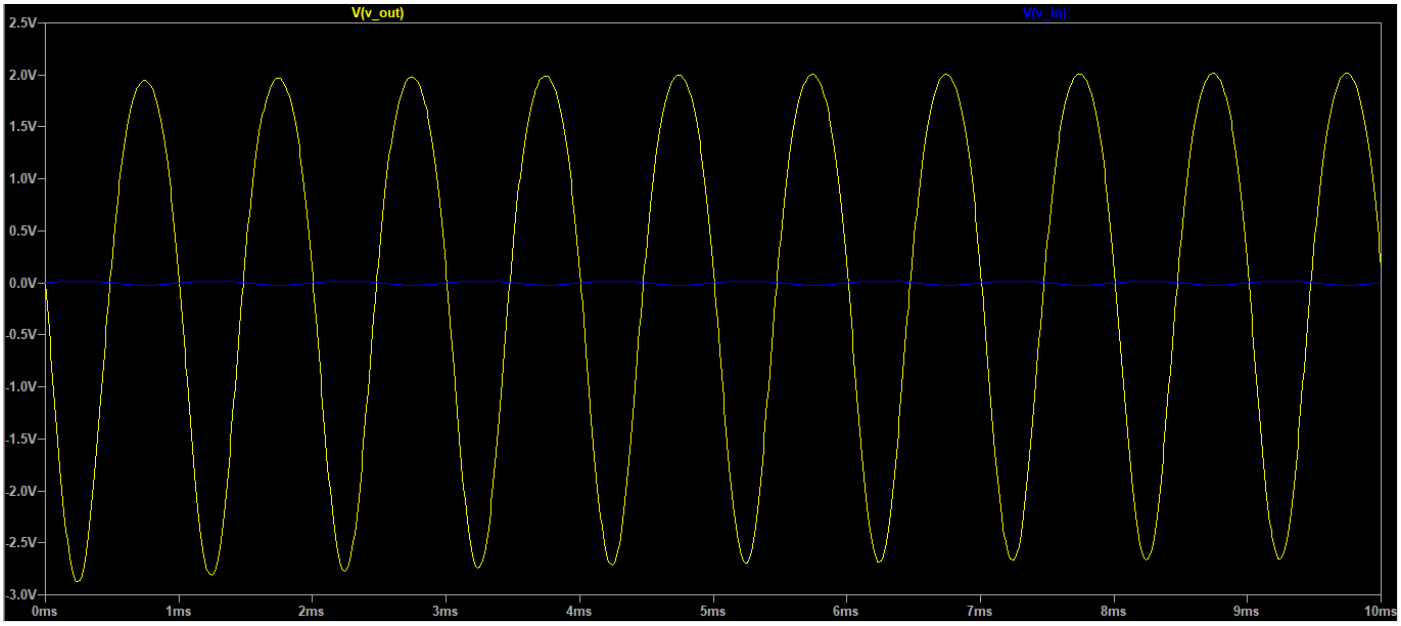
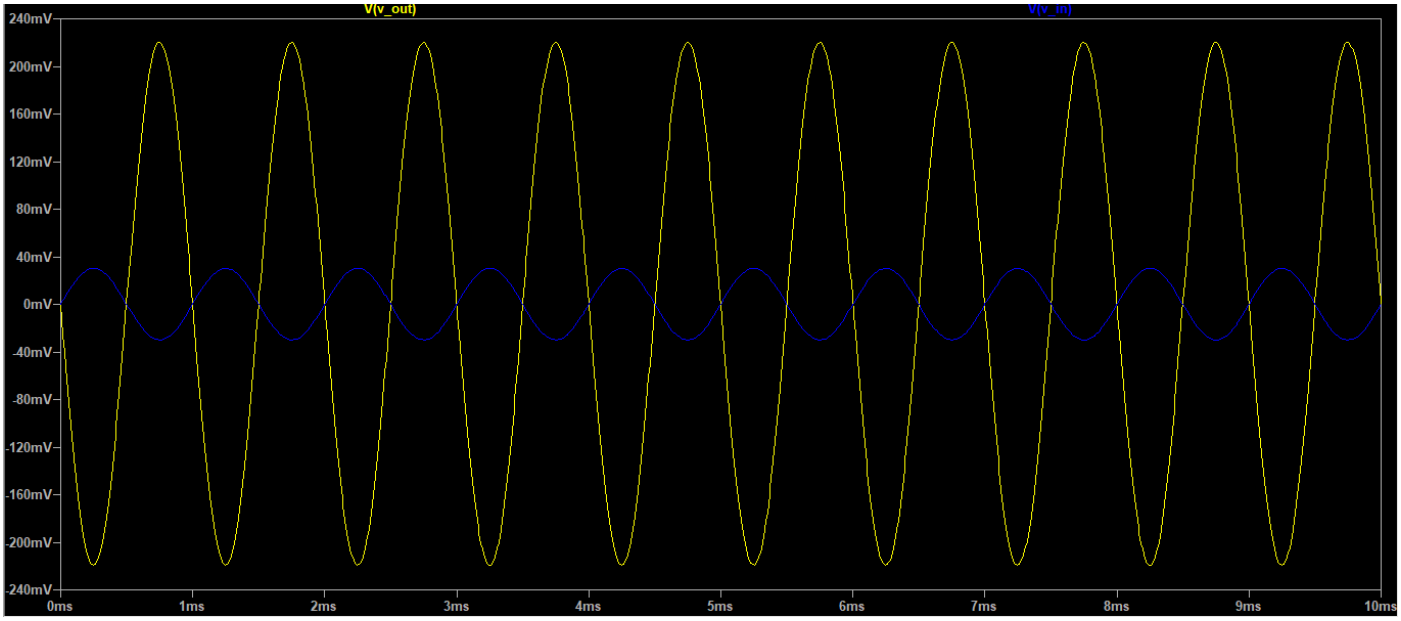

$$R_{\text{out of CE stage}} = \frac{V_{out}}{I_{out}} = \frac{0.0274194}{4.03225 \times 10^{-6}} = R_c = 6.8\ \text{k}\Omega$$

Input and Output Waveforms

With C_E



Without C_E



SPICE Netlist

Vs N002 0 SINE(0 50m 1k)

R2 Vb 0 3.9k

Re Ve 0 390

C2 Vb Vin 10µ

Rs Vin N002 2.2k

Q1 Vc Vb Ve 0 NPN

R1 N001 Vb 43.92k

Rc N001 Vc 6.8k

Cc1 Vout Vc 10µ

Vcc N001 0 15V

Rl Vout 0 5.6k

C1 Ve 0 100µ

.model NPN NPN

.model PNP PNP

.lib C:\Users\swaga\OneDrive\Documents\LTspiceXVII\lib\cmp\standard.bjt

*.step param 40k 55k 0.1k

*.op

*.ac dec 1 1k 1k

*.tran 10m

.backanno

.end

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.