Study of different modes of common collector amplifier

Analog Electronics Lab Experiment -2

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Lab Section: P5
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1. Objective

To study the common-collector amplifier, Darlington mode transistors, and bootstrapped emitter follower. Design the circuit on LT-Spice and calculate the following parameters

1) DC Bias Point
2) Input Resistance
3) Output Resistance
4) Voltage Gain
5) Show the waveforms for input and output voltages

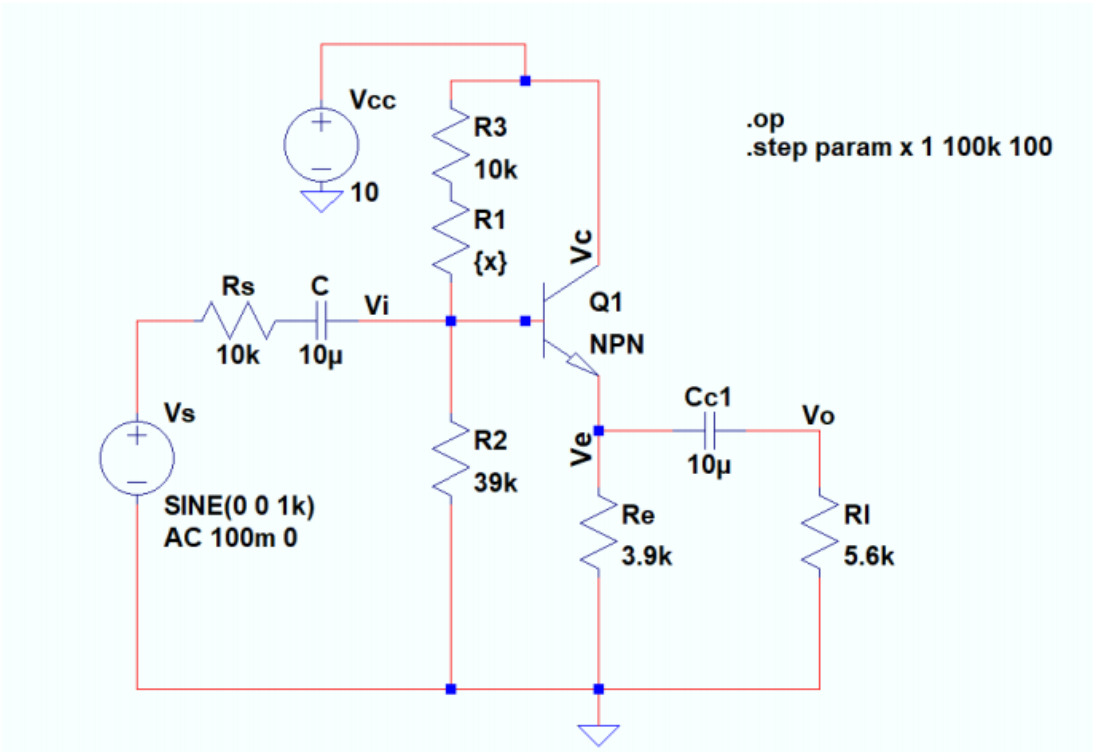
Given Information:
Load Resistance = 5.6k Ohms,
Input series resistance = 10k Ohms,
Coupling and Bypass Capacitor = 10uF
Emitter Resistance = 3.9k Ohms
Potential Divider consists of : 39k Ohms (Lower arm) and 10k + R Ohms (Upper arm)

Components provided : BJT, Capacitor, Resistor, Voltage Source AC and DC. wires

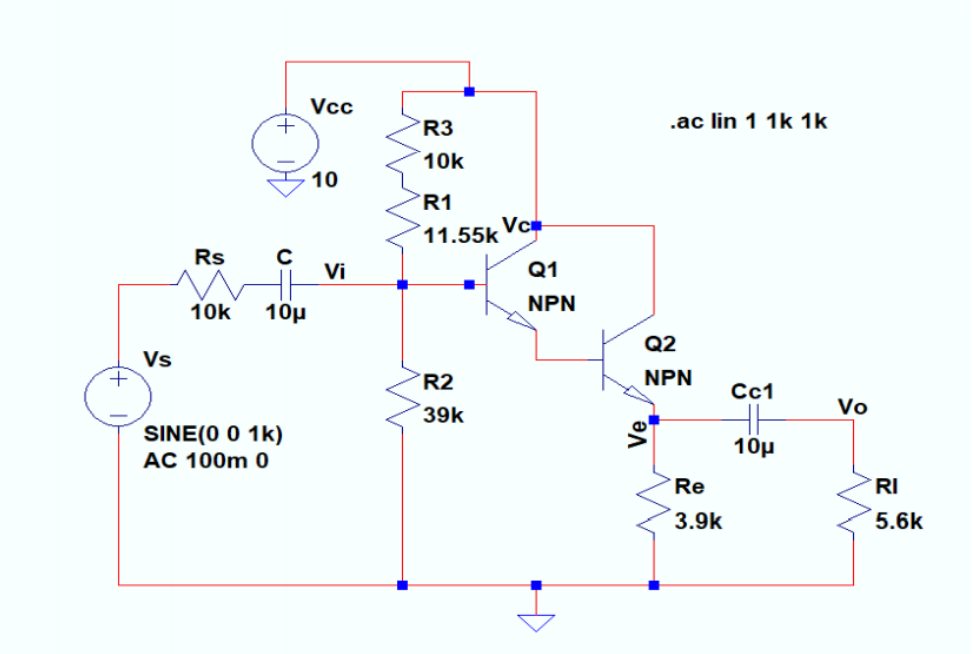
Assumptions: Assuming that the DC bias point i.e. $V_c - V_e = V_{bias}/2 = 5V$

2. Schematic Diagram

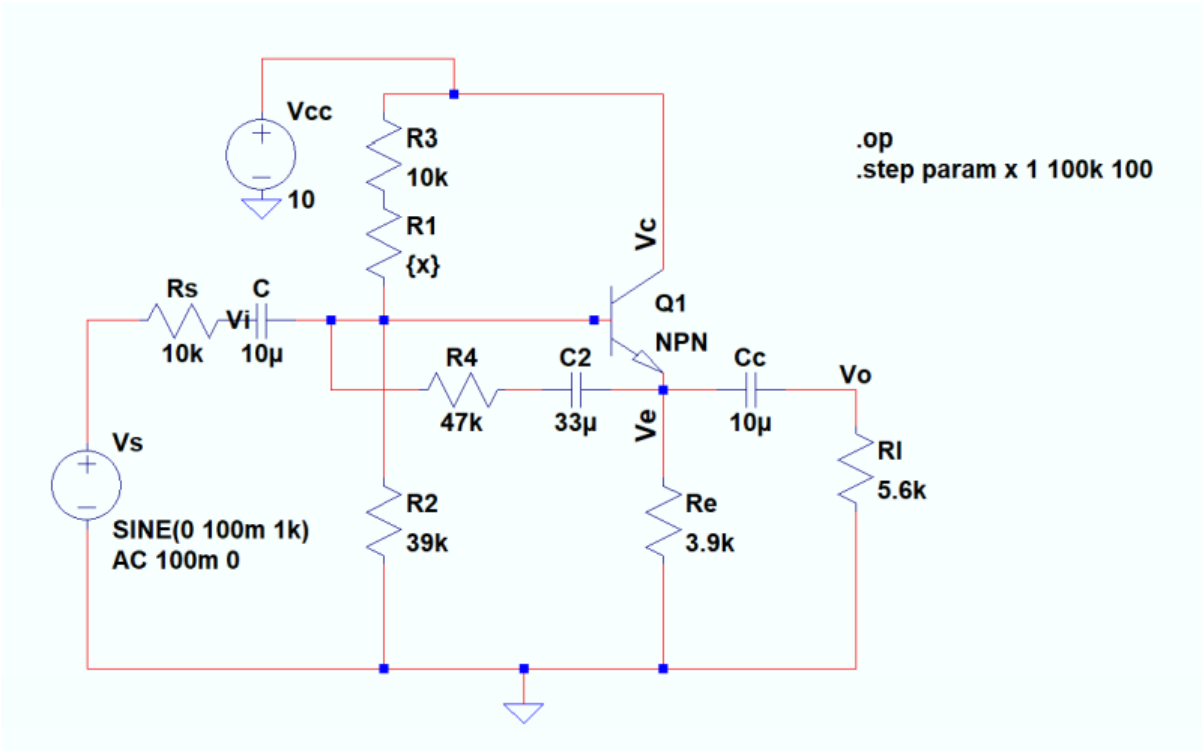
A. Common Collector amplifier Schematic :



B. Darlington mode transistor Schematic:

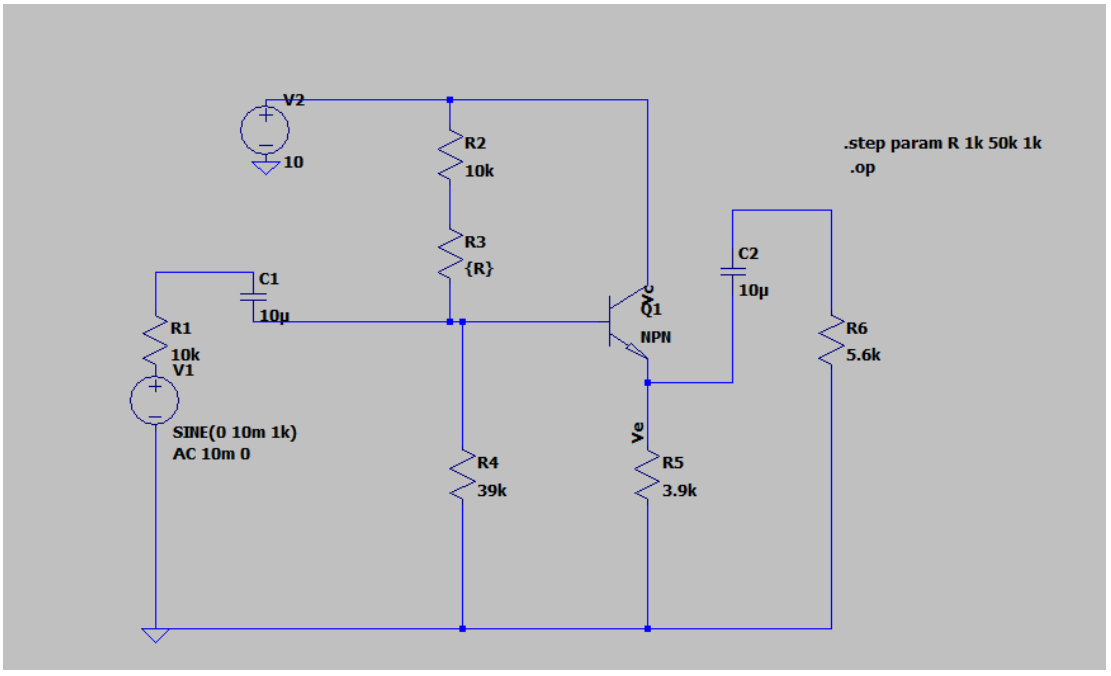


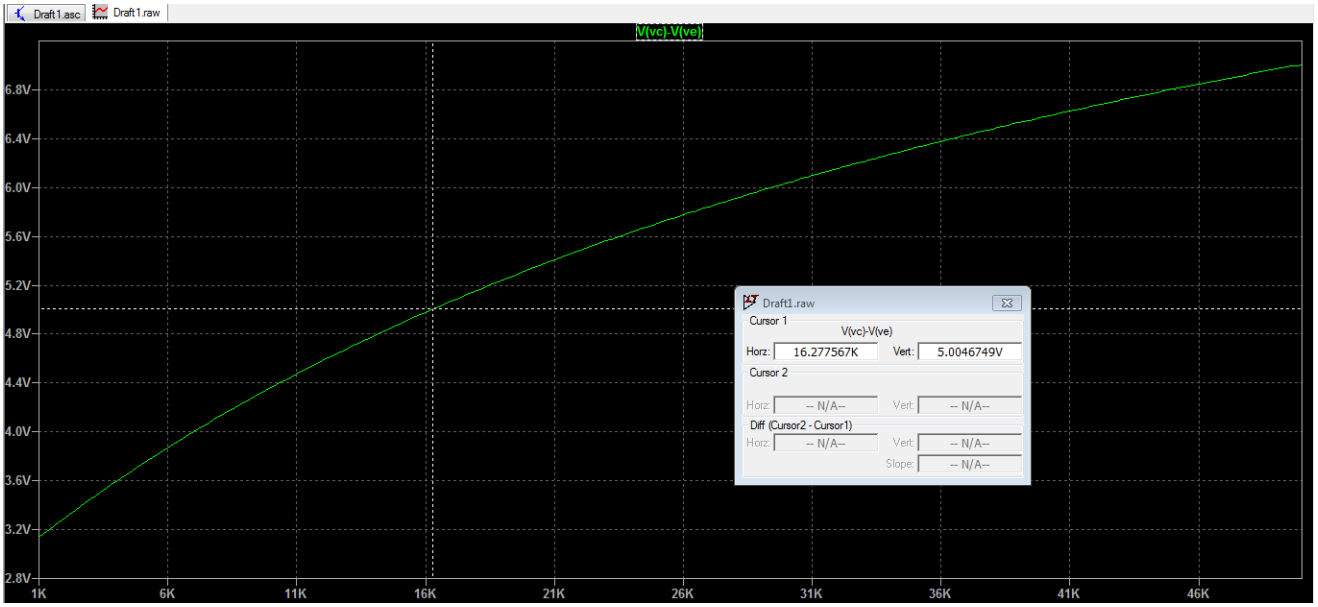
C. Bootstrapped emitter follower Schematic:



3. DC Bias Point Calculation

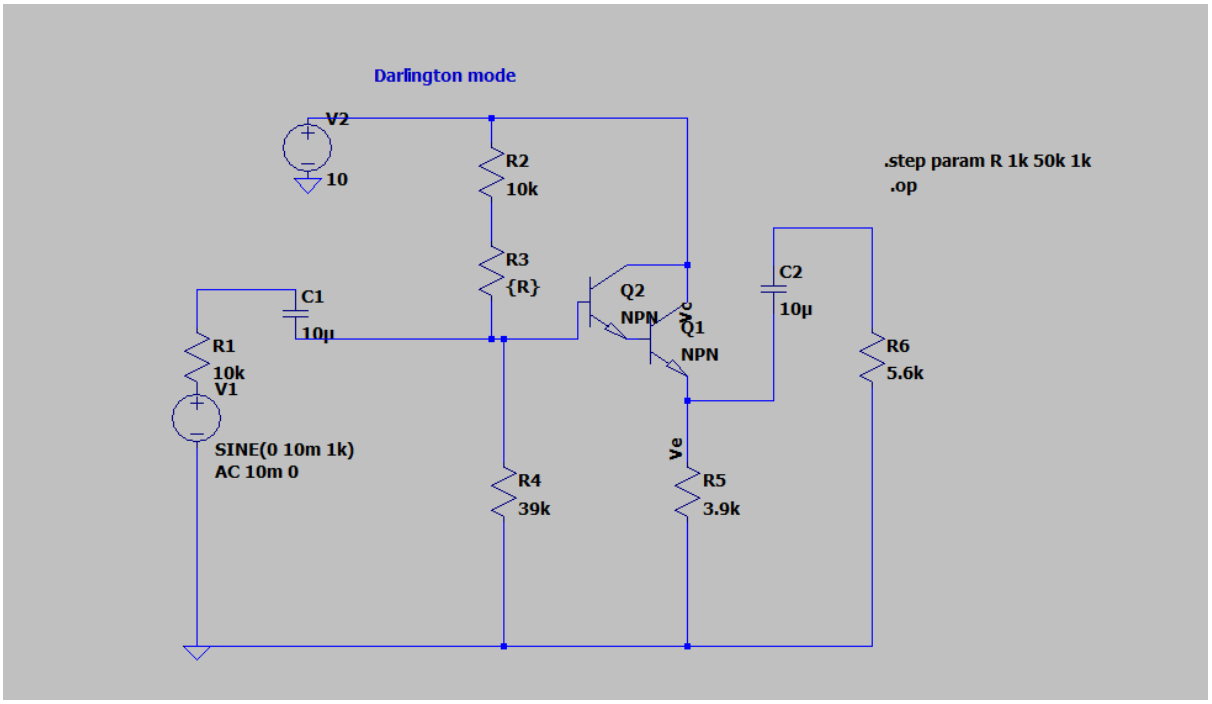
A. **Common Collector amplifier Schematic** :

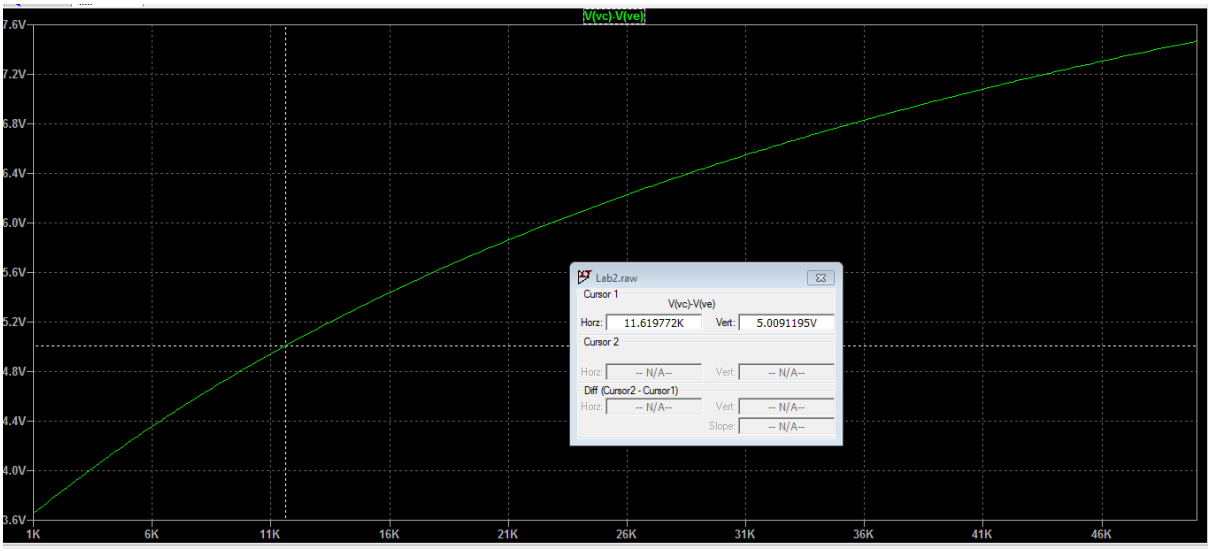




The value of R3 = 16.240304KOhms
So, the value of total resistance in upper arm = 10K + 16.240304K = 26.24K

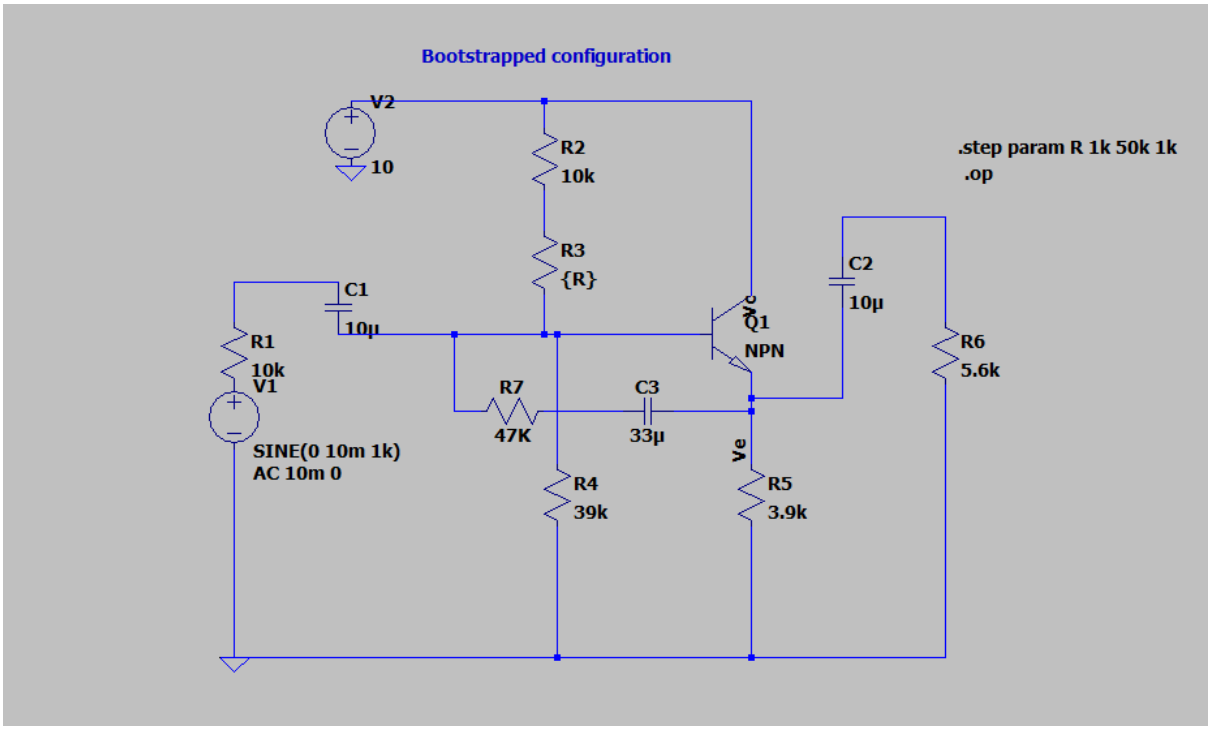
B. **Darlington Pair** :

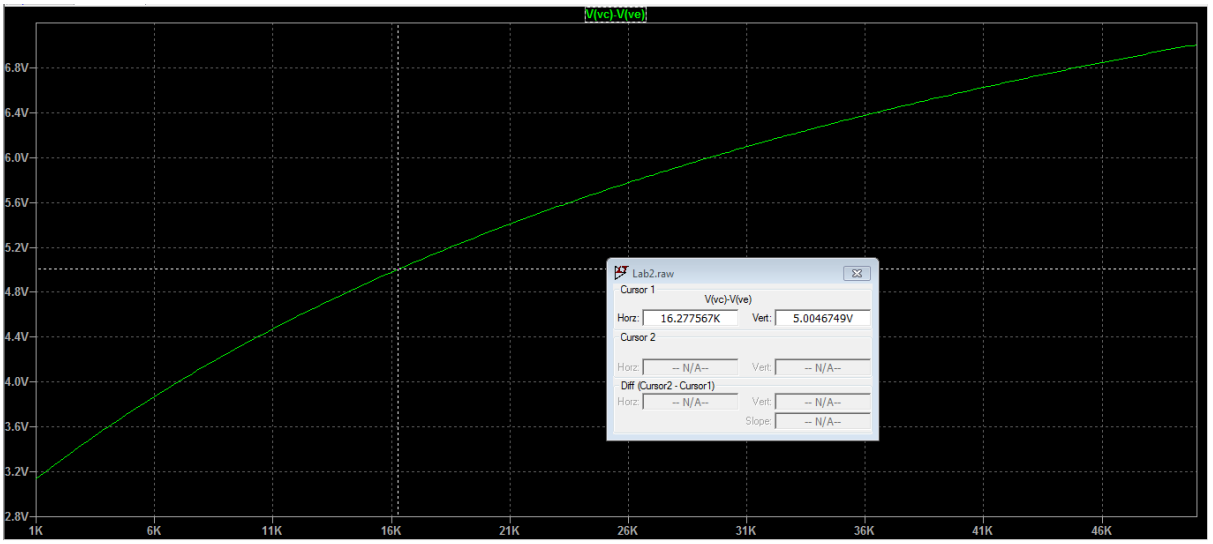




Here the value of R3 is 11.545247K
So, total resistance in upper arm is 21.545247K

C. **Bootstrapped configuration :**





Value of R3 = 16.277567K
So, total resistance in upper arm = 26.28 KOhms

4. Rin and Gain Calculation

For this, I used AC analysis at 1k Frequency

A. For Common Collector Configuration

```
      --- AC Analysis ---

frequency:     1000          Hz
V(vc):         mag:          0 phase:           0°          voltage
V(n002):       mag: 0.00598993 phase:   0.0348732°          voltage
V(ve):         mag: 0.00593708 phase:   0.0342834°          voltage
V(vi):         mag: 0.00598993 phase: -0.0261749°          voltage
V(n001):       mag:       0.01 phase:           0°          voltage
V(vout):       mag: 0.00593706 phase:    0.197121°          voltage
Ic(Q1):        mag: 2.55695e-006 phase:    0.101132°        device_current
Ib(Q1):        mag: 2.55695e-008 phase:    0.101132°        device_current
Ie(Q1):        mag: 2.58252e-006 phase:    -179.899°        device_current
I(Cc1):        mag: 1.06019e-006 phase:    -179.803°        device_current
I(C1):         mag: 4.01007e-007 phase:    -179.961°        device_current
I(Rl):         mag: 1.06019e-006 phase:    0.197121°        device_current
I(Re1):        mag: 1.52233e-006 phase:   0.0342834°        device_current
I(R3):         mag: 4.01007e-007 phase:    -179.961°        device_current
I(R2):         mag: 1.53588e-007 phase:   0.0348732°        device_current
I(R1):         mag: 2.21849e-007 phase:    -179.965°        device_current
I(Vs1):        mag: 4.01007e-007 phase:    -179.961°        device_current
I(Vcc1):       mag: 2.3351e-006 phase:    -179.893°        device_current
```

Av = 0.00593/0.00598 = 0.991
Rin = 0.00598/0.4uA = 14.95kohms

B. Darlington Pair

```
      --- AC Analysis ---

frequency:     1000          Hz
V(vc):         mag:          0 phase:          0°          voltage
V(n002):       mag:  0.0062586 phase:  0.0341002°          voltage
V(n003):       mag: 0.00620457 phase:  0.0335281°          voltage
V(vi):         mag: 0.00625861 phase: -0.0204126°          voltage
V(n001):       mag:       0.01 phase:          0°          voltage
V(ve):         mag: 0.00615054 phase:   0.032946°          voltage
V(vout):       mag: 0.00615052 phase:   0.195783°          voltage
Ic(Q2):        mag: 2.64888e-006 phase:  0.0997948°        device_current
Ib(Q2):        mag: 2.64888e-008 phase:  0.0997948°        device_current
Ie(Q2):        mag: 2.67537e-006 phase:     -179.9°        device_current
Ic(Q1):        mag: 2.62265e-008 phase:  0.0997948°        device_current
Ib(Q1):        mag: 2.62271e-010 phase:  0.0997932°        device_current
Ie(Q1):        mag: 2.64888e-008 phase:     -179.9°        device_current
I(Cc1):        mag: 1.09831e-006 phase:   -179.804°        device_current
I(C1):         mag: 3.7414e-007 phase:   -179.966°         device_current
I(Rl):         mag: 1.09831e-006 phase:   0.195783°        device_current
I(Re1):        mag: 1.57706e-006 phase:   0.032946°        device_current
I(R3):         mag: 3.7414e-007 phase:   -179.966°         device_current
I(R2):         mag: 1.33162e-007 phase:  0.0341002°        device_current
I(R1):         mag: 2.40715e-007 phase:   -179.966°        device_current
I(Vs1):        mag: 3.7414e-007 phase:   -179.966°         device_current
I(Vcc1):       mag: 2.43439e-006 phase:   -179.894°        device_current
```

Av = 0.00615052/0.00625861 = 0.9827
Rin = 0.00625861/0.3741uA = 16.7kohms

C. Bootstrapped mode

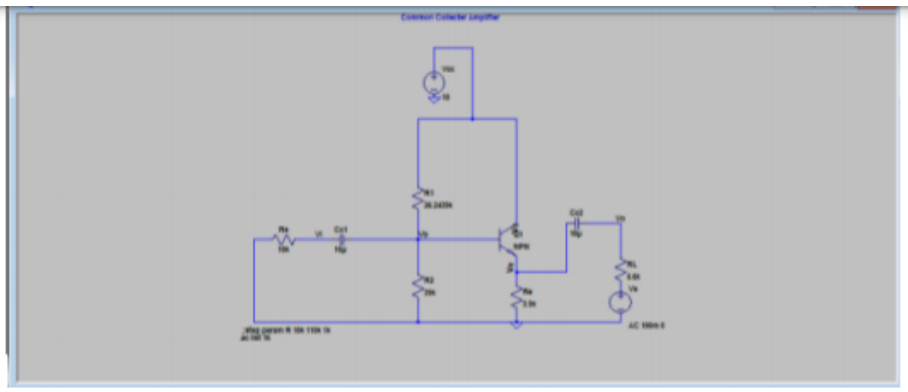
```
      --- AC Analysis ---

frequency:     1000          Hz
V(vc):         mag:          0 phase:          0°          voltage
V(n002):       mag: 0.00598327 phase:  0.0348556°          voltage
V(ve):         mag: 0.00593051 phase:  0.0342661°          voltage
V(vi):         mag: 0.00598328 phase: -0.0263619°          voltage
V(n001):       mag:       0.01 phase:          0°          voltage
V(vout):       mag: 0.00593048 phase:   0.197103°          voltage
V(n003):       mag: 0.00593051 phase:  0.0342138°          voltage
Ic(Q1):        mag: 2.553e-006 phase:   0.101112°          device_current
Ib(Q1):        mag: 2.553e-008 phase:   0.101112°          device_current
Ie(Q1):        mag: 2.57853e-006 phase:   -179.899°        device_current
I(C3):         mag: 1.12268e-009 phase:   -179.893°        device_current
I(Cc1):        mag: 1.05901e-006 phase:   -179.803°        device_current
I(C1):         mag: 4.01673e-007 phase:   -179.961°        device_current
I(R4):         mag: 1.12268e-009 phase:   0.106992°        device_current
I(Rl):         mag: 1.05901e-006 phase:   0.197103°        device_current
I(Re1):        mag: 1.52064e-006 phase:  0.0342661°        device_current
I(R3):         mag: 4.01673e-007 phase:   -179.961°        device_current
I(R2):         mag: 1.53417e-007 phase:  0.0348556°        device_current
I(R1):         mag: 2.21603e-007 phase:   -179.965°        device_current
I(Vs1):        mag: 4.01673e-007 phase:   -179.961°        device_current
I(Vcc1):       mag: 2.3314e-006 phase:   -179.893°         device_current
```

Av = 0.00593048/0.00598328 = 0.9911
Rin = 0.00598328/0.40167uA = 14.76kohms

5. Rout Calculations

a. For Common Collector Configuration



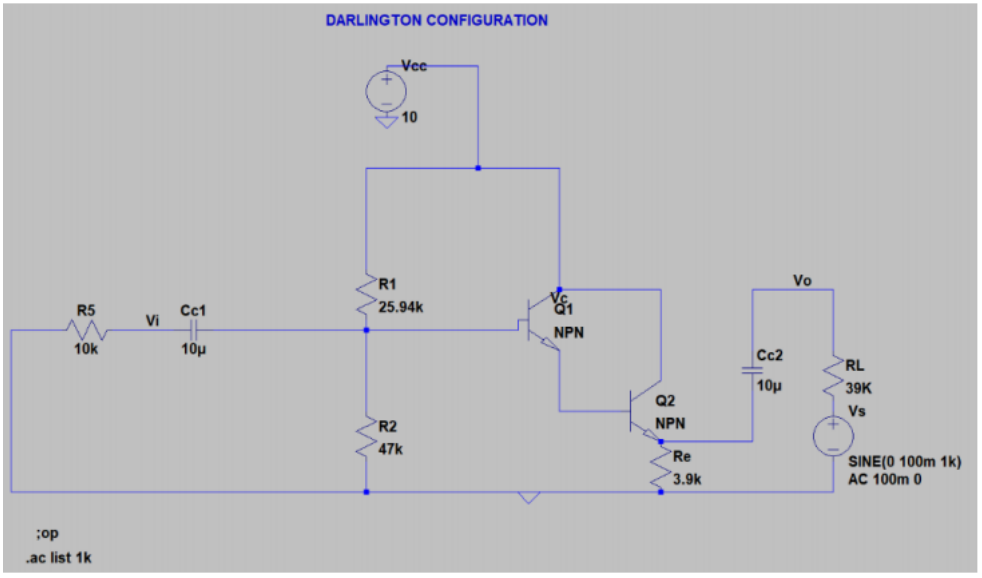
D:\LTSpice\examples\lb2 cc.asc

```
      --- AC Analysis ---

frequency:     1000          Hz
V(vc):         mag:          0 phase:          0°          voltage
V(vb):         mag: 0.00104315 phase:   0.106297°          voltage
V(ve):         mag: 0.00139133 phase:   0.120233°          voltage
V(vo):         mag: 0.00141947 phase:   -11.2666°          voltage
V(n001):       mag:        0.1 phase:          0°          voltage
V(vi):         mag: 0.00104315 phase:   0.197486°          voltage
Ic(Q1):        mag: 1.70811e-005 phase:   -179.838°        device_current
Ib(Q1):        mag: 1.70811e-007 phase:   -179.838°        device_current
Ie(Q1):        mag: 1.72519e-005 phase:   0.161987°        device_current
I(Cc2):        mag: 1.76086e-005 phase:   -179.839°        device_current
I(Cc1):        mag: 1.04315e-007 phase:   -179.803°        device_current
I(Rs):         mag: 1.04315e-007 phase:   0.197486°        device_current
I(Rl):         mag: 1.76086e-005 phase:   -179.839°        device_current
I(Re):         mag: 3.56752e-007 phase:   0.120233°        device_current
I(R2):         mag: 2.67474e-008 phase:   0.106297°        device_current
I(R1):         mag: 3.97483e-008 phase:   -179.894°        device_current
I(Vs):         mag: 1.76086e-005 phase:   -179.839°        device_current
I(Vcc):        mag: 1.71208e-005 phase:   0.161857°        device_current
```

Rout=80.612Ω

b. Darlington Pair



```
--- AC Analysis ---

frequency:     1000          Hz
V(vc):         mag:          0 phase:          0°          voltage
V(n001):       mag: 1.55473e-006 phase: -0.0336875°        voltage
V(n004):       mag: 0.00010383 phase:   0.022513°          voltage
V(vo):         mag: 0.000111547 phase:   -21.4137°         voltage
V(n003):       mag:        0.1 phase:          0°          voltage
V(vi):         mag: 1.55472e-006 phase:  0.0575015°        voltage
V(n002):       mag: 5.26926e-005 phase:  0.0216839°        voltage
Ic(Q1):        mag: 2.48487e-008 phase:   -179.977°        device_current
Ib(Q1):        mag: 2.48487e-010 phase:   -179.977°        device_current
Ie(Q1):        mag: 2.50972e-008 phase:  0.0233673°        device_current
Ic(Q2):        mag: 2.50972e-006 phase:   -179.977°        device_current
Ib(Q2):        mag: 2.50972e-008 phase:   -179.977°        device_current
Ie(Q2):        mag: 2.53482e-006 phase:  0.0233673°        device_current
I(Cc2):        mag: 2.56144e-006 phase:  0.0233584°        device_current
I(Cc1):        mag: 1.55472e-010 phase:  0.0575015°        device_current
I(R5):         mag: 1.55472e-010 phase:  0.0575015°        device_current
I(Rl):         mag: 2.56144e-006 phase:   -179.977°        device_current
I(Re):         mag: 2.66232e-008 phase:   0.022513°        device_current
I(R2):         mag: 3.30793e-011 phase: -0.0336875°        device_current
I(R1):         mag: 5.99355e-011 phase:    179.966°        device_current
I(Vs):         mag: 2.56144e-006 phase:   -179.977°        device_current
I(Vcc):        mag: 2.53463e-006 phase:  0.0233659°        device_current
```

Rout= 45.08Ω

c. Bootstrapped mode

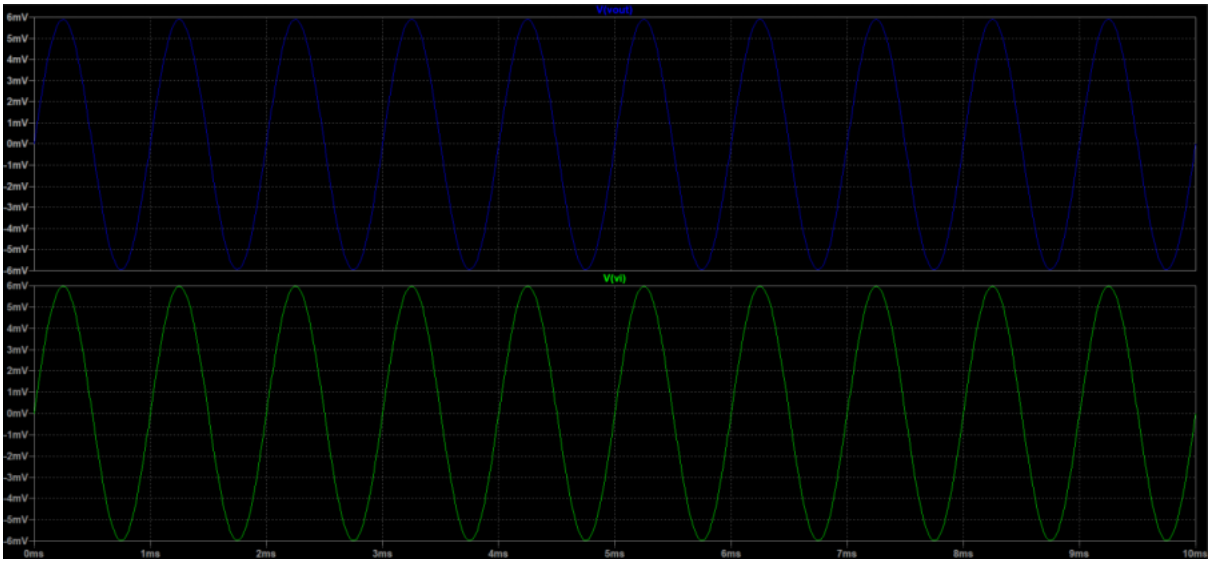
```
--- AC Analysis ---

frequency:     1000          Hz
V(n003):       mag:          0.1 phase:          0°          voltage
V(vi):         mag:  0.0010878 phase:   0.197659°          voltage
V(n001):       mag:  0.0010878 phase:    0.10647°          voltage
V(p001):       mag: 0.000412828 phase:    0.10647°         voltage
V(vc):         mag:           0 phase:          0°          voltage
V(ve):         mag: 0.00143612 phase:    0.11993°          voltage
V(vo):         mag: 0.00146338 phase:   -10.9158°          voltage
V(n002):       mag: 0.00143612 phase:   0.121356°          voltage
Ic(Q1):        mag: 1.70544e-005 phase:   -179.838°        device_current
Ib(Q1):        mag: 1.70544e-007 phase:   -179.838°        device_current
Ie(Q1):        mag: 1.7225e-005 phase:   0.161967°         device_current
I(C2):         mag: 7.41101e-009 phase:   0.167846°        device_current
I(Cc):         mag: 1.76006e-005 phase:    0.16109°        device_current
I(C):          mag: 1.0878e-007 phase:   0.197659°         device_current
I(R4):         mag: 7.41101e-009 phase:   0.167846°        device_current
I(Re):         mag: 3.68236e-007 phase:    0.11993°        device_current
I(R3):         mag: 4.12828e-008 phase:   -179.894°        device_current
I(Rl):         mag: 1.76006e-005 phase:   -179.839°        device_current
I(R1):         mag: 4.12828e-008 phase:   -179.894°        device_current
I(R2):         mag: 2.78924e-008 phase:    0.10647°        device_current
I(Rs):         mag: 1.0878e-007 phase:   0.197659°         device_current
I(Vcc):        mag: 1.70957e-005 phase:   0.161833°        device_current
I(Vs):         mag: 1.76006e-005 phase:   -179.839°        device_current
```

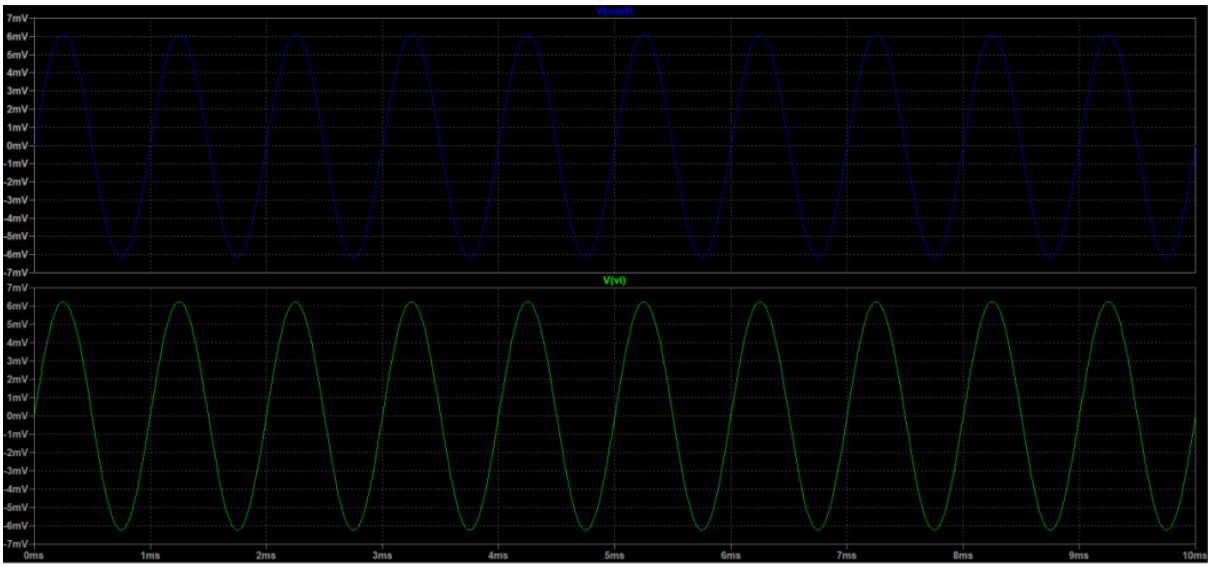
Rout = V(vout)/I(Vs) = 83.143 Ω

6. Input and Output Waveforms

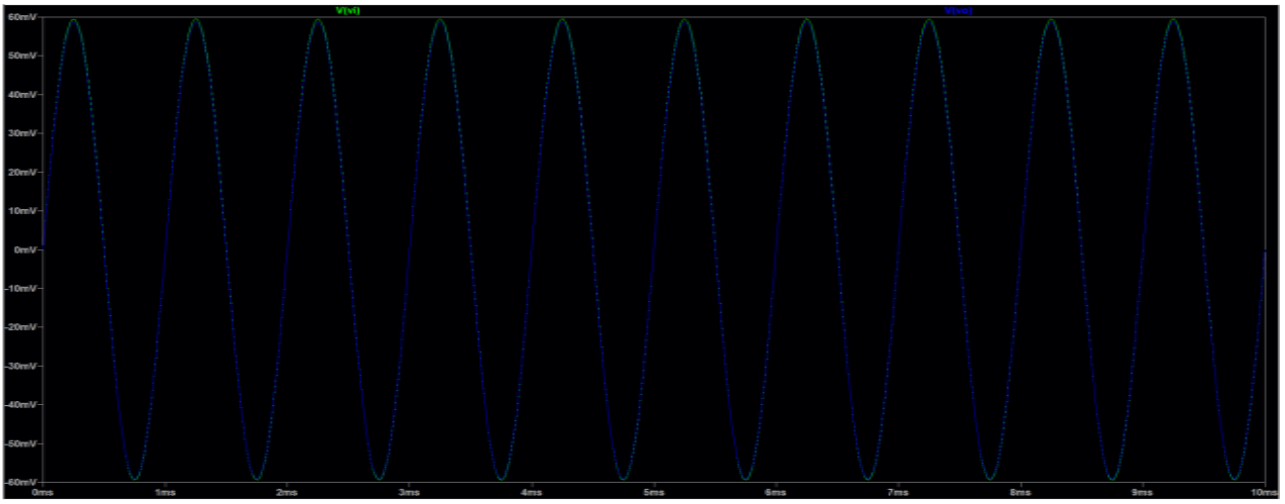
a. For Common Collector Configuration



b. Darlington Pair



c. Bootstrapped mode



7. LTSpice Net lists

A. common collector configuration

```
* E:\BITS Pilani\3-2\AnE\Labs\Lab2.asc

V1 P001 0 SINE(0 10m 1k) AC 10m 0

V2 Vc 0 10

R1 N003 P001 10k

R2 Vc N002 10k

R3 N002 N004 {R}

R4 N004 0 39k

R5 Ve 0 3.9k

R6 N001 0 5.6k

C1 N003 N004 10µ

C2 N001 Ve 10µ

Q1 Vc N004 Ve 0 NPN

.model NPN NPN

.model PNP PNP

.lib C:\Users\Jash Shah\Documents\LTspiceXVII\lib\cmp\standard.bjt

.step param R 1k 50k 1k

.op

* Common Collector amplifier Schematic

.backanno

.end
```

B. Darlington Pair

```
* E:\BITS Pilani\3-2\AnE\Labs\Lab2.asc

V1 P001 0 SINE(0 10m 1k) AC 10m 0

V2 Vc 0 10

R1 N003 P001 10k

R2 Vc N002 10k

R3 N002 N004 {R}

R4 N004 0 39k

R5 Ve 0 3.9k

R6 N001 0 5.6k

C1 N003 N004 10µ

C2 N001 Ve 10µ

Q1 Vc N005 Ve 0 NPN

Q2 Vc N004 N005 0 NPN

.model NPN NPN

.model PNP PNP

.lib C:\Users\Jash Shah\Documents\LTspiceXVII\lib\cmp\standard.bjt

.step param R 1k 50k 1k

.op

* Darlington mode

.backanno

.end
```

C. Bootstrapped emitter follower

```
* E:\BITS Pilani\3-2\AnE\Labs\Lab2.asc

V1 P001 0 SINE(0 10m 1k) AC 10m 0

V2 Vc 0 10

R1 N003 P001 10k
```

R2 Vc N002 10k

R3 N002 N004 {R}

R4 N004 0 39k

R5 Ve 0 3.9k

R6 N001 0 5.6k

C1 N003 N004 10µ

C2 N001 Ve 10µ

Q1 Vc N004 Ve 0 NPN

R7 N005 N004 47K

C3 Ve N005 33µ

.model NPN NPN

.model PNP PNP

.lib C:\Users\Jash Shah\Documents\LTspiceXVII\lib\cmp\standard.bjt

.step param R 1k 50k 1k

.op

* Bootstrapped configuration

.backanno

.end