

Department of Electronics & Telecommunication Engineering

University of Moratuwa

Course: B.Sc. (Eng.), Semester 04	
Subject: Electronics III	Subject code: EN2110
Simulation Assignment: Power Amplifiers	
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Group: 37	Date of Submission: June 25, 2021

Objectives: To study the behavior of standard types of power amplifiers using simulations.

Software: LTSpice

Note: You may modify the word document accordingly to insert the figures of simulation outputs.

Use the following SPICE directives for the transistor models, BC639 and BC640. These parameters are extracted from: <http://itwiki.org/index.php?title=Standard.bjt>.

BC639

```
.MODEL BC639 NPN IS=6.119E-14 NF=0.9948 ISE=5.844f NE=1.469 BF=130.4 IKF=0.8 VAF=54.27
NR=0.9905 ISC=1.342E-13 NC=1.183 BR=14.53 IKR=0.2049 VAR=30 RB=0.5 IRB=1E-06 RBM=0.5
RE=0.1114 RC=0.082 XTB=0 EG=1.11 XTI=3 CJE=1.234E-10 VJE=0.6917 MJE=0.338 TF=6.543E-10
XTF=223.8 VTF=1.892 ITF=10 CJC=3.49E-11 VJC=0.5 MJC=0.388 XCJC=0.15 TR=10n FC=0.9232
```

BC640

```
.MODEL BC640 PNP IS=6.1530E-14 NF=0.9911 ISE=1.382E-16 NE=1.089 BF=150.8 IKF=1.225
VAF=105.4 NR=0.9965 ISC=6.480f NC=1.022 BR=8.074 IKR=0.3627 VAR=18.20 RB=2 IRB=1E-06
RBM=2 RE=5.562E-02 RC=0.1449 XTB=0 EG=1.11 XTI=3 CJE=1.157E-10 VJE=0.7300 MJE=0.3751
TF=8.666E-10 XTF=1.231 VTF=3.008 ITF=0.4581 CJC=5.264E-11 VJC=0.6591 MJC=0.4533
XCJC=0.4401 TR=2.75E-07 FC=0.9427
```

PROCEDURE:

Simulation 1: Class 'A' Amplifier

a) Connect the circuit as shown in figure 1 and paste your circuit diagram.

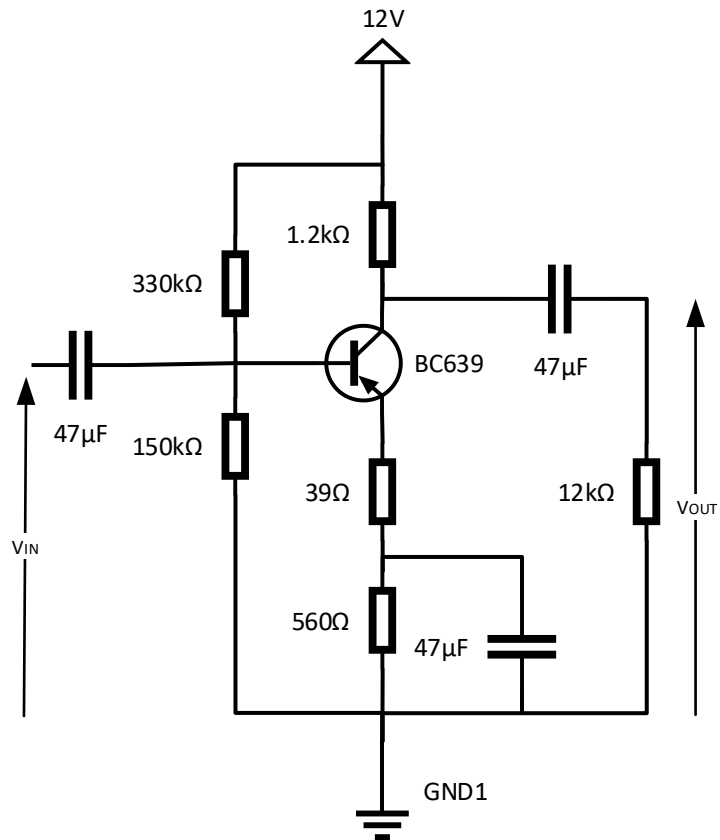
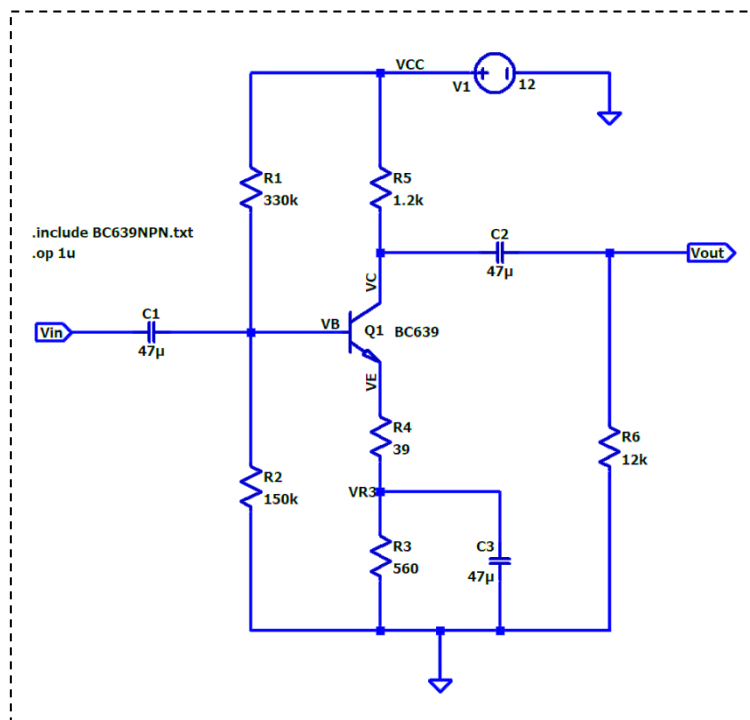


Figure1



b) Using the operating point simulations, obtain the DC bias voltages.

$$V_B = 2.05190 \text{ V}$$

$$V_E = 1.42698 \text{ V}$$

$$V_C = 9.16103 \text{ V}$$

c) Paste a screen capture of operating point simulation output window.

```
|          --- Operating Point ---
V(vcc) :          12          voltage
V(vb) :          2.0519      voltage
V(vr3) :          1.33408    voltage
V(ve) :          1.42698    voltage
V(vc) :          9.16103    voltage
V(vin) :          9.64348e-005 voltage
V(vout) :          5.16682e-012 voltage
Ic(Q1) :          0.00236581  device_current
Ib(Q1) :          1.64664e-005 device_current
Ie(Q1) :          -0.00238228 device_current
I(C3) :          -6.27016e-017 device_current
I(C2) :          -4.30568e-016 device_current
I(C1) :          9.64348e-017  device_current
I(R6) :          4.30568e-016  device_current
I(R5) :          0.00236581    device_current
I(R4) :          0.00238228    device_current
I(R3) :          0.00238228    device_current
I(R2) :          1.36793e-005  device_current
I(R1) :          3.01458e-005  device_current
I(V1) :          -0.00239596  device_current
```

d) Using the “signal” block, adjust the input signal at 10 kHz to the maximum output possible without clipping or distortion. Use probe options to measure and note down the maximum input & output values.

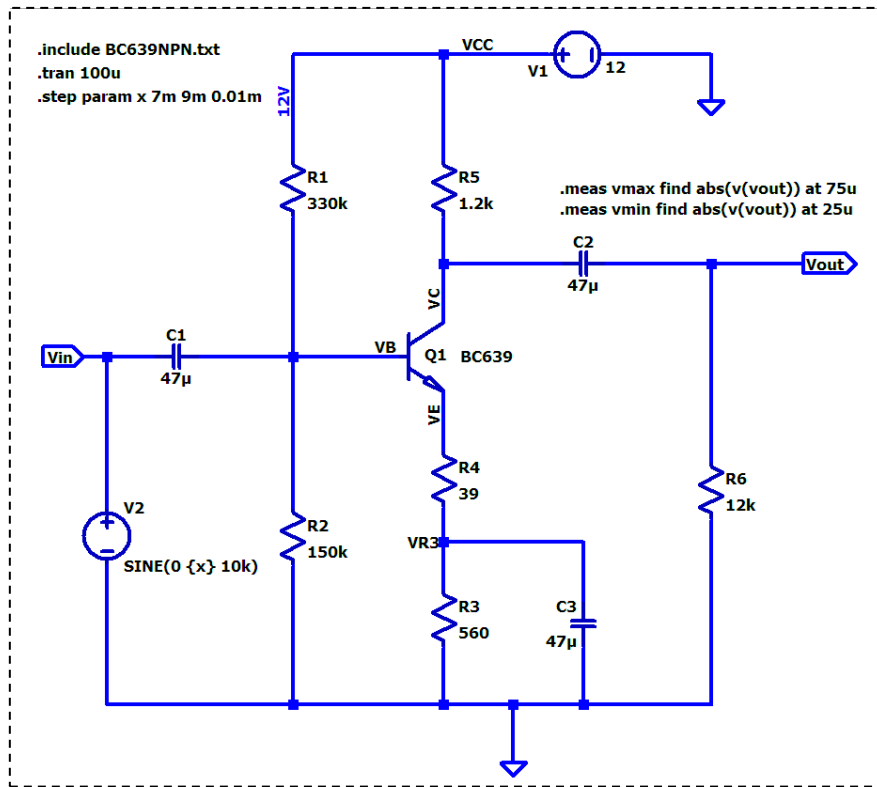
*In class A amplifiers output signal is just an amplified replica of the input signal. Therefore, both the positive and negative half cycles of the input signal **must be amplified in the same factor**. Below values were chosen according to that.*

$$V_I (\text{max}) = 8 \text{ mV}$$

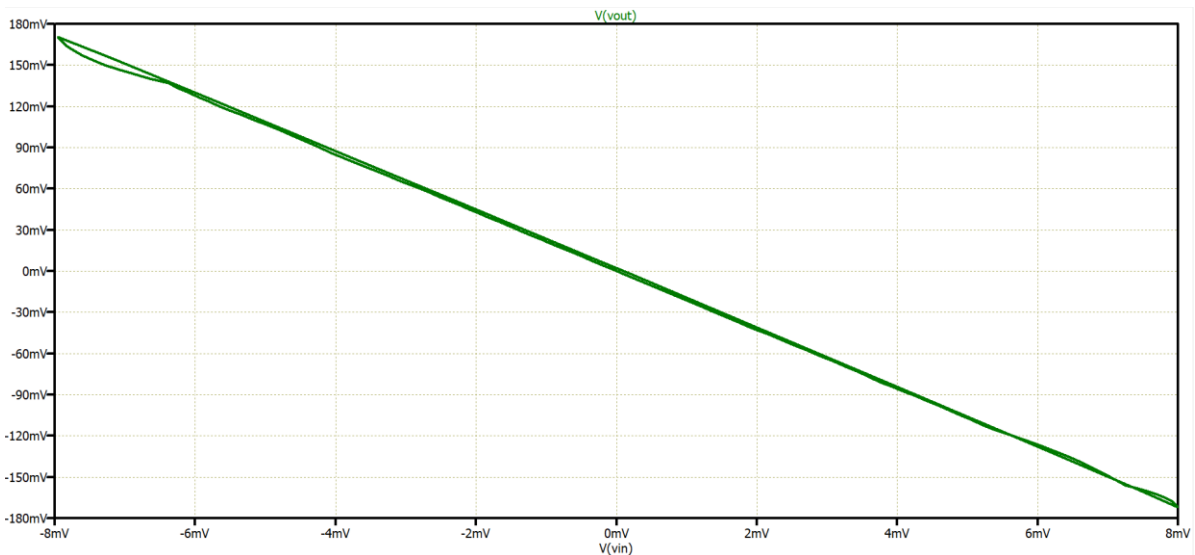
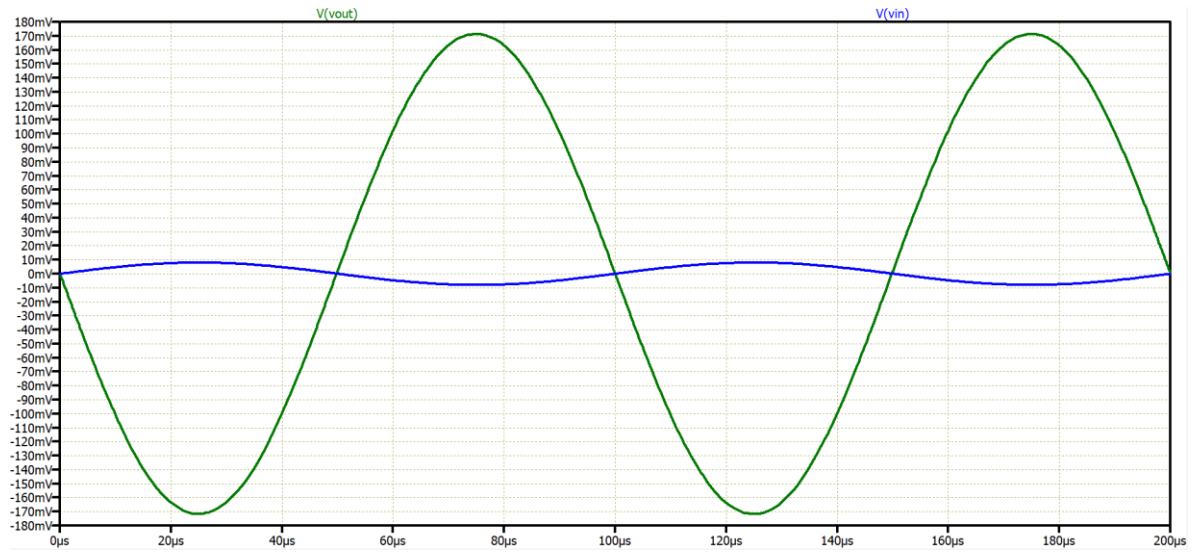
$$V_O (\text{max}) = 171.474 \pm 0.001 \text{ mV}$$

Values were found using the following simulation which measures the maximum and minimum of output signal over a period. It was observed that input signal is amplified in the same factor when the input signal's amplitude is near 8 mV. The corresponding output signal has an amplitude of $171.474 \pm 0.001 \text{ mV}$ in both the positive and negative half cycles of the input signal. When the input signal level exceeds this level (8 mV), positive half cycle of the input signal is amplified more than the negative half cycle of the input signal and therefore it was considered as a distortion.

Maximum and minimum output values for different input signals : [Power-Amplifier/Part-d.xlsx at main · bimalka98/Power-Amplifier \(github.com\)](#).



e) Paste the simulation output waveforms in both Y-T and X-Y modes



f) Calculate the efficiency of the amplifier at this input level.

$$\eta = \frac{AC \text{ Power at the load } (P_{out})}{Total \text{ Input Power } (P_{total})} = \frac{P_{L,AC}}{P_{total}}$$

$$\eta = \frac{V_p^2}{2 \cdot R_L} \div [V_{CC} \cdot (I_{R_1} + I_{R_5})]$$

$$\eta = \frac{V_p^2}{2 \cdot R_L \cdot V_{CC} \cdot (I_{R_1} + I_{R_5})}$$

$$\eta = \frac{(171.474 \text{ mV})^2}{2 \times 12k\Omega \times 12V \cdot (3.01458e - 005 + 0.00236581)}$$

In this expression $I_{R_1} \approx 0$ and therefore it can be neglected.

$$\therefore \eta = 4.315 \times 10^{-5}$$

g) Reduce the input signal to the half of the signal level of step(c). Measure and note down the voltage values.

When $V_{in} = 4 \text{ mV}$, then $V_{out} = 85.7483 \text{ mV}$ (Average of positive peak value and negative peak value)

Positive peak value : 85.9236 mV

Negative peak value : -85.5730 mV

h) Calculate the efficiency of the amplifier at this input signal level.

Same as before, in this expression $I_{R_1} \approx 0$ and therefore it can be neglected.

$$\eta = \frac{(85.7483\text{mV})^2}{2 \times 12k\Omega \times 12V \cdot (3.01458e - 005 + 0.00236581)}$$

$$\therefore \eta = 1.079 \times 10^{-5}$$

Simulation 2: Class 'B' Amplifier

Class 'B' push-pull amplifier with two symmetric power supplies. (Complementary symmetry)

- a) Connect the push-pull (complementary symmetry) class 'B' power amplifier shown in figure 2. Paste your circuit diagram.

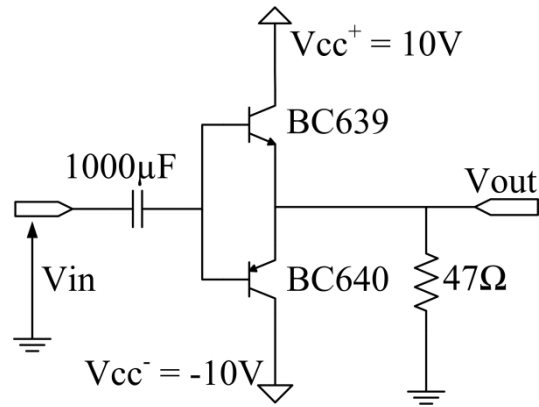
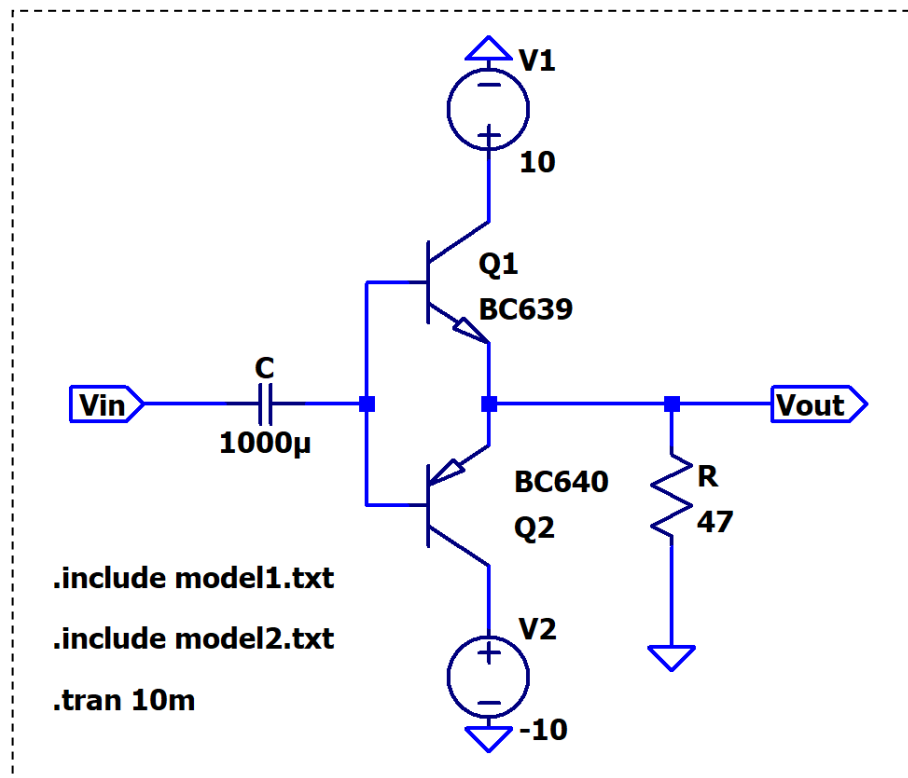


Figure 2



- b) Increase the input voltage to the clipping limit & measure the maximum input and output values

$$V_I(\max) = 10.69\text{V}$$

$$V_O(\max) = 9.9214431\text{V}$$

c) Calculate the efficiency of the amplifier.

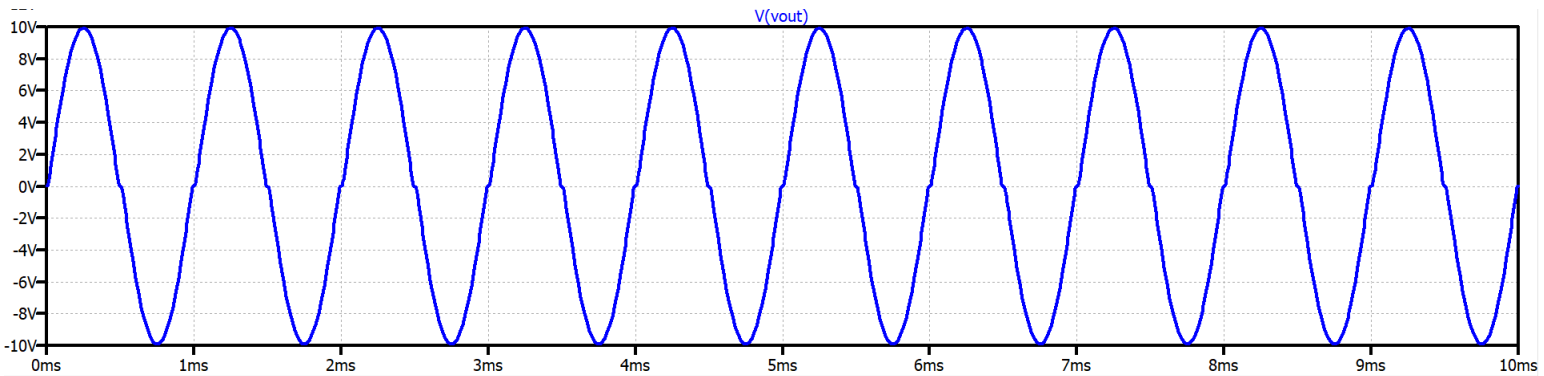
$$\text{Input Power}(P_{IN}) = \frac{2 \times V_{CC} \times V_{m(out)}}{\pi \times R_L} = \frac{2 \times 10 \times 9.9214431}{\pi \times 47} = 1.343869542 \text{ W}$$

$$\text{Power at the load}(P_L) = \frac{(V_{m(out)})^2}{2 \times R_L} = \frac{9.9214431^2}{2 \times 47} = 1.047181204 \text{ W}$$

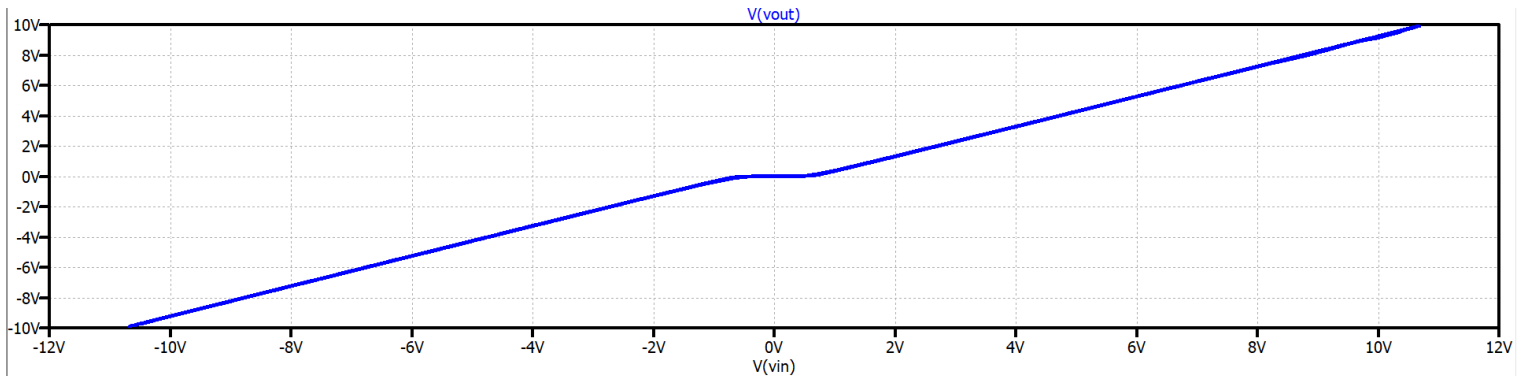
$$\text{Efficiency of the amplifier}(\eta) = \frac{P_L}{P_{IN}} = 0.7792283189 \cong 77.9228 \%$$

d) Observe the cross over distortion at the output, insert Y-T and X-Y mode output plots.

Y-T mode



X-Y mode



e) Comment on your observations in (d).

By looking at the above two figures, we can observe that the amplifier gives 0V as the output for the input range -582.21495mV to 582.21495mV (approximately). So, we can conclude that input voltage has to be larger than the VBE bias voltage to the transistor to turn on and give an output. So, for the input voltages with a magnitude lower than the bias voltage of the BE junction, output has become zero. This effect is known as the cross-over distortion.

Simulation 3: Class ‘AB’ Amplifier

a) Connect the offset complementary amplifier circuit as shown in figure 3. Paste your circuit diagram.

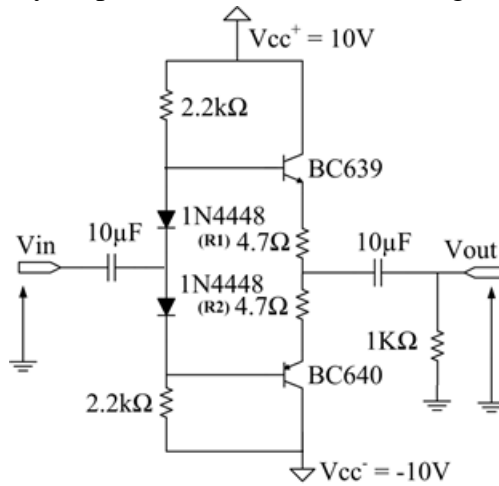
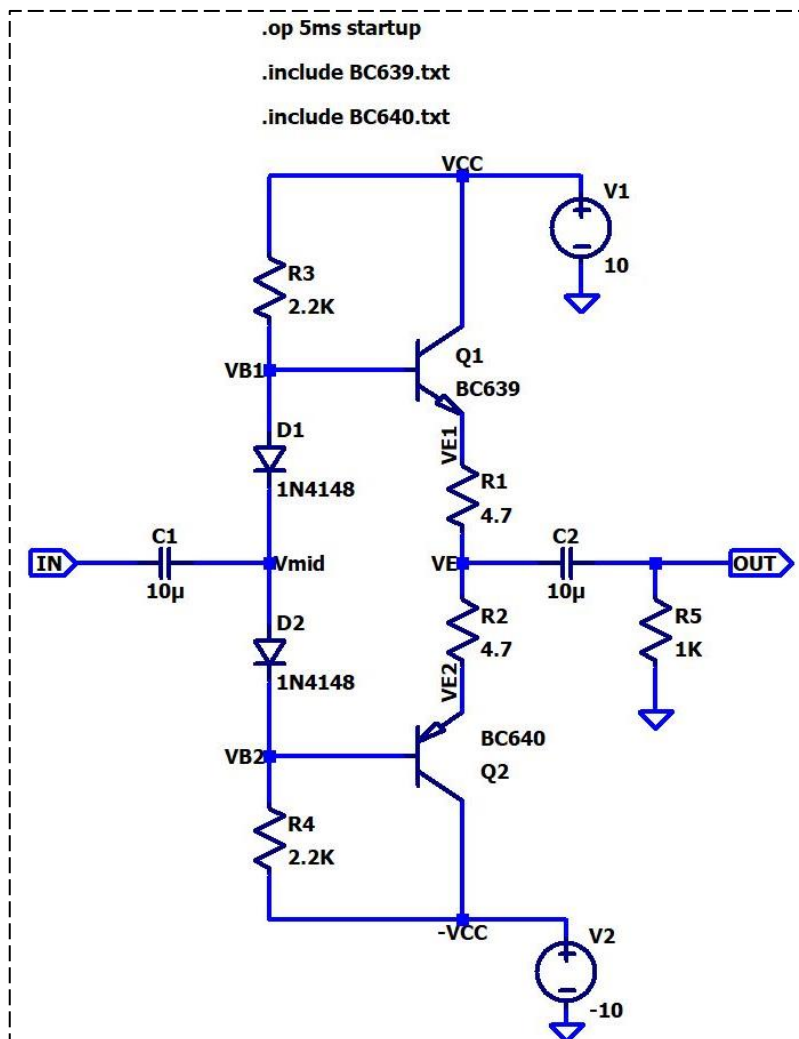


Figure 3



- b) Using the signal block, adjust the 10 kHz input signal to the maximum output possible without clipping. Adjust R_1 and R_2 to remove the cross over distortion occurring at the output. Measure and note down the maximum voltages.

$$V_I(\text{max}) = 9.457\text{V}$$

$$V_O(\text{max}) = 9.1009244\text{V}$$

- c) Calculate the efficiency of the amplifier at this input signal level.

$$\eta = \frac{\text{AC power decipated at the load}}{\text{Power delivered by the DC source}}$$

$$\eta = \frac{P_{L,AC}}{P_{IN}}$$

$$P_{L,AC} = \frac{V_O^2}{2R_L}$$

$$P_{L,AC} = \frac{9.1009244^2}{2 \times 1000}$$

$$P_{L,AC} = 0.0414134\text{W} = 41.4134\text{mW}$$

$$P_{IN} = \frac{2V_{CC}V_O}{\pi R_L}$$

$$P_{IN} = \frac{2 \times 10 \times 9.1009244}{\pi \times 1000}$$

$$P_{IN} = 57.9382\text{mW}$$

$$\eta = \frac{41.4134\text{mW}}{57.9382\text{mW}} = 0.714785 = 71.4785\%$$

- d) Reduce the output to about 60% of the maximum output voltage. Measure and note down the following voltages.

$$V_I = 5.5505\text{V}$$

$$V_O = 5.4605192\text{V}$$

- e) Calculate the efficiency of the amplifier at this input signal level.

$$P_{L,AC} = \frac{5.4605192^2}{2 \times 1000} = 14.9086\text{mW}$$

$$P_{IN} = \frac{2 \times 10 \times 5.4605192}{\pi \times 1000} = 34.7627mW$$
$$\eta = \frac{14.9086mW}{34.7627mW} = 0.428867 = 42.8867\%$$

f) Remove the input signal. Using operating point analysis, measure and note down the DC voltages V_{B1} , V_{B2} and V_E

$$V_{B1} = 651.181mV \quad V_{B2} = -652.569mV$$

$$V_{E1} = 16.1633mV$$

$$V_{E2} = -17.9814mV$$

$$V_E = -0.000909041V$$

Simulation files can be found at [Power-Amplifier/Laboratory Class Equivalent Simulation at main · bimalka98/Power-Amplifier \(github.com\)](https://github.com/bimalka98/Power-Amplifier).