EE 230 Experiment - 3

BJT Voltage Amplifiers (CE and CC)

13th August, 2021

Vinamra Baghel 190010070

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1 Common-Emitter Amplifier

1.1 Biasing Circuit

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Vinamra Baghel 190010070 Common-Emitter Amplifier: Biasing Circuit
.model bc547a NPN IS=10f BF=200 ISE=10.3f IKF=50m NE=1.3 BR=9.5 VAF=80 IKR=12m
   ISC=47p NC=2 VAR=10 RB=280 RE=1 RC=40 tr=0.3u tf=0.5n cje=12p vje=0.48 mje
   =0.5 cjc=6p vjc=0.7 mjc=0.33 kf=2f
*Netlist
r1 cc db 10k
r2 db gnd 2.2k
rc cc dc 1.2k
re e gnd 1k
Q c b e bc547a
vb db b 0
vc dc c 0
Vcc cc gnd 12
*Analysis
.op
.control
run
print i(vb) i(vc) v(b) v(c) v(e)
.endc
.end
```

Analysis

The first step is to apply **Thevenin's Theorem** to the base node of the transistor and ground. We can find the Thevenin equivalent of the voltage and resistors R1 and R2 as follows:

$$V_{Th} = \frac{V_{cc}.R_2}{R_1 + R_2} = 2.164V, \; and \; R_{Th} = \frac{R_1.R_2}{R_1 + R_2} = 1.803k\Omega$$

We then take the base and emitter branches and apply KVL to find $i_b = 7.22\,\mu$A as follows:

$$V_{Th} - i_b.R_{Th} - V_{be} - (\beta + 1).i_b.R_E = 0$$

We finally find the other values: $i_c = \beta.i_b = 1.444$ mA, $V_e = (\beta + 1).i_b.R_E = 1.45$ V, $V_b = V_e + 0.7 = 2.15$ V, and $V_c = V_{cc} - i_c.R_C = 10.26$ V.

Simulation

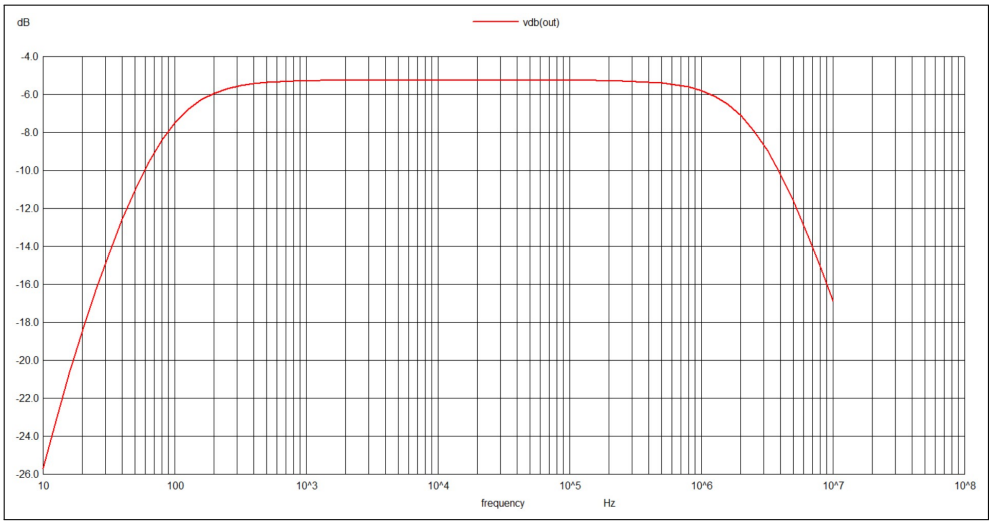
$i_b = 11.25\,\mu$A
$i_c = 1.463$ mA
$V_b = 2.14$ V
$V_c = 10.24$ V
$V_e = 1.47$ V

Learnings:

Biasing circuit DC analysis is important to know the operating voltage and transistor conditions.

1.2 Common-Emitter Amplifier (with bypass Capacitor CE): Midband Voltage Gain

```
Vinamra Baghel 190010070 Common-Emitter Amplifier: Midband Voltage Gain
.model bc547a NPN IS=10f BF=200 ISE=10.3f IKF=50m NE=1.3 BR=9.5 VAF=80 IKR=12m
   ISC=47p NC=2 VAR=10 RB=280 RE=1 RC=40 tr=0.3u tf=0.5n cje=12p vje=0.48 mje
   =0.5 cjc=6p vjc=0.7 mjc=0.33 kf=2f
*Netlist
r1 cc b 10k
r2 b gnd 2.2k
rc cc c 1.2k
re e gnd 1k
rs in in2 0
rl out gnd 100k
ce e gnd 100u
c1 in2 b 10u
c2 c out 10u
Q c b e bc547a
Vcc cc gnd 12
Vin in gnd dc 0 ac 10m
*Analysis
.ac dec 10 10 10Meg
.control
run
print v(out)*100
plot vdb(out)
.endc
.end
```



(a) Decibel plot of V_{out} vs frequency

0	1.000000e+01	2.151897e+00	-4.72095e+00
1	1.258925e+01	2.179284e+00	-6.67629e+00
2	1.584893e+01	1.840397e+00	-9.10569e+00
3	1.995262e+01	9.827154e-01	-1.19977e+01
4	2.511886e+01	-5.73120e-01	-1.53036e+01
5	3.162278e+01	-3.03608e+00	-1.89020e+01
6	3.981072e+01	-6.61294e+00	-2.25482e+01
7	5.011872e+01	-1.14225e+01	-2.58411e+01
8	6.309573e+01	-1.73696e+01	-2.82634e+01
9	7.943282e+01	-2.40545e+01	-2.93367e+01
10	1.000000e+02	-3.08288e+01	-2.88371e+01
11	1.258925e+02	-3.70168e+01	-2.69180e+01
12	1.584893e+02	-4.21578e+01	-2.40275e+01
13	1.995262e+02	-4.61037e+01	-2.06976e+01
14	2.511886e+02	-4.89523e+01	-1.73639e+01
15	3.162278e+02	-5.09191e+01	-1.42975e+01
16	3.981072e+02	-5.22355e+01	-1.16236e+01
17	5.011872e+02	-5.30985e+01	-9.36965e+00
18	6.309573e+02	-5.36566e+01	-7.50997e+00
19	7.943282e+02	-5.40142e+01	-5.99614e+00
20	1.000000e+03	-5.42421e+01	-4.77398e+00
21	1.258925e+03	-5.43868e+01	-3.79203e+00
22	1.584893e+03	-5.44785e+01	-3.00494e+00
23	1.995262e+03	-5.45365e+01	-2.37430e+00
24	2.511886e+03	-5.45731e+01	-1.86830e+00
25	3.162278e+03	-5.45962e+01	-1.46090e+00
26	3.981072e+03	-5.46108e+01	-1.13085e+00
27	5.011872e+03	-5.46199e+01	-8.60785e-01
28	6.309573e+03	-5.46256e+01	-6.36451e-01
29	7.943282e+03	-5.46291e+01	-4.45955e-01
30	1.000000e+04	-5.46312e+01	-2.79178e-01
31	1.258925e+04	-5.46322e+01	-1.27256e-01
32	1.584893e+04	-5.46324e+01	1.789384e-02
33	1.995262e+04	-5.46319e+01	1.639955e-01
34	2.511886e+04	-5.46305e+01	3.188227e-01
35	3.162278e+04	-5.46280e+01	4.906100e-01
36	3.981072e+04	-5.46238e+01	6.884860e-01
37	5.011872e+04	-5.46170e+01	9.229500e-01
38	6.309573e+04	-5.46061e+01	1.206412e+00
39	7.943282e+04	-5.45887e+01	1.553814e+00
40	1.000000e+05	-5.45612e+01	1.983355e+00
41	1.258925e+05	-5.45177e+01	2.517307e+00
42	1.584893e+05	-5.44488e+01	3.182904e+00
43	1.995262e+05	-5.43400e+01	4.013214e+00
44	2.511886e+05	-5.41684e+01	5.047748e+00
45	3.162278e+05	-5.38986e+01	6.332339e+00
46	3.981072e+05	-5.34765e+01	7.917314e+00
47	5.011872e+05	-5.28205e+01	9.852224e+00
48	6.309573e+05	-5.18129e+01	1.217421e+01
49	7.943282e+05	-5.02912e+01	1.488612e+01
50	1.000000e+06	-4.80519e+01	1.792107e+01
51	1.258925e+06	-4.48791e+01	2.109675e+01
52	1.584893e+06	-4.06163e+01	2.408010e+01
53	1.995262e+06	-3.52807e+01	2.640712e+01
54	2.511886e+06	-2.91641e+01	2.760375e+01

(b) Gain values

Midband Voltage Gain = **-54.6324**

Learnings:

Common-Emitter Amplifiers have **high gain** but poor R_{in} and R_{out}. Common-Collector Amplifiers have gain only unity but good input and output resistances (high R_{in} and low R_{out}). Using them together gives us optimum resistance and gain values.

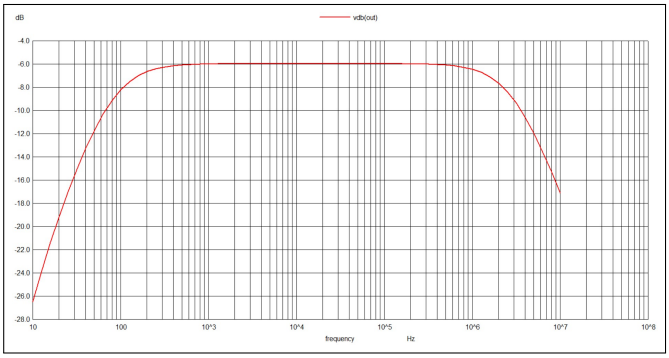
1.3 Common-Emitter Amplifier (with bypass Capacitor CE): Effect of RL on the Mid-band Gain

R_L = 12 kΩ

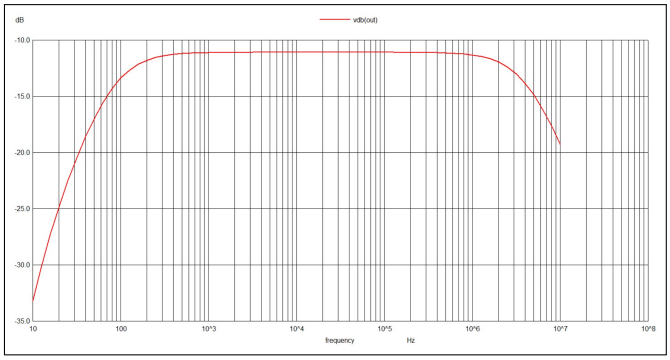
```
rl out gnd 12k
```

R_L = 1.2 kΩ

```
rl out gnd 1.2k
```



(a) Decibel plot of V_{out} vs frequency for R_L = 12 kΩ
Gain = -50.3408



(b) Decibel plot of V_{out} vs frequency for R_L = 1.2 kΩ
Gain = -27.9142

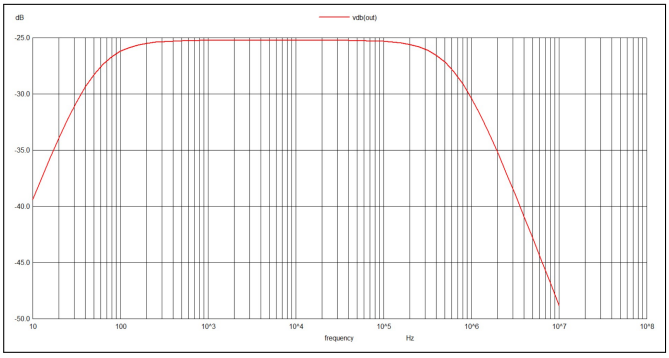
1.4 Common-Emitter Amplifier (with bypass Capacitor CE): Effect of RS on the Mid-band Gain

R_S = 10 kΩ

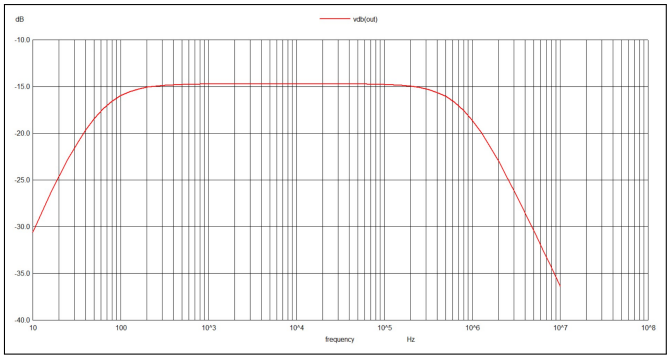
```
rs in in2 10k
```

R_S = 2.2 kΩ

```
rs in in2 2.2k
```



(a) Decibel plot of V_{out} vs frequency for R_S = 10 kΩ
Gain = -5.47875



(b) Decibel plot of V_{out} vs frequency for R_S = 2.2 kΩ
Gain = -18.3715

2 Two-stage Amplifier (CE and CC)

```
Vinamra Baghel 190010070 Two Stage Amplifier: Biasing Circuit
.model bc547a NPN IS=10f BF=200 ISE=10.3f IKF=50m NE=1.3 BR=9.5 VAF=80 IKR=12m
   ISC=47p NC=2 VAR=10 RB=280 RE=1 RC=40 tr=0.3u tf=0.5n cje=12p vje=0.48 mje
   =0.5 cjc=6p vjc=0.7 mjc=0.33 kf=2f
*Netlist
rs in in2 0
r1 cc b1 10k
r2 b1 gnd 2.2k
rc cc c1 1.2k
re1 e1 gnd 1k
re2 de2 gnd 10k
rl out gnd 10k
cap1 in2 b1 10u
cape e1 gnd 100u
cap2 e2 out 10u
Q1 c1 b1 e1 bc547a
Q2 cc b2 e2 bc547a
vb2 c1 b2 0
ve2 e2 de2 0
Vcc cc gnd 12
Vin in gnd dc 0 ac 10m
*Analysis
.ac dec 10 10 10Meg
.control
run
print v(out)*100
plot vdb(out)
.endc
.end
```

2.1 Biasing Circuit - Simulation

$i_{b2} = 8.075\,\mu\text{A}$
$i_{e2} = 957.609\,\mu\text{A}$

2.2 Midband Gain

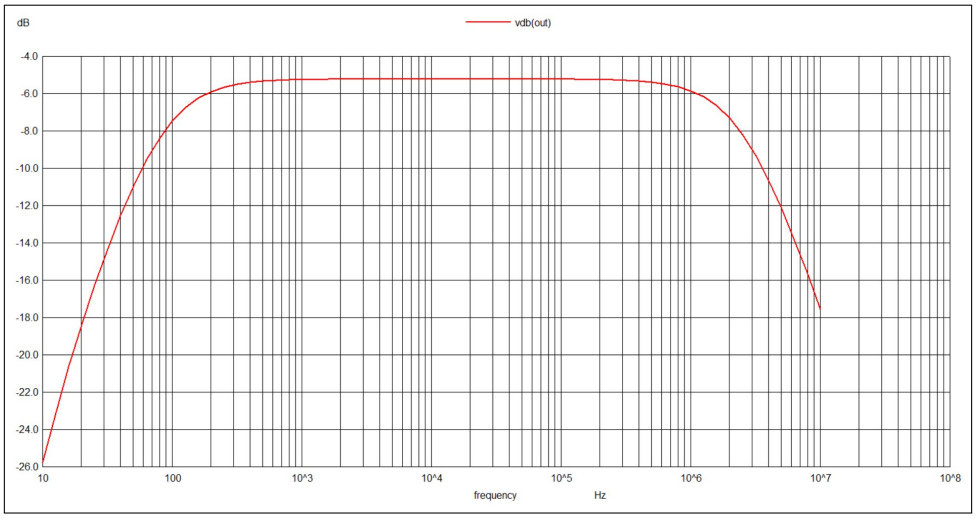


Figure 4: Decibel plot of V_{out} vs frequency

Gain = **-54.8072**

Files associated: https://github.com/VNMR-35/EE-230-Lab