

1. Experiment Purpose & Foreknowledge

Class B/AB power amplifiers operation will be understood and these amplifiers would be compared in terms of their efficiency and distortion.

Generally, the analog circuits have an input and output stage. The output stage should deliver the output signal to the load without loss of gain. The output stage is the final stage of the amplifier and the signal is large in that stage. Therefore, the small signal approximations and models are not appropriate to use. However, the linearity still is an important parameter.

The required amount of power should be delivered to the load **efficiently**. The power dissipated in the output stage transistor must be as low as possible.

If the input signal is delivered to load without distortion, then the equation below can be used,

$$V_o = KV_i$$

The circuit can be accepted as linear from the above equation but the large signal characteristics of the active components in electronic circuits are known as non-linear. Therefore, distortion is observed in the output signal.

In a non-linear operation, when the input signal $V_i = \sin \omega t \rightarrow$ the harmonics of the output signal due to the non-linear characteristic of the amplifier will be given by,

$$V_o = B_o + B_1 \sin \omega t + B_2 \sin 2\omega t + B_3 \sin 3\omega t$$

The output power of the fundamental frequency is given in equation:

$$P_1 = \frac{B_1^2}{2R_L}, \quad R_L : \text{Load resistance}$$

The total power which is delivered to load:

$$P = \frac{1}{2R_L} (B_1^2 + B_2^2 + B_3^2 + \dots)$$

The equation below gives us the relation between the output power in the fundamental frequency and the total power,

$$P = (1 + D^2) P_1$$

D shows the total harmonic distortion and it represents how much the input signal is distorted. "Distortion meter" is used to measure the distortion in the circuit. In distortion meter, a notch

filter is used to eliminate the signal in the fundamental frequency, then the power of the harmonics are summed. However, Fourier analysis in LTSPICE will be exploited for the calculation of total harmonic distortion.

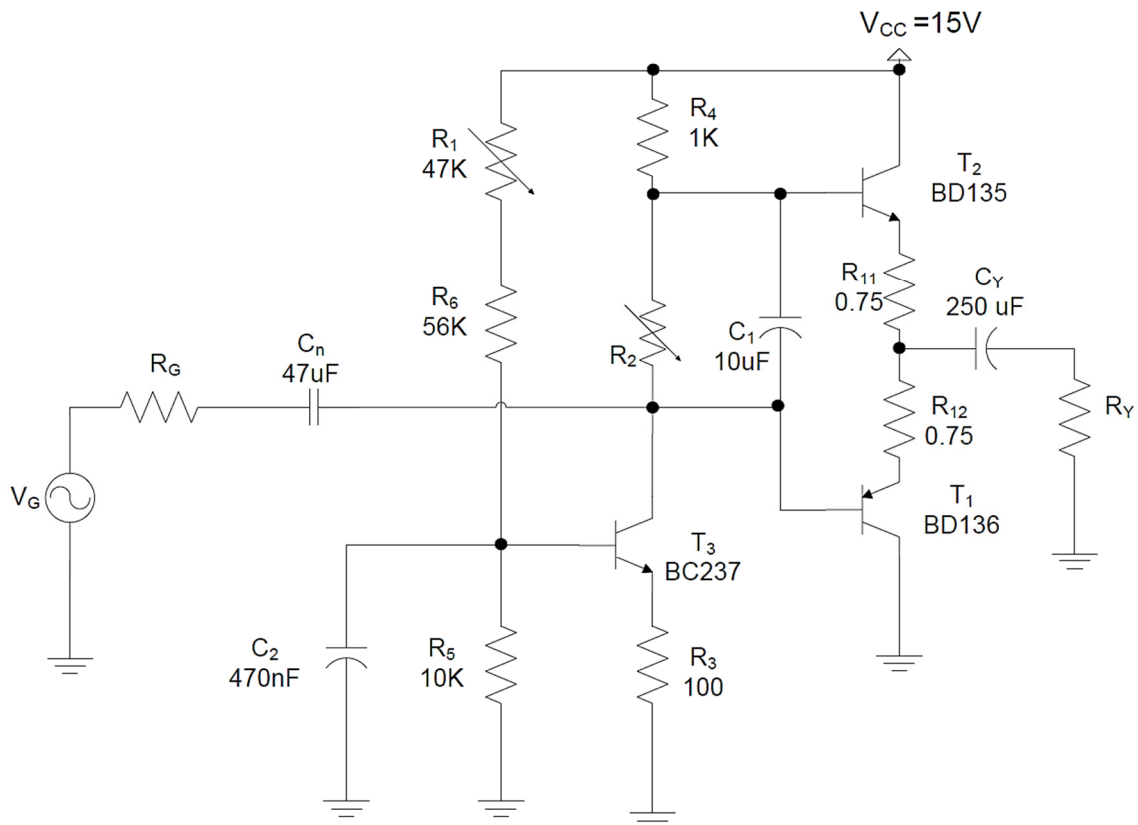
$$D_i = \frac{B_i}{B_1}, \quad D = \sqrt{D_2^2 + D_3^2 + D_4^2 + \dots}$$

Power amplifiers (A, B, AB, C, D, E, F, G, H) are classified according to their biasing point conditions.

In this experiment, only class B and AB operation would be observed. The output stages of these amplifiers are generally consist of a complementary pair of transistors connected in a push-pull configuration.

2. Experiment Setup

The circuit given below will be used to conduct AB and B class operation.

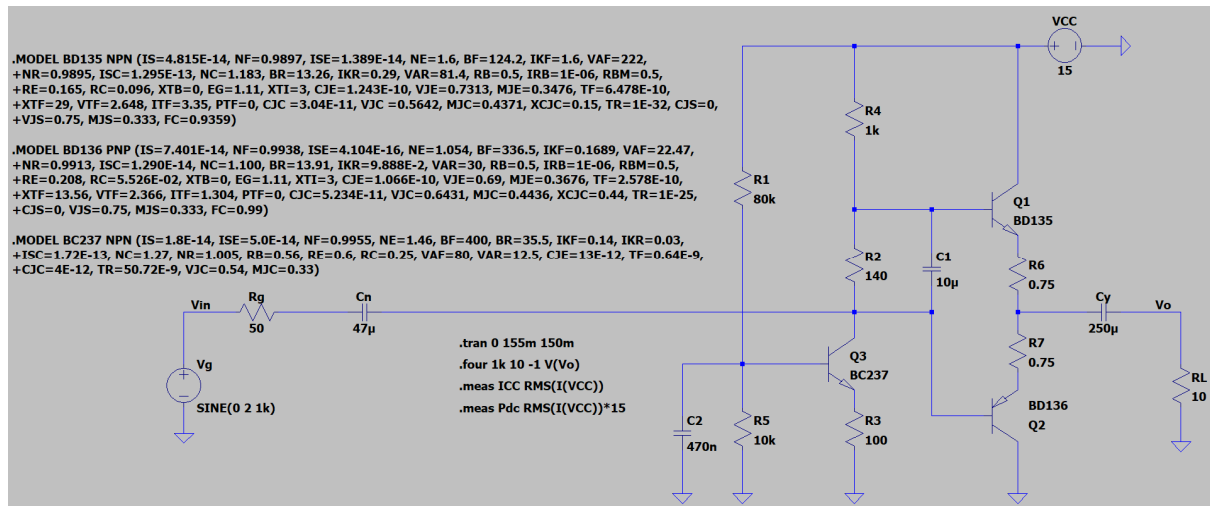


R2 will be adjusted in order to have either both the transistors in conduction or only one of them, and R1 can be used to make minor/precise changes in the operating conditions where the amount of voltage drop/change across R2 can be controlled via its current.

3. Experiment Procedure

- Apply a **1 kHz** sinusoidal input voltage (V_G) for both the B and AB class operations.

Required model descriptions are given at the end of this document.



This circuit has a start-up time of roughly 150 ms mainly due to C_n and C_y .

Check "View -> SPICE Error Log" in order to get the results of THD and supply power consumption calculations.

B Class Operation:

- 1) First adjust R_1 , R_2 and magnitude of the input wave in order to set the magnitude of V_o to desired levels in tables when the load resistance is 10Ω . Try to use the minimum input signal as possible but increase if necessary. R_1 should be between 50k-100k ohms and change its value such that the output signal looks symmetrical. Use R_2 to make sure a cross-over region occurs.
- 2) Do the same for 40Ω load resistance and fill in the table.

AB Class Operation:

- 1) Make sure there is no cross-over happening by adjusting R_2 . Fill the tables for both 10Ω and 40Ω loads.
- 2) Compare the differences between AB and B class operations. Discuss the results.

AB Class with Square Wave Input:

- 1) Apply a pulse wave input as PULSE(0 2 0 100n 100n 0.5m 1m). Compare the theoretically expected THD of a square wave and the measured distortion. Why is there a difference? Did you observe any droop at the output?

4. Experiment Results

$$P_Y = \frac{V_o^2}{2R_L} \quad P_{Supply} = V_{CC} * I_{CC} \quad \eta = \frac{P_Y}{P_{Supply}}$$

Load Resistance: $R_L = 10\Omega$			
V_o (V)	D (%)	I_{CC} (mA)	Efficiency (η)
0.5			
1			
1.5			
2			
2.5			
3			
4			
5			
6			

Load Resistance: $R_L = 40\Omega$			
V_o (V)	D (%)	I_{CC} (mA)	Efficiency (η)
0.5			
1			
1.5			
2			
2.5			
3			
4			
5			
6			

- Results of B Class Operation -

Load Resistance: $R_L = 10\Omega$			
V_o (V)	D (%)	I_{CC} (mA)	Efficiency (η)
0.5			
1			
1.5			
2			
2.5			
3			
4			
5			
6			

Load Resistance: $R_L = 40\Omega$			
V_o (V)	D (%)	I_{CC} (mA)	Efficiency (η)
0.5			
1			
1.5			
2			
2.5			
3			
4			
5			
6			

- Results of AB Class Operation -

Load Resistance: $R_L = 40\Omega$			
V_o (V)	D (%)	I_{CC} (mA)	Efficiency (η)
2.5			

- Results of AB Class Operation for Square Wave Input -

Analog Electronic Circuits Laboratory
Experiment I
Low Frequency Power Amplifiers



Model parameters of BD135: .MODEL BD135 NPN (IS=4.815E-14, NF=0.9897, ISE=1.389E-14, NE=1.6, BF=124.2, IKF=1.6, VAF=222, NR=0.9895, ISC=1.295E-13, NC=1.183, BR=13.26, IKR=0.29, VAR=81.4, RB=0.5, IRB=1E-06, RBM=0.5, RE=0.165, RC=0.096, XTB=0, EG=1.11, XTI=3, CJE=1.243E-10, VJE=0.7313, MJE=0.3476, TF=6.478E-10, XTF=29, VTF=2.648, ITF=3.35, PTF=0, CJC =3.04E-11, VJC =0.5642, MJC=0.4371, XCJC=0.15, TR=1E-32, CJS=0, VJS=0.75, MJS=0.333, FC=0.9359)

Model parameters of BD136: .MODEL BD136 PNP (IS=7.401E-14, NF=0.9938, ISE=4.104E-16, NE=1.054, BF=336.5, IKF=0.1689, VAF=22.47, NR=0.9913, ISC=1.290E-14, NC=1.100, BR=13.91, IKR=9.888E-2, VAR=30, RB=0.5, IRB=1E-06, RBM=0.5, RE=0.208, RC=5.526E-02, XTB=0, EG=1.11, XTI=3, CJE=1.066E-10, VJE=0.69, MJE=0.3676, TF=2.578E-10, XTF=13.56, VTF=2.366, ITF=1.304, PTF=0, CJC=5.234E-11, VJC=0.6431, MJC=0.4436, XCJC=0.44, TR=1E-25, CJS=0, VJS=0.75, MJS=0.333, FC=0.99)

Model parameters of BC237: .MODEL BC237 NPN (IS=1.8E-14, ISE=5.0E-14, NF=0.9955, NE=1.46, BF=400, BR=35.5, IKF=0.14, IKR=0.03, ISC=1.72E-13, NC=1.27, NR=1.005, RB=0.56, RE=0.6, RC=0.25, VAF=80, VAR=12.5, CJE=13E-12, TF=0.64E-9, CJC=4E-12, TR=50.72E-9, VJC=0.54, MJC=0.33)

(LTSPICE requires you to add '+' sign at the beginning of each new line!)
