ECE 3274
Power Amplifier Project (Push – Pull)
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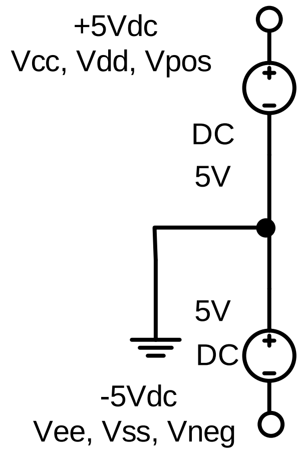
1. Objective

This project will introduce two common power amplifier topologies, and illustrate the difference between a Class-B and a Class-AB amplifier. Power supply Vpos = 5Vdc Vneg = -5Vdc.



2. Components

Qty	Device
1	2N3904 NPN Transistor
1	2N3906 PNP Transistor
3	1N4001, 1N4002 Diode

3. Introduction

Up to this point, we have studied primarily small signal, linear class A amplifiers. These amplifiers are designed to maximize linearity (that is, reduce the magnitude of harmonics generated by the amplifier) at the expense of efficiency. While these amplifiers work well in many situations, it is often desirable to design an amplifier that is much more energy-efficient.

3.1 Class-B Amplifier

This lab introduces two amplifier topologies: The Class-B amplifier, and the Class-AB amplifier. The Class-B amplifier consists of two transistors in a push-pull configuration. Figure 1 shows a common configuration using a 2N3904 transistor and a 2N3906 transistor. When the amplifier is in its quiescent state, no current flows in the collector of either transistor, meaning that the transistors are off. When the input signal either raises the base to approximately 0.7V or falls below - 0.7V from the quiescent point, then the upper or lower transistor turns on and begins to conduct. Since the transistors are in an emitter-follower configuration, the output voltage tracks the Vb base voltage less v_{be}.

It is important to note that because the transistors do not conduct until the input reaches 0.7V; some information is lost in the output signal, creating a crossover region in the output signal in which the output signal is zero.

3.2 Class-AB Amplifier

The Class-AB amplifier is an attempt to remove the nonlinearities generated by the Class-B amplifier while still maintaining its relatively high efficiency. This is done by adding two emitter resistors and three diodes (or diode-configured transistors) to force a voltage difference between the bases of the transistors. This keeps both transistors on with no input signal, but when an input signal is applied, the transistors alternate between on and off, thus increasing efficiency and delivering all of the emitter current above the quiescence current to the load.

Figure 2 shows the Class-AB amplifier schematic. Each diode has an on voltage of approximately 0.53V, giving a total base voltage separation of $1.59V_{DC}$. This is enough to turn both transistors on $V_{BE} = 0.7V_{DC}$. Remember that when a large signal is applied, though, one transistor turns off and one remains on.

4. Requirements

The **Class-B** amplifier should meet the following requirements:

Requirement	Specification
Load Power:	50 mW
Load Resistance:	10 Ω
V_{BE}:	$0.7V_{DC}$
Input Resistance:	Between 500Ω and 700 Ω
Base Resistors	$R_{b1} = R_{b2}$
Low Frequency Cutoff	Between 100 Hz and 300 Hz
High Frequency Cutoff	Between 50 kHz and 200 kHz
Power Supply Voltage	Vcc = 5Vdc Vee = -5Vdc

Table 1. Class-B amplifier requirements.

The **Class-AB** amplifier should meet the following requirements:

Requirement	Specification
Load Power:	50 mW
Load Resistance:	10 Ω
Collector Current:	10mA, quiescent
V_{BE}:	$0.7V_{DC}$
Diode voltage V_D:	$0.53V_{DC}$
Input Resistance:	Between 500Ω and 700 Ω
Low Frequency Cutoff	Between 100 Hz and 300 Hz
High Frequency Cutoff	Between 50 kHz and 200 kHz
Base Resistors	$R_{b1} = R_{b2}$
Emitter Resistors	$R_{e1} = R_{e2}$
Power Supply Voltage	Vcc = 5Vdc Vee = -5Vdc

Table 2. Class-AB amplifier requirements.

5. Prelab Design Project

You will design two amplifiers a Class-B power amplifier, and a Class-AB power amplifier circuits shown in Figures 1 and 2 respectively. You should refer to your class notes, textbook, instructor, and other reference material to help you design the circuits. Start with the DC design and then move onto the AC design you will need to find the peak output V_L, and I_L. Use the following fixed component values in your circuit:

Component	Value
R_i	150Ω
C_{byp} (both supplies)	0.1µF, 0.047uf, or .01uf

Table 3. Fixed component values.

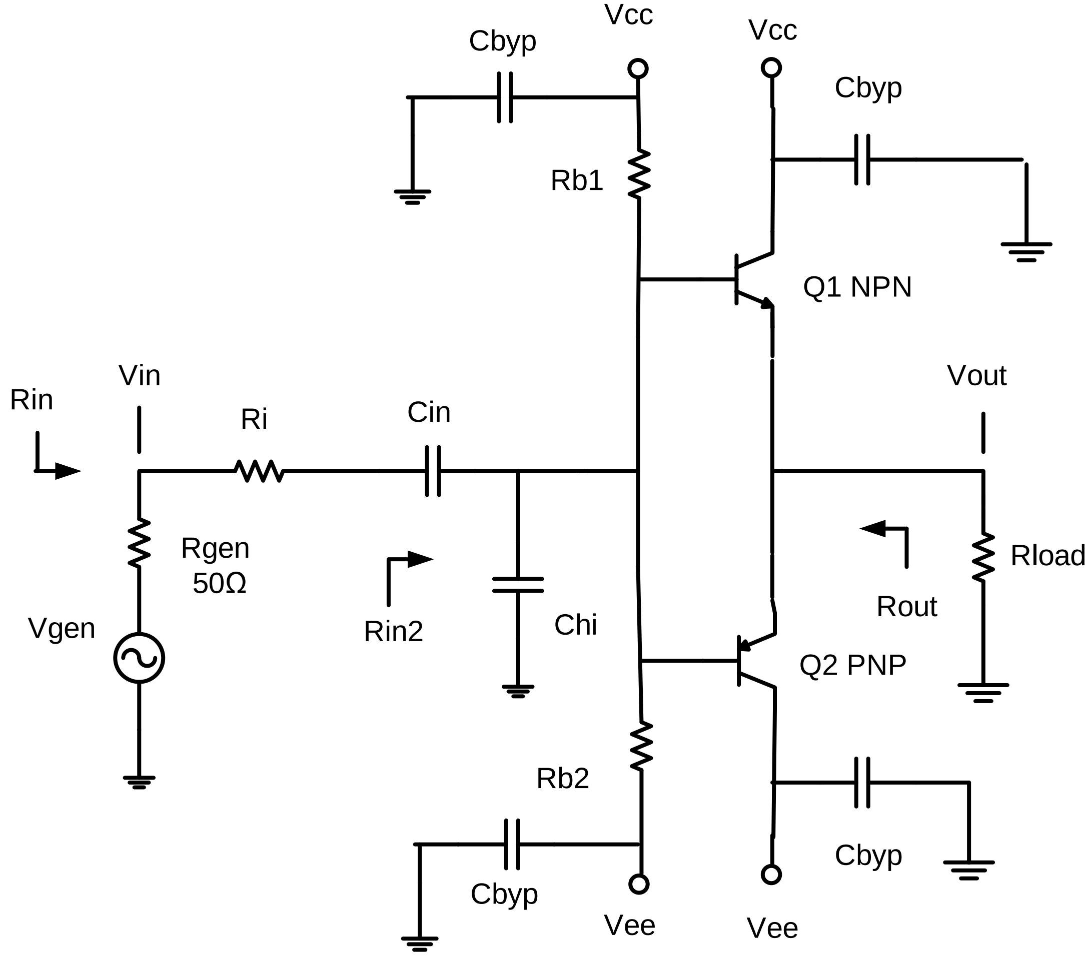


Figure 1. Class-B Power Amplifier.

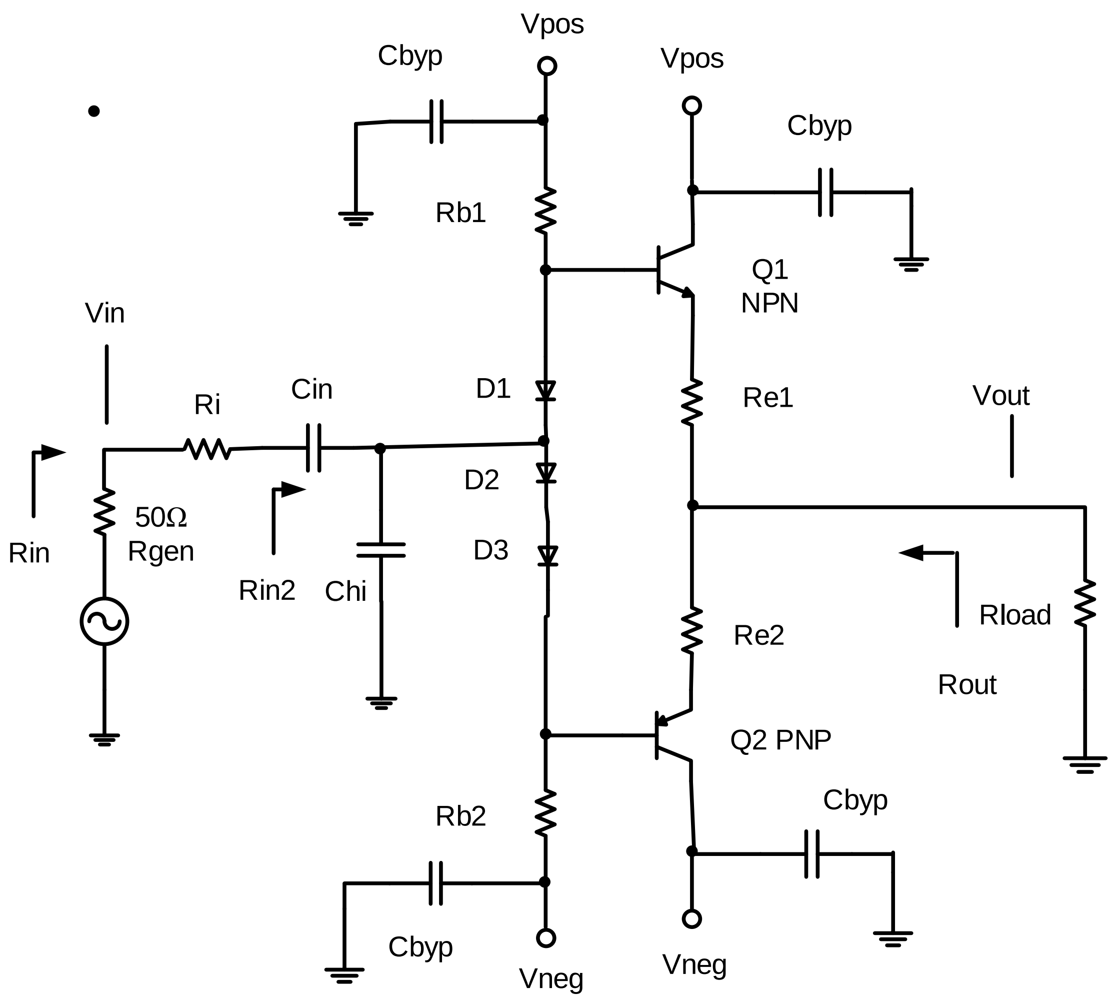


Figure 2. Class-AB Power Amplifier.

5.1 DC Bias

Begin by designing the base resistors for the Class-B amplifier. The two resistors should be equal, so that with no input signal both transistors are off. It may help to use symmetry in the circuit and look only at one-half with the output voltage at the peak value. The other half be a mirror image.

The **maximum** value of the **base resistors** dictated by the maximum peak base current required and $V_{BE} = 0.7V_{DC}$. Based on the power requirement, determine the maximum peak base current (assume a worst-case **Beta value of 100** here) and the minimum voltage drop across the base resistors. The combination of these values will set the maximum resistor values. The minimum values set by the input resistance specification. Remember that you are using a bipolar (±5V) power supply. Read the schematic carefully.

For the **Class-AB** amplifier, you will need to perform a similar procedure. Since the diodes are forward-biased in all cases, simply treat them as ideal voltage sources equal to 0.53V and $V_{BE} = 0.7V_{DC}$. This creates a potential between the transistor bases. Use symmetry to divide the circuit and write equations to determine R_e and R_b evaluate at Vout peak. Ensure that the voltage at the output is at 0V, or as close as you can get it. Once again, when calculating the base and emitter resistors, assume the worst-case **Beta value of 100**.

Note that there is no single correct answer and that your design may differ significantly from your colleagues. You should show all work and walk through all calculations. You must calculate and show all of the following values for both amplifiers (as needed). **Note:** Because we do not know the estimated I_C, we will use the 10mA for both designs to find estimated transistor parameters ro, beta AC, and beta DC. The Ic = (β +1 /β) Ie where Ie = Iload all of the peak load current flows thru the load resistor. Iload = ie = ic + ib

Component Values	**Amplifier Parameters**	**Voltages and Currents**
R_{b1}	Beta dc	V_{ce}
R_{b2}	Beta ac	V_{be}
R_{e1} (Class-AB)	r_π	V_e
R_{e2} (Class-AB)	r_o	I_c
		I_b
Table 4. DC Bias and Amplifier Parameters		

5.2 AC Design

Design the ac characteristics of the amplifiers. **All calculations are at Vout peak**. You must calculate and show all of the following values. C_{in} is given for the class B. Must be found for the class AB.

Component Values	**Amplifier Parameters**	**Voltages, Currents, and Power**
C_{in}	Voltage Gain	v_{in}
C_{hi}	Current Gain	v_{out}
	Power Gain (in dB)	i_{in}
	Low Frequency Cutoff	i_{out}
	High Frequency Cutoff	p_{in}
	Input Resistance	p_{out}
	Output Resistance	

Table 5. Small Signal (AC) amplifier Parameters

5.5 Computer-aided Analysis Class B, Class AB

Once you have completed your two amplifier designs, use LTspice to analyze their performance, and **include the LTspice schematics**. Use the 1N4002 diodes. Generate the following plots:

- **(a)** A time-domain plot (waveform) of the input and output, adjust the input such that the it meets the required output voltage. The output should not have any distortion or clipping for the Class-AB amplifier. Calculate the midband gain and indicate it on the plot. Compare this to your calculated values.
- **(b)** An FFT of your time-domain waveform. Circle and indicate the height of any strong harmonics, in dB relative to your fundamental frequency.
- **(c)** A frequency sweep of the amplifier (**the plot of class B will look different)** from 10 Hz to 1 MHz. Indicate the high and low frequencies on the plot (these should correspond to the half-power, or -3dB points). Compare these to your calculated values.

Note: The **ClassB** AC sweep will be incorrect because the Vout will be zero for low levels of input. The Av and Rout are both found by using transient waveforms plots at 5kHz of Vin, Vout to find **Av = Vout / Vin** use the peak value at design Vin, Vout.

Find Rout = (Voc – Vload) / (Vload / Rload) use the peak value at maximum Vout. Plot **Voc = Vout with Rload = 10Meg** and plot
Vload = Vout with Rload = Given Rload.

6. Lab Procedure.

Note: if you amp is **oscillating** make sure the **bypass capacitors** are in place, and add a **220pf capacitor** to the **base of each BJT** to ground

6.1. Construct the Class-B amplifier shown in Figure 1. Remember that the 50Ω resistor is internal to the function generator and is not in your circuit. Record the values of the Q-point, the bias resistors and the capacitors you used in the circuit. **If your Class B has noise** on the output, bypass the collectors of the BJTs. If it still has, noise put a 220pF capacitor on the bases of each transistor to ground.

6.2. Measure the following values:

- **(a)** Voltage, current, and power gains **use Vin= from design Vpp at 5kHz**.
- **(b)** Maximum undistorted peak-to-peak output voltage.
- **(c)** Input and output resistance **use Vin= from design Vpp at 5kHz**
- **(d)** Output power.
- **(e)** Threshold (turn-on) voltage.

Recall that input impedance is given by $R_{in} = v_{in}/i_{in}$, output impedance is given by $R_{out} = (v_{oc}-v_{load})/i_{load}$, voltage gain is given by $A_v = v_{out}/v_{in}$, and current gain is given by $A_i = i_{load}/i_{in}$. Calculate the current from a known resister and the voltage across it.

Additionally, plot the following:

- **(a)** Input and output waveform.
- **(b)** FFT showing the fundamental frequency and first few harmonics.
- **(c)** Frequency response from 10 Hz to 1 MHz (set the input voltage to a value that does not cause distortion across the entire passband of the amplifier).

6.3. Construct the Class-AB amplifier shown in Figure 2. Remember that the 50Ω resistor is internal to the function generator and is not in your circuit Record the values of the Q-point, the bias resistors and the capacitors you used in the circuit. Use the 1N4001 diodes. If your Class AB has noise on the output, bypass the collectors of the BJTs. If it still has, noise put a 220pF capacitor on the bases of each transistor to ground.

6.4. Measure the following values:

- **(a)** Q-points: V_{CE}, V_{BE}, V_E,V_C, V_B and I_c, and.
- **(b)** Voltage, current, and power gains **use Vin = from design Vpp at 5kHz**.
- **(c)** Maximum undistorted peak-to-peak output voltage.
- **(d)** Input and output resistance **use Vin = from design Vpp at 5kHz**
- **(e)** Low and high cutoff frequencies (half power point).
- **(f)** Output power.

Recall that input impedance is given by $R_{in} = v_{in}/i_{in}$, output impedance is given by $R_{out} = (v_{oc}-v_{load})/i_{load}$, voltage gain is given by $A_v = v_{out}/v_{in}$, and current gain is given by $A_i = i_{load}/i_{in}$.

Additionally, plot the following:

(a) Input and output waveform at the maximum undistorted value.
(b) FFT showing the fundamental and first few harmonics.
(c) Frequency response from 10 Hz to 1 MHz (set the input voltage to a value that does not cause distortion across the entire passband of the amplifier).

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Power Amplifier Project
Report Data Sheet

Name:		**Lab Date:**	
Group:		**CRN:**	
GTA name		**Bench #**	

Remember to include units for all answers and to label all printouts. There are a total of six (6) printouts in this lab. **If in class**: Only one set of printouts is required per group.

6.1. Component values for class-B power amplifier.

R_{b1}:		**R_{b2}:**		**R_L:**		**Cin:**		**Chi:**	

6.2. Class-B power amplifier. **Do Not** connect the **load resistor** until you verify the Q-point and the output voltage is ≈ 0Vdc. There are three printouts here. Remember **Av** and **Rou**t are derived from the **waveform plots at 5kHz**.

Capacitor Value:	Cin:		Chi:			
Vin @ 5kHz Gain:	Voltage:		Current:		Power:	
Voltage Output:	Max:					
Resistance:	Input		Output			
Output Power:	P_{RMS}:					
Threshold Voltage:	V_{TH}:					

6.3. Component values for class-AB power amplifier.

R_{b1}:		**R_{b2}:**		**R_L:**		**Cin:**	
R_{e1}:		**R_{e2}:**				**Chi:**	

6.4. Class-AB power amplifier. . **Do Not** connect the **load resistor** until you verify the Q-point and the output voltage is ≈ 0Vdc. There are three printouts here.

Capacitor Values:	Cin:		C_{hi}:			
Q-Point (Q1):	V_{CE}:		V_{BE}:		V_E:	
	V_B:		I_c:		V_C:	
Q-Point (Q2):	V_{CE}:		V_{BE}:		I_C:	
	V_B:		V_E:		V_C:	
Vin @ 5kHz Gain:	Voltage:		Current:		Power:	
Voltage Output:	Max:					
Resistance:	Input		Output			
Frequency Response:	Low:		High:			
Output Power:	P_{RMS}:					