Power Amplifier Class Comparisons

Solid State Devices

Student Name: _____

Acknowledgements

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Purpose

In this lab, the student will analyze four different classes of amplifiers and compare their efficiencies.

Systems Rationale

Amplifiers, especially audio amplifier, are found in many consumer products and applications. An amplifier usually can be broken down into two sections: the pre-amplifier (pre-amp) and the power-amplifier (power-amp). The pre-amp section takes a small voltage signal and amplifies the voltage so there is a voltage gain. The power-amp section amplifies the current. Many power-amps are now a single chip component. Even though a power-amp may be a single-chip design, it still falls within a distinct class of amplifiers.

System Concepts

This system covers the following system concepts (signified by an X):

_X_ S1. A system can be defined in terms of its functional blocks i.e., a "structured functional unit."
_X_ S2. A system has a purpose, transforms inputs into outputs to achieve a goal.
___ S3. A system is defined by the flow of materials, energy and information, between its functional units.
___ S4. A system may be open or closed. In an open system additional inputs are accepted from the environment.
___ S5. A system is more than the sum of its parts. Individual components can never constitute a system.
___ S6. A system provides feedback to the operator and services to the user. Some system functions may involve operator action.
___ S7. Systems have unique problems.

Student Learning Outcomes

Appropriate SLOs for the lab activity are below. For a complete list of course SLOs visit: http://www.esyst.org/Courses/Solid_State/_delivery/index.php

13. State the two main functions of a transistor.
15. Identify basic methods for biasing MOSFETs as amplifiers and switches.
17. Identify the basic methods for biasing a BJT as an amplifier and a switch.
18. Identify basic transistor amplifier circuits such as common emitter/source, common base/gate, and common collector/drain.

20. Name the basic characteristics of an amplifier (gain, input and output impedance, frequency response, voltage/power output limits, etc) and state how each is expressed.
21. Calculate the gain of an amplifier from input and output voltages (or powers) and calculate the gain of cascade amplifiers.
46. Name the basic classes of amplifiers, state the approximate efficiency of each and indicate where each type is generally used.

Prerequisite Knowledge & Skills

- The student should be able to explain the theory of operation of a Class A amplifier.
- The student should be able to explain the theory of operation of a Class B amplifier.
- The student should be able to explain the theory of operation of a Class AB amplifier.
- The student should be able to explain the theory of operation of a Class D amplifier.

Learning Objectives

Relevant knowledge (K) or skill (S) student learning outcomes include:

S1. The student will be able to measure the power amplifier supply voltage.

S2. The student will be able to measure the power amplifier supply current.

S3. The student will be able to measure the power amplifier output voltage.

S4. The student will be able to measure the power amplifier output current.

S5. The student will be able to calculate the efficiency of a power amplifier.

Process Overview

The student will test a Class A, Class B, Class AB, and then a Class D amplifier. The student will determine the power input and the power output of each amplifier. From this information, the student will determine the power efficiency of each amplifier.

Time Needed

Lab Performance:
It should take students approximately 3 hours to work through the entire lab.

Lab Deliverables:
(This is left to the instructor.)

Components (listed per amplifier), Equipment, and Supplies

Class A Amplifier (from discrete components)	Quantity
TIP29 (NPN Power Transistor)	1
220 uF Electrolytic Capacitor (35 V)	2
1 KOhm Resistor (1/4 Watt)	1
20 Ohm Power Resistor (7 Watts or greater)	1
TO-220 Heatsink	1
Class B Amplifier (from discrete components)	**Quantity**
TIP29 (NPN Power Transistor)	1
TIP30 (PNP Power Transistor)	1
2N3904 (NPN Transistor)	1
1N914 (Switching Diode)	1
2.2 Ohm Resistor (1/4 Watt)	2
270 Ohm Resistor (1/4 Watt)	1
1 KOhm Resistor (1/4 Watt)	1
5.6 KOhm Resistor (1/4 Watt)	1
220 uF Electrolytic Capacitor (35 V)	2
Class AB Amplifier (from discrete components)	**Quantity**
TIP29 (NPN Power Transistor)	1
TIP30 (PNP Power Transistor)	1
2N3904 (NPN Transistor)	1
1N914 (Switching Diode)	2
2.2 Ohm Resistor (1/4 Watt)	2
270 Ohm Resistor (1/4 Watt)	1
1 KOhm Resistor (1/4 Watt)	1
5.6 KOhm Resistor (1/4 Watt)	1
220 uF Electrolytic Capacitor (35 V)	2
Class D Amplifier (from an IC package)	
TPA3122D2 Class D Audio Amplifier (DIP package) from DigiKey	1
1 Ohm Resistor (1/2 Watt)	1
10 KOhm Resistor (1/4 Watt)	2
.22 uF Capacitor	3
.68 uF Capacitor	2
1 uF Capacitor	4
470 uF Capacitor	3
22 uH Inductor	2
Class D Amplifier (assembled evaluation board)	
TA-2024 D-class Audio Amplifier Board from Sure Electronics	1
Equipment and Supplies	
15 Watt Speaker or greater	2
Speaker wire (3’ length, 18 gauge)	2
12 Volt Power Supply	1
Multimeter	1
Oscilloscope	1

Special Safety Requirements

Some amplifiers do get hot, especially the Class A type. Do not touch the components when they are powered up and allow them to cool for at least one minute after powering down. Also, load sounds can cause ear damage. It is recommended that the speakers be muffled in some fashion; maybe by placing a damping material around them such as a blanket.

Lab Preparation

1. The student should review the specification sheets on the following components, prior to starting this lab activity: TIP29, TIP30, 1N914, TPA3122D2, and TA2024. By reviewing the specification sheets, the student will acquire the pin-outs and also develop a general understanding of the functionality of the device.

Introduction

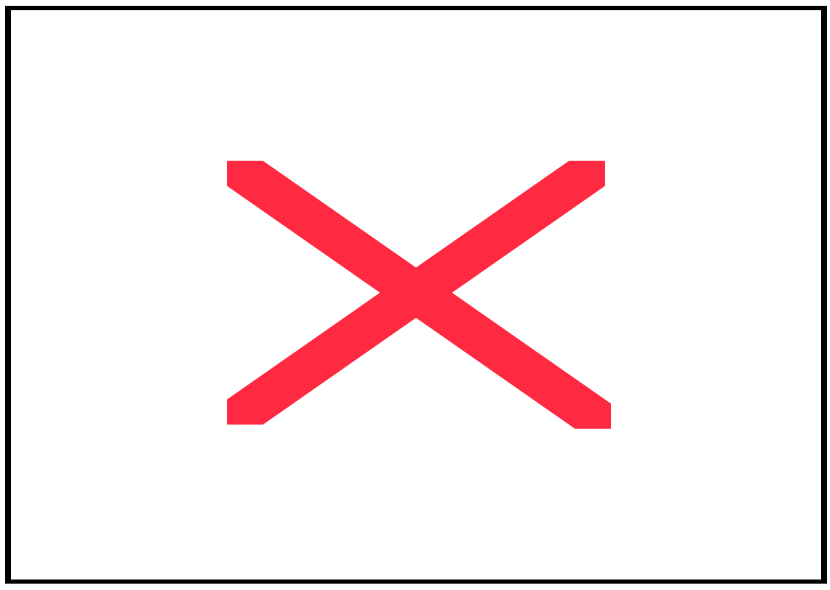
One of the skills of a technician is to measure and to make determinations and conclusions based on those measurements. This is an everyday occurrence for most technicians. This lab helps in the development of those skills.

Task

In many technician positions there is a need for the technician to measure the efficiency of a part, component, assemble, or product. In the following example you will assemble Class A, B, AB, and D amplifiers and calculate the efficiency of each in the relationship to a supplied signal frequency. You will create a summary report of your findings for each amplifier and create a recommendation list on which type of amplifier to use various functions.

Performance for a Class A Amplifier

1. Assemble the following Class A amplifier circuit.



2. Power up the circuit and measure the V_{CE} of the transistor and the collector current (I_C). V_{CE} should be around ½ V_{cc}. If it is not, power down the circuit and inform your instructor.
   V_{CE} = _____ Volts
   I_C = _____ Amps

3. Connect an oscilloscope across V_{CE}.

4. Using a Function Generator, place a 10 KHz sine wave signal at the input to the circuit. While viewing the Oscilloscope, adjust the amplitude of the input signal to obtain the maximum V_{CE} signal possible without "clipping".

5. Use a Multimeter to measure the supply voltage and supply current.
   Power supply voltage = _____ Volts
   Power supply current = _____ Amps
   Power in = Volts * Amps = _____ Watts

6. Use a Multimeter to measure the AC voltage across the speaker and the AC current flowing to the speaker.
   Output voltage = _____ Volts
   Output current = _____ Amps
   Power out = Volts * Amps = _____ Watts

7. Calculate the efficiency of the amplifier by using the following equation.
   
   Efficiency for this Class A amplifier is _____%.

8. Viewing V_{CE} on the oscilloscope, is there any distortion of the sine wave signal?
   _____

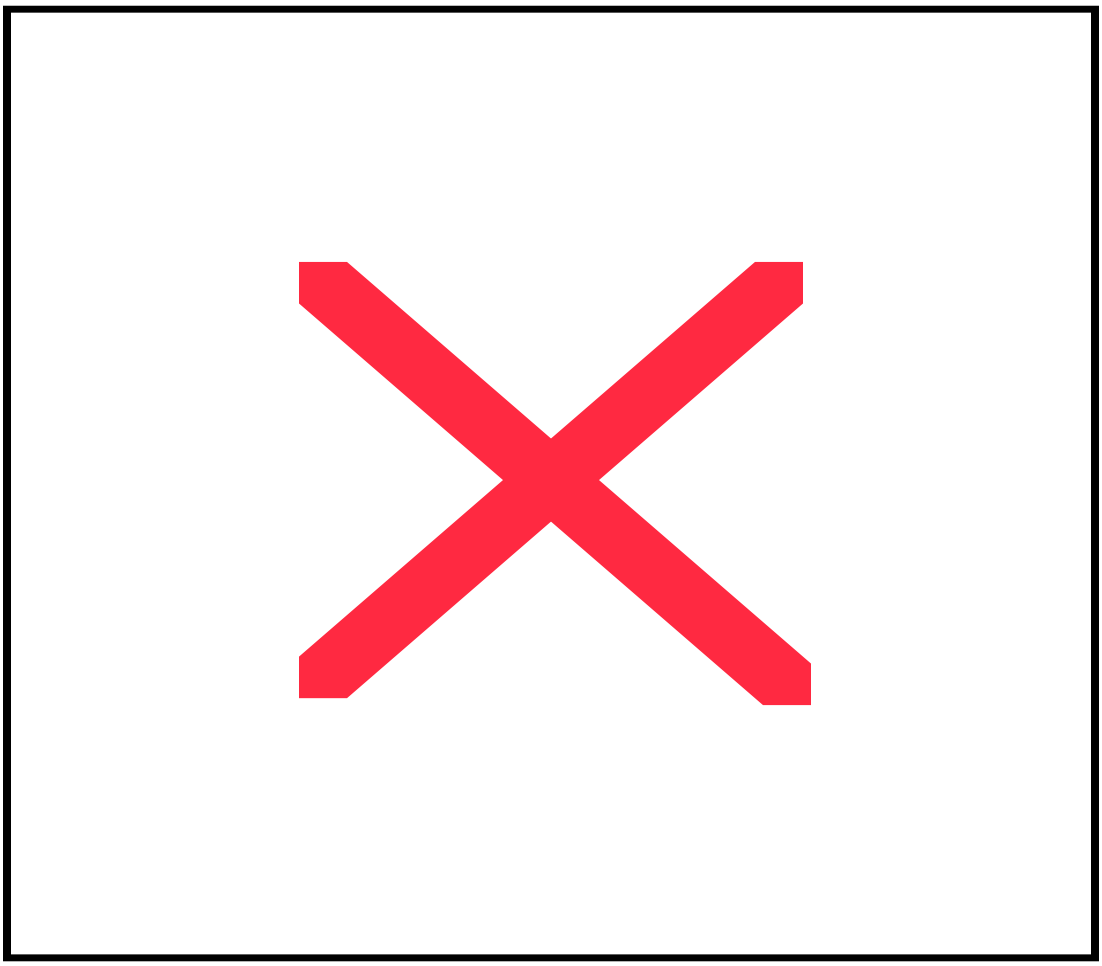
9. Remove the function generator signal.

10. Input a music signal to the amplifier from a computer, MP3 player, or a CD player.

11. Adjust the input signal strength so that the output signal is comfortable to listen to. How does the output signal sound quality wise?
    _____
    _____

Performance for a Class B Amplifier

1. Assemble the following Class B amplifier circuit.



2. Power up the circuit and measure the voltage at the junction of the two 2.2 Ohm resistors with respect to ground.
   Voltage = _____ Volts

3. Measure the quiescent current through the collector of the TIP29 transistor.
   Quiescent current = _____ mA.

4. Connect an Oscilloscope at the junction of the two 2.2 Ohm resistors with respect to ground.

5. Using a Function Generator, place a 10 KHz sine wave signal at the input to the circuit. Adjust the amplitude of the input signal to obtain the maximum output signal possible without “clipping”.

6. Use a Multimeter to measure the supply voltage and current.
   Power supply voltage = _____ Volts
   Power supply current = _____ Amps
   Power in = Volts * Amps = _____ Watts

7. Use a Multimeter to measure the AC voltage across the speaker and the AC current flowing to the speaker.
   Output voltage = _____ Volts
   Output current = _____ Amps
   Power out = Volts * Amps = _____ Watts

8. Calculate the efficiency of the amplifier by using the following equation.
   
   Efficiency for this Class B amplifier is _____%.

9. With the Oscilloscope still connected, is there any distortion of the sine wave signal at the junction of the two 2.2 Ohm resistors?
   _____

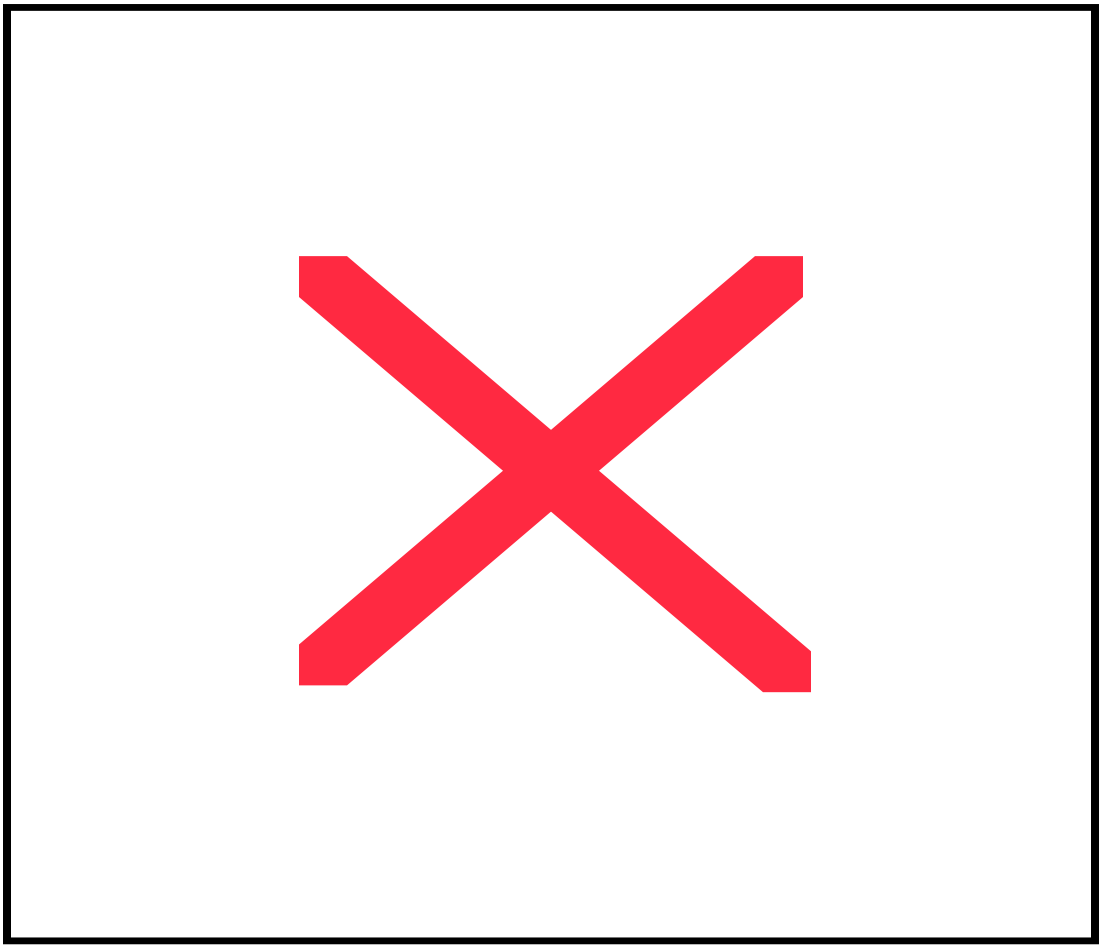
10. Remove the Function Generator signal.

11. Input a music signal to the amplifier from a computer, MP3 player, or a CD player.

12. Adjust the input signal strength so that the output signal is comfortable to listen to. How does the output signal sound quality wise?
    _____
    _____
    _____

Performance for a Class AB Amplifier

1. Assemble the following Class AB amplifier circuit.



2. Power up the circuit and measure the voltage at the junction of the two 2.2 Ohm resistors with respect to ground. Both transistors should be conducting therefore the voltage should be ½ of V_{CC}. If not, power down the circuit and contact your instructor.
   Voltage = _____ Volts

3. Measure the quiescent current through the collector of the TIP29 transistor.
   Quiescent current = _____ mA.

4. Connect an Oscilloscope at the junction of the two 2.2 Ohm resistors with respect to ground.

5. Using a Function Generator, place a 10 KHz sine wave signal at the input to the circuit. Adjust the amplitude of the input signal to obtain the maximum output signal possible without "clipping".

6. Use a Multimeter to measure the supply voltage and current.
   Power supply voltage = _____ Volts
   Power supply current = _____ Amps
   Power in = Volts * Amps = _____ Watts

7. Use a Multimeter to measure the AC voltage across the speaker and the AC current flowing to the speaker.
   Output voltage = _____ Volts
   Output current = _____ Amps
   Power out = Volts * Amps = _____ Watts

8. Calculate the efficiency of the amplifier by using the following equation.
   
   Efficiency for this Class AB amplifier is _____%.

9. With the Oscilloscope still connected, is there any distortion of the sine wave signal at the junction of the two 2.2 Ohm resistors?
   _____

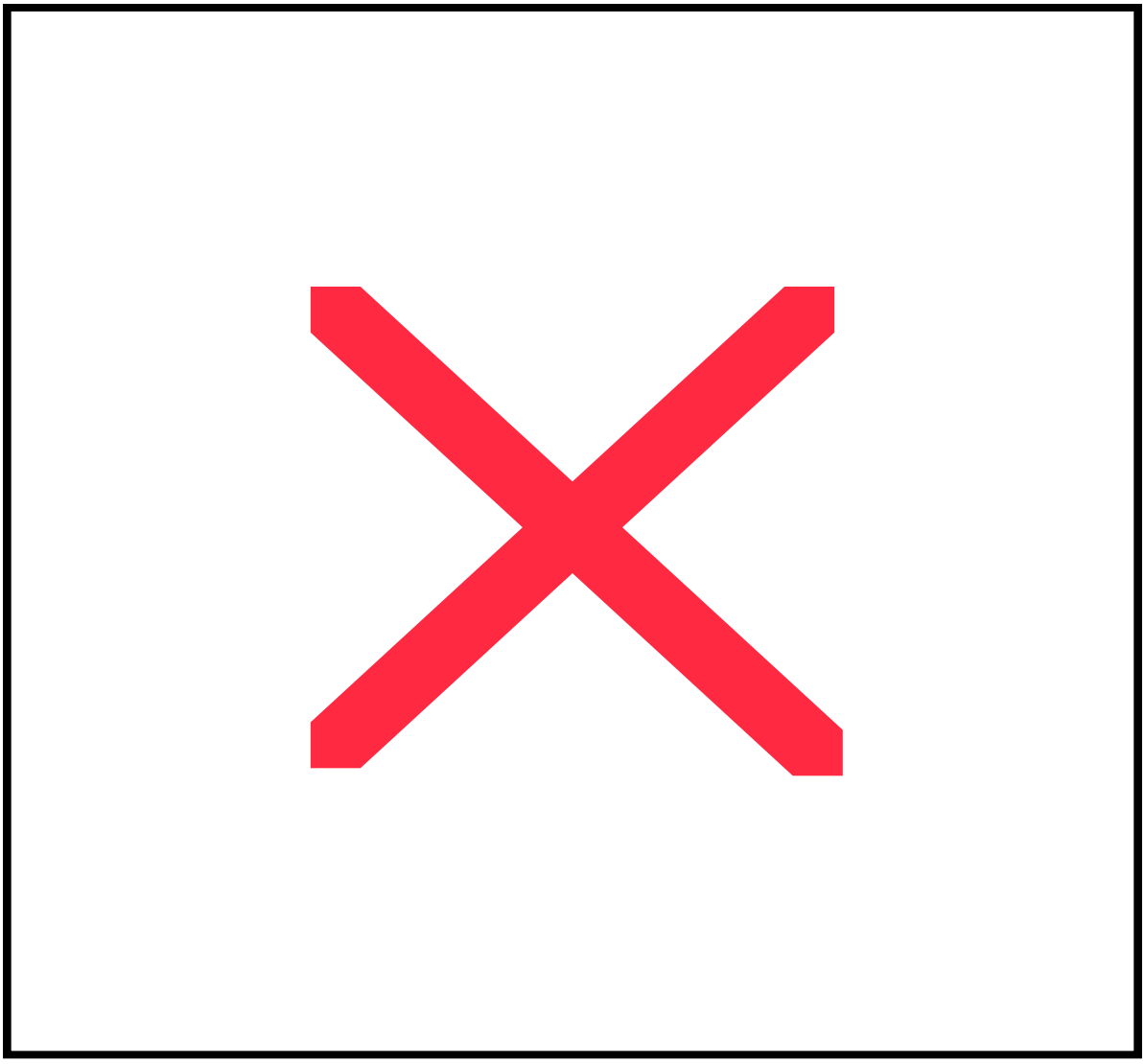
10. Remove the Function Generator signal.

11. Input a music signal to the amplifier from a computer, MP3 player, or a CD player.

12. Adjust the input signal strength so that the output signal is comfortable to listen to. How does the output signal sound quality wise?
    _____
    _____
    _____

Performance for a Class D Amplifier

1. Assemble the following Class D amplifier circuit. Since this configuration is for stereo operation, the audio input signal will be fed into both channels.



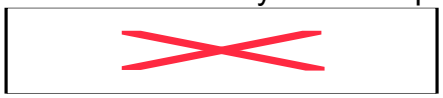
2. Power up the circuit and place the Oscilloscope across one of the speakers.

3. Using the Function Generator, place a 10 KHz sine wave signal at the input to the circuit. Adjust the amplitude of the input signal to obtain the maximum output signal possible without “clipping”.

4. Use a Multimeter to measure the supply voltage and current.
Power supply voltage = _____ Volts
Power supply current = _____ Amps
Power in = Volts * Amps = _____ Watts

5. Use a Multimeter to measure the AC voltage across one of the speakers and the AC current flowing to that speaker. Since the input power was calculated with both channels operating, the measured AC current value needs to be doubled to account for both channels.
Output voltage = _____ Volts
Output current (total for both channels) = _____ Amps
Power out = Volts * Amps = _____ Watts

6. Calculate the efficiency of the amplifier by using the following equation.



Efficiency for this Class D amplifier is _____%.

7. With the Oscilloscope still connected across one of the speakers, is there any distortion of the sine wave signal?

_____

8. Remove the Function Generator signal.

9. Input a music signal to the amplifier from a computer, MP3 player, or a CD player.

10. Adjust the input signal strength so that the output signal is comfortable to listen to. How does the output signal sound quality wise?

_____
_____
_____

Comparing Efficiencies

Fill in the following table with the efficiencies arrived at for each class of amplifier.

Amplifier Class	Efficiency in %
Class A	
Class B	
Class AB	
Class D	

Based on your results, which is the most efficient? Which one is the least efficient? Which one sounded the best? Which one sounded the worse?

The most efficient is Class _____.
The least efficient is Class _____.
The best sounding is Class _____.
The worst sounding is Class _____.

Deliverable(s)

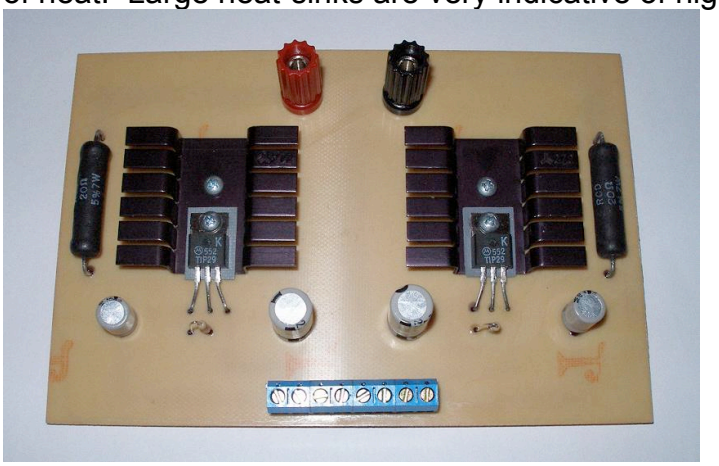
The student should provide the instructor with the lab results and also a written summary of what he or she has learned from performing this lab.

Grading

Your instructor will let you know if and how this lab will be graded.

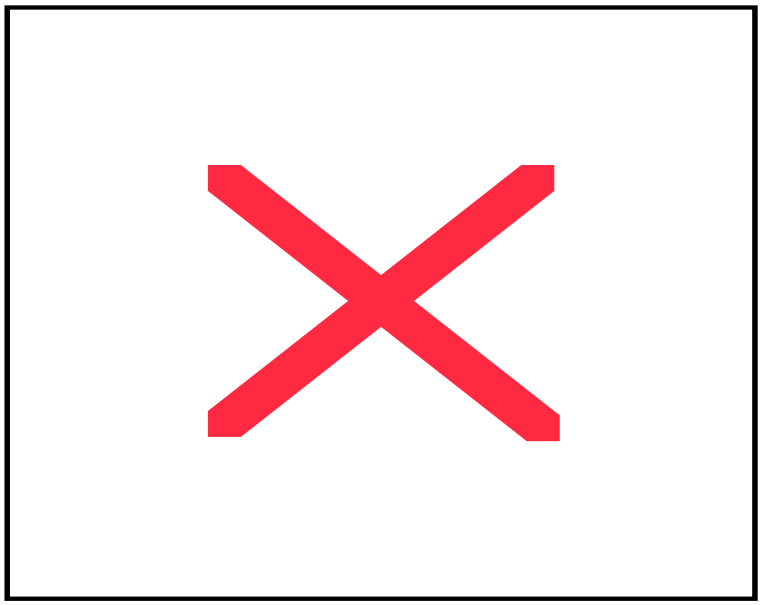
Pictures

Picture 1 is a stereo Class A amplifier based on the Class A amplifier circuit found in this lab. The author made this unit. Notice the large heat-sinks required for dissipation of heat. Large heat-sinks are very indicative of high inefficiency.



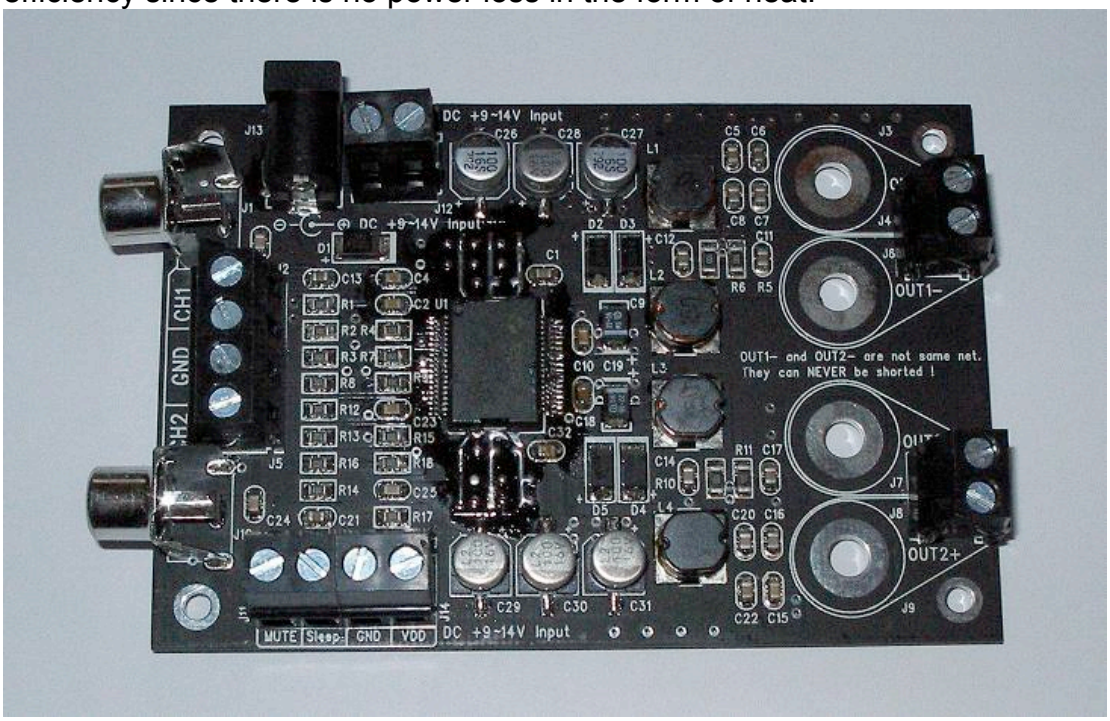
Picture 1

Picture 2 is a stereo Class AB amplifier based on the Class AB amplifier circuit found in this lab. The board was designed by the author and manufactured by ExpressPCB. The printed circuit board file is included with this lab and is named: amplifier_AB.pcb



Picture 2

Picture 3 is of a TA-2024 (15 Watt per channel) D-class Stereo Audio Amplifier Board from Sure Electronics. Notice the lack of any heat-sinks. This is indicative of high efficiency since there is no power loss in the form of heat.



Picture 3