Amplifier Classes

Audio amplifiers have been put into different “classes” The class is dictated by the way the output stages operate. For audio we have five basic classes but one of them pertains to how the power supply operates.

Class A amplifiers are probably the best sounding of all the classes. The output stages operate at a constant current equal to or greater then the current which the load requires. This means that the output devices (Bipolar, Tubes, Mosfets, IGBTs) are never driven into cut off. They conduct through 360 degrees of the output waveform. All analog amplifiers have input and driver stages which pretty much all operate in pure class A mode. They can because their heat dissipation is relatively low. What are the disadvantages to pure class A amplifiers. Heat! A reasonable powered amplifier dissipates enormous amounts of heat. Please refer to the discussion on Amplifier Efficiency to see some simple calculations of how efficient a class A amplifier is. For this discussion let’s use an average figure of say 15% which is a conservative number. This means that for every 100 watts of power into our amplifier, 85 watts go out as heat and 15 watts go to the loudspeakers! Not a very good situation if you must pay the electric bill.

Class A amplifiers are configured in either single ended or push pull. Single ended means that the output stage consists of a single amplifying device (Transistor, tube etc.) and it is normally driven from a constant current source but in tube designs it is a transformer. The amplifying device has no ability to sink current, only source current to the load. A push pull stage has two devices, each one delivering current to the load on each half cycle of the waveform. Some consider this type a “hard biased class B” output stage.

For an amplifier to be classified as “Class A” it is required that the standing current in the output stage be equal to or greater than the maximum load current. This means that if we are using a typical 4 ohm speaker, its impedance may drop to say 1.5 ohms at some frequency. If we have a 50 watt per channel amplifier this requires 14.14 volts to be developed across the load (speaker). So with a 4 ohm load, the current is 14.14/4 = 3.53 amps RMS or 5A peak. With a 1.5 ohm load it is 9.42 amps RMS or 13.32A peak. So in order for our amplifier to remain in pure class A (assuming the typical 4 ohm speaker goes to 1.5 ohms) it must idle at 9.42 amps RMS PER CHANNEL.
Let’s see how the numbers turn out. The 50 watt amplifier runs off supply rails of about +/-25 volts (let’s also assume that this is regulated). The wattage at idle is 13.32 x 50 = 666 watts per channel. This is a total of <u>**1332 watts of heat**</u> when the amplifier is just sitting around doing nothing! Let us compare this to if the amplifier ONLY had to drive a 4 ohm load the dissipation would be 5 x 50 = 250 watts per channel and <u>**500 watts total**</u>, still not an insignificant amount of heat.

Any company who claims to have a pure class A amplifier (of reasonable power output and I do not mean 3 watts per channel) for the automobile is simply not telling the consumer the truth.

There are those who will say that “our amplifier model XX operates in class A up to YY watts and then it switches into class B. This is none sense, a class A amplifier by definition NEVER operates in class B - period.

Class A amplifiers have some disadvantages as far as the power supply is concerned. Due to the high idling current, the power supply must be well filtered to avoid hum and noise. In an amplifier running off 60Hz AC this hum can be significant and the best way to eliminate it is by using fully regulated power supplies. In a car amplifier there is no 60Hz but in order to keep he signal free of noise, regulators in the power supply rails should be used. The common mode rejection ratio is very poor in class A amplifiers and the regulators help to allow the rejection of power supply noise and ripple.

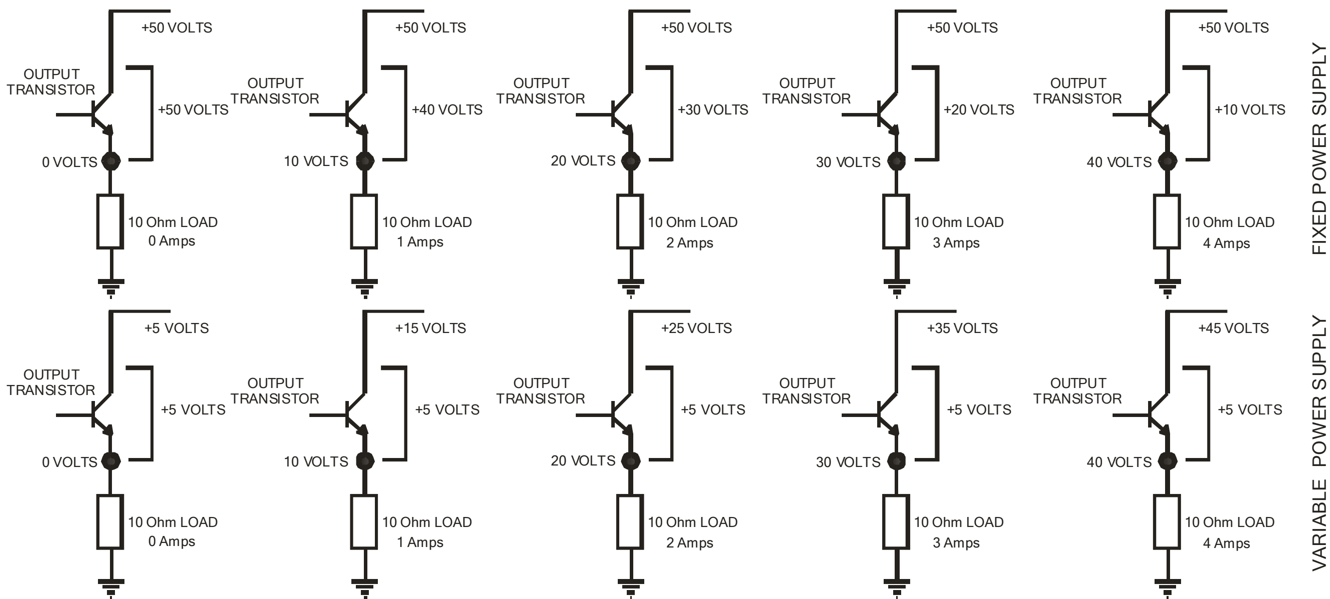
Class B amplifiers are those that only conduct through 180 degrees of the output wave form and are all push pull by design. The output stage has device(s) for both halves of the waveform. This means that when the positive device is conducting and sourcing current to the load, the opposite device is cut off (not conducting). This is kind of analogous to two people on opposite ends of a rope. One pulls and the other can relax and visa versa. During the time at which one person ceases to pull and the other starts to pull, the rope is limp (in a cut off stage). This is the region in which one half of the output stage stops conducting and there is a short period of time before the other half begins conducting. This time interval is what we call "crossover distortion". It manifests itself as a small time step on the sinewave on both the positive and negative going halves of the sinewave.

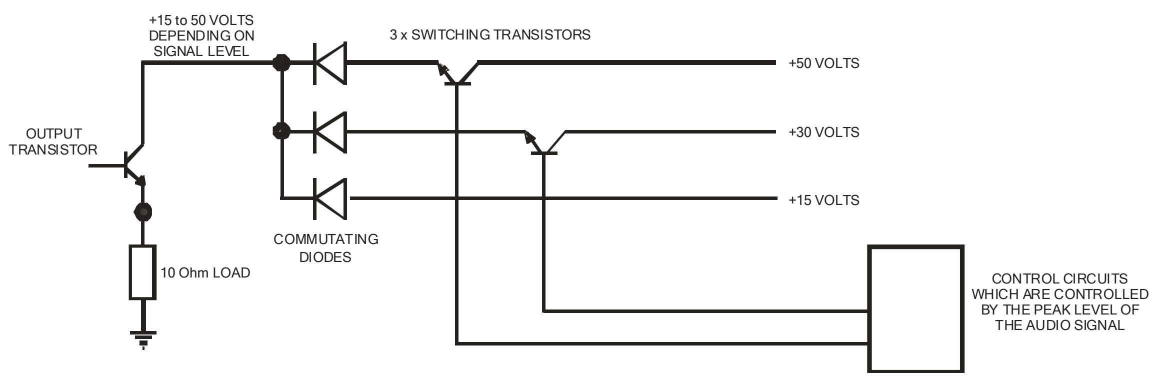
In order to reduce this crossover distortion to a small value we introduce a small idling current in the output devices. This current is normally in the order of milliamps. What this does is causes the output devices to conduct for slightly more than the 180 degrees. Depending on the amount of idle current introduced this may be up to 200 degrees and more. Technically the output stage runs in class A up to a very small power output. Consider a 100 watt amplifier which has the idling current set at 50mA which is not untypical. The load is 4 ohms(R). Power is I x I x R. So 0.05 x 0.05 x 4 = 0.01 watts. This amp runs in class A up to a power level of 10 milliwatts – hardly class A but theoretically it is. If we idle this 100 watt amplifier hard at say 500mA, it will run in class A up to a power level of 0.5 x 0.5 x 4 = 1 watt!
I assure you that a 100 watt class B amplifier idling at 0.5 amp (500mA) will run hot. The typical rail voltage is +/-35v and the dissipation at idle is 35 x 0.5 x2 = 35 watts for each channel.

Class A-B amplifiers are just a variation of a class B amplifier as described above. Most amplifiers made today are A-B simply because a pure class B would be unacceptable for audio owing to its high distortion at crossover. Otherwise the two are identical.

Class D amplifiers are of the switching variety. Technically they are Pulse Width Modulated switching power supplies where the modulation is the audio signal. Typically a high frequency carrier (50KHz-500KHz) is converted to a triangle waveform. This triangle waveform is fed into a comparator together with the incoming audio signal. The resultant PWM waveform is fed into an output stage which alternately switches either the positive switches on or negative switches on depending on the polarity of the incoming waveform. Since the Mosfet switches are either on or off, their efficiency is close to 100% but not quite there! Losses in the Mosfets are due to their finite on resistance and the losses which occur during their transition from off to on and back to off states. The high frequency pulse train must then be demodulated back to an analog form in order that the loudspeaker can reproduce it. This is done with a passive L-C filter whose cut off frequency is normally higher than the highest audio frequency the amplifier is being asked to reproduce. So in a 20Hz-20KHz amplifier a 25-30KHz cut off filter would be used. Feedback is nearly always implemented to get the distortion low, the output impedance low and the noise low.

Class G amplifiers are really not a separate class but rather a variation of a class A-B amplifier. Their difference is almost entirely in the power supply. Referring to our notes under amplifier efficiency, it can be seen that if the amplifier is driving lower levels of signal, there is a large amount of net voltage impressed across the output devices. Multiply this net voltage by the current through the devices and we get HEAT! How can we reduce this heat? Well the current is “fixed” in that we need it to drive the speaker. So if we can reduce the value of the supply voltage we shall reduce the V-I product = HEAT.





Let us examine the above diagrams. A single transistor shown for simplicity but the bottom half of the output stage is a symmetrical PNP transistor

In the first row we see that the power supply is fixed at 50 volts. The load is 10 ohm (easy arithmetic). When the output is 0, the current through the transistor is 0 amps and VxI = 0 watts, when the output is 10 volts, the current through the transistor is 1 amp and the VxI = 40x1 = 40 watts (there is a net of 40 volts across the transistor). As we move to the right the calculations are similar just the V-I product changes as the output goes higher and the net voltage across the output transistor becomes lower.

As we can see the V-I product of the transistor generates the heat. If we could magically make the supply voltage track at say 0.001 volts <u>**ABOVE**</u> the required signal then the V-I product would always be 0.001 x [the current through the transistor]. If the current was 1 amp then V-I

= 0.001 x 1 = 0.001 watts. Very nice indeed but a dream. If the current was 10 amps the V-I would be 0.001 x 10 = 0.01 watts, both insignificant dissipation figures in the transistor. This scenario is of course is not possible so we get to a practical situation.

In the second row of the above diagram, I have kept the supply voltage 5 volts ABOVE the required output voltage. So in each case the V-I product is always 5 x [the output current] since the voltage across the output transistor is always 5 volts.

The table below pertains to the first row of the main diagram. (Fixed Power Supply)

Output voltage	Output current amps	Voltage left Across the Output transistor	Dissipation in the output transistor in watts
0	0	50	0
10	1	40	40x1=40
20	2	30	30x2=60
30	3	20	20x3=60
40	4	10	10x4=40
50	5	0	0x5=0

The table below pertains to the second row of the main diagram. (Variable Power Supply)

Output voltage	Output current amps	Voltage left Across the Output transistor	Dissipation in the output transistor in watts
0	0	5	5x0=0*
10	1	5	5x1=5
20	2	5	5x2=10
30	3	5	5x3=15
40	4	5	5x4=20
50	5	0	0x5=0**

* Not 100% true as we have idling current but is still very small.
** Not true in practice as the transistor is NOT a perfect switch so its saturation voltage may be 0.5 to 3 volts depending on the max current flowing through it.

As we can see from the right columns of each table, the dissipation in the output transistors is greatly reduced in the second example.

The third part of the main diagram is a practical implementation of a variable power supply or Class G. The output stage has an initial supply voltage of 15 volts. As the peak value of the output increases, a control circuit monitors this. Just before the output signal is clipped, the second transistor which is supplied from a 30 volt rail is turned on, the 30 volts is applied to the main amplifier’s transistor through one of the commutating diodes. Thus the transistor now has a “new” supply of 30 volts AS LONG AS THE SIGNAL IS ABOVE THE INITIAL 15 volts. The procedure is repeated when the signal reaches the 30 volt threshold then the supply is switched to 50 volts. Not as good as a continuously variable tracking supply but far better than a single fixed supply. With typical music the supplies will vary between the 15 and 30 volt rails 90% of the time and only peaks will require that the supply be switched to the 50 volt level.

The table below compares the practical circuit to the first two rows, the first which is a fixed supply of 50 volts and the second which bumps the supply in 5 volt increments. This second example is practical but would require FIVE power supplies at 5v, 15v, 25, 35v and 50v and this would be a high parts count circuit.
The table below pertains to the last circuit of the main diagram.

Output voltage	Output current amps	Voltage left Across the Output transistor	Dissipation in the output transistor in watts
0	0	15	15x0=0
10	1	5	5x1=5
20	2	10	10x2=20
28	3	2	2x3=6
32	3.2	18	18x3.2=57.6
40	4	10	10x4=40
50	5	0	0x5=0

As we see the dissipation in the output stage is lower than the single supply method but not as low as the 5 stage power supply. In our experience a 3-4 stage is a practical maximum.

Class H is just a subtle variation of class G and was really only used by Soundcraftsman in their older amplifiers.