

Amplifier Efficiency

There have been many published facts about this topic and much more unsubstantiated things written and spoken about this subject. I hope to put forward some facts that will lay those unsubstantiated theories to rest.

A 100% efficient amplifier is just that, power in = power out, no losses, no heat and of course NOT POSSIBLE. There is no such thing as a 100% efficient amplifier.

There are several factors which affect how much heat an amplifier shall dissipate. We shall assume a perfect power supply and only concentrate on the audio amplifier at first. I shall come back to the efficiency of the power supply. The class of the amplifier determines how efficient the circuit is.

Class A the output stage conducts all the time that is through the full 360 degrees of the waveform.

Class B each half of the output stage conducts for 50% of the time that is through 180 degrees of the waveform

Class A/B is just a class B amplifier with the output stage idling current set to some tens or maybe hundreds of milliamps.

Class D are PWM amplifiers and have no relationship with analog designs.

Let us begin with **class A amplifiers**.

Class A amplifiers fall into two categories, single ended and push pull. Single ended types are less efficient than their push pull counterparts. Typical efficiency for single ended is from about 0% (No this is not a misprint) to 25% and push pull up to 35%. Single ended class A amplifiers shall be discussed since push pull versions are too a large degree high bias class B designs. So the following discussion will pertain to a single ended design.

The current in the output stage should be EQUAL or slightly higher than the load (speaker) current. This shall assure us that at no time will the output stage switch into class B. The following is a simple example of a pure class A amplifier rated at 50 watts into 4 ohms.

Output voltage at speaker = 14.14v RMS or 20v peak

Output current through speaker is $14.14/4 = 3.53A$ RMS or 5A peak

The power supply must be +/- 20v constant but we must include the inevitable losses in the output transistors as they are NOT perfect switches so +/- 24v will be used.

Since we must have a constant current in the output transistors of 3.53A RMS or 5A peak and the power supply is perfectly regulated to maintain +/- 24v the dissipation in the output stage UNDER IDLE conditions is $48 \times 5 = 240$ watts (we must use the whole value of the power supply as both devices are conducting all of the time)- and this is ONLY ONE channel. A stereo amplifier shall dissipate 480 watts! The problem becomes worse if we design for a loudspeaker which is nominally 4 ohms but dips to say 2 ohms (not unusual).....well be my guest and double the above dissipation numbers only because into 2 ohms the peak current is 10 amperes.

So any company who claims to have a pure class A amplifier for mobile use of more than a few watts per channel (and I have never heard of any company offering a 2 watt/channel car amplifier) is telling a tall story. **The idling current of this 50w/ch amplifier optimized just for 4 ohm loads would be $480/12 = 40$ amperes** and this does not include any power supply efficiency calculations. Typically one can add 10-15% for power supply inefficiency. So the package efficiency is $100/552 = 18.1\%$ not exactly conducive to long battery life!

There are amplifiers where the idling current is reduced and so at higher power levels the amplifier does switch to a class B type.

Another problem with Class A amplifiers is that their CMRR (Common Mode Rejection Ratio) is poor. The CMRR is a measurement of how effectively an amplifier rejects noise or ripple on the power supply rail(s). A typical class B amplifier has a CMRR of over 80dB whilst a class A amplifier is 30-40dB worse. Due to the very high idling current, a class A amplifier's power supply has a few volts of ripple, whilst a class B amplifier which has very low idling current has a power supply with millivolts of ripple. The class A amplifiers noise can be improved by using an electronic regulator which filters out most of the power supply noise BUT to use these the power supply voltage pre-regulator must be higher. So in our example above the power supply could be as high as +/- 30v. Dissipation (including the regulators) is now $60 \times 5 = 300$ watts and make two channels and this is 600 watts and then add in the power supply inefficiency and we have 690 watts. Efficiency is now $50 + 50 / 690 = 14.5\%$wow we now have a 50w/ch amplifier idling at 57.5 amperes. One more bombshell, at idling the amplifier's efficiency is 0%, a big fat zip. Why well the output is zero and $0 / 690 = 0$. As the power increases, efficiency will rise. At 3 watts per channel efficiency is 0.87%!

Now for class B amplifiers

Class B amplifiers by definition have zero dissipation in the output stages at idle BUT all amplifiers for audio are designated A-B. The reason we introduce a small amount of idling current in the output transistors in order to get rid of crossover distortion. This current in an amplifier of say 100 watts is typically 30-70mA. Let us use the same numbers as in the class A example.

Power supply is +/-24v.

Load is 4 ohms.

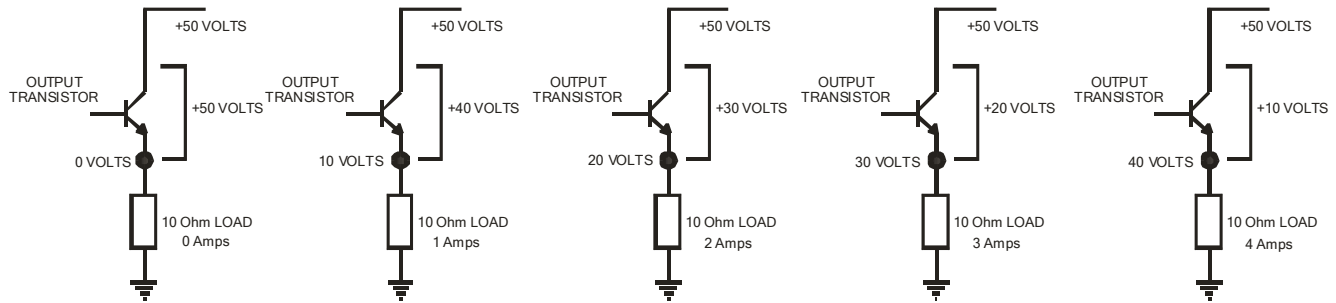
Output voltage is 14.14v

RMS current in load is 3.53A or 5A peak or 3.18A average current.

Since the amplifier is a push-pull design (all class B amps are) we only consider half the power supply voltage. So $3.13 \times 24 = 76.32$ watts and we get 50 watts out of it. Efficiency is 65.5%. If the output transistors were perfect switches the efficiency would be 78%.

The efficiency of a class B amplifier changes with output power. Let's examine a simple example. Let's say we have a power supply of +/- 50v. We also have a 10 ohm load (easy for calculation). Let's assume the output moves 10 volts positive. Then 20 volts until it reaches the rail of 50 volts. The output transistors are perfect for this example, NO LOSSES.

Output voltage	Output current	Voltage left	Dissipation in the
amps		Across the	output transistor in watts
Output transistor			
0	0	50	0
10	1	40	$40 \times 1 = 40$
20	2	30	$30 \times 2 = 60$
30	3	20	$20 \times 3 = 60$
40	4	10	$10 \times 4 = 40$
50	5	0	$0 \times 5 = 0$



So as you can see the dissipation in the output transistors increase to a peak and then decrease. If we did this volt by volt maximum dissipation in the output transistors would be at 44% of absolute unclipped power.

The class A-B amplifiers we use and talk about are operating in class A mode only to extremely low power levels. Let's see what's happening. The 50w/ch amplifier is set to idle at say 50mA (0.05 amperes) and we have a 4 ohm load. Remember Ohm's Law. $I \times I \times R = \text{Power}$. $0.05 \times 0.05 \times 4 = 0.01$ watts. Yes 0.01 watts or 10mW. A typical 50 watt amplifier runs in class A up to TEN THOUSANDTHS OF A WATT, NO MORE NO LESS.

Lastly **Class D** (PWM) amplifiers.

This type of amplifier uses MOSFETS as switches. A high frequency carrier is mixed with the audio signal and the output Mosfets are on or off depending on the average level of the audio signal. Simply put when a positive pulse of audio exceeds the absolute value of the carrier, then the positive Mosfet turns on. This action happens at the frequency of the carrier (Typically > 100KHz). A low pass filter removes the carrier from the signal to be applied to the speaker and what is left is amplifies audio. There are numerous ways of achieving this result but at the end of the day the Low Pass filter must be used to remove the high frequency carrier. Class D amplifiers for low frequencies are fine but in our opinion they kind of suck for full range. Due to the fact that the output Mosfets are either on or off, there are much smaller losses than their analog counterparts. Efficiencies as high as 95% are attainable but typically 80-90% is practical and this varies with output power and load. The higher the power, the higher the efficiency, the lower the load, the lower the efficiency. The efficiency numbers manufacturers quote are those at maximum output into the highest impedance (4 ohms?) but this is misleading since who can play their amplifier at maximum power?

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