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500W subwoofer design using Class D technology

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With active subwoofers demanding typical power levels up to 500W, building the amplifiers to meet the requirement is not without difficulty. Consider using a 50% efficient Class AB amplifier, and it's not hard to imagine a power source that generates masses of heat, is very large, heavy and prohibitive in cost.

While Class D amplifiers certainly help, by increasing efficiency levels up to the 90% mark, the fact they are generally deployed in an open loop mode means that other performance constraints impinge.

In open loop mode, any noise that's generated by the power supply will influence what you hear – there is no supply rejection. This means that the Class D supply, though smaller than that of the Class AB design, has to be well regulated and low in output impedance – and is therefore expensive. Furthermore, to maintain very low distortion and noise (THD+N), attention must be paid to bridge design. Care must be taken in dead time control to balance distortion with dissipation in the bridge.

Consider then a closed loop Class D amplifier. It can be shown that the addition of a feedback loop has a very positive influence on the performance of our 500W subwoofer and greatly simplifies the design process.

For the power supply, a basic switcher can now be used - or an unregulated supply - so long as it's capable of delivering the requisite volts and amps. In this case 500W driving 4Ω requires a ±35V supply with a peak capacity of 17.5A.

The feedback also assists with balancing distortion and dissipation in the bridge. In Class D amplifiers a certain amount of cross conduction is allowed in the bridge, the more cross conduction allowed, the lower the distortion but the higher the dissipation. Feedback reduces the distortion level to such a degree that cross conduction can be significantly reduced, resulting in cool running and an exceptional THD+N performance (Figure 1).

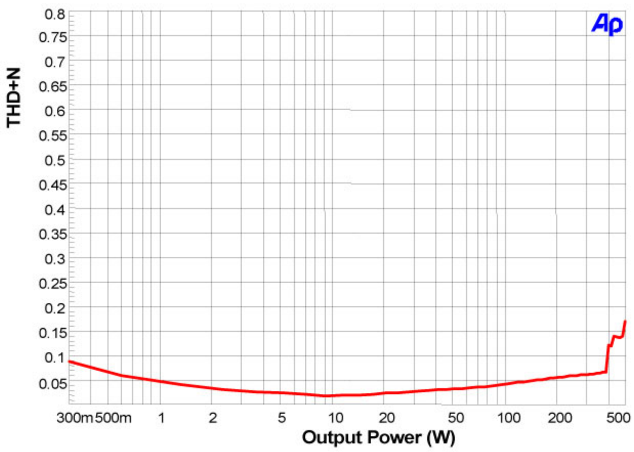

Figure 1. THD+N up to 500W

The design's 90% efficiency implies dissipation in the amplifier of around 50W, mostly in the bridge components. Assuming an ambient temperature of 40°C inside the subwoofer and a maximum operating temperature of 85°C, then we need a heatsink capacity of around 1°C/W. In practice the power content of music is never continuous so a smaller heatsink is sufficient.

Figure 2 shows the architecture of the feedback design. It's worthwhile noting that while this implementation delivers 500W into 4Ω, the output stage is scalable and so, with appropriate supply rail modification, the design can be adapted to a wide range of output powers and load impedances.

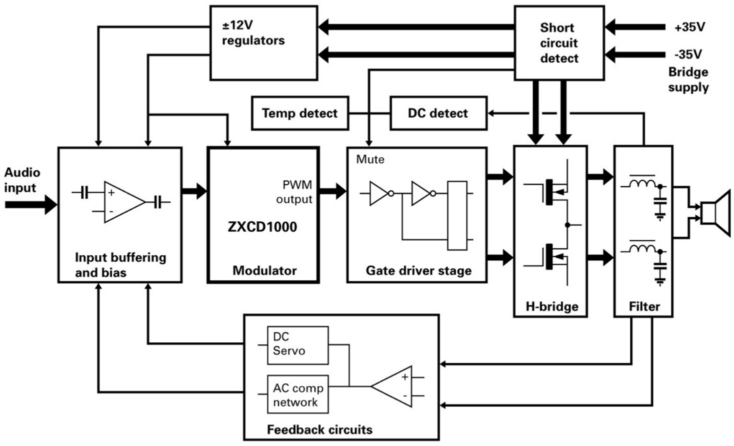

Figure 2. Amplifier schematic diagram

A single ended input signal is buffered into the ZXCD1000 modulator. The buffering is provided by an AD8512 which enables the level shift and gain control required as well as providing the summing point for the feedback signal.

The signal is AC coupled into the buffer and a low pass filter sets the cut off frequency for the amplifier. The frequency response is set to be flat up to 250Hz, with a -3dB point at around 5kHz (Figure 3).

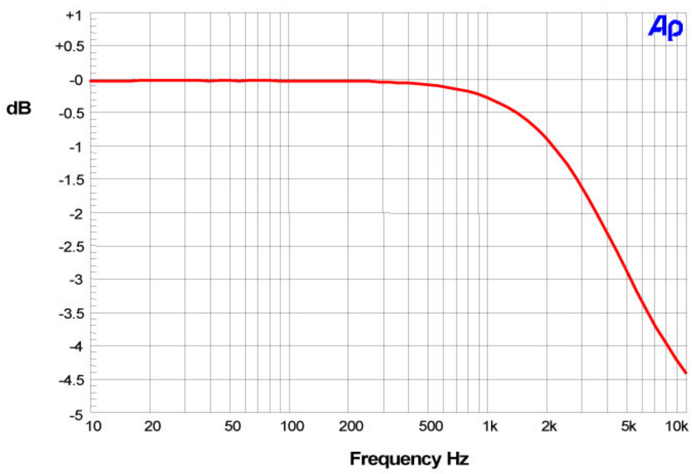

Figure 3. Amplifier frequency response

At the heart of the design, the ZXCD1000 modulator converts the analog audio input to a PWM output to drive the power bridge. The device works by comparing the audio signal to a precise 200kHz triangular wave, producing an accurate pulse width modulated signal.

The resultant signal is applied to a conditioning gate drive circuit, which generates the signals suitable for driving the bridge while preserving fast, well controlled switching edges.

An HIP4081A gate driver generates the switching waveforms to drive the all N-channel H-bridge based on FDP3682 MOSFETs. These TO220 devices are chosen for their combination of current handling, low on-resistance, and high switching speed. Dead time control is achieved with simple discrete components that affect the balance between distortion and dissipation.

A specially designed filter recovers the audio signal before delivery to the speaker. The iron powder distributed air gap inductors used are highly linear and are chosen not to saturate at the highest levels of drive current. The capacitors used are RF quality components.

The feedback is taken after the filters. This means that compensation is achieved for bridge mismatches, inconsistencies in the filters and for any power supply errors.

One additional benefit of the feedback loop is a reduction in amplifier output impedance. This results in the superior damping factor of the circuit, around 285, a characteristic more often associated with linear amplifiers.

A second AD8512, generates the compensation signal in the feedback loop. The signal is first attenuated to a level appropriate to the input signal amplitude and then follows two paths for DC and AC compensation.

The signal is integrated by a DC servo amplifier which compensates for any DC offsets generated through the system, assisting with anti-pop issues and eliminating standing current through the speaker.

The AC signal is conditioned and fed back into the input amplifier. Selection of the conditioning components is critical to loop stability and greatly benefits from initial computer simulations before final implementation.

The design provides short circuit, DC and thermal protection. A mute/soft start circuit provides anti-pop at start-up, while anti-pop at power down is assured by subsidiary regulators.

The final result is a compact high performance Class D amplifier which can be easily implemented in any active subwoofer. The feedback architecture not only ensures good quality audio but also reduces the demands on peripheral circuits to such a degree that the final solution is highly cost effective.

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