ANALOG edge℠

Dealing with EMI in Class D Audio Applications

Application Note AN-1737

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EMI – The Basics

Electromagnetic Interference (EMI) is an unwanted disturbance caused in an electrical circuit by electromagnetic radiation emitted from an external source. EMI encompasses two aspects. Emissions refer to the scope to which equipment generates radiated noise. Susceptibility is the scope to which equipment is affected by emissions generated from other electromagnetic waves. The degree to which the designer controls unintended emissions may make the task of susceptibility easier. In order to understand emissions, it is important to understand antennas. *Figure 1* below shows the well-known physical relationship between wavelength and frequency:

$$\lambda = \frac{Velocity \;\; of \;\; Light}{Frequency \; x \sqrt{\epsilon_r}} = \frac{300}{f\,(MHz) \; x \sqrt{\epsilon_r}}$$

ϵ_r is the relative permittivity

Figure 1. Wavelength as a Function of Frequency

The shortest length required to be an efficient antenna is λ/4. In the case of air, permittivity is 1, but in the case of FR4 or glass-epoxy PCBs, permittivity is reduced to approximately 4.8. The effect causes a signal traveling a trace to slow once it reaches the dielectric gradient created by the FR4 material, causing essentially, a "wavelength-shortening" effect. For example:

A 200 MHz signal has a quarter wavelength in air of 16.7 cm.

In an inner-layer PCB trace, it is: $16.7/4.8^{(1/2)} = 7.6$ cm.

A PCB trace can act as an unintentional antenna even at lengths shorter than λ/4, increasing both emissions and susceptibility. Surface traces also exhibit this wavelength-shortening effect, as one side of the dielectric serves to change the overall permittivity of the transmission.

Unintended antennas, such as PCB traces, are the key culprit behind radiated noise in digital systems. As we will see, the Class D audio amplifier is, in essence, a digital system from the perspective of radiated emissions. Unintended antennas in circuit boards can include long traces, vias, leads, and unpopulated PCB connectors or headers.

The Class D Audio Amplifier

The Class D audio amplifier has emerged as a popular topology for the consumer market due to its high efficiency. It modulates a high-frequency square wave by the incoming analog signal. A low-pass filter, typically a 2-pole Butterworth, is used to filter the high-frequency content and recover the original audio signal. In "filterless" topologies, the inductance of the speaker itself is incorporated as part of the filter. One common Class D topology, Pulse Width Modulation (PWM), uses a fixed-frequency waveform and changes the duty cycle to create a moving average of the signal after a low-pass filter, as seen in ***Figure 2.***

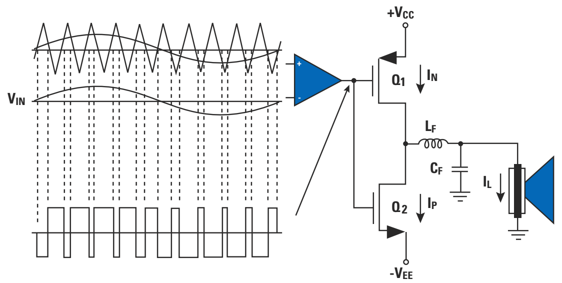

Figure 2. The Class D Audio Amplifier PWM

The benefits of a switching topology are apparent – high efficiency, low-power consumption, and small thermal designs. But increased efficiency is not without cost. In order to drive efficiencies up, a sharp rapidly-switching square wave is required. This can lead to the same undesirable artifacts that are present in digital systems, as the spectral energy is highly concentrated on the edges of the square wave.

Countering EMI

To counter EMI, it is essential to include PCB floor planning as part of the circuit design. General PCB guidelines for dealing with EMI include:

- Appropriate placement of decoupling capacitors between power and ground
- Avoidance of traces cut within ground or power planes
- Adequate termination of all high-frequency clock lines
- Proper filtering of PCB connectors
- Avoid loop antennas

Optimally, you will stop radiation by suppressing the source of current that is feeding the antenna.

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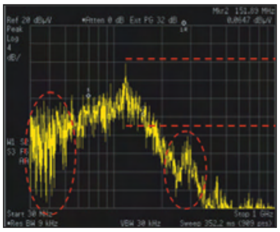
For the audio designer, it is important to consider the following:

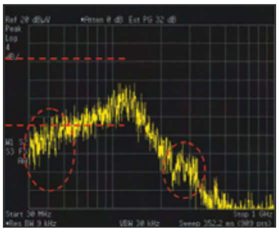
- Keep traces from the audio amplifier to the speaker as short as possible. Traces and wires act as antennas with significant radiation occurring once the length reaches λ/4
- For filterless Class D systems, the trace and wire connecting the amplifier's output to the speakers will likely be the largest source of emissions

The practice of placing ferrite beads in series with the loudspeakers close to the amplifier can be effective. Regarding EMI suppression purposes, ferrite beads act as resistors, but because $R_{DC} = 0$, there is no DC voltage drop. This makes them useful in cases where frequencies of interest are significantly below 1 MHz. Also, it is important to under- stand that the ferrite bead is effective when considered part of a two-element voltage divider. The ferrite will usually serve as the series element, and the shunt element is a capacitance – either a physical capacitance or a lumped capacitance. The transfer function indicates the system will be damped to the extent that resonance effects are significantly diminished.

The primary difficulty with periodic square waves inherent in Class D is the concentration of energy at the harmonic intervals. In the push to create a "quiet" low-EMI Class D amplifier, one approach is to spread the spectrum of the switching so the energy at any one point in the spectrum is reduced. Efficiency and low THD+N are maintained, but radiated noise and EMI can be significantly reduced, as seen in ***Figure 3***.



Fixed-Frequency



Spread-Spectrum

Figure 3. Comparison of Fixed-Frequency and Spread-Spectrum Modulation

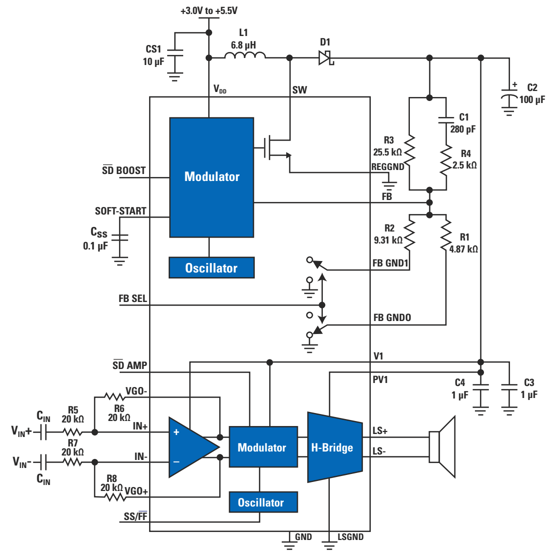


Figure 4. LM48511 – A Spread-Spectrum Modulated Class D Amplifier

The LM48511 is a spread-spectrum modulated Class D audio amplifier. It also includes a built-in boost regulator, which drives the supply voltage to 7V, increasing amplifier output power and the audio-sound pressure level compared to an unboosted amplifier. The boost regulator allows the amplifier to maintain a constant output level, even when powered from a decaying voltage source such as a battery.

The LM48511 amplifier features a logic-selectable, spread-spectrum modulator that reduces EMI, eliminating the need for output filters or chokes. As shown in ***Figure 4***, the spread-spectrum modulator feeds a standard H-bridge which drives the bridge-tied load speaker. In spread-spectrum mode, the switching frequency varies randomly by 10% around a 330 kHz center frequency, decreasing EMI emissions radiated by the speaker and associated cables and traces.

Electromagnetic interference is a system-level concern, and it is essential for today's audio engineer to design with EMI in mind, including the best possible design practices and judicious choice of components and materials.

For an expanded version of this article as well as additional reference information, please visit: edge.national.com ■

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