Texas Instruments

Developer's Guide

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Class-D Output Snubber Design Guide

The design for a class-D audio system sometimes requires a snubber circuit on the output. This design guide includes what a snubber circuit does and how to design one if needed.

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1 What Is an Output Snubber?

An output snubber is an RC network placed at the output of a switching audio amplifier. The snubber dampens any ringing or overshoot on the PWM output waveform. The stray inductance in the IC leads, IC bond wires, and PCB traces causes the overshoot and ringing. Having an output snubber provides a low-impedance drainage path to ground for the energy stored in these inductances. Without a provided path, the stored current finds a path through parasitic capacitance on the PCB and causes the overshoot and ringing.

2 System-Level Impact of Ringing and Overshoot

Overshoot can stress the output MOSFETs of a class-D device by overvoltage. The overshoot and ringing are also potential sources of EMI. The snubber also improves the total harmonic distortion (THD) of the amplifier. The overshoot and ringing at the output are present in the feedback signal to the amplifier. The amplifier must then try to eliminate this overshoot and ringing from the signal. The amplifier cannot completely remove this signal, which is then present on the output as distortion.

3 Designing an Output Snubber

To design the proper output snubber, measure the voltage spike at the output pin. Use Section 4 in *Voltage Spike Measurement Technique and Specification*, SLEA025, as a reference in performing this measurement.

Figure 1 shows the basic output circuit. Inclusion of a bypass capacitor, $C_{(BYPASS)}$, is necessary in the design because it is part of the current path for snubbing the inductance of the high-side FET. The terminals of $C_{(BYPASS)}$ must be close to the power pins and the ground pins of the IC. $R_{(x)}$ and $C_{(x)}$ should be close to the output pin and the ground pins of the IC. This is necessary to reduce the series inductance of the PCB traces. Figure 1 has labels of *High-side FET current-loop* and *Low-side FET current-loop* for the current loops formed by $R_{(x)}$ and $C_{(x)}$. If $R_{(x)}$ and $C_{(x)}$ are not present, the current stored in the drain, source, and lead inductances has no place to sink during dead time. This current then flows through parasitic capacitances on the PCB and appears on the waveform as ringing. Good control of the high-side and low-side current loops is necessary for good protection from overvoltage spikes and for good EMI results.

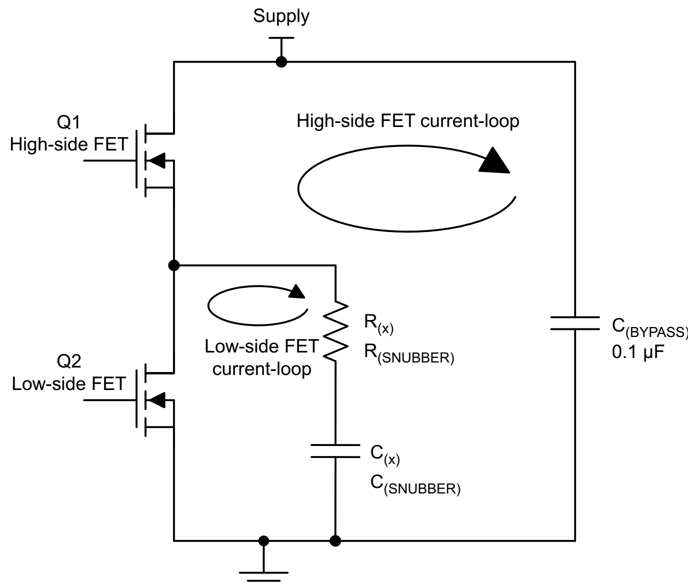

Figure 1. One-Half of the Typical H-Bridge Output Stage With Snubbers

For $R_{(x)}$ start with a value of 10 Ω and use a surface-mounted device (SMD) to keep the series inductance (ESL) low. For $C_{(x)}$ select a small value of 470 pF to 1000 pF, and also an SMD. Use the techniques listed in SLEA025 to measure the spike and the associated ringing. Measure the frequency of the ringing. If there is no ringing, use a higher value resistor for $R_{(x)}$ or a smaller capacitor for $C_{(x)}$. The final $C_{(x)}$ should be labeled as $C_{(1)}$ and the ringing frequency is $f_{(1)}$.

Change $C_{(x)}$ to a value that is about 1.5 to 2 times the previous value. Keep $R_{(x)}$ the same. Again, measure the frequency of the ringing on the waveform. If no ringing is available to measure, change $C_{(x)}$ to a slightly smaller value. Label the value of $C_{(x)}$ as $C_{(2)}$ and the ringing frequency as $f_{(2)}$.

Use Equation 1 to calculate the value for L.

$$L = \left[\frac{1}{(C_{(2)} - C_{(1)}) \times 4 \times \pi^2}\right]\left[\frac{1}{f_{(2)}^2} - \frac{1}{f_{(1)}^2}\right] \quad (1)$$

where L is the value of the stray inductance that requires snubbing.

L is a bulk inductance and is not any individual inductance.

Find the appropriate values of $C_{(x)}$ and $R_{(x)}$. Use Equation 2 to calculate the appropriate $R_{(x)}$.

$$R_{(x)} = 2 \times \pi \times f_{(x)} \times L \quad (2)$$

The ringing frequency $f_{(x)}$ is for a given $C_{(x)}$. If the application is to use $C_{(1)}$ for the snubber capacitor then use $f_{(1)}$ in the equation to calculate the proper $R_{(x)}$ (or use $C_{(2)}$ and $f_{(2)}$).

To account for tolerances and differences in production units, use a value that is 0.7 to 0.8 of the calculated $R_{(x)}$. Too high a value for $R_{(x)}$ could allow for a spike, but too low a value for $R_{(x)}$ could cause the snubber to draw excessive current and overheat. Use Equation 3 to calculate the power loss in the resistor.

$$P = C_{(x)} \times V^2 \times f_{(S)} \quad (3)$$

where:

- V is the supply voltage
- $f_{(S)}$ is the switching frequency

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