

Application Note

How to Decrease the Acoustic Noise on LED Drivers



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Abstract

Due to the excellent stability and low cost feature, global dimming LED drivers are widely used in automotive displays and HUDs. The LP886x-Q1 series is a mature design in the market because of its large dimming ratio and system stability. However, due to varying requirements for LED current and dimming ratios in different applications, acoustic noise can occur in practical implementations. This document primarily discusses the causes of such noise and presents corresponding designs to decrease noise.

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1 Introduction

LED driver modules always contains batteries, LED drivers and LEDs. In auto market, most batteries are based on 12V systems and the voltage ranges from 9V to 16V. The output voltage ranges from 25V to 45V. Therefore, most LED drivers are using BOOST topology. Nowadays, more display modules are implemented in cars, such as cluster, center information display, rear seat display and head-up displays. The size of these displays becomes larger. This requires more LEDs integrated, which leads to higher output voltage. When the output voltage increases, it requires higher loop stability and system stability for the whole system.

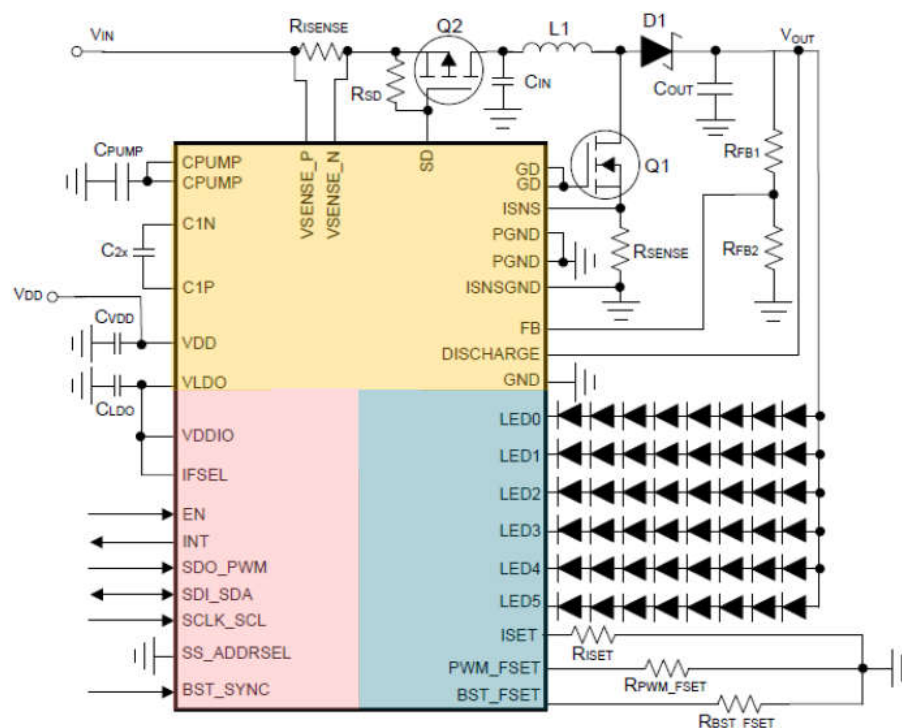


Figure 1-1. LED Driver Block Diagram

Sometimes the customer can hear noise when the LED driver is running. The larger the output current, the louder the noise. The acoustic noise phenomenon observed in multi-layer ceramic capacitors (MLCCs) is primarily attributed to the piezoelectric effect inherent in ceramic materials. Owing to the distinctive multi-layer ceramic construction, MLCCs exhibit proportional mechanical stress variations when subjected to time-varying electric fields across the terminals. When the resultant vibration frequency falls within the human audible range (20Hz–20kHz), acoustic emissions manifest as acoustic noise.

The acoustic noise emitted by inductors primarily arises from magnetostriction: when subjected to high-frequency alternating currents, the core material undergoes periodic microscopic strain under the time-varying magnetic field, inducing mechanical vibration. This vibration couples with the surrounding structure and air, generating acoustic waves. This phenomenon, distinct from piezoelectricity, constitutes a parasitic magneto-mechanical energy conversion, commonly observed in circuits with pulsed currents such as an LED driver circuit.

Acoustic noise in LED drivers poses significant challenges in modern lighting systems. These issues arise from switching operations, magnetic components, and poor circuit design. Excessive noise not only compromises electromagnetic compatibility (EMC) but also degrades user experience and system reliability. To address these challenges, engineers must adopt a holistic approach combining schematic design and PCB layout optimization. This article explores strategies to mitigate noise at both stages, verifying compliance with industry standards and enhancing performance.

In summary, this application note is a design guide for users to decrease the noise on LED drivers.

2 Inductor Acoustic Noise and Designs

Identifying acoustic noise sources is essential. In LED drivers, the two main types are inductor-generated and capacitor-generated noise. To determine which component generates the acoustic noise, a simple method can be used: use a long solid object (such as a pencil), place one end against the inductor, and hold the other end against your ear. If noise is detected through the pencil, the inductor is the noise source.

Once the noise source is confirmed as the inductor, measure the SW node waveform and the inductor current waveform. Typically, frequency components within the 20Hz to 20kHz acoustic range can be observed in these waveforms.

Several factors can contribute to inductor acoustic noise, including a discrepancy between the inductance value and design specifications, insufficient inductor saturation current, excessive input-output voltage differential, and loop instability. Upon identification of the inductor exhibiting acoustic noise, the current waveform may be measured utilizing a current probe.

Inappropriate inductor selection can contribute to acoustic noise. As shown in Figure 2-1, the detection of periodic spikes in the inductor current waveform is indicative of inductor saturation-induced anomalies, which subsequently result in acoustic noise generation. To mitigate this phenomenon, replacement with an inductor exhibiting an elevated saturation current is recommended, which prevents complications associated with saturation effects.



Figure 2-1. Inductor Current Waveform With Spikes (Green)

The observation of periodic dropout in the inductor current waveform can be attributed to output overvoltage or an excessive input-output voltage differential, leading to the device's inability to sustain output regulation under fixed switching frequency conditions. To address this phenomenon, it is recommended to increase the input voltage or reduce the switching frequency, thereby verifying stable output voltage regulation.

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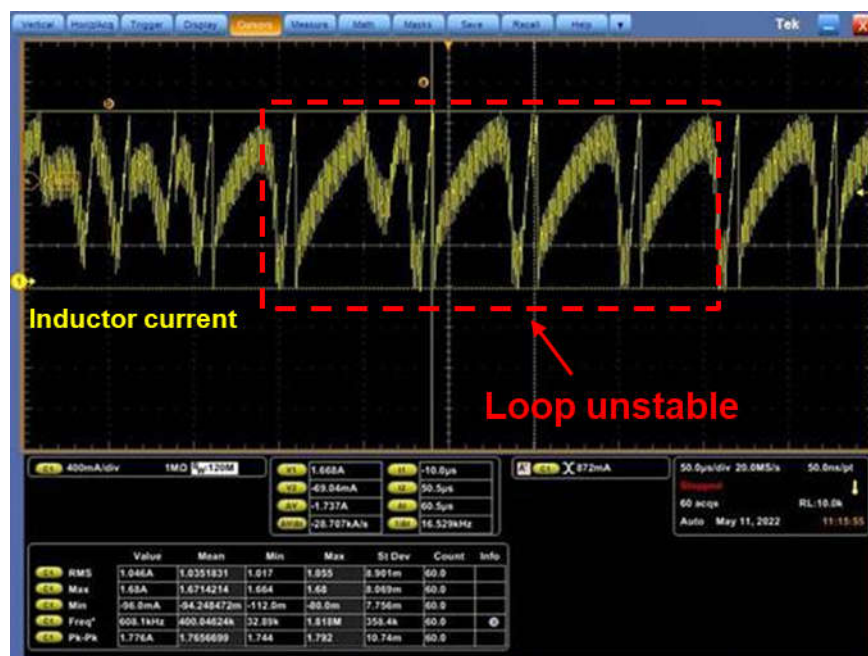


Figure 2-2. Title Here

As depicted in , the inductor current waveform exhibits unstable characteristics, with low-frequency ripple components coupled into the switching frequency, resulting in acoustic noise emission from the inductor. At this juncture, the schematic design should be systematically examined with particular attention to loop compensation parameters. All TI LED drivers are typically accompanied by proprietary calculation files, which enable preliminary verification of loop response characteristics, as demonstrated in Figure 2-3.

Cout_effective_actual	20	uF	
Gain Margin Gap	6.0	dB	If gap > 3dB, external compensation is recommended
External compensation used	Yes		
Recommended R4 (FB)	162.0	kOhm	
Recommended C _{comp} (FB)	96.1	nF	
R4_actual	162	kOhm	
C _{comp} _actual	100	nF	
Pole_C _{COMP}	6.7	Hz	Recommend In the range of 1~10Hz
Gain Margin Gap_actual	2.7	dB	Recommend the range of +/-3dB

Figure 2-3. LP8866-Q1 Calculation File

In BOOST switching converter configurations, the phase margin should generally exceed 45 degrees while maintaining a gain margin above 10 dB. Additionally, the crossover frequency is required to surpass 1 kHz as a minimum specification. Loop response conducted on the LED driver circuit shown in Figure 2-4 revealed a phase margin of less than 45 degrees, which fails to satisfy the specified design requirements. Following iterative optimization of the loop compensation network, the recalculated loop response parameters are shown in Figure 2-5.

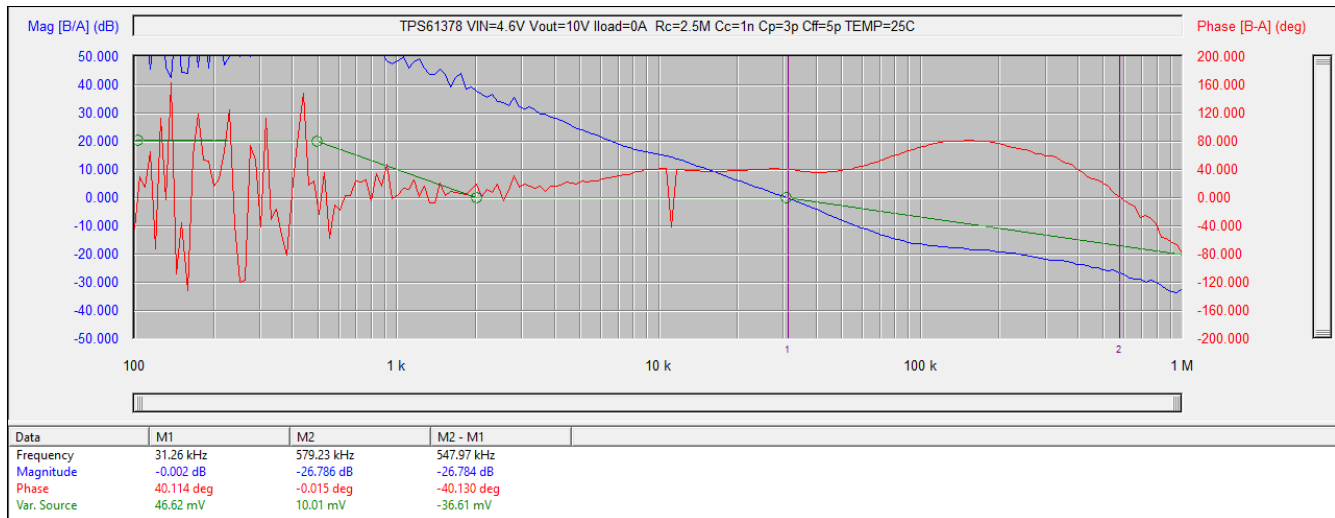


Figure 2-4. Loop Response Result for Unstable Loop (Phase Margin = 40 Degrees)

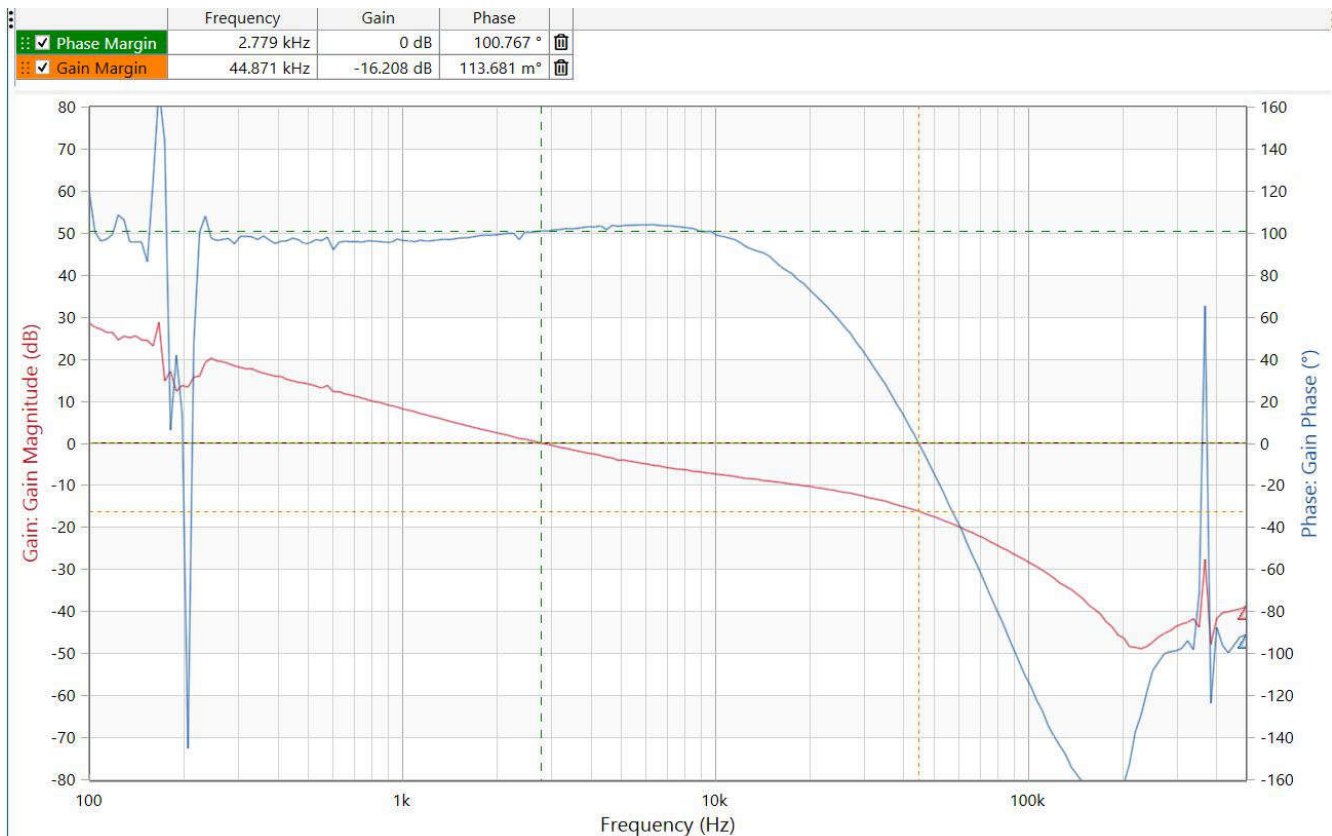


Figure 2-5. Loop Response Result for Stable Loop (Phase Margin = 100 Degrees)

Furthermore, inappropriate component selection constitutes an additional potential noise source. Particular attention must be paid to thermal characteristics of inductive components, as certain ferrite core materials exhibit significant parameter drift across operational temperature ranges, which can precipitate instability under varying thermal conditions.

For comprehensive validation, full-load testing across specified temperature profiles must be conducted, with particular emphasis on low-temperature characterization. This procedure verifies that loop stability margins remain within acceptable bounds throughout the entire operational temperature range. Deviations observed during thermal cycling must be systematically addressed through iterative compensation network adjustments.

3 Capacitor Acoustic Noise and Solutions

In LED driver circuits, capacitor acoustic noise is mainly induced by the LED PWM frequency. As listed in [Table 3-1](#), the relationship between LED PWM frequency and dimming resolution for the LP8866-Q1 driver is shown. Theoretically, audible noise can occur when the LED PWM frequency falls within the human-audible range (20Hz to 20kHz). However, in practical implementations, the magnitude of acoustic emissions correlates with multiple factors including output current, dimming mode, PCB layout, and capacitor type. Upon detection of audible capacitor noise, a modest reduction in dimming resolution can be implemented to elevate the LED PWM frequency beyond the audible threshold. Nevertheless, dimming resolution requirements typically impose an upper limit on LED PWM frequency. Subsequent sections addresses mitigation strategies for scenarios where the LED PWM frequency is constrained to a fixed value.

Table 3-1. LED PWM Frequency and Dimming Resolution on LP8866-Q1

R_PWM_FSET (kΩ)	LED PWM Frequency (Hz)	PWM Dimming Resolution (Bits)
3.92	152	16
4.75	305	16
5.76	610	15
7.87	1221	14
11	2441	13
17.8	4883	12
42.2	9766	11
124	19531	10

LED drivers typically offer multiple dimming modes. For LP8866-Q1, three operational modes are available: PWM dimming, analog dimming, and hybrid dimming. Among these, PWM dimming and hybrid dimming are mainly employed in practical applications. As illustrated in [Figure 3-1](#) and [Figure 3-2](#) (where the upper trace represents the PWM input signal and the lower trace depicts the LED current waveform), distinct operational characteristics are observed.

In PWM dimming mode, the LED current waveform strictly follows the input PWM duty cycle, while the switching frequency is determined by the R_PWM_SET resistor configuration. Notably, in high-current applications, piezoelectric effects become more pronounced, thereby increasing susceptibility to audible noise generation.

Conversely, hybrid dimming operates as follows: When the input PWM duty cycle exceeds 12.5%, the LED current maintains a constant value proportional to the input duty cycle. Only when the input duty cycle falls below 12.5% does the system transition to PWM operation at 12.5% of the maximum current. This methodology confers dual advantages: At high currents, the constant-current operation eliminates both audible noise and visible flicker; at low currents, the controlled PWM operation ensures consistent LED luminance while mitigating severe piezoelectric effects inherent in conventional PWM dimming.

The strategic implementation of hybrid dimming thus resolves the fundamental trade-off between noise suppression and dimming precision in LED driver applications. Therefore, upon detection of acoustic noise emissions during PWM dimming operation, implementation of hybrid dimming mode is recommended as a mitigation strategy. Hybrid dimming is the first choice if there is no other concern.

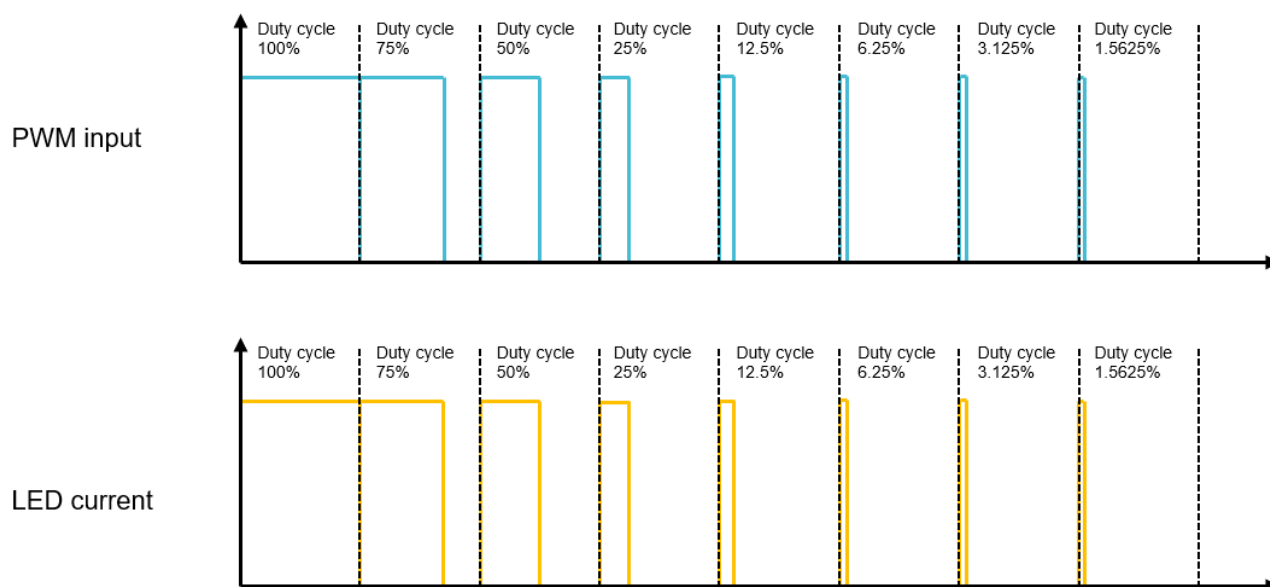


Figure 3-1. LP8866-Q1 PWM Dimming Mode

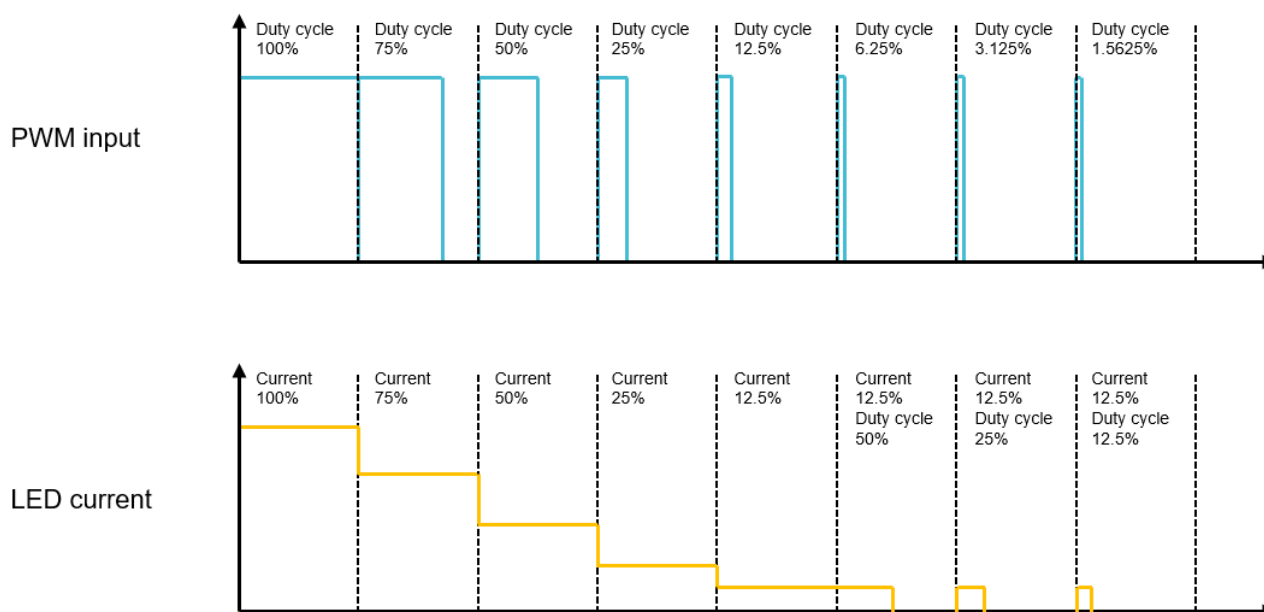


Figure 3-2. LP8866-Q1 Hybrid Dimming Mode

The latest LP8872-Q1 LED driver from Texas Instruments incorporates a proprietary enhanced pulse-width modulation (EPWM) algorithm specifically engineered to attenuate audible noise emissions while maintaining fixed dimming resolution. This innovation is activated via configuration of the EPWM_MODE bit within the device register configuration.

Besides the reason related to the dimming frequency, another possible cause of capacitor audible noise is an excessively high input voltage.

BOOST devices all have a minimum on-time. As the voltage differential between the input and output decreases, the on-time per switching cycle becomes shorter. Once this minimum on-time is triggered, the device maintains output voltage regulation by reducing the switching frequency. This is how PFM works, as shown in [Figure 3-3](#). When the reduced switching frequency falls within the audible range of the human ear, it results in audible noise.

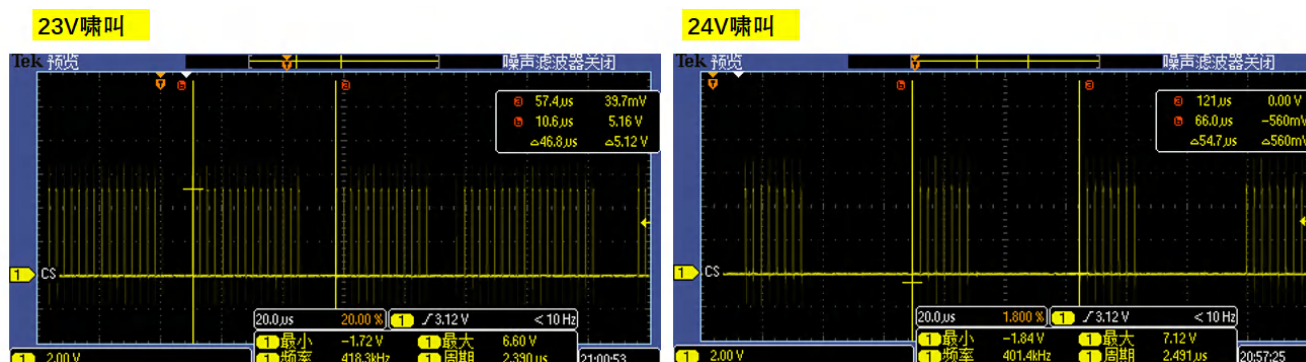


Figure 3-3. Switching Frequency in LP8866-Q1 PFM

In some applications, the input voltage test range is 9–22V. According to the datasheet, the minimum switching time of LP8866-Q1 is 150ns. At a switching frequency of 400kHz and an output voltage of 24V, the maximum input voltage is approximately 21V, which cannot meet the requirement. In this case, LP8872-Q1 can be considered, since its minimum switching time is 60ns, corresponding to a maximum input voltage of approximately 22.5V.

Besides switching to a device with a smaller minimum switching time, the issue can also be addressed by increasing the output voltage. Taking an output voltage of 24V as an example, if the output voltage needs to be increased by 1V, since the LED driver's output is a current source, the resistor can be selected by determining the maximum output current. Assuming each LED channel has a maximum of 90mA, the maximum VLED current for six channels is 540mA, which requires a resistor of approximately two ohms. Considering high-temperature testing and heat dissipation concerns, three 6.8ohm resistors in 1206 package connected in parallel are selected here, as shown in Figure 3-4. If you plan to use this approach, please contact TI technical support and carefully consider the resistor value and package size.

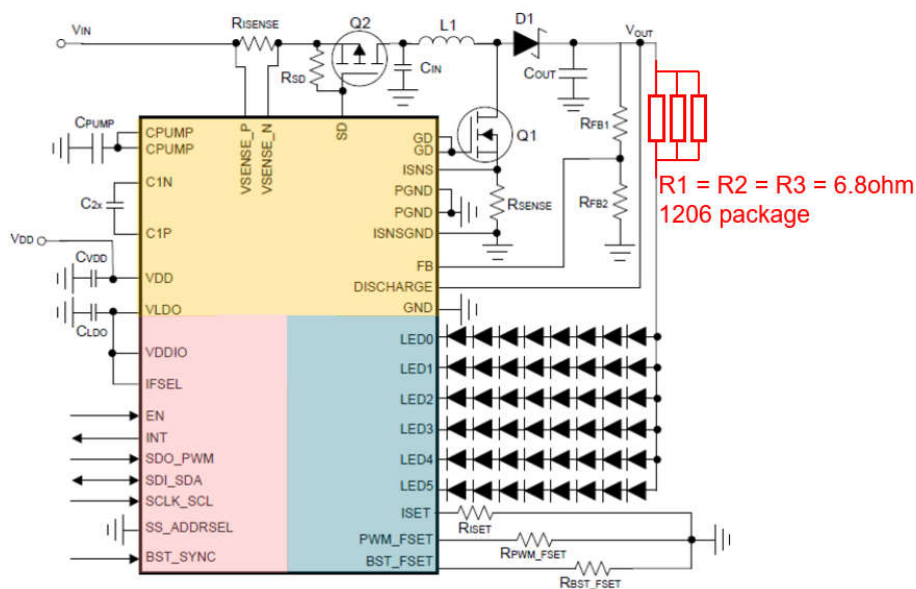


Figure 3-4. External Resistor on VLED

From the layout and capacitor selection side, there are several PCB layout techniques that can effectively mitigate audible noise emissions in LED driver circuits. As illustrated in Figure 3-5, where multiple ceramic capacitors are typically deployed at the driver output stage, an orthogonal placement configuration of adjacent MLCCs is recommended. Specifically, arranging two capacitors at 90° relative orientation attenuates the cumulative piezoelectric effect through counteracting mechanical displacements. This geometric

countermeasure reduces the net vibrational amplitude by inducing opposing strain vectors in the ceramic dielectric layers, thereby suppressing acoustic emissions within the human-audible frequency range.

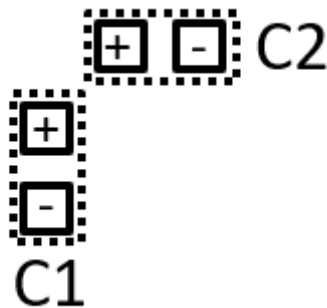


Figure 3-5. Ceramic Capacitors Layout

In PCB layout design, the implementation of symmetric capacitor placement across opposing substrate surfaces constitutes an effective noise suppression strategy. Furthermore, augmentation of the PCB substrate thickness (for example, $\geq 1.6\text{mm}$) is empirically validated to mitigate audible emissions through mass-stiffness modification of the structural resonance profile.

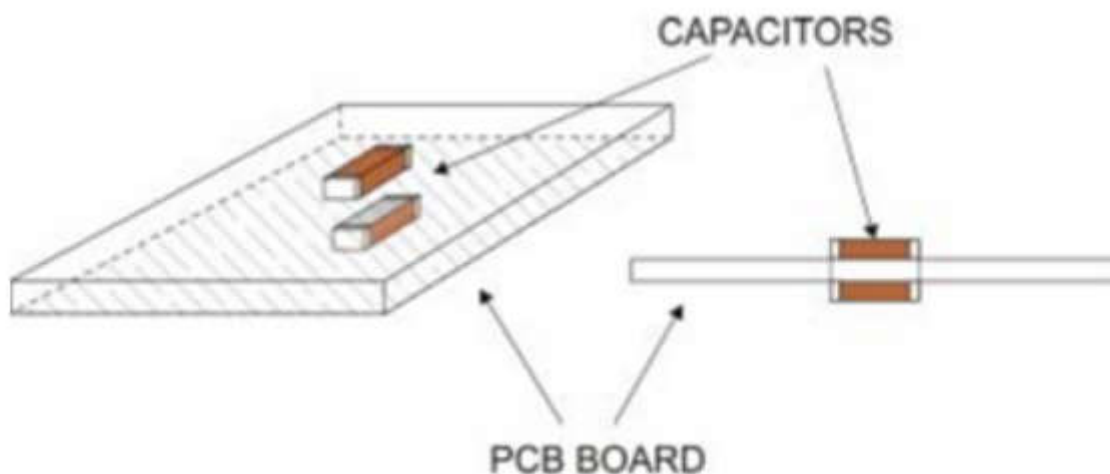


Figure 3-6. Capacitors on Both Sides of PCB

In capacitor selection methodology, audible noise suppression can be achieved through two primary approaches: substitution of ceramic capacitors with electrolytic alternatives, or implementation of specialized ceramic capacitor designs. As depicted in [Figure 3-7](#), engineered multi-layer ceramic capacitors (MLCCs) featuring mechanically isolated mounting configurations exhibit substantially attenuated piezoelectric effects. This attenuation occurs through decoupling of mechanical vibrations from the printed circuit board (PCB) substrate, as the capacitor terminals do not establish direct physical contact with the PCB surface. Consequently, the transmission path for strain-induced acoustic emissions is disrupted, resulting in significantly reduced audible noise generation.

■ TERMINAL ELECTRODE STRUCTURES

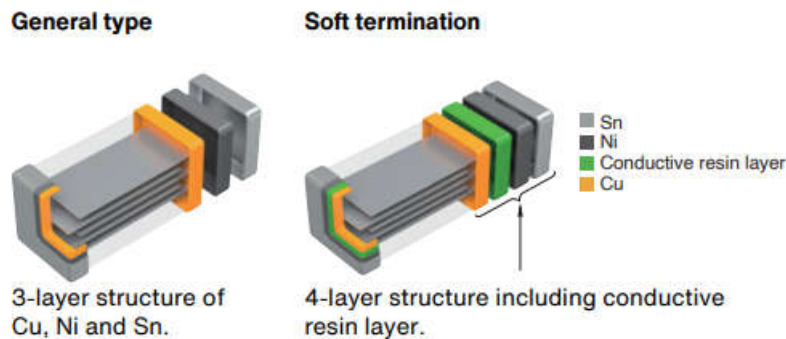


Figure 3-7. Specialized Ceramic Capacitors

Alternatively, strategic replacement of ceramic capacitors with electrolytic counterparts in non-critical decoupling positions can eliminate piezoelectric noise sources entirely, though this approach necessitates careful consideration of equivalent series resistance (ESR) characteristics and lifetime implications. The selection between these methodologies must be informed by rigorous analysis of circuit requirements, thermal constraints, and acoustic performance specifications.

4 Summary

Noise reduction in LED drivers requires a dual focus on schematic design and PCB layout optimization. Key strategies include selecting low-noise components (for example, ferrite cores, SSFM ICs), implementing EMI filters and snubber circuits, and optimizing layout to minimize loop areas and thermal stress. By integrating these practices, engineers can achieve compliant, reliable, and quiet LED driver designs.

5 References

1. Texas Instruments, [LP8866-Q1 Automotive Display LED-backlight Driver with Six 200 mA Channels](#), datasheet.
2. Texas Instruments, [LP8872-Q1 Automotive Display LED-Backlight Driver with Six 150 mA Channels](#), datasheet.
3. Texas Instruments, [How to reduce acoustic noise of MLCCs in power applications](#), technical article.
4. TDK, [TDK - CGA4J1X7R0J106K125AE](#), datasheet.

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