Application Report
SLUA821–March 2017

UCC28880, UCC28881 Audible Noise Reduction Techniques

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1 Introduction

The economical UCC28880 and UCC28881 high voltage switcher/controllers were designed for offline buck converters for low power applications to meet size and cost constraints. These devices use an On/Off control scheme, like many others available today, that could potentially allow the effective switching frequency to drop into the audible band and generate noise. By following the recommended design techniques in this application note for UCC28880 and UCC28881 the problem can be avoided by staying quite over the entire operating range.

2 Functional Schematic

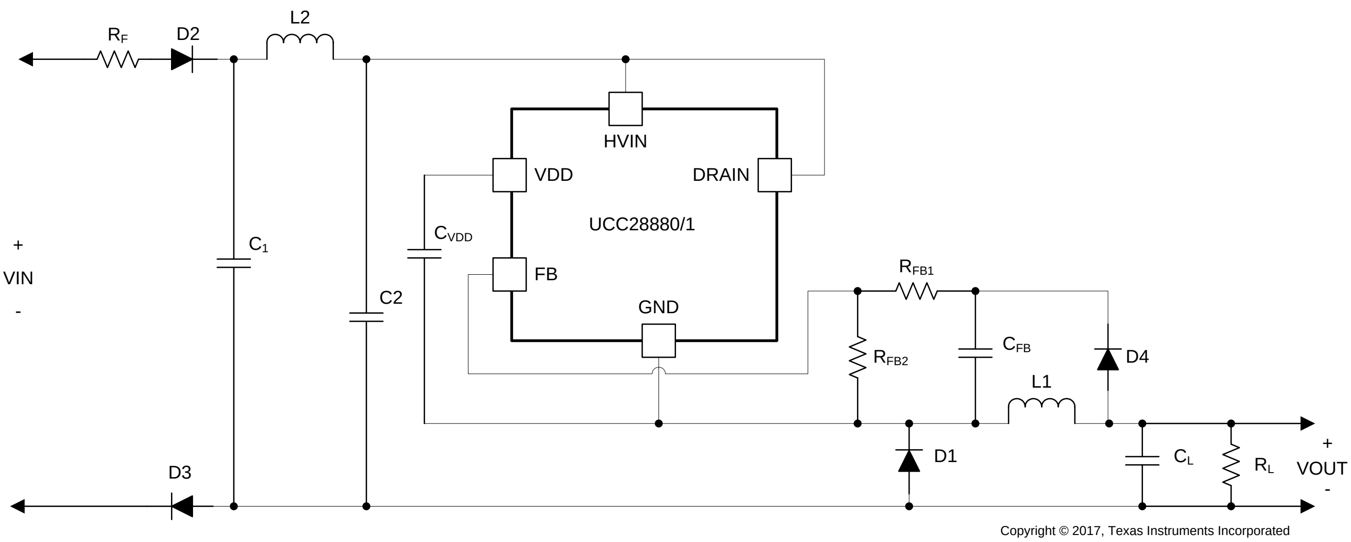

Figure 1. Offline High-Side Buck Converter with On and Off Control

3 Circuit Operation

The UCC28880 and UCC28881 uses what is known as On/Off control. This control scheme samples the output during the freewheeling period through the R_{FB1} and R_{FB1} resistor dividers and when the voltage at the feedback pin is less than 1.02 V it delivers 62-kHz of pulse width modulated (PWM) packets to maintain the output voltage. The PWM packets are controlled by peak current mode control.

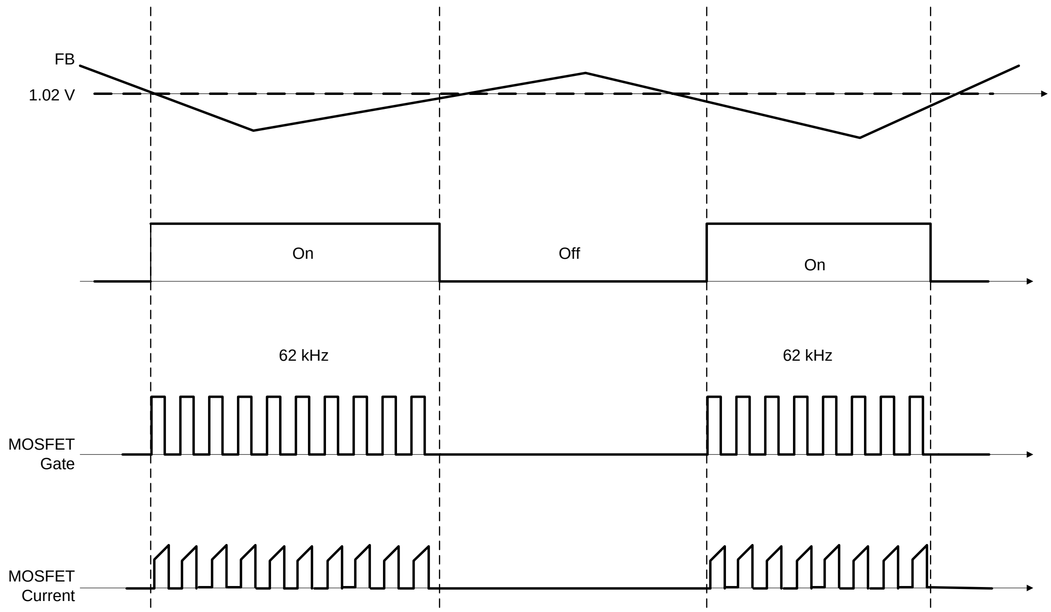

Figure 2. On/Off Control Diagram

The output inductor (L_1) is sized based on internal peak current limit (I_{LIMIT}), output current (I_{OUT}) and PWM switching frequency of typically 62 kHz. The inductor selected should as close to the calculated value as possible.

Table 1. UCC28880 I_{LIMIT} Specification

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{LIMIT}	Current limit	Static, –40°C			300	mA
		Static, 25°C	170	210	260	mA
		Static, 125°C	140			mA

Table 2. UCC28881 I_{LIMIT} Specification

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{LIMIT}	Current limit	Static, –40°C			630	mA
		Static, 25°C	330	440	570	mA
		Static, 125°C	315			mA

NOTE: V_{HVIN} = 30 V, $T_A = T_J$ = –40 °C to 125°C in Table 1 and Table 2.

$$I_{OUT} < 0.9 \times I_{LIMIT} \tag{1}$$

$$L_1 = \frac{V_{OUT} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}{2 \times \left(I_{LIMIT} - I_{OUT}\right) \times 62\,kHz} \tag{2}$$

Resistors R_{FB1} and R_{FB1} are also used to adjust the output voltage and capacitor C_{FB} is used to set PWM packet timing (t_{FB}). The initial t_{FB} is set to 1/10th the product of the output capacitance (C_L) and load impedance (R_L) and then will be fine-tuned based on actual circuit performance.

$$t_{FB} = (R_{FB1} + R_{FB2}) \times C_{FB} = C_L \times R_L \times 0.1 \quad (3)$$

Control Methodology will operate in the Audible Range (<20 kHz).

Due to variations in peak current (I_{LIMIT}) at maximum load the effective switching frequency will vary from 62 kHz down to 31 kHz. As the load decreases below 80% the converter can and will enter the audible range (<20 kHz) The output ripple voltage and inductor ripple current will look similar to Figure 3 as the load decreases.

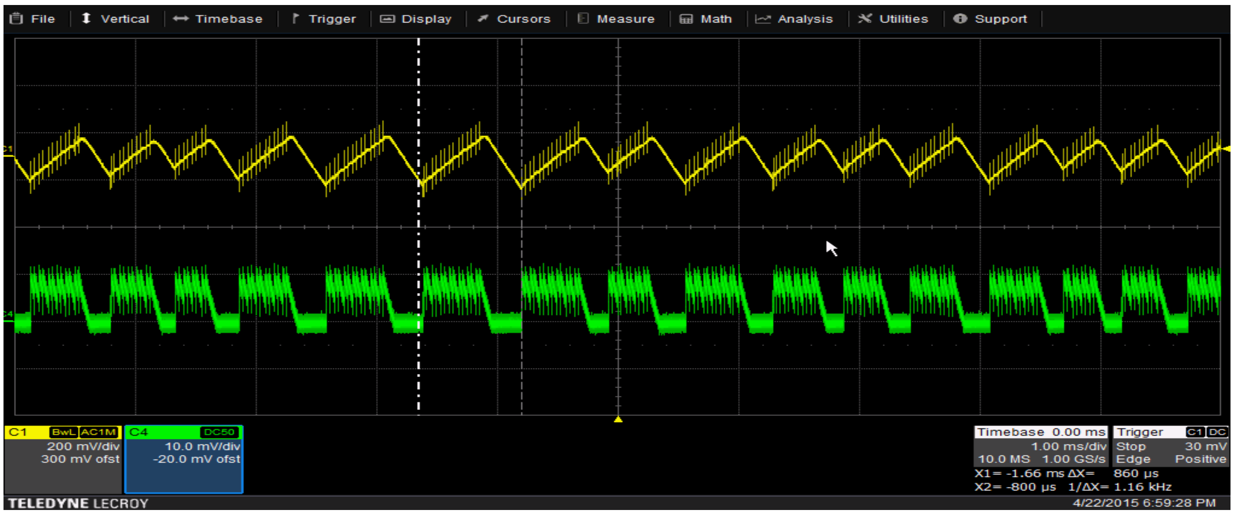

Figure 3. Output Ripple Voltage (V_{OUT} = CH1) and Inductor Ripple Current (I_{L1} = CH4)

4 Sources of Audible Noise

Any components in the design that have energy packets being delivered through them at 20 kHz or less can vibrate. This can include capacitors, diodes, inductor's wires, connectors.

5 Determining the Source of Audible Noise

CAUTION

Follow high-voltage safety practices.

1. A sheet of paper can be rolled up into a tube and used like a hearing aid. Put one side of the paper tube to your ear and point the other end of the tube toward the power supply circuit board in operation. This can help you find the audible component.
2. A non-conductive stick can be used to determine which device is vibrating and creating the audible noise. A number 2 wooden pencil with an eraser can be used for this. Touch the suspected component that is contributing to the audible noise. If the sound dulls this may be the source of the audible noise.

6 Things the Designer Can Do to Reduce Audible Noise

1. Select the output inductor (L_1) as close to the recommended value as possible. This will ensure at full load the effective switching frequency is as close to the maximum as possible. This calculation was covered earlier in this application note.
2. Set the t_{FB} time constant as small as possible to get the converter to operate at the maximum frequency possible. This may affect load regulation of the power converter and may require pre-load resistor (R_L) as shown in Figure 1. A Zener clamp or a series pass regulator on the output may be required to regulate the output voltage at light loads. Please refer to Figure 4 for the circuit configuration.

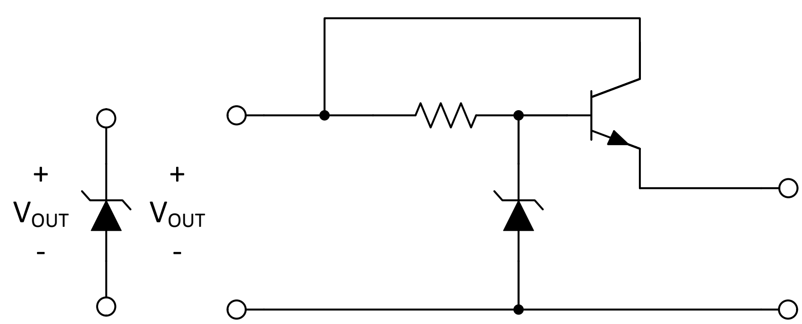

Figure 4. Zener Shunt or Series Pass Regulator to Improve Load Regulation

3. Select a buck inductor (L_1) that is varnished and/or encased in magnetic potting material. TDK and Wurth have a family of inductors that are encased in potting material. Avoid inductors that are not varnished and/or encased in magnetic potting material. Examples of these types of inductors can be found in Figure 5.

Figure 5. Potted and Varnished Inductor, Inductor without Varnishing and Potting.

4. Use electrolytic input and output capacitors because they are less likely to create audible noise over ceramic capacitors that have piezoelectric characteristics. Please note that some electrolytic capacitors can vibrate and create audible noise as well. They may have to be attached to the board in rubber silicon or encased in potting material to reduce vibrations and make the design less audible.
5. Glue down any possible components that could vibrate with epoxy, rubber silicon or other like adhesive.
6. In rare cases it may be necessary to varnish/encase the entire power supply in potting material to reduce audible noise. There are many companies that make these electronics insulation resins and polymers for these applications such as Elantas Electrical Insulation, Epic Resins and ITW Engineered Polymers.

Figure 6. Potted Power Supply

7. After the initial design is complete and the audible noise is removed. It is recommended to do temperature, production and verification testing. This process should involve multiple boards and devices to verify the design.

7 Summary

The UCC28880 and UCC28881 economic offline buck converters use an On/Off control technique that can make the design susceptible to audible noise (<20 kHz) As this application note discussed the audible noise can be reduced by properly selecting input and output capacitors; as well as, inductors that are vanished and encased in magnetic potting materials. In some cases it may require varnishing and/or encasing the design in potting material.

8 Recap of Recommendations

1. Select the output inductor (L_1) as close to the recommended value as possible.
2. Set the tFB time constant as small as possible to get the converter to operate at the maximum frequency possible.
   (a) Preloading, Zener and/or series pass regulator may be needed to improve load regulation.
3. Select a buck inductor (L_1) that is varnished and or encased in magnetic potting material.
4. Avoid using ceramic capacitor for input and output capacitors, electrolytic capacitors are a better choice.
5. Glue down components that can vibrate.
6. Encapsulate the power supply in potting material.
7. Conduct temperature, production and verification testing to account for variations in component and device tolerances.

9 Reference Material

1. UCC28880 Data Sheet, High Voltage Switch for Non-isolated AC/DC Conversion
2. UCC28881 Data Sheet, 700-V, 225-mA Low Quiescent Current Off-Line Switcher

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