60 V and 100 V, Low I_Q Boost/SEPIC/Inverting Converters for Compact, Efficient, Low EMI Power Supplies

By **Joey Yurgelon**, **Jesus Rosales**, and **Mark Marosek**

Automotive and industrial markets demand cool running power supplies that fit tight spaces and meet low EMI standards. The LT8362, LT8364, and LT8361 switching regulators meet these demands in boost, SEPIC, or inverting topologies. Each supports a wide, 2.8 V to 60 V input range for industrial or automotive environments, low I_Q Burst Mode® capability, and optional SSFM for reduced EMI. With built-in rugged power switches of 60 V/2 A, 60 V/4 A, and 100 V/2 A, including efficient operation up to 2 MHz, these devices can deliver high power in small spaces while meeting stringent thermal and EMI requirements.

Automotive Input Transients and Preboost

With the dramatic increase of electronic content in today's automobiles, the number of power supplies has multiplied with many required to directly convert a wide ranging battery voltage to a usable regulated output. With a minimum input voltage of 2.8 V, all members of the LT836x family can operate during cold crank or stop-start events; the maximum input voltage capability of up to 60 V handles high input voltage transients such as load dump.

This wide input voltage range makes the LT836x family ideal for automotive preboost applications. Automotive buck regulators require a preboost stage in applications where battery input voltage can drop below the buck output voltage. The LT8361, LT8362, and LT8364 provide the necessary boosting during low battery levels, and turn off with minimal power consumption during normal or load dump battery voltages.

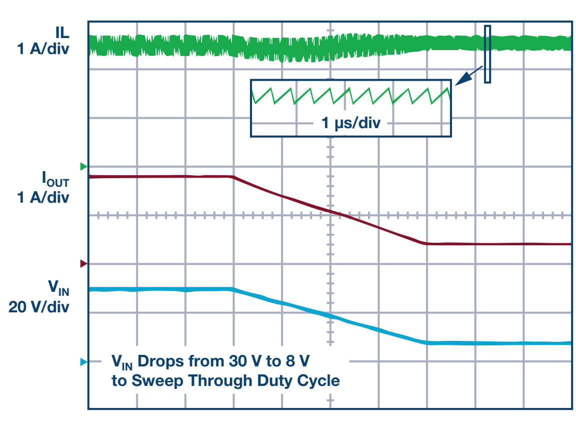


Figure 1. LT836x converters provide the full slope compensation necessary for proper operation at peak switch current limit, without the dc reduction of peak switch current limit vs. duty cycle.

Rugged Power Switches

A key requirement for any switching regulator is to provide enough power for a given application over the entire input voltage range while also guaranteeing reliability. Rugged power switches with voltage/peak current offerings of 60 V/2 A (LT8362), 60 V/4 A (LT8364), and 100 V/2 A (LT8361) enable a wide range of applications. The high power switch voltage ratings of the LT836x family extend output voltage capability in addition to extending the input voltage range for SEPICs and inverting converters.

Maximizing Power Delivery: Flat Current Limit vs. Duty Cycle

To maximize power delivery over the entire input voltage range, the power switches of the LT836x family maintain their peak switch current limit over the entire duty cycle range. The advertised current of the switch is available without compromise. This is a significant advantage over converters that may exhibit a fall of 30% or more in peak switch current limit at high duty cycles.

Current-mode dc-to-dc converters typically add slope compensation to their peak switch current limit to avoid subharmonic oscillations when that peak switch current limit is met. The drawback is a reduction of peak switch current limit as duty cycle increases (as input voltage lowers). The LT836x family provides the full slope compensation necessary for proper operation at peak switch current limit, without the dc reduction of peak switch current limit vs. duty cycle.

2 MHz Operation: Compact Power Supplies Above AM Band

To meet the demand for compact power supplies, dc-to-dc converters use high switching frequencies to minimize component size and cost. Furthermore, the requirements for operation above the AM band in automotive applications has driven frequencies to 2 MHz.

Traditionally, high switching frequencies result in increased switching losses and limited duty-cycle range. The LT836x family minimizes ac switching losses using fast power switch drivers and features low minimum on- and off-times, enabling support of a wide conversion range even at 2 MHz. For instance, the LT836x family can achieve lower losses and a higher duty-cycle range than many applications that would traditionally run at 400 kHz to maximize efficiency. Thermal performance for each of the covered topologies—inverting, boost, and SEPIC—is shown in Figure 2.

Burst Mode Operation: High Efficiency at Light Load

High efficiency at light loads is a critical feature in automotive environments where extending battery life is of utmost importance. The LT836x family offers high efficiency at light loads with optional Burst Mode operation—selectable using the SYNC/MODE pin (see Table 2). Burst Mode operation uses single-switch pulses spaced evenly at a lower switching frequency to reduce switching losses, while minimizing output voltage ripple. The LT836x family can draw as little as 9 µA from the input pin when in deep sleep or in pass through mode in a preboost application.

SSFM Mode: Three Topologies Passing CISPR 25 Class 5

The LT836x family is capable of meeting CISPR 25 Class 5 standards using spread spectrum frequency modulation (SSFM) mode and proper board layout with some filtering.

Designers have traditionally avoided using switching regulators throughout EMI sensitive environments. A switcher's large capacitors and troublesome hot loops elevate the importance of PCB layout to achieve good EMI performance and small solution size, placing a burden on board design and manufacture. The available factory demonstration circuits for the LT8362, LT8364, and LT8361 include the requisite input/output filters and feature exemplary PCB layout to meet CISPR 25 Class 5 standards (as tested) when SSFM mode is selected (see Table 2). By essentially removing the converter from the EMI equation, application development time and cost are reduced. Figure 4 shows EMI test results for a boost solution.

Best of Both: Burst Mode Operation and SSFM

Until recently, selecting SSFM mode for low EMI meant having to use the less efficient pulse-skipping mode at light load, but the LT836x family does not require this trade-off. By simply adding a 100 kΩ resistor from SYNC/MODE pin to ground (see Table 2), the LT836x family seamlessly transitions from SSFM mode to Burst Mode operation when loads become light. The result is low EMI and high efficiency over all loads.

Packages, Pin Compatibility, and Temperature Grades

For customers who prefer leaded packages, each part is offered in a pin compatible 16(12)-lead MSE TSSOP with four pins removed for HV pin spacing. For a smaller solution size, the LT8362 and LT8364 are also offered in DFN packages. The LT8362 (3 mm × 3 mm) 10-lead DFN is pin compatible with the LT8364 by placing it onto the (4 mm × 3 mm) LT8364 12-lead DFN PCB space (see Figure 6). All packages include a thermally enhanced exposed ground pad and are offered in E, I, and H temperature grades.

Boost/SEPIC/Inverting: FBX Pin for Positive or Negative Outputs

By offering a single FBX pin that allows for both positive and negative output voltages, all topologies are within reach. An inverting application is just as accessible as that of a boost or SEPIC, reducing design time and effort.

Boost Converters

For applications requiring output voltages greater than the input, the LT836x family is ideal for many boost converter applications given the 2.8 V to 60 V input capability and range of power switch ratings. For large conversion ratio designs, operating in discontinuous conduction mode (DCM) might be the best solution; continuous conduction mode (CCM) can deliver higher output power.

The converter in Figure 7 shows an LT8364 low I_Q, low EMI, 2 MHz, 24 V boost converter with SSFM that passes CISPR 25 Class 5 radiated and conducted EMI (Figure 4). With an input of 12 V, this application easily reaches a peak efficiency of 94%.

SEPIC Converters

Automotive and industrial applications often operate from input voltages that can be above and below the required output voltage. For applications where the dc-to-dc converter is required to both step-up and step-down its input, a SEPIC topology is often the solution. SEPICs support applications that require output disconnect, ensuring no output voltage during shutdown and tolerating output short-circuit faults since there is no dc path from input to output. With switch ratings of 60 V/100 V, and low minimum on- and off-times, wide input voltage ranges are achievable. The LT836x family offers an optional BIAS pin, which serves as a second input supply for the $INTV_{CC}$ regulator for improved efficiency.

The SEPIC converter in Figure 8 uses the LT8361 to showcase the versatility of a 100 V rated switch. The switch voltage rating must be greater than the addition of maximum input and output voltages. With a 48 V input to 24 V output, the switch can easily handle the required 72 V. With use cases where the input is greater than the output, the BIAS pin can offer improved efficiency when connected to V_{OUT}. Operating with SSFM, this application passes CISPR 25 Class 5 radiated and conducted EMI (Figure 9). Peak efficiency with a 12 V input is 88%.

Inverting Converters

Negative supplies are commonly used in today's electronics. However, many applications only have a positive input voltage from which to operate. The LT836x family, when configured in the inverting topology, can regulate from a positive input voltage that is above or below the magnitude of the negative output voltage. As with the SEPIC topology, the high 60 V/100 V switch ratings and low minimum on- and off-times allow wide input voltage ranges.

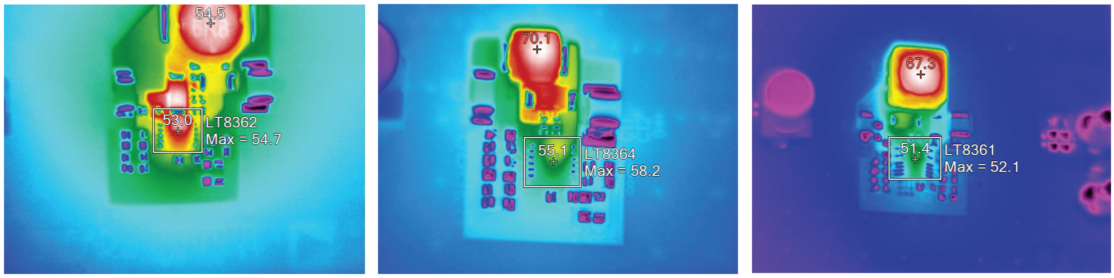
Operating at 2 MHz, the LT8362 offers an easy way to create a negative voltage from a positive input supply, as shown in Figure 10—a low I_Q, low EMI, 2 MHz, –12 V inverting converter with SSFM. With the rugged 60 V switch, this application can operate with inputs up to 42 V ($|V_{OUT}| + V_{IN}$ 60 V). With a V_{IN} of 12 V, a peak efficiency of 85% can be achieved. Operating with SSFM, this application passes CISPR 25 Class 5 radiated and conducted EMI (Figure 11).

Conclusion

To satisfy the automotive and industrial market demand for compact, efficient, low EMI power supplies, the LT836x family provides the rugged LT8362 (60 V/2 A), LT8364 (60 V/4 A), and LT8361 (100 V/2 A) switching regulators for boost, SEPIC, and inverting topologies. These devices are a significant improvement over alternatives due to low I_Q Burst Mode operation, flat switch current limit over duty cycle, low loss switching for 2 MHz operation, and a wide 2.8 V to 60 V input range.

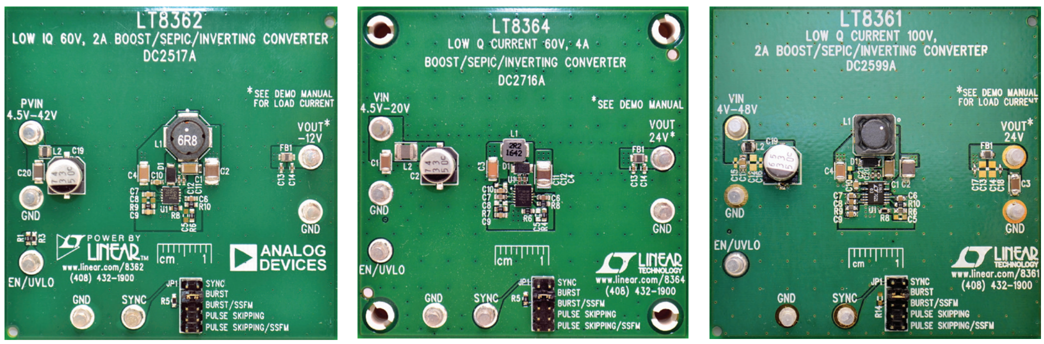
Low EMI performance is achieved through proper demo board layout and filter design with SSFM mode to meet CISPR 25 Class 5 EMI standards.

Design development is simplified with 16(12)-lead MSE pin compatibility for all parts and footprint compatibility for LT8362 (3 mm × 3 mm 10-lead DFN) and LT8364 (4 mm × 3 mm 12-lead DFN). All members of the LT836x family are available in E, I, and H temperature grades.



(a) LT8362 DC2517A Inverting Converter (b) LT8364 DC2716A Boost Converter (c) LT8361 DC2599A SEPIC Converter

Figure 2. Thermal performance of LT8362 Cuk inverting, LT8364 boost, and LT8361 SEPIC solutions.



(a) LT8362 low EMI Inverting Converter (b) LT8364 Low EMI Boost Converter (c) LT8361 Low EMI SEPIC Converter

Figure 3. Compact, EMI friendly converter solutions.

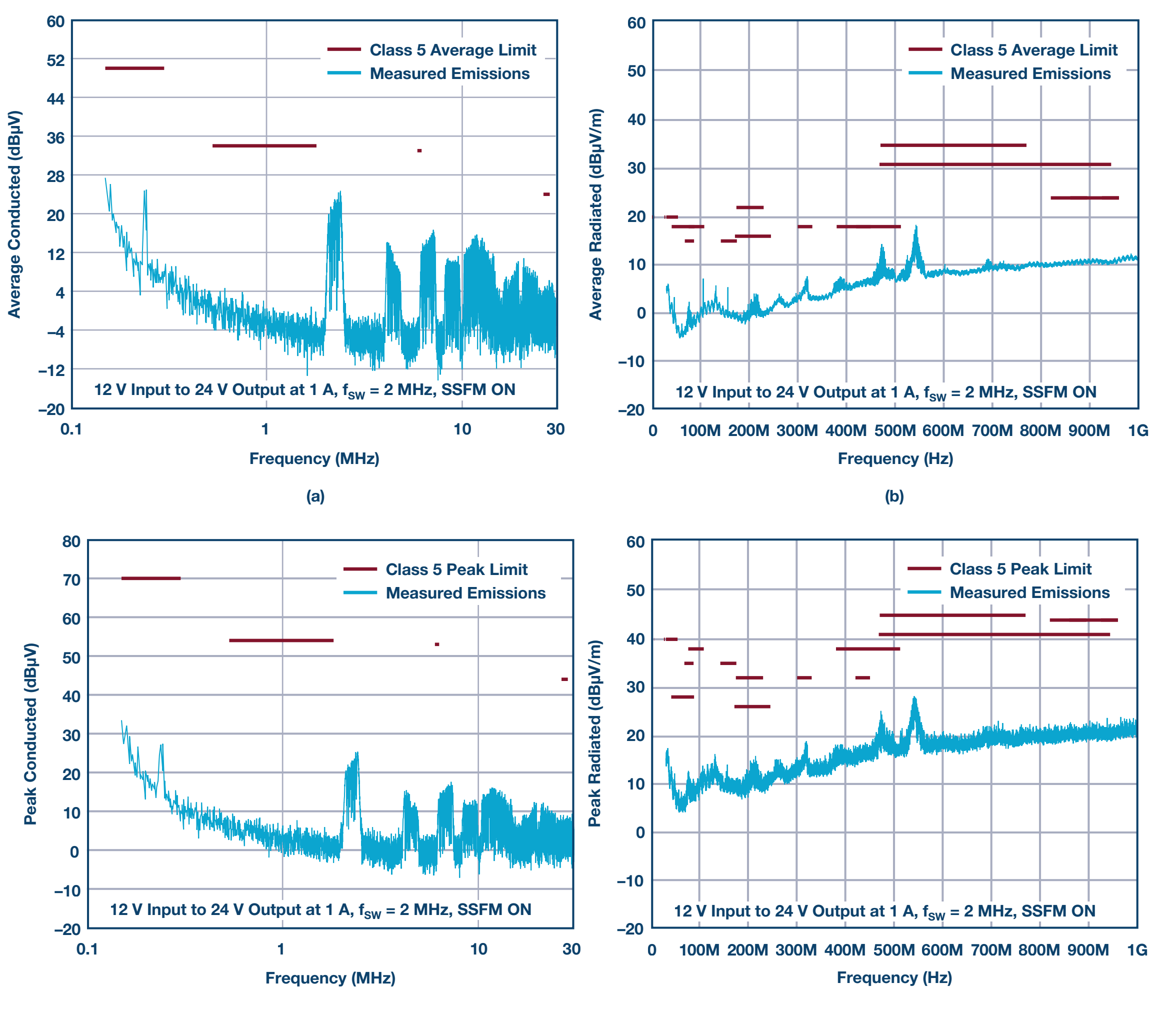


Figure 4. EMI test results for LT8364 boost solution.

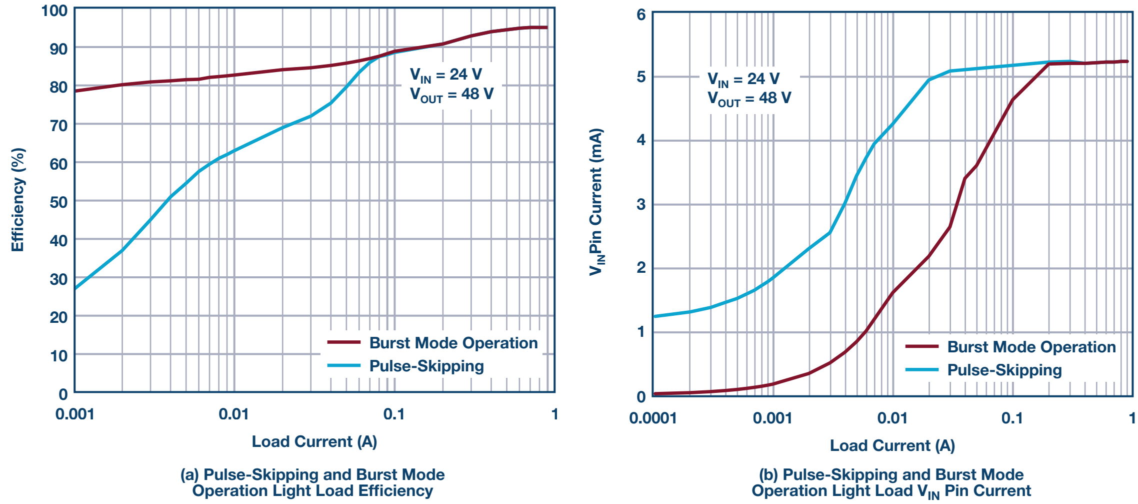


Figure 5. Pulse-skipping vs. Burst Mode operation for LT8362 boost solution (24 V input to 48 V output).

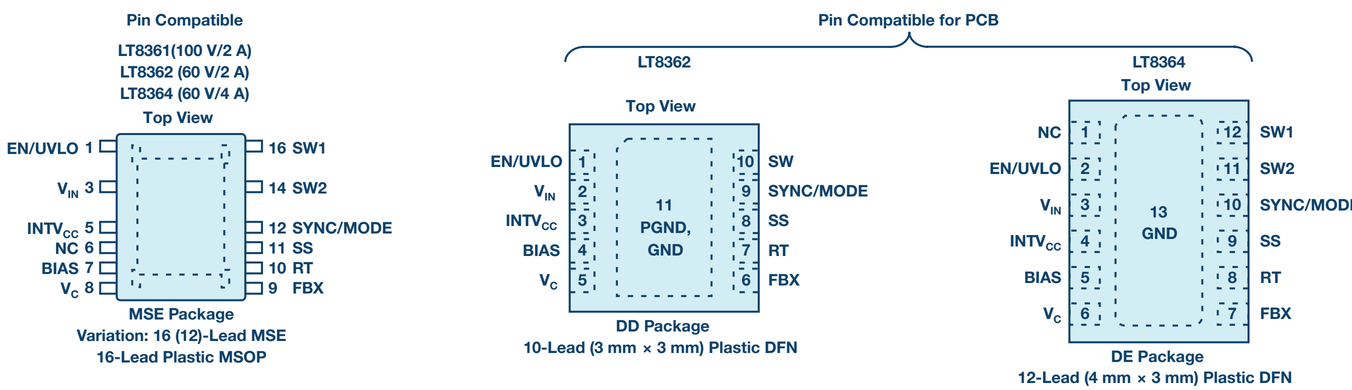


Figure 6. Pin compatibility of packages for the LT8361, LT8362, and LT8364.

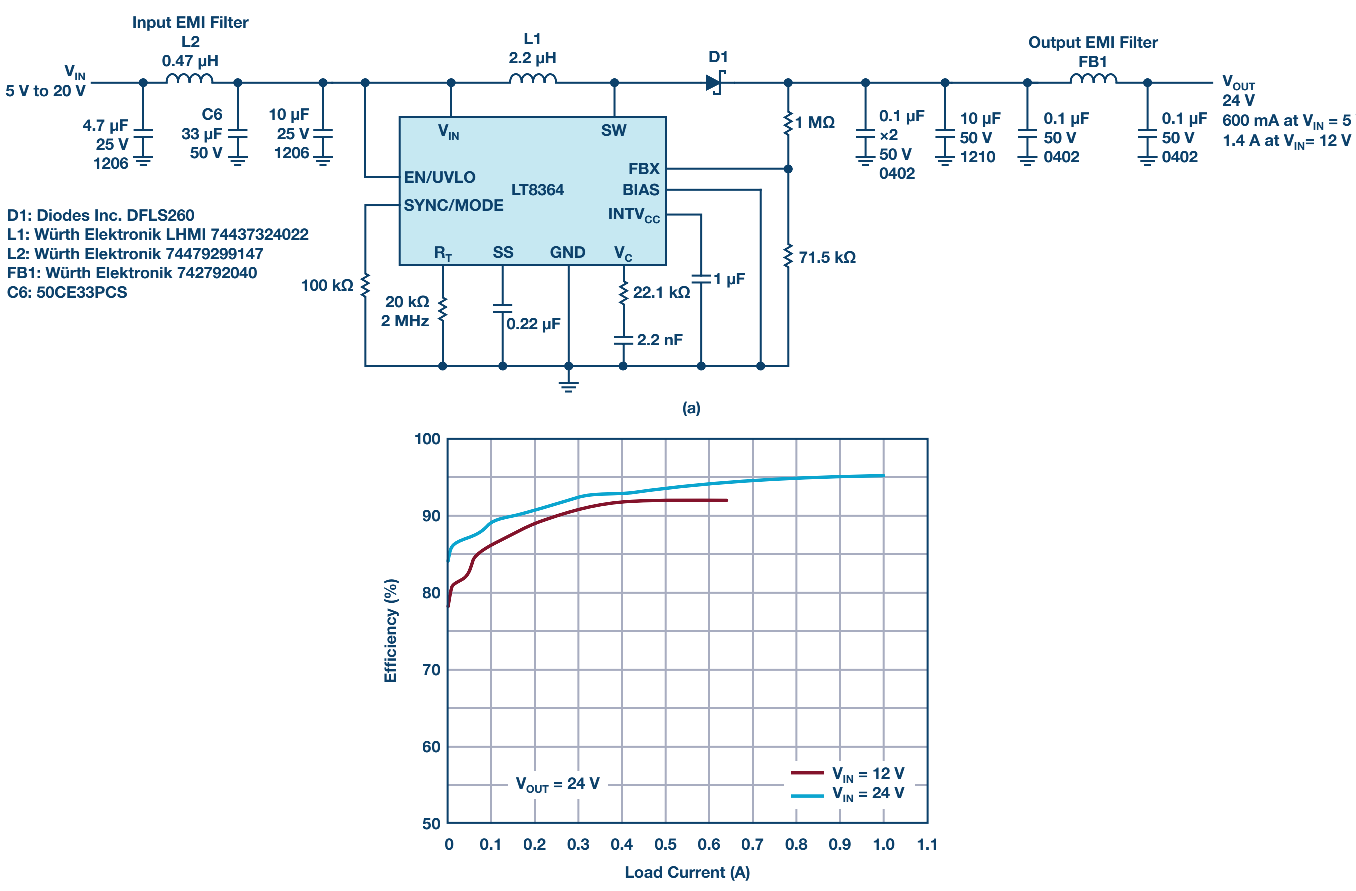


Figure 7. LT8364, 2 MHz, 24 V output boost converter passes CISPR 25 Class 5 EMI (see Figure 4).

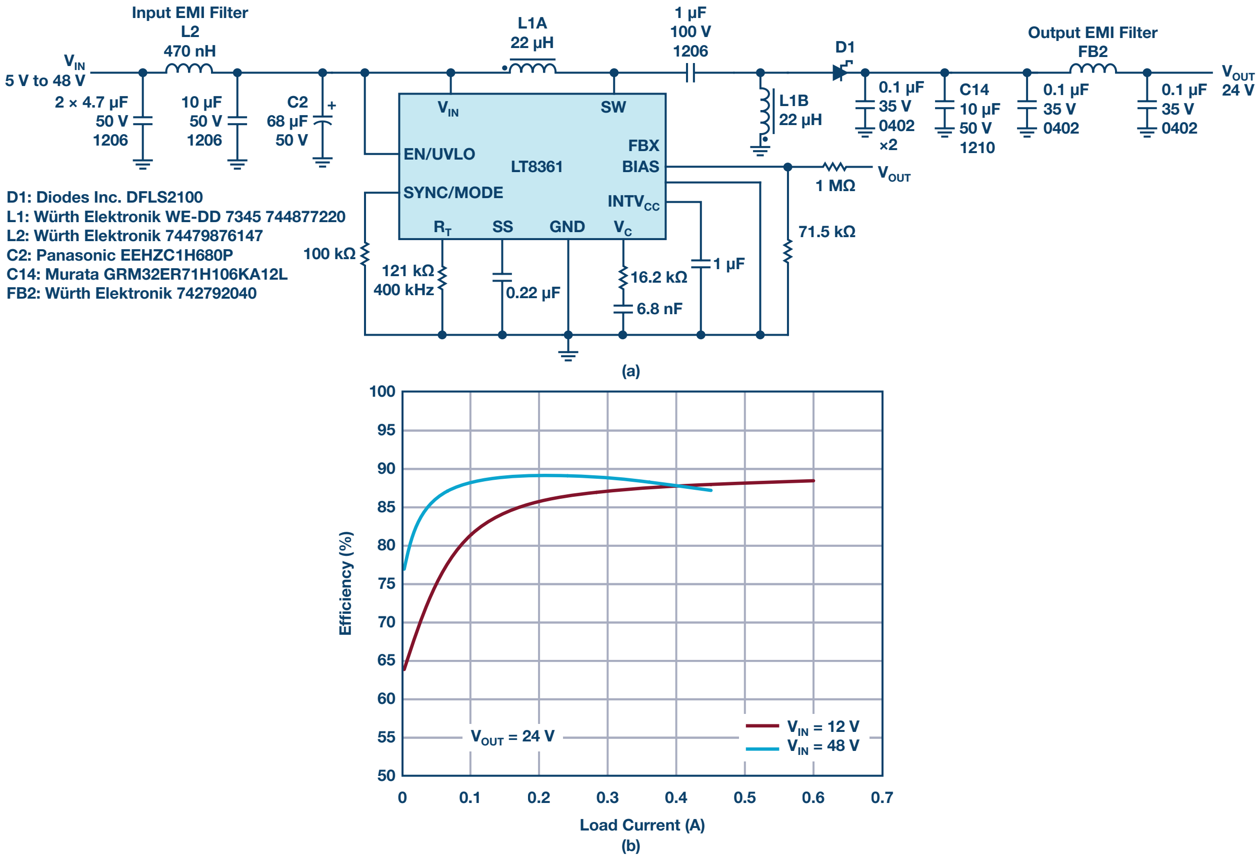


Figure 8. LT8361, 400 kHz, 24 V output SEPIC converter passes CISPR 25 Class 5 EMI.

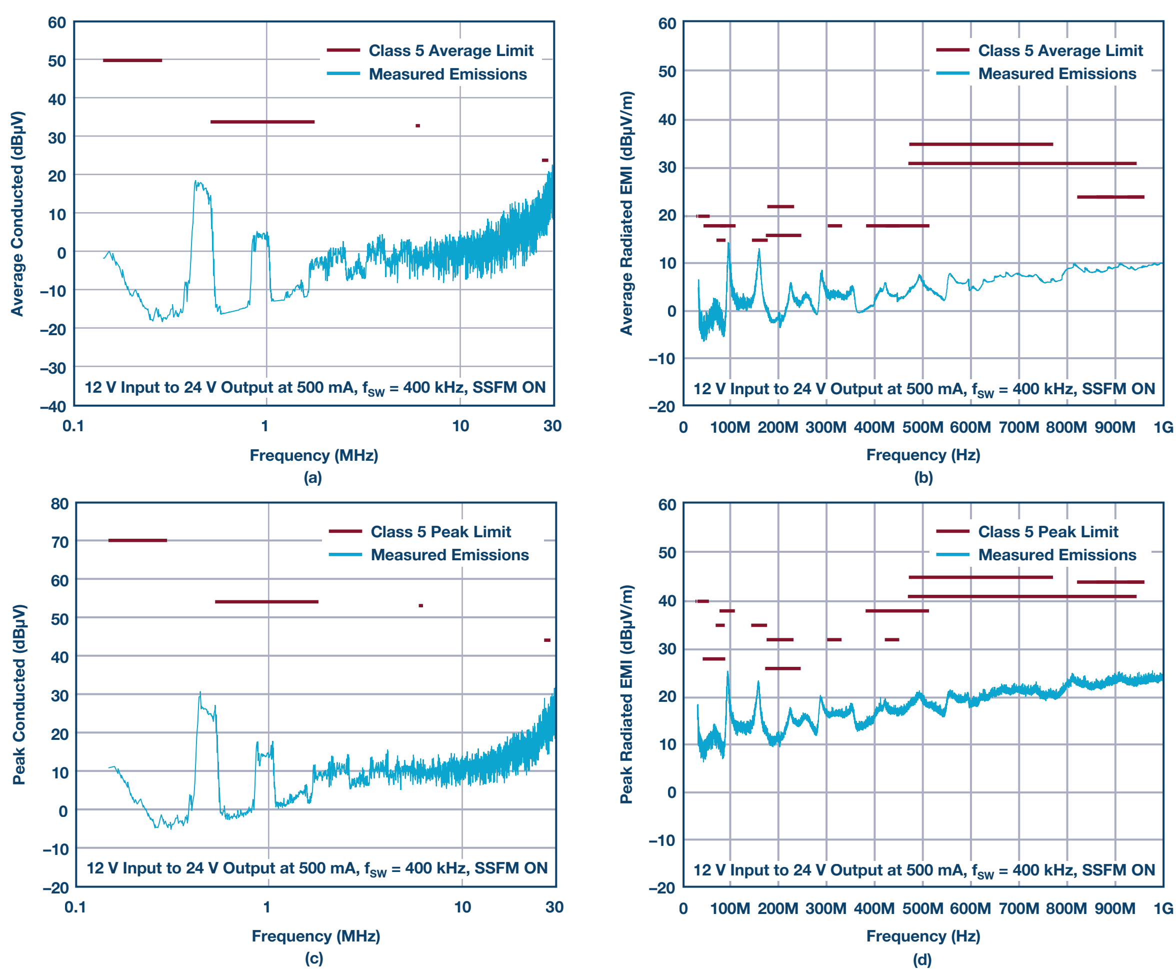


Figure 9. EMI test results for LT8361 SEPIC solution.

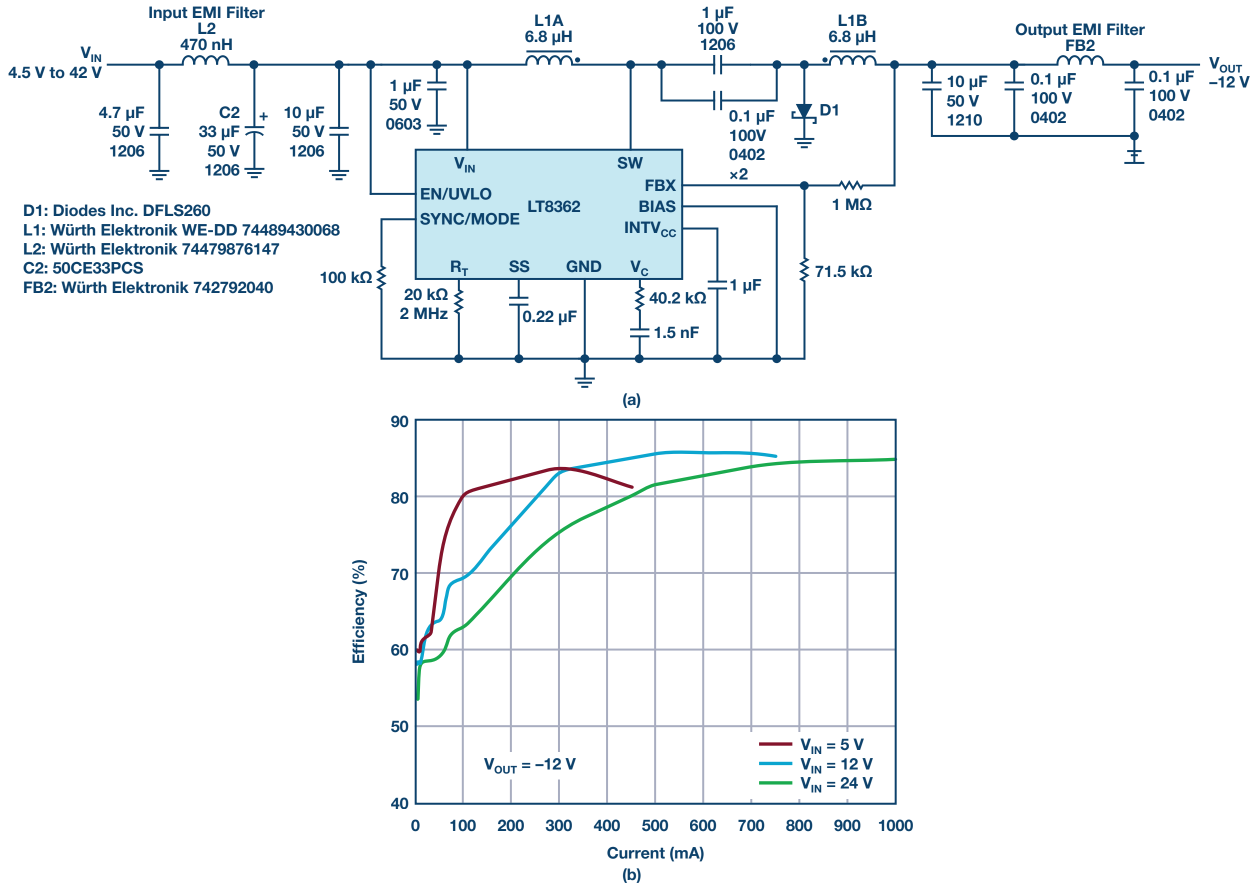


Figure 10. LT8362, 2 MHz, –12 V output, inverting converter passes CISPR 25 Class 5 EMI.

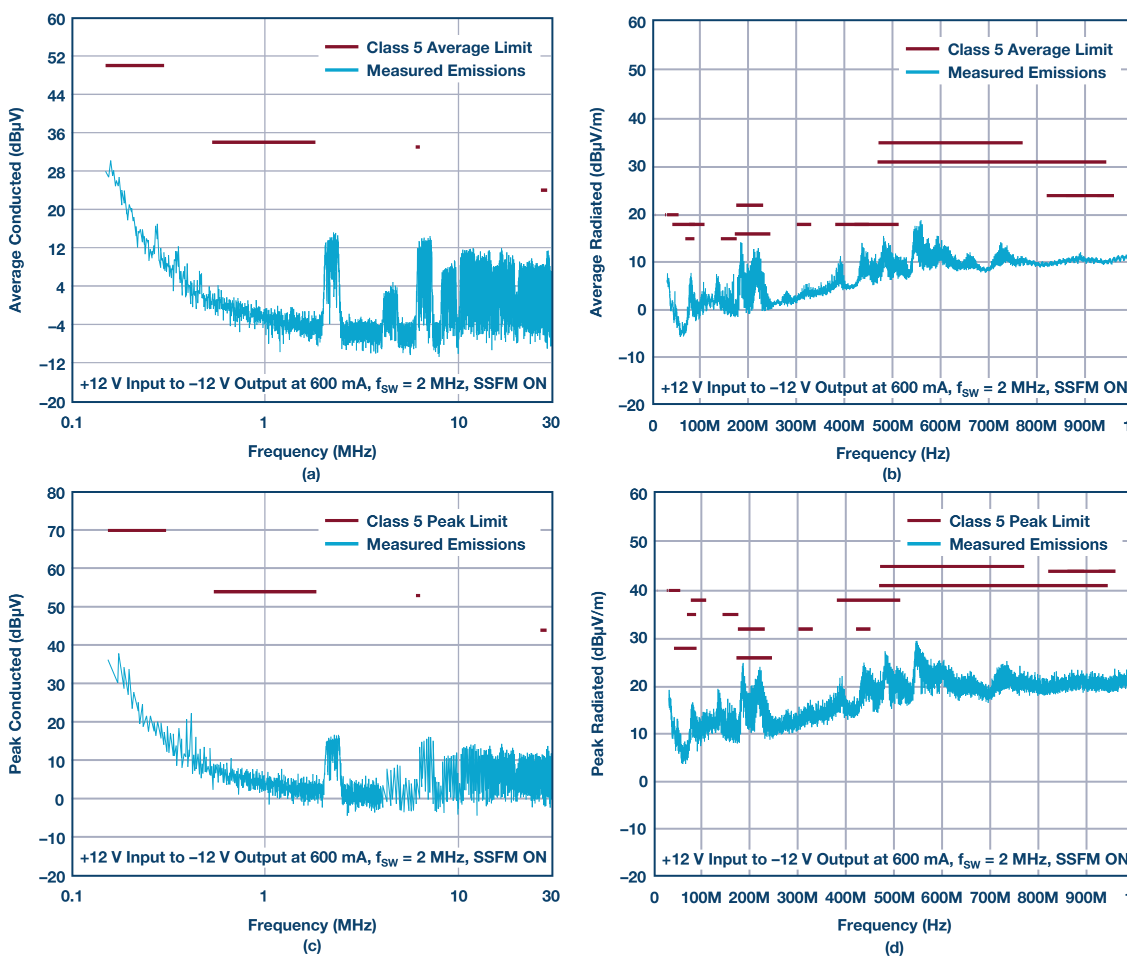


Figure 11. EMI test results for LT8362 inverting solution.

Table 1. Low I_Q Boost/SEPIC/Inverting Converters; Devices Described in this Article Are Highlighted.

	LT8362	LT8364	LT8361	LT8330	LT8331	LT8335
Bust Mode I_Q	9 µA	9 µA	9 µA	6 µA	6 µA	6 µA
Input Voltage Range	2.8 V to 60 V	2.8 V to 60 V	2.8 V to 60 V	3 V to 40 V	4.5 V to 100 V	3 V to 25 V
Programmable, Fixed, Switching Frequency	300 kHz to 2 MHz	300 kHz to 2 MHz	300 kHz to 2 MHz	2 MHz	100 kHz to 500 kHz	2 MHz
Spread Spectrum Frequency Modulation for Low EMI	Yes	Yes	Yes			
Power Switch Voltage/ Current	60 V/2 A	60 V/4 A	100 V/2 A	60 V/1 A	140 V/0.5 A	28 V/2 A
Package	3 mm × 3 mm DFN, 16(12)-lead MSE	4 mm × 3 mm DFN, 16(12)-lead MSE	16(12)-lead MSE	3 mm × 2 mm DFN, TSOT-23	16(12)-lead MSE	3 mm × 2 mm DFN
Temperature Grades	E, I, H	E, I, H	E, I, H	E, I, H	E, I, H	E, I, H

Table 2. LT836x Family Capable Modes of Operation.

SYNC/MODE Pin Input	Capable Modes of Operation
(1) GND or <0.14 V	Burst Mode operation
(2) External clock	Pulse-skipping/sync
(3) 100 kΩ resistor to GND	Burst/SSFM
(4) Float (pin open)	Pulse-skipping
(5) $INTV_{CC}$ or > 1.7 V	Pulse-skipping/SSFM
Temperature Grades	E, I, H

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