

Automotive USB Type-C Power Solution: 45 W, 2 MHz Buck-Boost Controller in a 1 Inch Square

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USB Type-C is a relatively new, high power USB peripheral standard used in computer and portable electronic devices. The USB Type-C standard has driven changes in the USB power delivery specification, allowing for increased bus voltages (up to 20 V) and current delivery capability (up to 5 A) from the long-standing 5 V USB standard. Connected USB-C devices can recognize each other and negotiate a bus voltage—from the default 5 V USB output to several higher preset voltage steps—for faster battery charging and higher power delivery where needed, up to 100 W.

The simple, compact buck regulators and linear regulators used in battery chargers that require only USB 5 V at 500 mA to 2 A do not sufficiently cover the full range of Type-C USB power. The increased voltage range, 5 V to 20 V, of Type-C USB power delivery requires more than just step-down voltage conversion from 9 V to 36 V (or 60 V) automotive batteries, or other charging sources. An adjustable buck-boost converter is needed with the ability to both step-up and step-down the input-to-output voltage.

Additionally, for high power automotive USB chargers, a buck-boost converter should support a 10 A or higher peak switch current rating and offer low EMI performance. The ability to set the switching frequency outside the AM radio band and maintain a small solution size are sought-after features. High voltage monolithic converters (with onboard switches) are not capable of sustaining such high peak switch currents without burning up.

The **LT8390A** is a unique 2 MHz, synchronous 4-switch buck-boost controller. At 2 MHz switching frequency, it can deliver output voltages between 5 V and 15 V (up to 45 W at 3 A) to provide power to a connected USB-C device from a car battery. This high controller switching frequency keeps the solution size small, the bandwidth high, and the EMI outside of the AM radio band. Both spread spectrum frequency modulation and low EMI current-sense architecture help LT8390A applications pass the rigors of the CISPR 25 Class 5 automotive EMI standard.

High Power Density Conversion: Size (and Power), Efficiency, Heat

The design of a voltage regulator system operating in an automotive or portable electronics environment is constrained by the space required for the circuit, as well as the heat it generates during operation. These two factors impose an upper bound of achievable power levels while operating within the given design constraints.

Increasing the switching frequency of a design allows for the use of smaller inductors, which is often the largest footprint component in wide input voltage 4-switch buck-boost voltage regulator designs. The LT8390A's 2 MHz switching frequency capability enables the use of a much smaller inductor size than a 150 kHz or 400 kHz design. A complete design is shown in Figure 1. Along with a smaller inductor, this solution uses only ceramic output capacitors, eliminating the need for bulky electrolytic capacitors. All the components necessary for this design, including the IC, are contained within a small, 1" inch square footprint, as shown in Figure 1.



Figure 1. Efficient, low EMI USB Type-C power solution that fits in a 1" square.

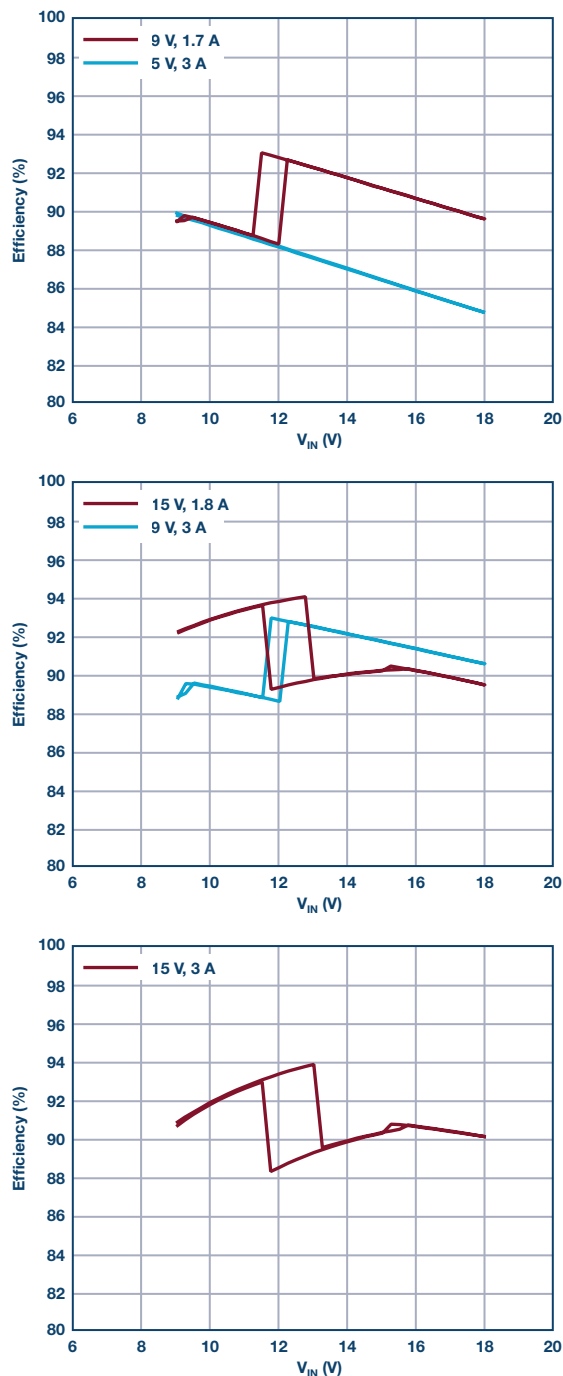


Figure 4. The LT8390A voltage regulator system remains in the 94% to 84% efficiency range across all output voltages generated when powered from an automotive SLA battery.

Seamless Output Voltage Transitions

The LT8390A's output voltage can be adjusted without shutting down the converter by using logic-level signals to drive MOSFETs that adjust the resistor divider off the output to change the set voltage. A USB PD source controller device with GPIO pins can be used in conjunction with the LT8390A system to facilitate the negotiation process between host and USB-connected device and to set the desired bus voltage.

Figure 5 demonstrates how smoothly the output of the LT8390A system transitions from one output voltage to another. When powered from a 12 V input source, each transition to an increased output voltage takes at most 150 μ s to settle, as measured from the rising edge of the digital control signal. During these changes in the output voltage, the buck-boost controller goes through mode transitions—between buck, boost, and buck-boost operation—depending on the relation of input to output voltages. These mode transitions are performed in a controlled manner, preventing excessive overshoot or sagging of the output voltage.

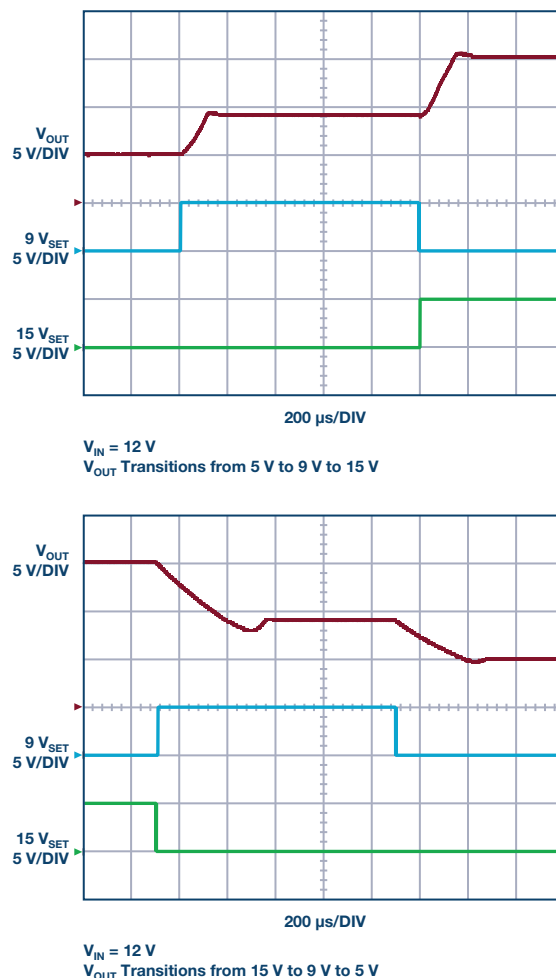


Figure 5. The output of the LT8390A system smoothly transitions between 5 V, 9 V, and 15 V outputs while maintaining continuous power deliver to the output.

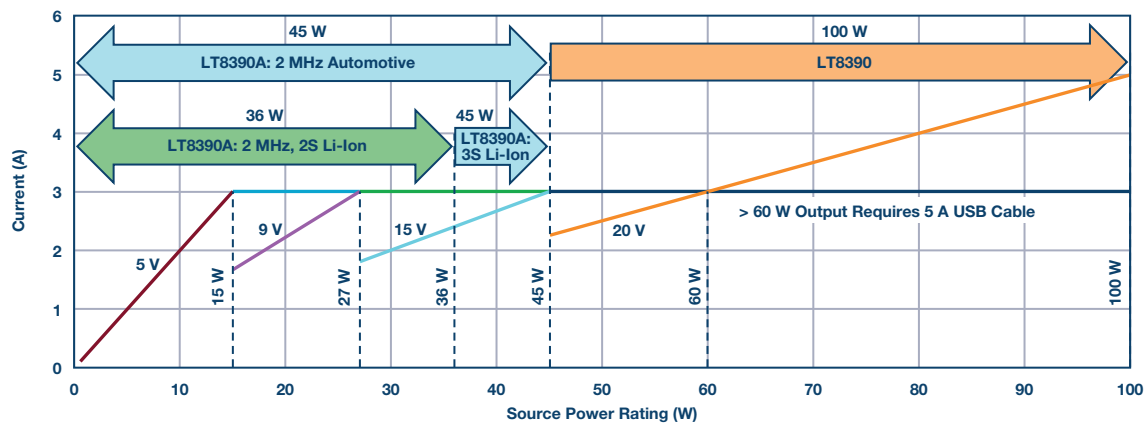


Figure 6. The LT8390A and LT8390 cover a wide range of output power levels for USB power delivery.

Expanding Beyond 45 W

To push the output power level beyond 45 W requires operating at a lower switching frequency to reduce switching losses, which might otherwise thermally stress the MOSFETs at this power level. As an alternative to the LT8390A, the LT8390 operates between 150 kHz and 600 kHz with the same feature set as LT8390A—allowing low EMI, high power buck-boost designs. A 400 kHz LT8390 system, utilizing a larger inductor and output capacitor, easily achieves 100 W of output power from an automotive battery input with acceptable temperature rise. Figure 6 illustrates the power capabilities of the LT8390A and LT8390 product line from various battery-powered inputs.

Conclusion

The new USB standard for voltage regulators powering connected devices permits higher power transfer by increasing the output voltage range and current delivery that regulators can provide. Portable and automotive battery-powered USB-C charger devices require a wide V_{IN}/V_{OUT} buck-boost regulator to deliver a bus voltage above or below the input voltage. The LT8390A provides up to 45 W of output power in a small footprint, made possible by its 2 MHz switching frequency. For power levels exceeding 45 W, the LT8390 can be used with a slightly larger solution size and lower switching frequency.

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