Hundreds of Watts, 60V In or Out: Synchronous 4-Switch Buck-Boost Converter is Easy to Parallel to Minimize Temperature Rise

Keith Szolusha

The LT3790 is a 4-switch synchronous buck-boost DC/DC converter that regulates both constant voltage and constant current at up to 98.5% efficiency using only a single inductor. It can deliver hundreds of watts and features a 60V input and output rating, making it an ideal DC/DC voltage regulator and battery charger when both step-up and step-down conversion are needed.

A single LT3790 converter can deliver high power due to its synchronous switching topology, but eventually the switching and/or conduction losses at higher power can overwhelm a single converter with excessive board heating. Although heat can be mitigated with bulked up heat sinks, additional external gate drivers, and/or forced airflow, it may be better to simply tie together two or more converters in parallel to spread the load. This is easy to do with the LT3790 buck-boost regulator.

120W, 24V, 5A OUTPUT BUCK-BOOST VOLTAGE REGULATOR

The buck-boost converter shown in Figure 1 regulates 24V with 0A–5A load at up to 98.5% efficiency. It operates from an input voltage range of 8V to 56V. Adjustable undervoltage and overvoltage lockout protect the circuit. It has short-circuit protection and the $\overline{\text{SHORT}}$ output flag indicates when there is a short circuit on the output. It features DCM operation at light load for lowest power consumption and reverse current protection. The sense resistor R_{OUT} sets the output current limit during

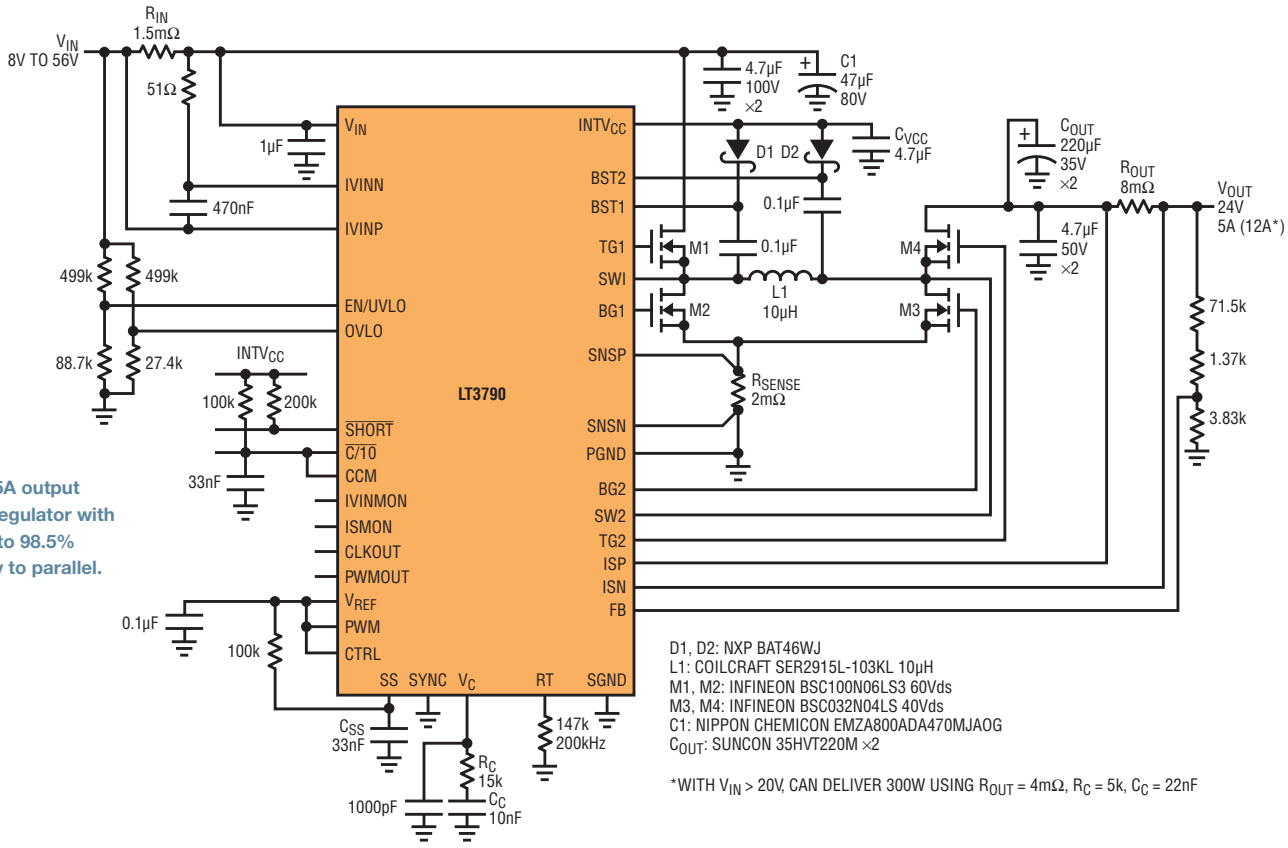
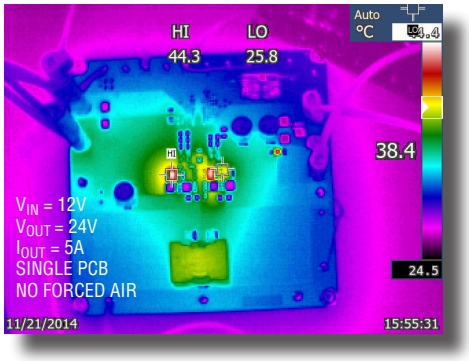


Figure 1. 120W, 24V, 5A output buck-boost voltage regulator with 8V–56V input has up to 98.5% efficiency and is easy to parallel.

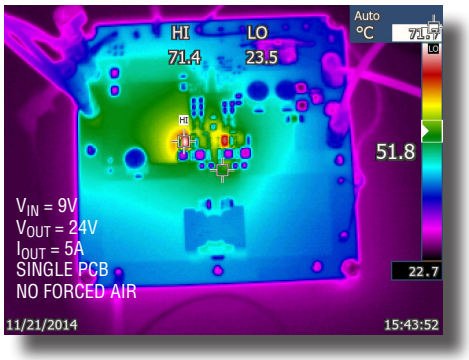
D1, D2: NXP BAT46WJ
L1: COILCRAFT SER2915L-103KL 10µH
M1, M2: INFINEON BSC100N06LS3 60Vds
M3, M4: INFINEON BSC032N04LS 40Vds
C1: NIPPON CHEMICON EMZA800ADA470MJAOG
C_{OUT}: SUNCON 35HVT220M ×2

*WITH V_{IN} > 20V, CAN DELIVER 300W USING R_{OUT} = 4mΩ, R_C = 5k, C_C = 22nF

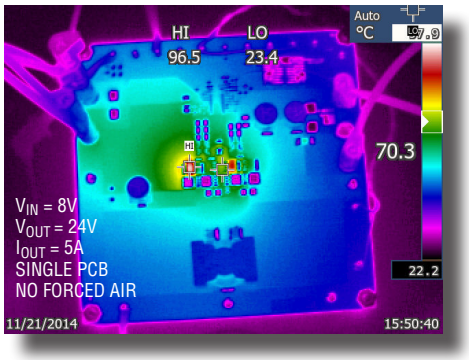
Figure 2. Single 24V, 5A converter shown in Figure 1 has a maximum of 20°C temp rise on any component at 12V input (a) and 50°C at 9V input (b). Even at 8V input (c), the hottest component reaches only 96.5°C without forced airflow or heat sinking.



(a)

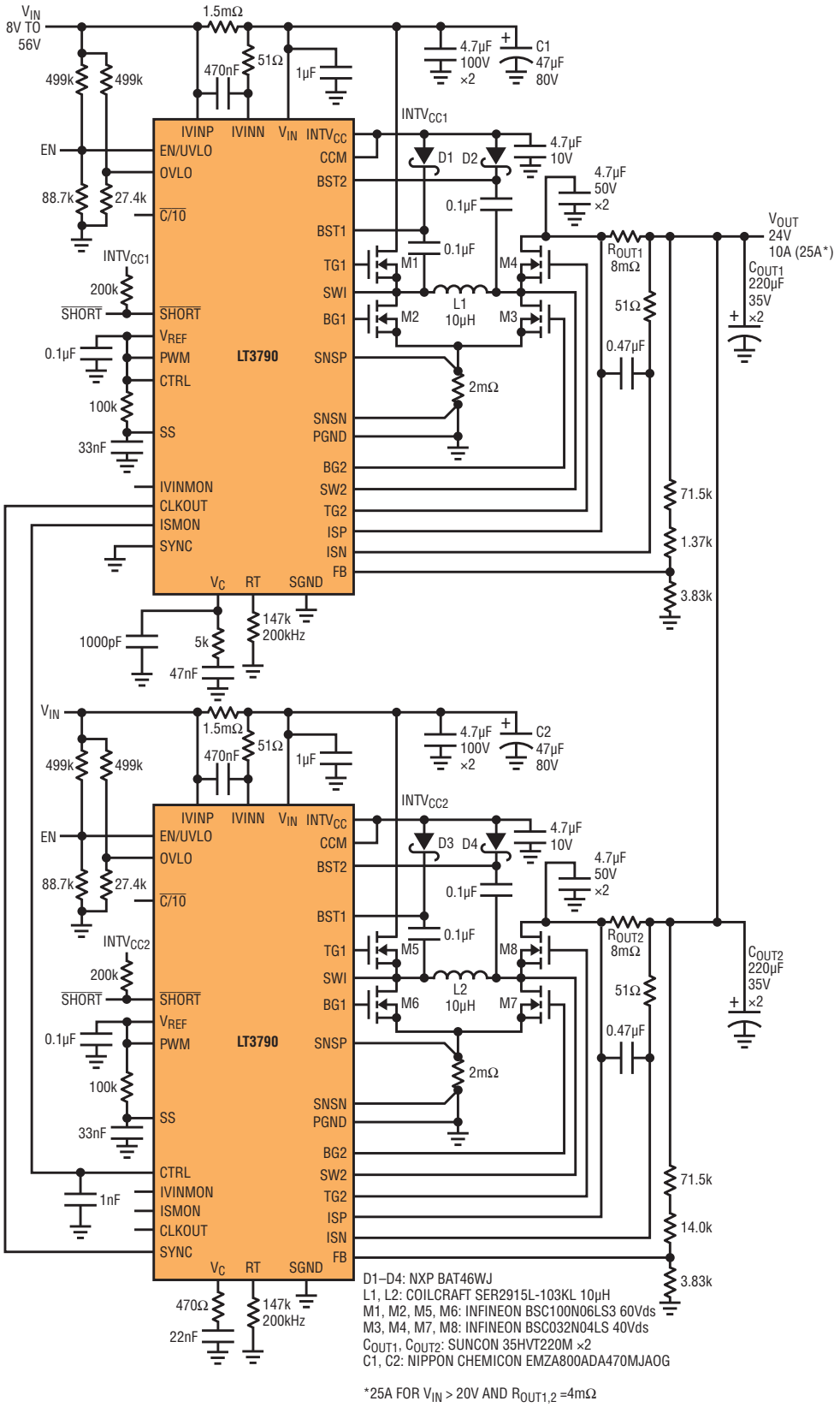


(b)



(c)

Figure 3. Two LT3790 24V voltage regulators are easy to parallel for double the output with limited discrete component temperature rise.



The CLKOUT pin of the master can be directly tied to the SYNC input pin of the slave for 180° phase-interleaving of the two parallel converters. The 180° phase difference between the converters reduces overall converter output ripple, instead of doubling it. If more than two converters are connected in parallel, they can be synchronized to either operate phase-shifted or in-phase with an external clock source, or daisy-chaining CLKOUT pins.

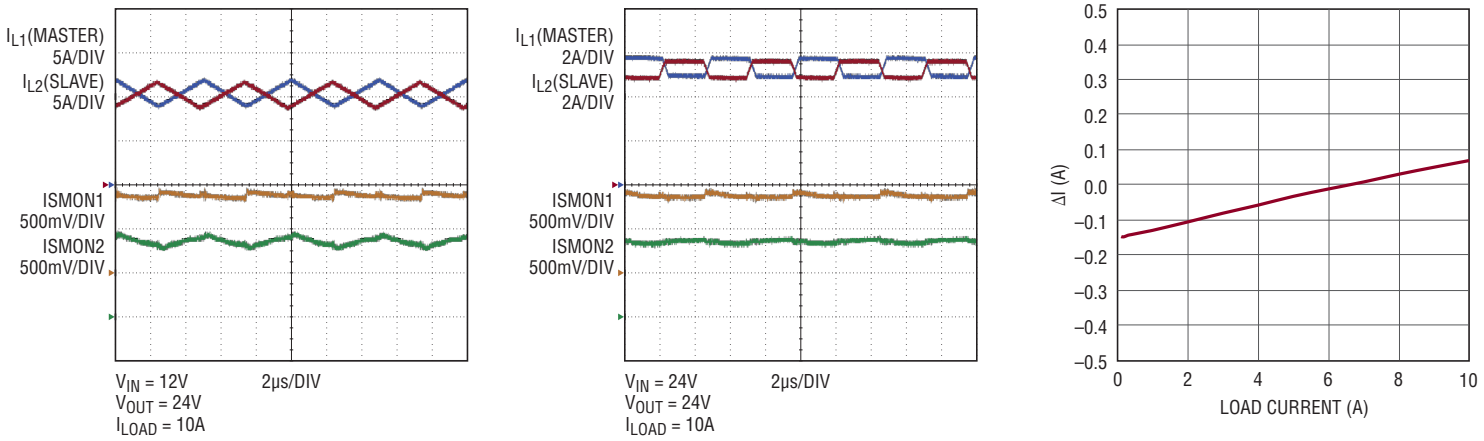


Figure 4. Parallel converter inductor and output current matching

both a short-circuit and overload situations, making this a robust application.

The temperature rise of this 120W board at 12V input is only 20°C on the hottest component (a switching MOSFET) as shown in Figure 2a. There is still margin for either higher output power at 12V input, or the same 120W from a lower V_{IN} without excessive component temperature rise—note that higher output power requires a correspondingly increased output current limit. When operated down to 8V input with 120W output, the components on this standard 4-layer LT3790 PCB remain below 97°C (at room temp) without forced airflow or heat sinking. To deliver significantly higher power with the same, limited temperature rise and input voltage range, two or more LT3790 converters can easily be connected in parallel.

PARALLEL CONVERTERS, CONSTANT VOLTAGE MASTER, CONSTANT CURRENT SLAVE

Ideally, paralleled switching converters share the load equally throughout the entire output range. The LT3790's ability to run in either constant voltage or constant current operation allows one master converter to control the output voltage, while its current monitor output (ISMON) tells one or more slave converters how much output current to regulate (CTRL input) in order to match its own output level. Current matching between multiple converters is nearly ideal using this technique.

The CLKOUT pin of the master can be directly tied to the SYNC input pin of the slave for 180° phase-interleaving of the two parallel converters. The 180° phase difference between the converters reduces overall converter output ripple, instead of doubling it. If more than two converters are connected in parallel, they can be synchronized to either operate phase-shifted or in-phase with an external clock source, or daisy-chaining CLKOUT pins.

Figure 3 shows a 24V, 10A (or 25A under certain conditions, see figure) voltage regulator formed by running two LT3790s in parallel. By using two parallel circuits, the maximum temperature rise on any one discrete component is only 20°C for the M3 and M7 MOSFETs at 12V input and 50°C at 9V input.

The top converter (master) in Figure 3 regulates the 24V output voltage and commands the current level that is regulated by the bottom (slave) converter. The ISMON output of the master indicates how much current the master is providing, and by connecting ISMON directly to the CTRL input of the slave, the slave is forced to follow the master. The LT3790 ISMON output level and CTRL input level are identically mapped so that a direct connection from one to the other is possible, and doing so forces the total output current to be shared equally between the

Ideally, paralleled switching converters share the load equally throughout the entire output range. The LT3790's ability to run in either constant voltage or constant current operation allows one master converter to control the output voltage, while its current monitor output (ISMON) tells one or more slave converters how much output current to regulate (CTRL input) in order to match its own output level.

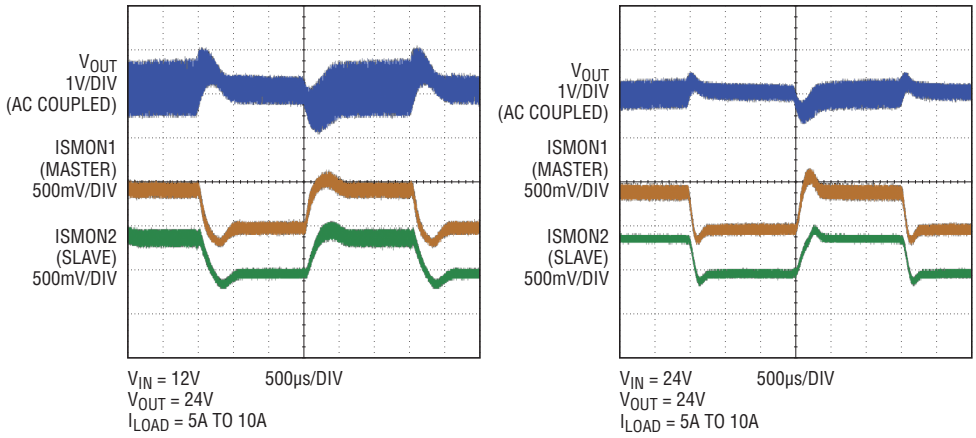


Figure 5. Parallel converter transient response evenly shares current

parallel converters, as shown in Figure 4. Note that the output voltage of the slave is set slightly higher (28V) so that the voltage feedback loop of the slave is not in regulation, allowing it to follow the master.

LOOP ANALYSIS FOR STABILITY

Transient response and network analyzer loop analysis can be used to measure stability. A transient response of 50% to 100% current, shown in Figure 5, demonstrates a properly compensated converter and equally shared load current. Further analysis with the network analyzer gives us the details of the separate converters. The noise injection point and measurement to generate control loop bode plots is different for the constant voltage regulator master and the constant current regulator slave. Separately, each loop can be measured by injecting the perturbation signal and measuring the loop response, as shown in Figure 6.

The constant current slave must have its loop broken and signal injected in the current loop feedback path instead of the traditional voltage feedback path since that is the feedback loop in use during parallel operation. The master bode plot in Figure 7 demonstrates the stability of the system.

CONCLUSION

The LT3790 synchronous buck-boost controller delivers over 100W at up to 98.5% efficiency to a variety of loads, and it is easy to parallel multiple converters for even higher power outputs. The ability to control either output voltage or current, combined with the level-matching of the ISMON output amplifier and the CTRL input amplifier, simplifies the connection of a master voltage regulator and one or more slave current regulators. The result is high power 60V buck-boost regulation that can deliver hundreds of watts at high efficiency. ■

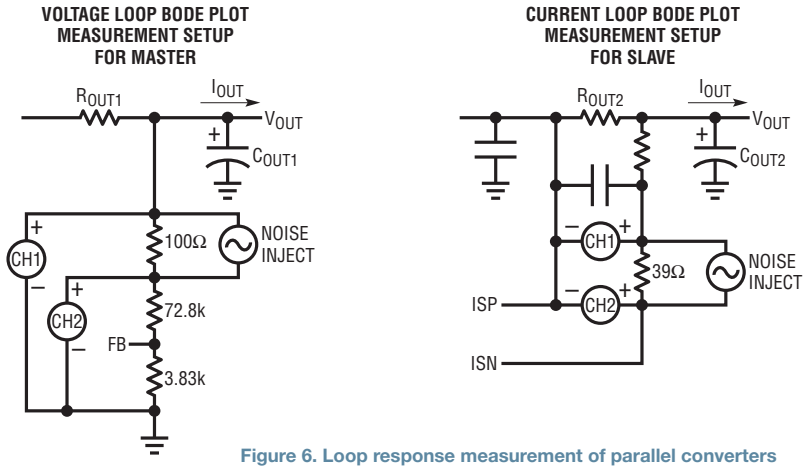


Figure 6. Loop response measurement of parallel converters

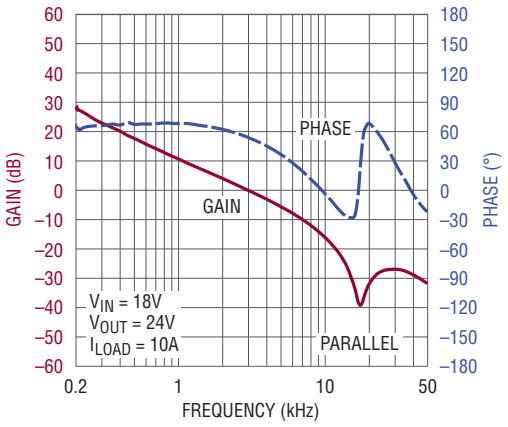


Figure 7. Bode plot shows measured results for parallel system.