

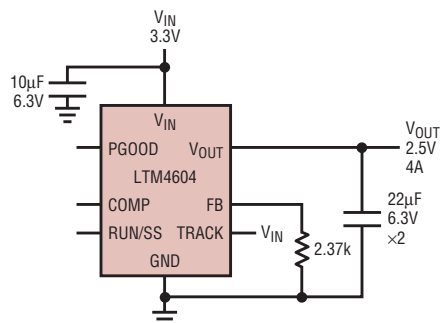
# Low Voltage, High Current Step-Down $\mu$ Module Regulators Put a (Nearly) Complete Power Supply in a 15mm $\times$ 9mm $\times$ 2.8mm Package

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## Introduction

Endlessly increasing power density requirements are a major driving force behind the continuous need to find new power supply solutions. Switching regulators are the top choice for high current applications because of their high efficiency and high performance, but high power density doesn't come for free with a switcher. Components must be carefully chosen and laid out to maximize efficiency, transient response and thermal performance. Making a high density switching power supply requires significant design and test time, or does it?

The LTM4604 and LTM4608 LTC  $\mu$ Module switching regulators make it possible to create high density designs with minimal effort. Both are high density power supplies for  $\leq 5.5V$  input voltage, high output current, step-down applications. Each  $\mu$ Module regulator comes in a 15mm  $\times$  9mm LGA surface mount package and is nearly self-contained—only a few passive components are required to complete a power supply design. The switching controller, MOSFETs, inductor and all support components are



**Figure 1. Only a few components are required for a 2.5V/4A design with LTM4604.**

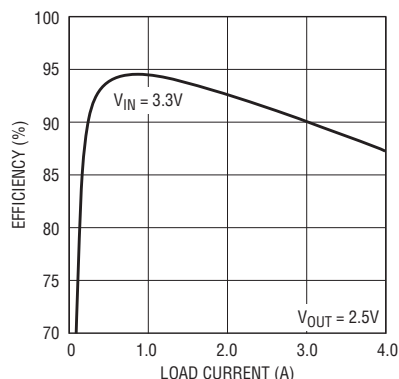
already carefully chosen and laid out in the package. Low profile packages (2.3mm and 2.8mm, respectively) allow them to be easily mounted in unused space on the bottom of PC boards and simplify thermal management.

The LTM4604 features a 2.375V to 5.5V input range and a 0.8V to 5V output range, while the LTM4608 takes a 2.7V to 5.5V input to a 0.6V to 5V output. The LTM4604 can deliver up to 4A continuous current with up to 95% efficiency. The slightly higher profile of the LTM4608 allows it to deliver up to 8A continuous current thanks to its high efficiency design and low thermal impedance package.

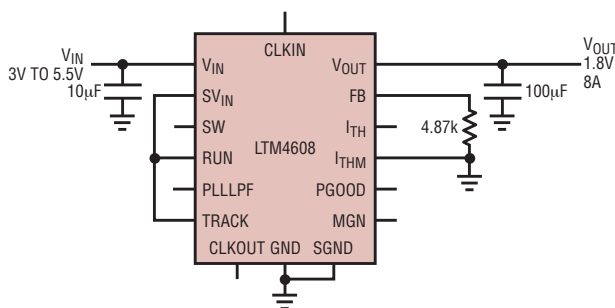
## Easy Design with Few Components

Figure 1 shows a typical 2.5V/4A design with LTM4604 and Figure 2 shows the resulting efficiency. Ceramic input capacitors are integrated into the  $\mu$ Module package—additional input capacitors are only required if a load step is expected up to the full 4A level. Additional required output capacitance is typically in the range of 22 $\mu$ F to 100 $\mu$ F. A single resistor on the FB pin sets the output voltage.

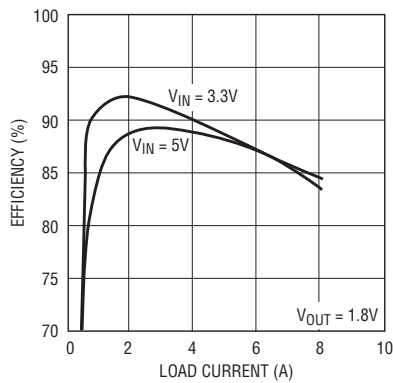
For applications needing more output current, the LTM4608 fits the bill. Figure 3 shows a 1.8V/8A design with LTM4608 and Figure 4 shows its efficiency. As with the LTM4604, the number of necessary external components has been reduced to a minimum, significantly simplifying the design effort. Nevertheless, a very fast transient response to the line and load changes is guaranteed by the optimized design of the  $\mu$ Module's high switching frequency and current mode control architecture. Furthermore, a number of features can be enabled on the LTM4604 and LTM460408 to suit the needs of various applications.



**Figure 2. High efficiency is achieved with the LTM4604 in the application of Figure 1**



**Figure 3. Only a few components are required for a 1.8V/8A design with the LTM4608.**



**Figure 4.** High efficiency is achieved with the LTM4608 in the application of Figure 3.

## Wealth of Features

Both LTM4604 and LTM4608 feature RUN pin control, output voltage tracking selections and power good indicators. For systems requiring voltage sequencing between different power supplies, the sequencing function can be implemented by controlling the RUN pins and the PGOOD signals with a few additional components. Fault protection features include overvoltage protection, over current protection and thermal shutdown.

The LTM4608 offers some additional features. Burst Mode® operation, pulse-skipping mode or continuous current mode can be selected to improve light load efficiency. Burst Mode operation provides the highest efficiency at very light load, while forced continuous current mode leads to the lowest output ripple. Pulse-skipping mode offers a compromise between Burst Mode operation and continuous mode, offering good light load efficiency while keeping output voltage ripple

down. Programmable output voltage margining is supported for  $\pm 5\%$ ,  $\pm 10\%$  and  $\pm 15\%$  levels. The LTM4608 also allows frequency synchronization and spread spectrum operation to further reduce switching noise harmonics.

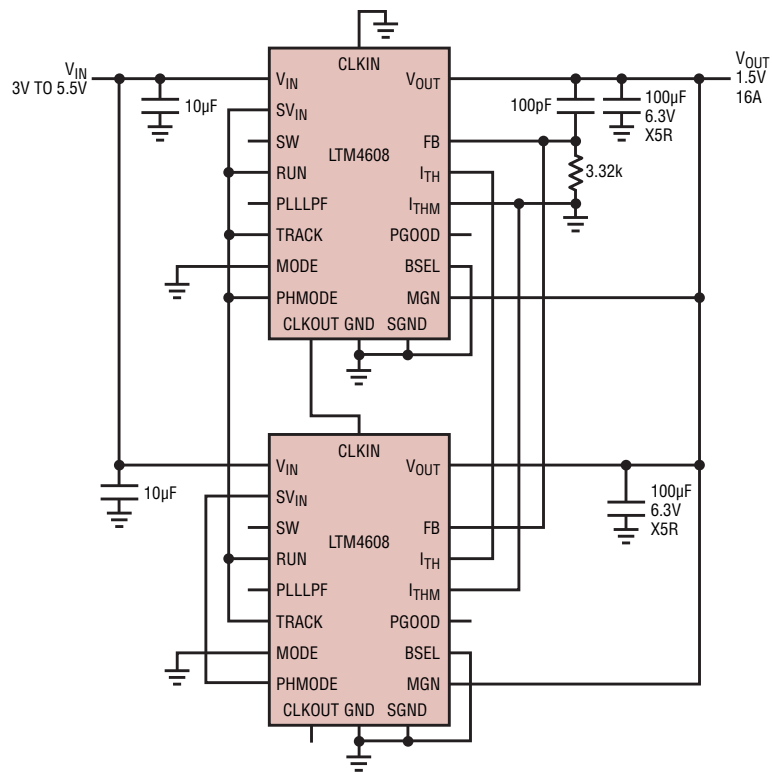
## Parallel for More Power

With cycle-by-cycle current mode control, the LTM4604 and LTM4608 can be easily paralleled to provide more output power with excellent current sharing. The LTM4608 includes CLKIN and CLKOUT pins to make it

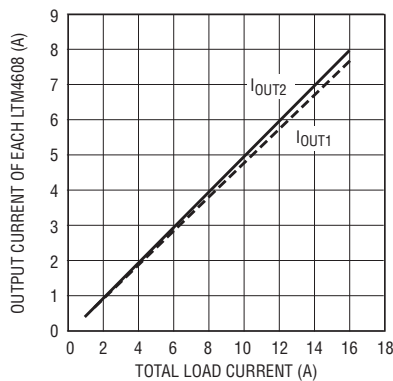
possible to operate paralleled devices out of phase of one another to reduce input and output ripple. A total of 12 phases can be cascaded to run simultaneously with respect to each other by programming the PHMODE pin of each LTM4608 to different levels.

Figure 5 shows an example of two LTM4608s in parallel to provide 16A output current. Figure 6 shows the measured current sharing performance of the circuit, illustrating that the DC current sharing error is less

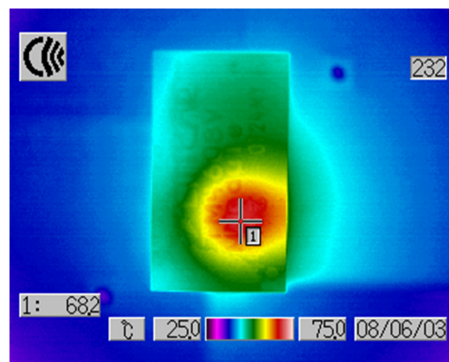
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**Figure 5.** Two LTM4608s are easily paralleled to provide 1.5V/16A output with interleaved switching operation.



**Figure 6.** Bench test shows excellent current sharing between two paralleled LTM4608s over the entire load range.



**Figure 7.** Good thermal balance is maintained between two paralleled LTM4608 boards supplying 16A output current.

bias supply. Another boost converter and an inverter generate  $V_{ON}$  and  $V_{OFF}$ , which also use the 5V supply as input.

When power is first applied to the input, the RUN-SS1 capacitor starts charging. When its voltage reaches 0.8V, Switcher 1 is enabled. The capacitor at the RUN-SS1 pin controls the ramp rate for the Switcher 1 output,  $V_{LOGIC}$  and inrush current in L1. Switchers 2, 3 and 4 are controlled by the BIAS pin, which is usually connected to  $V_{LOGIC}$ . When the BIAS pin is higher than 2.8V, the capacitors at the RUNSS-2 and RUN-SS3/4 pin begin charging to enable Switchers 2, 3 and 4. When  $AV_{DD}$  reaches 90% of its programmed voltage, the PGOOD pin is pulled low. When  $AV_{DD}$ ,  $V_{OFF}$  and E3 all reach 90% or their programmed voltages, the  $C_T$  timer is enabled and a 20 $\mu$ A current source begins to charge  $C_T$ . When the  $C_T$  pin reaches 1.1V, the output PNP turns on, connecting E3 to  $V_{ON}$ . Figure 2 shows the start up sequence of the circuit in Figure 1.

If one of the regulated voltages,  $V_{LOGIC}$ ,  $AV_{DD}$ ,  $V_{OFF}$  or E3 dips more than 10%, the internal PNP turns off to shut down  $V_{ON}$ . This action protects the panels, as  $V_{ON}$  must be present to turn on the TFT display. The PGOOD

pin can drive an optional PMOS device at the output of the boost regulator to disconnect the load at  $AV_{DD}$  from the input during shutdown. The converter uses all ceramic capacitors. X5R and X7R types are recommended, as these materials maintain capacitance over a wide temperature range.


All four switchers employ a constant frequency, current mode control scheme. Switching regulator 1 uses a feedback scheme that senses inductor current, while the other switching regulators monitor switch current. The inductor current sensing method avoids minimum on-time issues and maintains the switch current limit at any input-to-output voltage ratio. The other three regulators have frequency foldback scheme, which reduces the switching frequency when its FB pin is below 0.75V. This feature reduces the average inductor current during start up and overload conditions, minimizing the power dissipation in the power switches and external components.

### Layout Considerations

Proper PC board layout is important to achieve the best operating performance. Paths that carry high switching current should be short and wide to

minimize parasitic inductance. In a buck regulator, this loop includes the input capacitor, internal power switch and Schottky diode. In a boost regulator, this loop includes the output capacitor, internal power switch and Schottky diode. Keep all the loop compensation components and feedback resistors away from the high switching current paths. The LT3513 pin out was designed to facilitate PCB layout. Keep the traces from the center of the feedback resistors to the corresponding FB pins as short as possible. LT3513 has an exposed ground pad on the backside of the IC to reduce thermal resistance. A ground plane with multiple vias into ground layers should be placed underneath the part to conduct heat away from the IC.

### Conclusion


The LT3513 is a comprehensive, but compact, power supply solution for TFT-LCD panels. Its wide input range and low power dissipation allow it to be used in a wide variety of applications. All four of the integrated switching regulators have a 2MHz switching frequency and allow the exclusive use of the ceramic capacitors to minimize circuit size, cost and output ripple. 

*LTM4604, LTM4608, continued from page 29*  
than 5% at full load. Excellent current sharing results in well balanced thermal stresses on the paralleled LTM4608s, which in turn makes for a more reliable system. Figure 7 demonstrates the small temperature difference between these two paral-

leled LTM4608 boards supplying 16A output current.

### Conclusion

The LTM4604 and LTM4608 15mm  $\times$  9mm  $\mu$ Module regulators are complete power supply solutions for low input voltage and high output cur-

rent applications. They significantly simplify circuit and layout designs by effortlessly fitting into the tightest spaces, including the bottom of the PCB. Despite their compact form, these  $\mu$ Modules are rich in features, and they can be easily paralleled when more output current is needed. 

*LTC4352, continued from page 27*

generates a 4.1V supply at the  $V_{CC}$  pin. For  $V_{IN}$  below 4.1V,  $V_{CC}$  follows approximately 50mV below  $V_{IN}$ . The 0.1 $\mu$ F  $V_{CC}$  capacitor is still needed for bypassing and LDO stability.

### Conclusion

An ever-present theme in electronic system design has been to pack more computation in smaller form factors and tighter power budgets. Another

trend has been to lower the voltage of distributed power, which increases the current to maintain power levels. Given these constraints, board designers must scrutinize each diode in a high current power path for its power and area consumption.

The LTC4352 MOSFET controller provides the same functionality as a diode but at higher efficiencies and cooler temperatures, especially as currents increase. It also incorporates

useful features such as fast switch control, 0V operation, undervoltage and overvoltage protection, open MOSFET detection, ability to allow reverse current, Hot Swap capability, and fault and status outputs. All of this functionality comes wrapped in space-saving 12-pin DFN (3mm  $\times$  3mm) and MSOP packages, making it possible to produce an ideal diode solution in a smaller footprint than conventional diodes. 