LT1681 and LTC1698 Team Up to Provide a Complete Solution for 48V Input, 2-Transistor Synchronous Forward Converters

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While the need for 48V input networking equipment grows, logic voltages continue to fall well below 5V. Designing an efficient supply to convert high voltages (typically 36V to 72V) to low voltages (1.8V to 5V) without tying up too much board space can be quite a challenge. Although the synchronous buck regulator offers simplicity and high efficiency, low duty cycle and isolation requirements make it unsuitable for this application. The synchronous forward converter offers efficiency and isolation, but few controllers have supported this topology until now.

Introducing the LT1681 and LTC1698

The new LT1681 controller contains all the necessary functions for a synchronous forward converter and works together with the LTC1698 secondary controller to provide a comprehensive solution when output isolation is necessary. The LT1681's features include current mode operation up to 250kHz, leading-edge blanking, input undervoltage and overvoltage protection, primary and synchronous secondary gate drivers and a thermal shutdown pin. The LTC1698 interfaces directly with the LT1681 and provides an error amplifier and reference, output current limit and overvoltage protection and gate

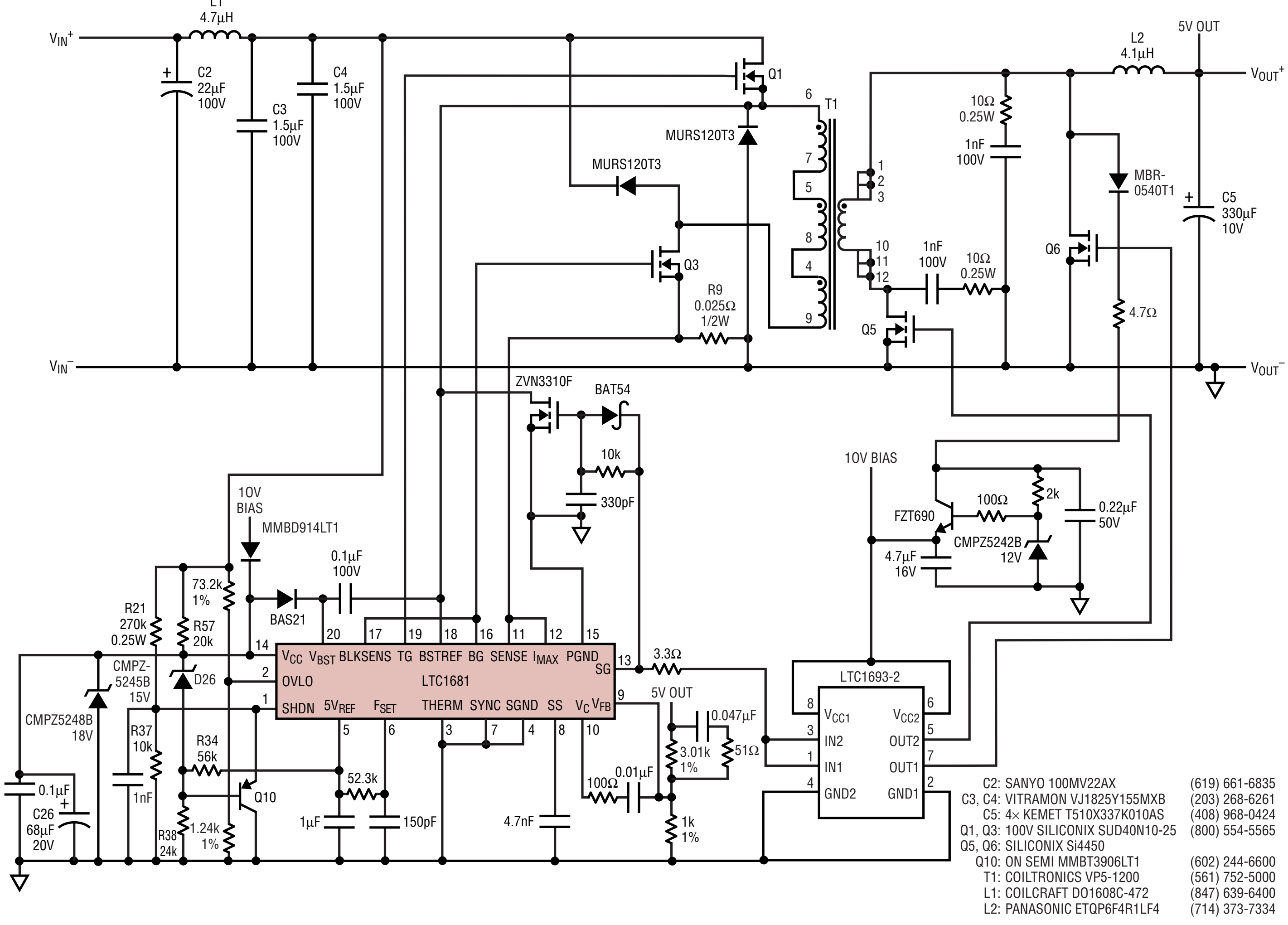

Figure 1. 36V–72V DC to 5V/7A synchronous forward converter

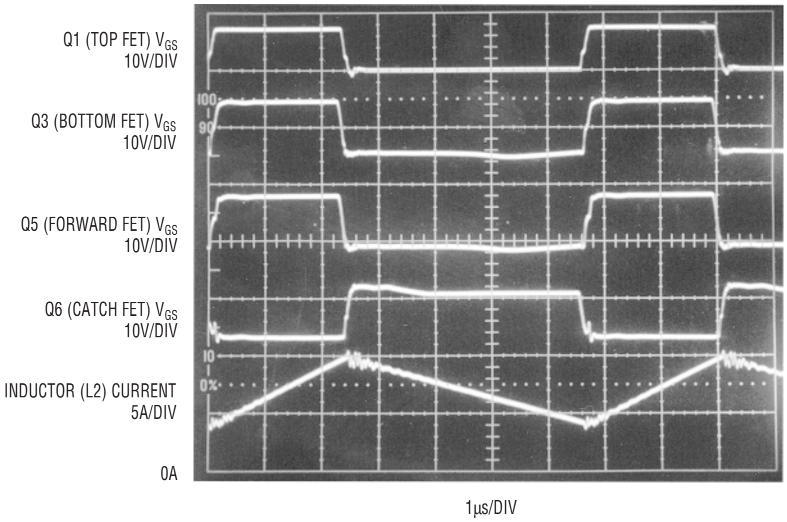

Figure 2. 48V in to 5V/7A gate voltage and inductor current waveforms

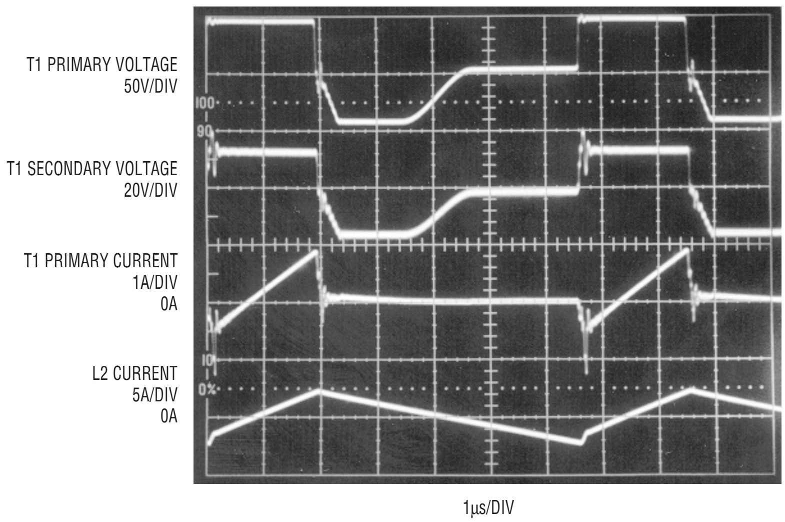

Figure 3. 48V in to 5V, no-load waveforms

drivers. The LT1681 is available in 20-lead SO and DIP packages. The LTC1698 is available in 16-lead SO and SSOP packages.

LT1681 48V to 5V Supply

Figure 1 shows a 150kHz nonisolated supply used to convert a 36V–72V input to a 5V output using off-the-shelf components. Compared to the conventional 1-transistor forward converter, the 2-transistor design shown uses lower voltage MOSFETs and provides lossless recovery of the transformer's mutual and leakage energy. The LT1681's duty cycle is limited to 50% to avoid transformer saturation. The LT1681 is capable of driving external MOSFETs directly. The high-side driver is designed for operation up to 72V. Overvoltage lockout (OVLO) is used to inhibit switching if the input voltage exceeds 75V.

Operation of the supply begins with the application of input voltage. Current through the trickle-start resistor, R57, charges C26 (connected to the LT1681's V_{CC} pin. D26, R38 and Q10 hold the shutdown pin (SHDN) low, lowering supply current to less than 2µA, allowing C26 to charge. R21 and R37 disable the supply when the input voltage is below approximately 36V. Assuming the input voltage is between 36V and 72V, switching begins when V_{CC} exceeds approximately 15V. R34 provides hysteresis, ensuring that switching continues as energy is drawn from C26. Once the supply is running, the secondary voltage is rectified to form a bias supply for the LT1681. If the output voltage collapses under fault conditions, V_{CC} may fall below its 8.4V minimum and the start-up sequence will begin again.

The power stage is very similar to a synchronous buck converter. Energy is transferred to the output inductor and the load when the top (Q1), bottom (Q3) and forward (Q5) FETs are on and the catch FET (Q6) is off. During the second half of the cycle, the top, bottom and forward FETs are off and the catch FET is on, allowing T1 to reset and energy in the output inductor to be transferred to the load. Timing of the synchronous gate (SG) output guarantees that the catch FET is off whenever the primary (top and bottom) FETs are on. The full-load waveforms are shown in Figure 2. Synchronous operation allows the output inductor current to remain continuous with no load. Excess energy is returned to the input through T1 during the first portion of the cycle in which the negative inductor current rises towards zero (see Figure 3).

R9 is used to sense primary current. The LT1681's maximum current sense input (SENSE) voltage is 150mV. The LT1681 turns the top switch on slightly before and off slightly after the bottom switch, ensuring that the bottom switch controls both turn-on and turn-off. Leading edge blanking can then be implemented by connecting the blank sense pin (BLKSENS) to the bottom FET gate. BLKSENS disables the current sense amplifier until the gate reaches 5V, eliminating leading edge spikes (a common problem in current mode control). An independent 350mV threshold I_{MAX} pin is included to prevent current runaway during the blanking period. An additional thermal shutdown comparator (THERM) is available for use with a thermistor for board-level thermal protection.

The LTC1698 Joins the LT1681 for an Isolated 48V to 5V Supply

The LTC1698 secondary synchronous forward controller synchronizes with the LT1681 via a small pulse transformer and drives the secondary MOSFETs and optocoupler directly, eliminating the need for drivers and secondary references. Referring to the block diagram in Figure 4, pulses from T2 are fed into the SYNC pin. A positive edge forces the catch gate output (CG) high and the forward gate output (FG) low. A negative edge forces the forward gate high and the catch gate low. In the event that the synchronous signal is lost, special circuitry within the LTC1698 forces both gates low within two switching cycles. This prevents cross conduction and negative undershoot during turn-off. The LTC1698 includes a 1.23V reference and 2MHz gain-bandwidth-voltage error amplifier. A 5× inverting buffer drives a ground-referenced optoisolator, eliminating the output feedforward path associated with '431-type references. A MARGIN pin allows the output voltage to be adjusted ±5%. Additional features include a power-good signal, secondary current limit and user-adjustable overvoltage protection.

Figure 5 fills in the details of the Figure 4. Many of the features found in an isolated telecom power module are included. MOSFET Q7 and associated circuitry form an active, fast start-up circuit. This eliminates the dissipation and long turn-on time associated with a trickle-start resistor. Once started, an extra winding on transformer T1 powers the LT1681. Operational amplifier U5 allows differential remote sensing of the output voltage. An efficiency graph of this circuit is shown in Figure 6. Other output voltages (1.8V, 2.5V or 5.0V) can be realized by substituting components in the same basic circuit.

text continued on page 17; Figure 5 on page 12

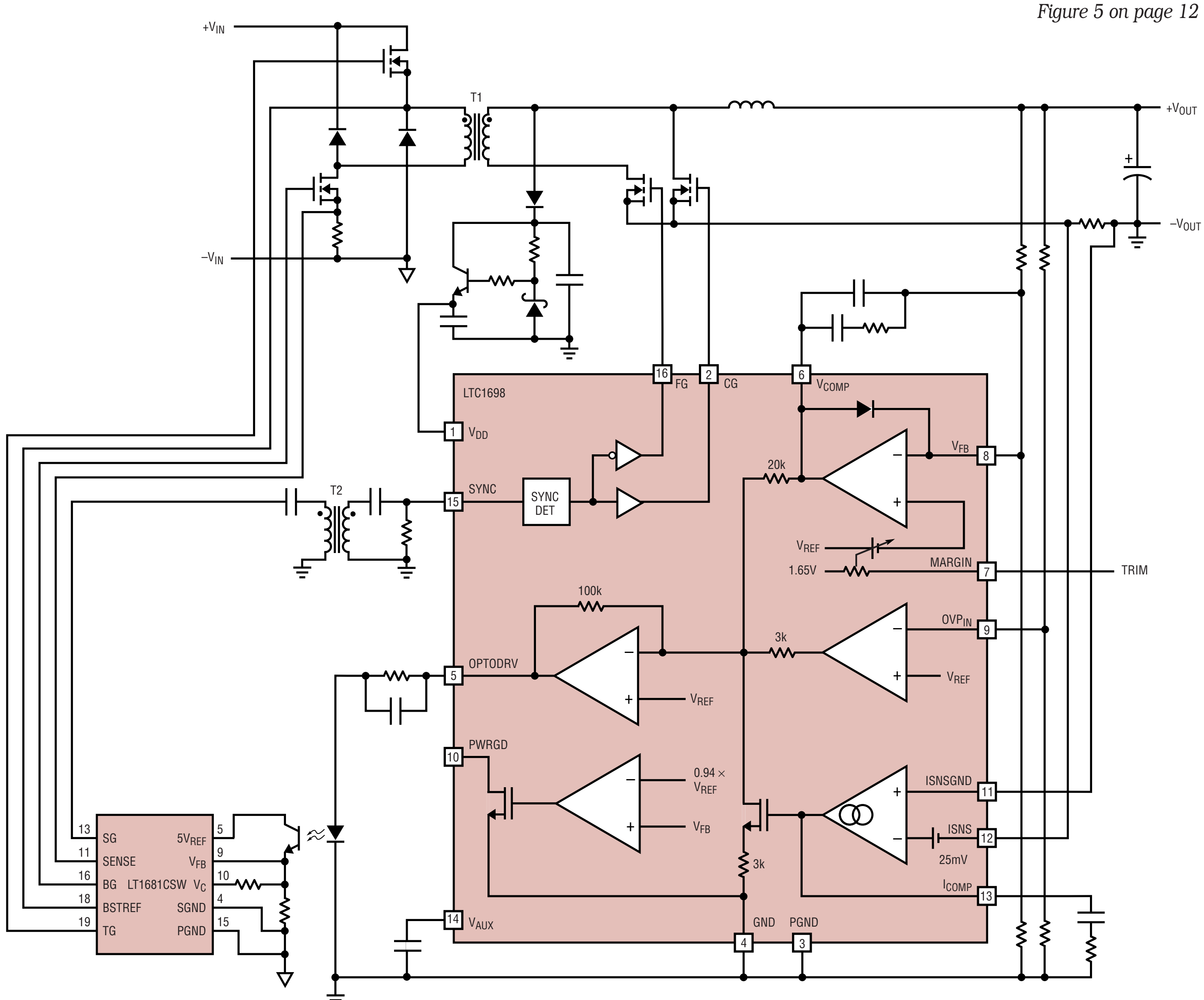

Figure 4. LT1698 simplified block diagram

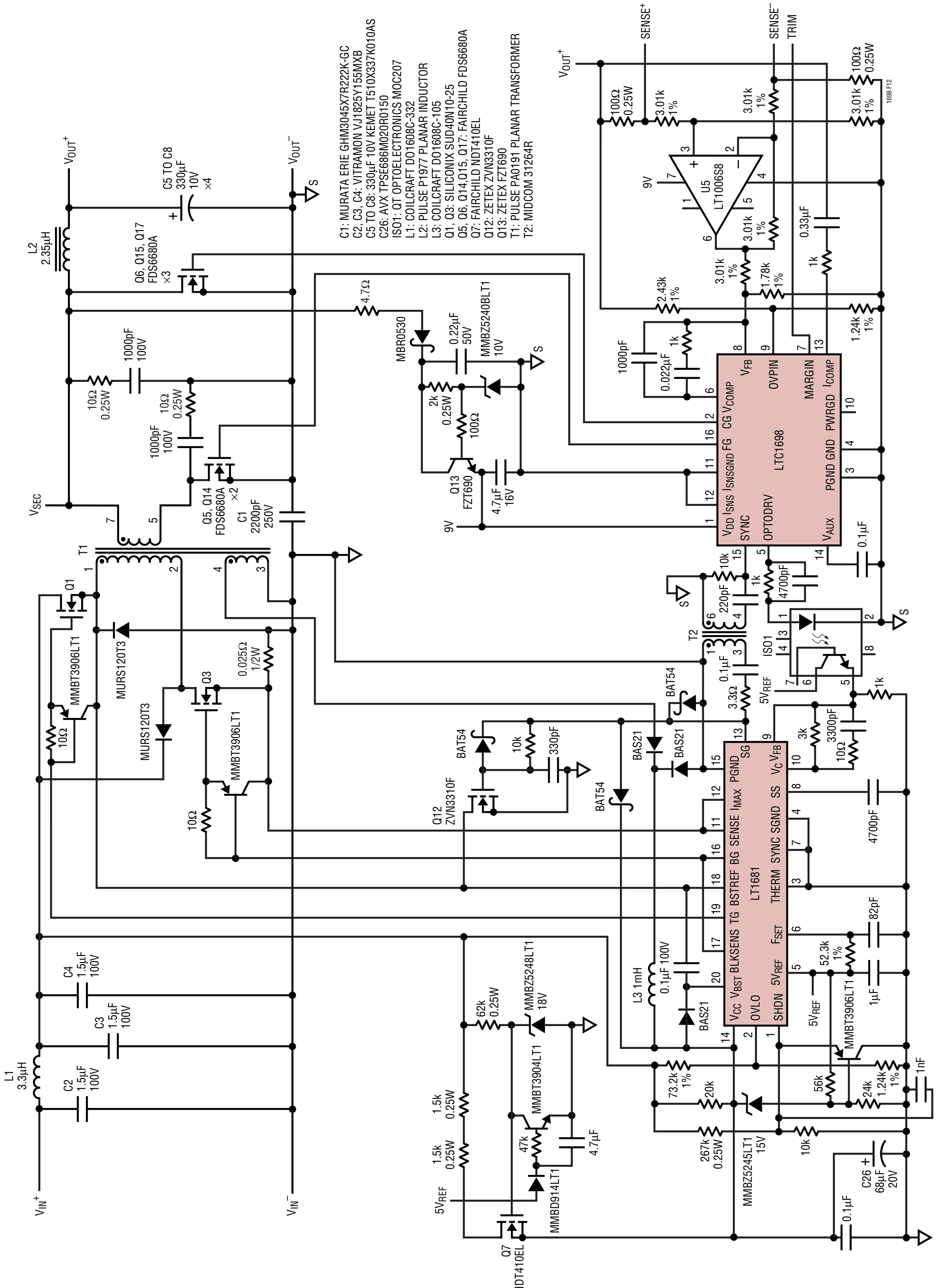

Figure 5. 36V–72V DC to 3.3V/20A synchronous forward converter with fast start and differential sense

LT1681/LTC1698, continued from page 11

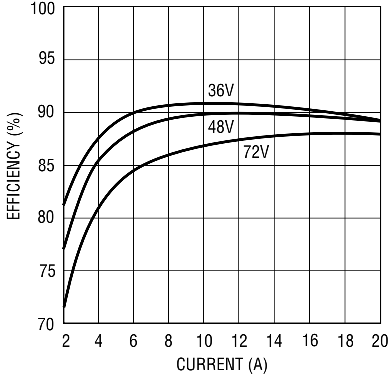

Figure 6. LT1681/LTC1698 efficiency for circuit in Figure 5

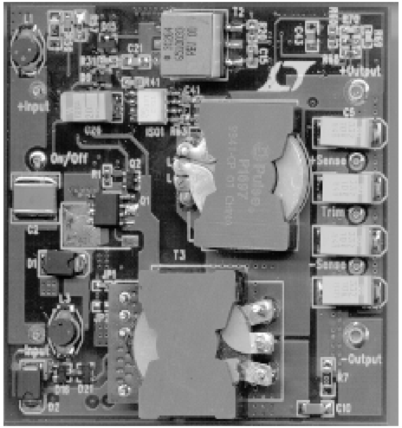

Figure 7. 48V to 3.3V/20A supply

Conclusion

The LT1681 and LTC1698 combine to provide a complete solution for synchronous forward converters. LT1681's current-mode operation to 250kHz combined with 72V high-side driver reduces circuit size and complexity. The LTC1698's built-in error amplifier, reference and synchronous gate driver make it the perfect solution for isolated applications. Together, they are the ideal choice for high input to low voltage output DC/DC converters.

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