How to Design a Thin DC/DC Power Module with Low Temperature Rise Using eGaN® FETs

Motivation

As computers, displays, smart phones and other consumer electronics systems become thinner and more powerful over the past decade, addressing the challenge of thinning the power converter and getting more power out of limited space whilst not increasing the surface temperature sees an increase in demand. This application note will look into designing a 44 V to 60 V input, 12 V to 20 V, 12.5 A output, thin DC/DC power module with low temperature rise using eGaN FETs in the simple and low-cost synchronous buck topology.

Design of a Thin and Highly Efficient eGaN-FET-based Synchronous Buck Converter

The synchronous buck topology is popular in DC/DC step-down converter design for its simplicity, easiness in control, and low cost. The schematic diagram of the eGaN-FET-based synchronous buck converter is shown in Figure 1. The 100 V rated eGaN FET EPC2218 with R_{DSon} of 3.2 mΩ as shown in Figure 2 is selected for the power stage. The uP1966A gate driver that features high driving strength is used to drive the FETs. The synchronous bootstrap circuit with EPC2038 that ensures 4.9 V gate voltage is used for the high-side gate drive. Digital control that allows sub-10 ns dead-time and flexibility in control scheme development is employed. In order to optimize the efficiency, two small on-board switch-mode power supply circuits are used to generate the housekeeping 5 V and 3.1 V voltages for the gate driver and the digital controller respectively.

Electrolytic capacitors and output inductor are usually the tallest components in the synchronous buck converter. Increasing the switching frequency would reduce the required filter capacitance and inductance, allowing the use of lower-profile passive components. However, switching loss increases with the frequency, reducing the efficiency and increasing heat dissipation. The tradeoff between thinner components and high efficiency and good thermal performance must be balanced.

The switching frequency of the converter is optimized at 400 kHz, high enough to allow the use of a 6.5 mm tall, 4.8 µH inductor, whilst maintaining low switching loss and thus high overall efficiency and good thermal performance.

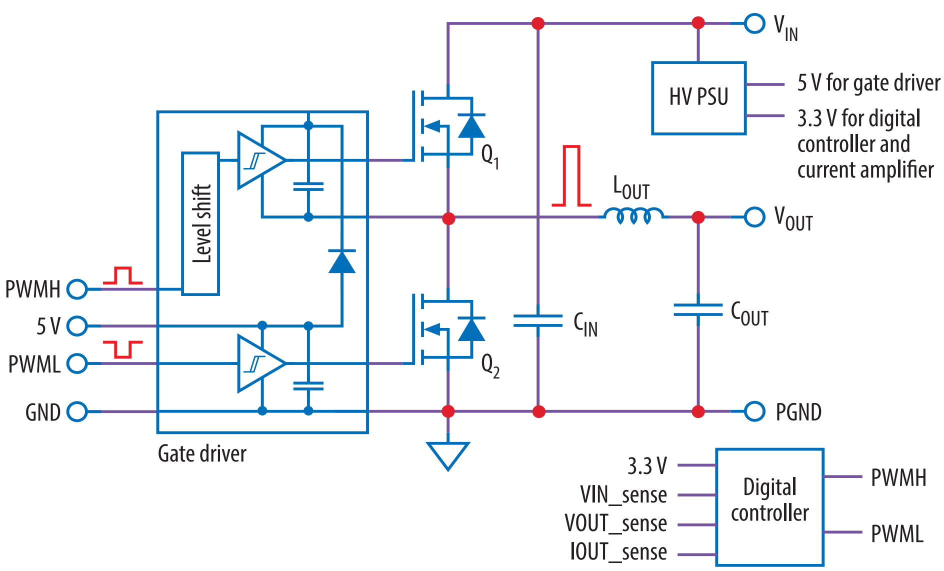

Figure 1. Simplified schematic of the eGaN FET-based synchronous buck converter

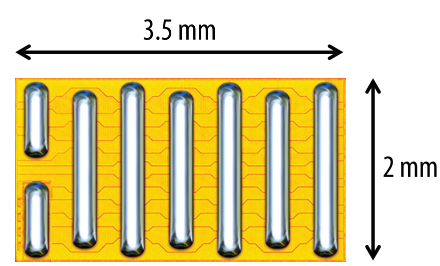

Figure 2. Photo of the bump side of EPC2218

Thermal management is very important to ensure proper and reliable operation. The wafer level chip scale package (WLCSP) of the eGaN FETs makes them easy to cool down. The addition of a heat-spreader or heatsink (HS) can significantly reduce the surface temperature of the converter and potentially increase the current rating of the power devices. To make provisions for a heat-spreader/heatsink, the circuit board is designed with three mechanical spacers that accept M2 x 0.4 mm thread screws and can be used to easily attach a heat-spreader/heatsink as shown in Figure 3. It only requires a thermal interface material (TIM), a custom shape heat-spreader/heatsink, a thin insulation layer for the components with exposed conductors such as capacitors and resistor and screws.

Experimental Validation

The synchronous buck converter **EPC9153** in Figure 4 was built with a heat-spreader to verify the design. The component thickness is 6.5 mm. The switch-node voltage v_{SW} waveform at 12.5 A output current is shown in Figure 5; the switching is seen to be fast and clean.

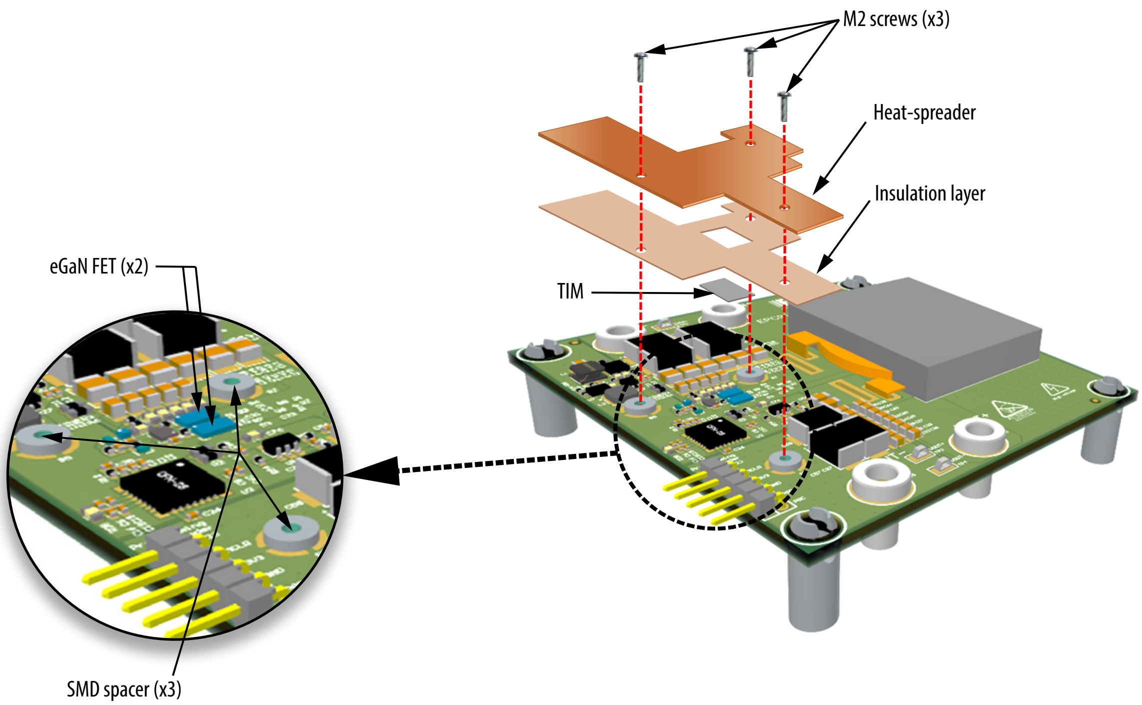

Figure 3. Illustration of the heat-spreader assembly

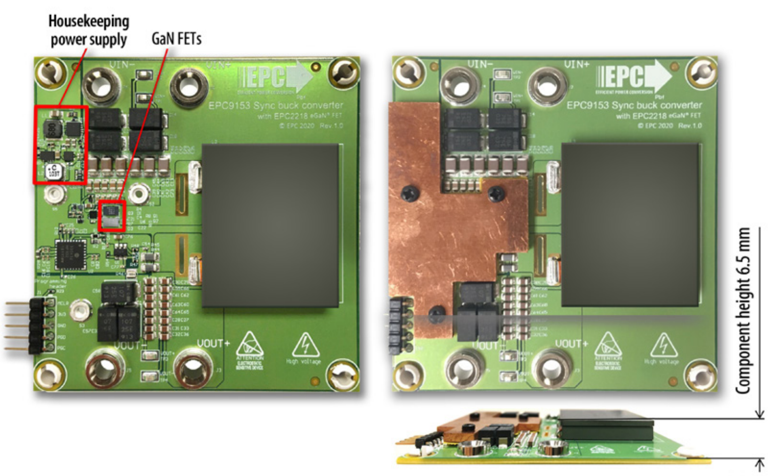

Figure 4. Photo of the 56 V to 20 V, 250 W synchronous buck converter EPC9153 without (left) and with (right) the heat-spreader installed

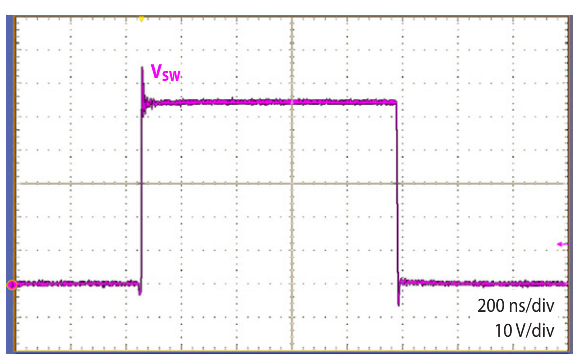

Figure 5. Switch-node voltage v_{SW} waveform at 12.5 A output current

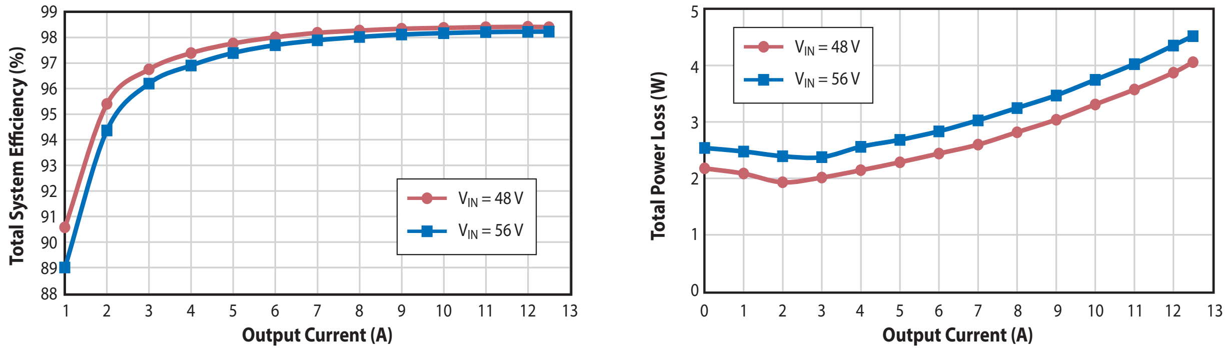

Figure 6. Total system efficiency including the housekeeping power consumption at 20 V output and different input voltages

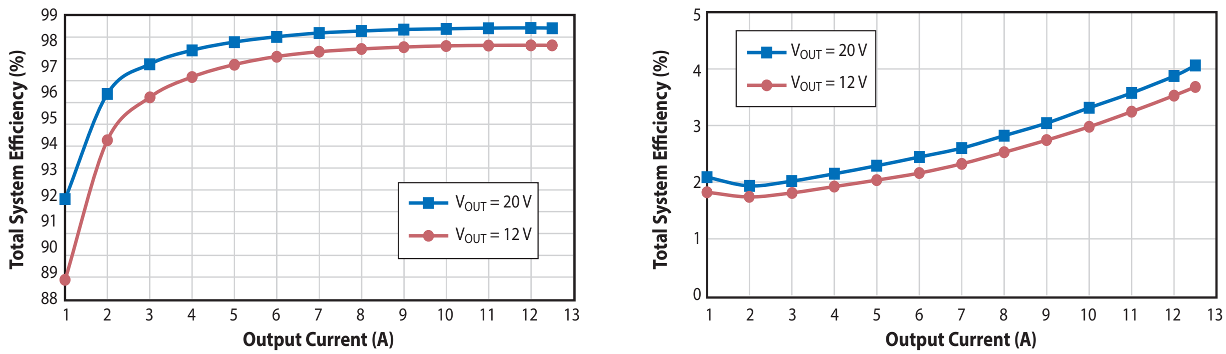

Figure 7. Total system efficiency including the housekeeping power consumption at 48 V input and different output voltages

The overall power efficiency and power loss of the synchronous buck converter operating at different input voltages and 20 V output, and 48 V input and different output voltages are shown in Figure 6 and Figure 7 respectively. It is seen to achieve over 98% and 97.6% full load efficiency at 20 V and 12 V output respectively.

The thermal image of the converter operating at 56 V to 20 V, 12.5 A output current with the heat-spreader and without forced air cooling is shown in Figure 8. A temperature rise of only 37°C is achieved. It can be seen that the FETs are capable of carrying more current given a relaxed temperature rise or forced air.

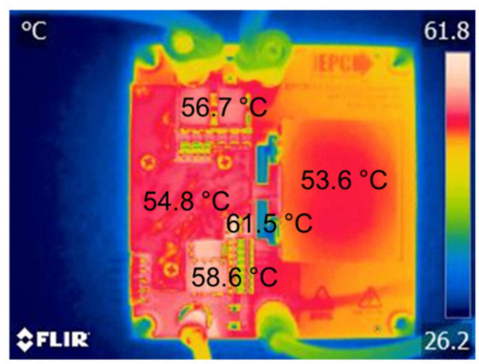

Figure 8. Thermal image of the synchronous buck converter operating at 56 V to 20 V and 12.5 A output and thermal steady state with the heat-spreader and without forced air

Conclusions

A 44 V to 60 V input, 12 V to 20 V, 12.5 A output, eGaN-FET-based synchronous buck converter with 6.5 mm component height is designed and achieves 98.2% peak efficiency and less than 40°C temperature rise at 20 V output. The eGaN FETs improve the overall efficiency with their fast switching capability. The WLCSP of the eGaN FETs makes it easy to cool them down and achieve low temperature rise.