Loss Model for Gallium Nitride DC-DC Buck Converter

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Abstract

In recent years, more research has been done on Enhancement Mode Gallium Nitride (eGaN) converters as the world is moving towards more power efficient converters. The process to make converters more efficient was bit complicated and slow in 20th century. With help of simulation tools such as MATLAB and LTspice, this process has become much faster and reliable in modern era. In order to make this process even faster, one of the important aspects in power electronics is to evaluate different losses in the converter. A model for estimating power losses for eGaN DC-DC buck converter (12V/1.2V) was created (figure 1). This loss model was calculated for different frequencies and compared experimentally, theoretically and in simulation. This research also investigates the constant variables which help realize the difference between theoretical and experimental losses of eGaN respect to output current.

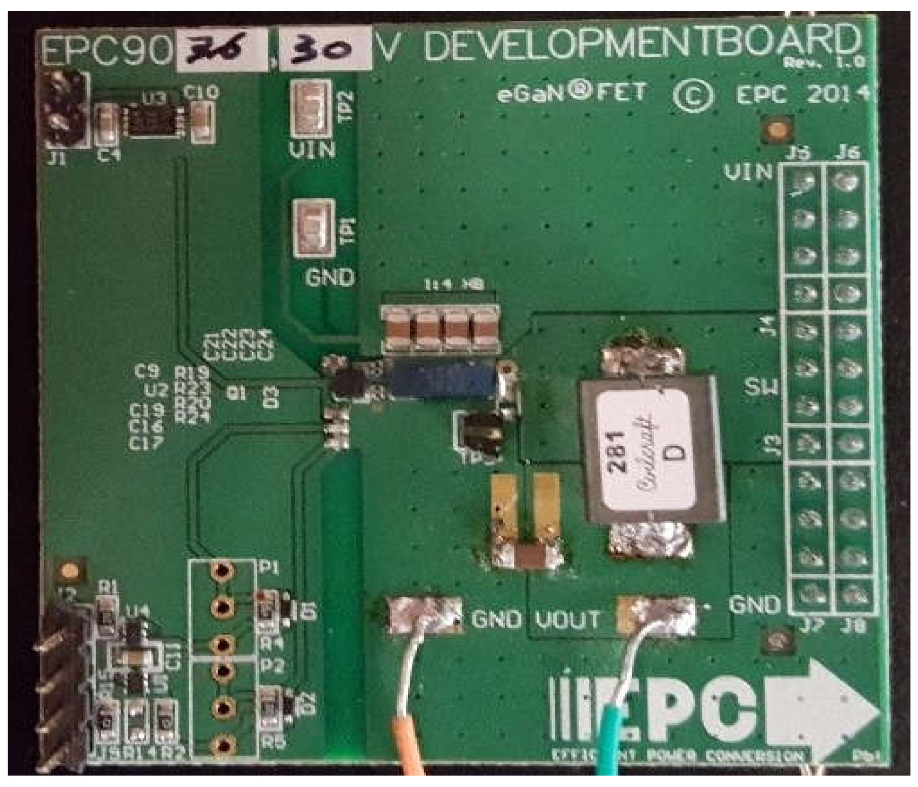

Figure 1: eGaN DC-DC Buck Converter

Method

To study the loss model theoretically, individual losses in eGaN buck converter were calculated using the datasheets provided by EPC, Coilcraft, and Digikey for eGaN transistor, inductor, and capacitor respectively (figure 2). For the experimental analysis, input power and output power measured on the board to find total loss to compare it with theoretical model (figure 3). To verify the experimental findings, LTspice was used to simulate the experimental model with inclusion of all the losses (figure 3).

Different Types of Losses

- Switching loss on high side
- Conduction loss on high side and low side
- Inductor loss
- Capacitor loss
- Gate drive loss
- Dead-time loss
- Output capacitance loss on high side and low side
- Core loss

Figure 2: Theoretical loss model

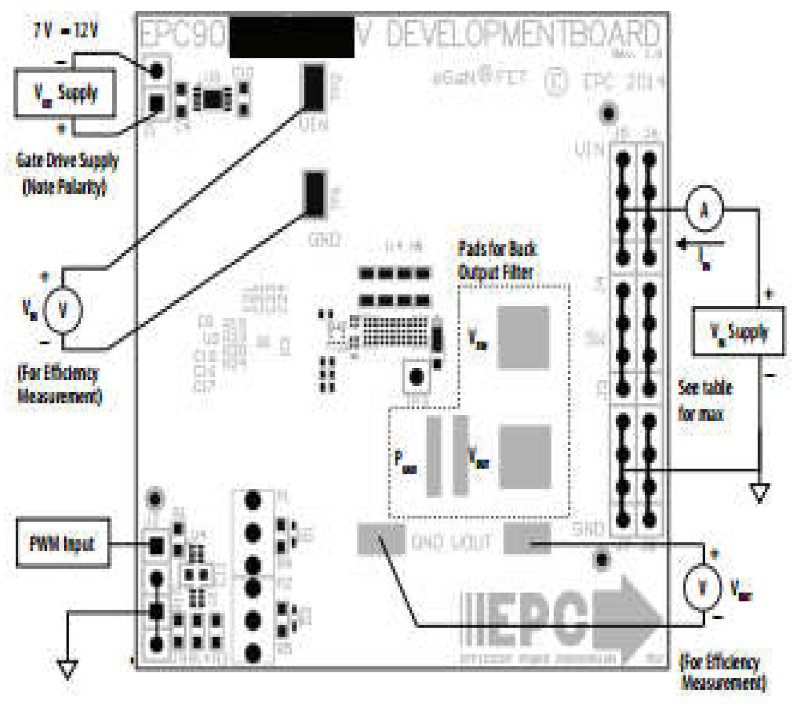

Figure 3: Connections for Experimental analysis

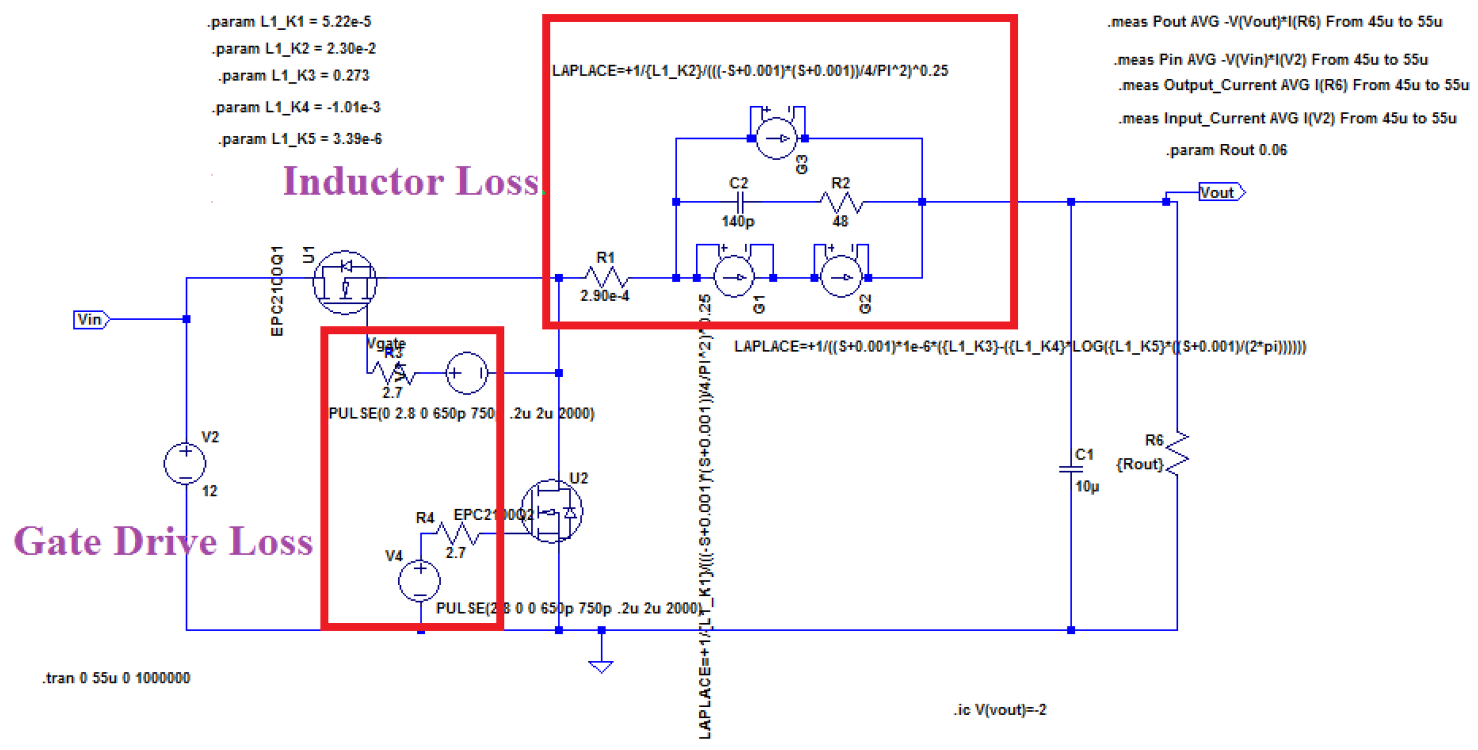

Figure 4: LTspice simulation

Discussion & Results

The experimental, theoretical, and Ltspice efficiencies compared at 1MHz and 500kHz (figure 5 and 7). In both cases, initially experimental efficiency was higher than theoretical efficiency at lower output currents before falling below theoretical efficiency. The loss difference at 1 MHz and 500kHz showed similar trends (figure 6 and 8). The loss difference approached 0 watts approximately at 10 A at both instances. The second order polynomial matched the best on the loss difference trend in both cases. An educated guess indicated that DC resistance (DCR), equivalent series resistance (ESR), and Rdson on the high side and low side of transistors may caused the loss difference. New tests on the board has been done to provide the evidence.

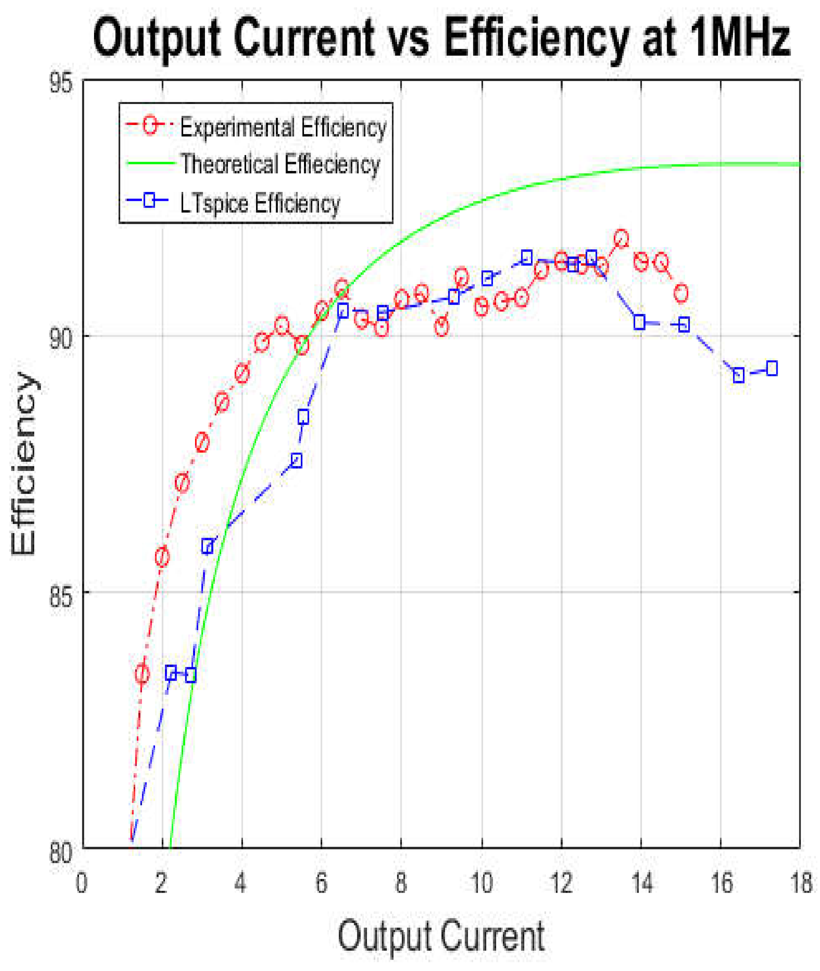

Figure 5

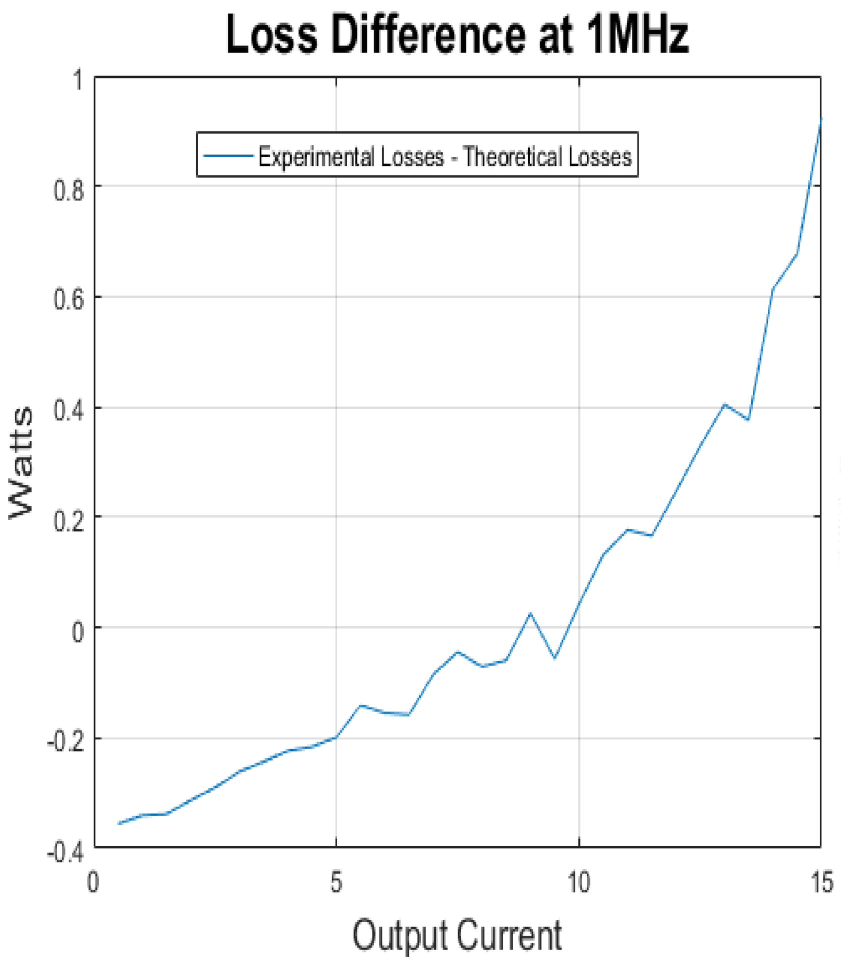

Figure 6

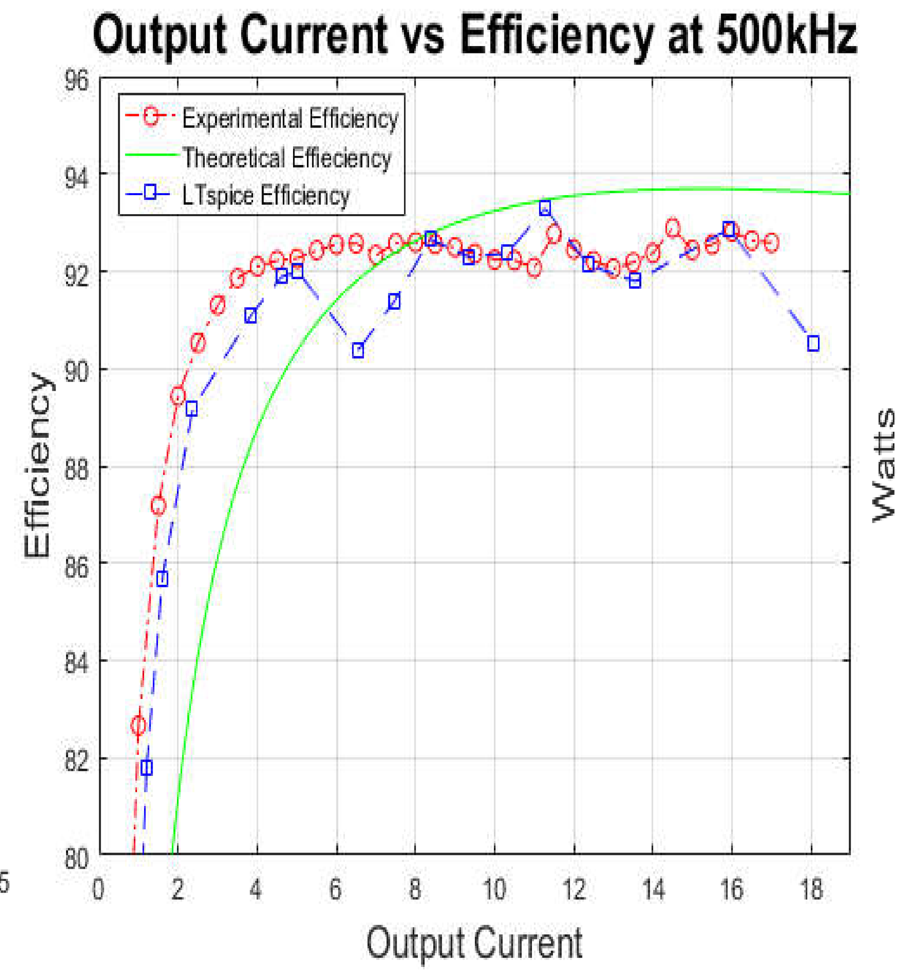

Figure 7

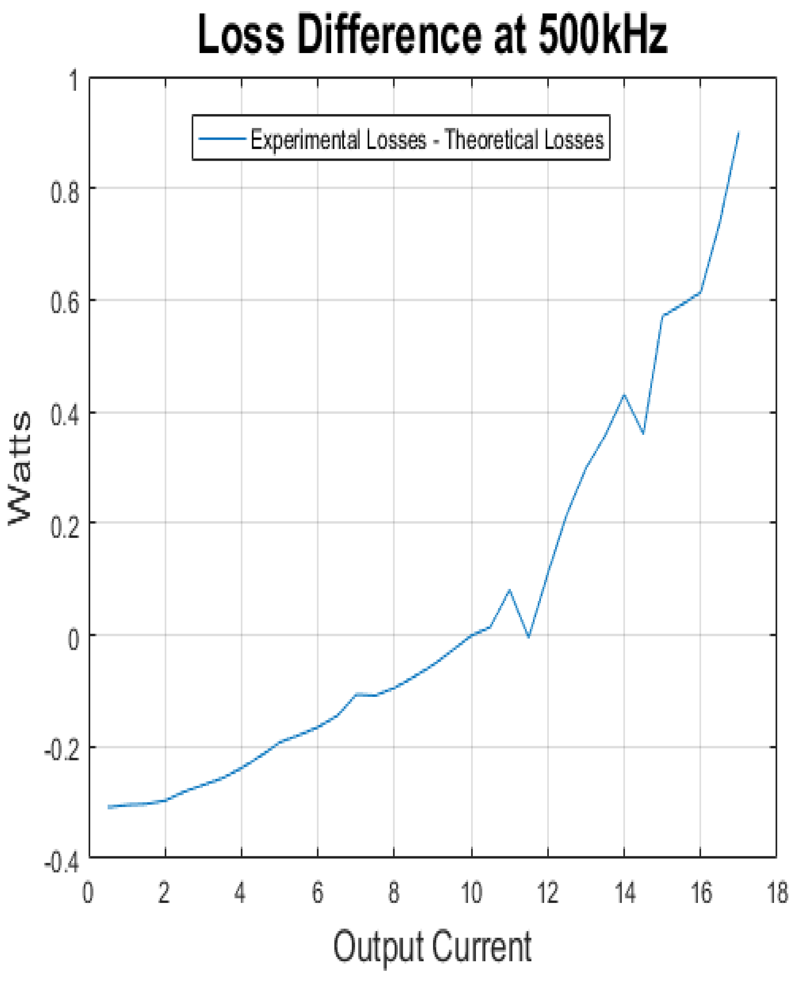

Figure 8

Conclusion

New tests on the inductor suggested that the loss difference occurred because of the DCR value and it is slightly higher than from the theoretical value. The measurement was not precise enough to conclude that ESR also contributes to loss difference but it is a possibility. Rdson on the high side and low side of transistors do not contribute or contribute less to neglect it. Other variables such as output capacitance, total gate charge, gate to source charge etc. also require explicit measurement.

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