Paper Title

Turn ON and Turn OFF characteristics of GaN

GaN devices have different turn on and turn off characteristics than other electrical switches. First of all, their parasitic capacitance values are very small resulting in that GaN devices are capable of switching faster. Thus, it is possible to operate in higher frequencies with lower switching loss. In this study, a GaN device (GS66508B – GaN Systems) is modeled in Simulink and its turn on and turn off characteristics are investigated with a synchronous buck converter circuit. As studied in many papers before, GaN device is modeled as in the Figure 1.

Figure 1: GaN Device Model schematic

Figure 2: Synchronous Buck Converter schematic

Then this model implemented in a synchronous buck converter as shown in Figure 2. For simplicity, let’s call the control switch as Top Switch and synchronous switch as Bottom Switch. Comparison to IGBTs and MOSFETs, GaN devices have different reverse conduction characteristics. In their body there is no reverse diode but they are capable of reverse conducting by themselves. The Ids-Vds characteristic graph is given in Figure 3 where it is seen that GaN is a bidirectional device. Even though the forward conduction characteristic is similar to IGBT or MOSFET, the reverse conduction characteristic is different than them. During the reverse conduction, with respect to the applied gate-source voltage it holds a positive Vsd voltage which makes the reverse conduction loss significantly higher. Therefore, the dead time optimization is important for GaN devices; however, this is out of scope for this paper.

Figure 3: Ids – Vds Graph for GaN device

As declared before, GaN is modeled and its model is used to investigate Turn ON and Turn OFF characteristics. In the beginning, the capacitances are kept constant and the inductances are neglected to obtain main switching characteristic. The Ids(t) and Vds(t) for Top Switch are given in the Figure 4 and Figure 6. For the corresponding switching periods, the Ids-Vds curves traced by the device are the ones in the Figure 5 and Figure 7. Sonuçların yorumlanması gerek!

Figure 4: Ids(t) and Vds(t) for Top Switch during Turn OFF

Figure 5: Ids – Vds Curve for Top Switch Turn ON

Figure 6: Ids(t) and Vds(t) for Top Switch during Turn OFF

Figure 7: Ids – Vds Curve for Top Switch Turn OFF

On the other hand, Ids(t) and Vds(t) for Bottom Switch are given in Figure 8 and Figure 10 and Ids-Vds curves are Figure 9 and Figure 11. In these figures dead time is included also. For the turn on period of the Bottom Switch, it is seen that when the Top Switch is being turned off, Bottom Switch starts to conduct. Due to the dead time, applied gate-source voltage is -3V for Bottom Switch when it starts conduction. Then, Bottom Switch’s gate-source voltage increased up to 6V to reduce reverse conduction loss. As a result, even though the current was flowing on the channel in dead time, applying new gate source voltage changes nothing but only it reduces the Vsd. Since in literature, the turn-on moment is defined as the moment when new gate-source voltage is applied, it makes hard to understand GaN behavior and makes a confusion about when Bottom Switch is being turned on: at the moment when it starts to conduct or at the moment when its gate source voltage is increased. In order to end this confusion it is recommended to call **active turn-on** when the switch starts to conduct current and to call **passive turn-on** the moment when the new gate source-voltage is applied. Therefore, when the top switch channel current decreases it actively turns on the bottom switch and the reverse conduction starts on the channel of Bottom Switch. Then, when the dead time ends, new gate source voltage passively turns on the device. This denotation is unnecessary for IGBT and MOSFET because during the reverse conduction the body diode is active or the current commutates from the body diode to channel.

Figure 8: Ids(t) and Vds(t) for Bottom Switch during Turn OFF

Figure 9: Ids – Vds Curve for Bottom Switch Turn ON

Figure 10: Ids(t) and Vds(t) for Bottom Switch during Turn OFF

Figure 11: Ids – Vds Curve for Bottom Switch Turn OFF