Digitalized Power Electronics for Incorporating IoT and AI

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Abstract

The concept and the example of Power Electronics 2.0 are shown in this paper. Power Electronics 2.0, which is a combination of IoT, AI, and power electronics, is an essential technology for the power electronics industry to continue to grow in the future. Power Electronics 2.0 will directly connect manufacturers and users, and will enable power electronics to continue to evolve and respond to each user's individual needs by utilizing the large amount of data generated by power electronics equipment.

1. Introduction

In order for the power electronics industry to continue to grow in the future, it needs to change to a different competitive axis from the traditional one of "good products at low prices". One of these axes of competition is the concept of "Power Electronics 2.0" [1]. Power Electronics 2.0, which integrates IoT and AI, will directly connect manufacturers and users, and will enable power electronics to continue to evolve and respond to each user's individual needs by utilizing the large amount of data generated by power electronics equipment. If the business model of power electronics is changed from a flow-based model to a stock-based model (subscription-based model), the power electronics industry will be able to continue to grow in the future.

2. Concept of Power Electronics 2.0

Fig. 1 shows the concept of "Power Electronics 2.0" [1], where the power electronics is digitalized for IoT and AI implementation. Table I shows a comparison between conventional power electronics and Power Electronics 2.0. Power Electronics 2.0, which is a combination of IoT, AI, and power electronics, is an essential technology for the introduction of the subscription-based business model. This is because the essence of the revolution enabled by IoT is to directly connect the manufacturers and users, and to learn how the users actually use the products. With the addition of AI, the power electronics that are individualized for each user will be able to maximize user value. Beyond that, there will be the power electronics that continues to evolve and respond to the individual needs of each user, whose functions and performance will increase with increasing use. The three key technologies to enable Power Electronics 2.0 are (1) sensors and network connections for IoT, (2) digitalized programmable hardware whose characteristics can be changed by software, and (3) AI based on big data.

3. Programmable Digital Gate Driver IC for GaN FETs

As a research case study of programmable hardware for

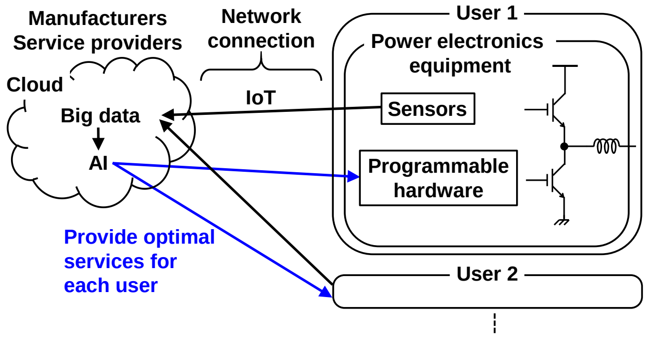

Fig. 1. Concept of "Power Electronics 2.0" [1].

Table I Comparison between conventional power electronics and proposed Power Electronics 2.0

	Conventional power electronics	Power Electronics 2.0
Business model	Selling off products	Subscription-based
Value	Good products at low prices	Provide personalized services to each user
Keywords	High performance, high reliability	IoT, AI, Digital
User's usage status	Unknown	Collect and analyze user data by IoT and AI
Hardware	Fixed	Programmable with software

Power Electronics 2.0, a digital gate driver (DGD) that digitalizes the gate driver circuit is described. DGD [2], where the gate driving current (I_G) is dynamically controlled using a software during the turn-on/off transients, is a promising technology to solve the conventional trade-off between the switching loss (E_{LOSS}) and the current ($I_{OVERSHOOT}$) or voltage overshoot of power devices. The impact of the digital gate driver is as follows. (1) High flexibility because the characteristics can be changed by software. (2) Anyone can use DGD because the parameters of the digital gate driver circuit can be optimized automatically by software. (3) Various needs of different users can be met by simply rewriting the objective function for the optimization in software.

GaN FETs provide low on-resistance and fast switching, which makes them suitable for realizing high efficiency and small volume power converters. GaN FETs, however, are very difficult to use because of its ultrafast switching operation, which causes large and high frequency voltage and/or current ringing, causing device reliability and EMI problems. To solve the problem, a 5 V, 300 MSa/s, 6-bit DGD IC, where the gate current is varied in 64 levels for each of 16 3.3-ns time intervals, is developed for GaN FETs [3]. Figs. 2 and 3

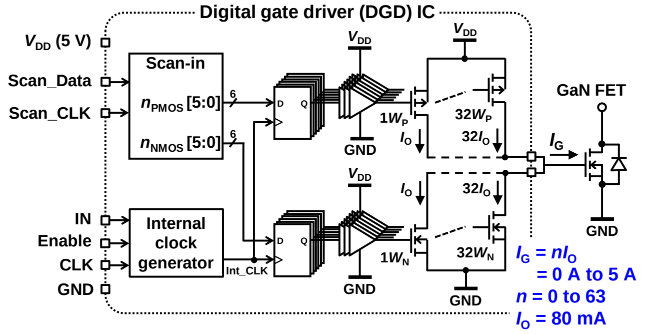

Fig. 2. Circuit schematic of 5 V, 300 MSa/s, 6-bit DGD IC for GaN FETs.

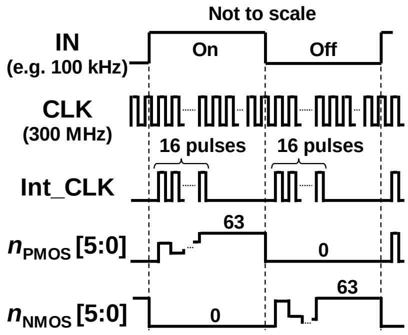

Fig. 3. Timing chart of 300 MSa/s, 6-bit DGD IC.

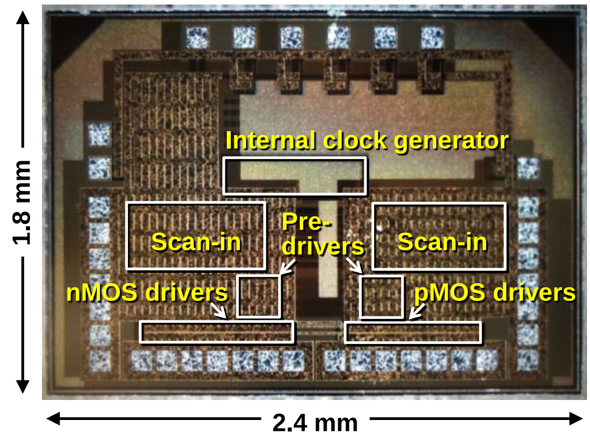

Fig. 4. Die photo of DGD IC fabricated with 180-nm BCD process.

show a circuit schematic and a timing chart of the developed DGD IC for GaN FETs, respectively. Fig. 4 shows a die photo of the developed DGD IC fabricated with 180-nm BCD process. The parameters for DGD are automatically optimized using a simulated annealing algorithm [2] through repeated switching measurements. Fig. 5 shows the measured E_{LOSS} vs. $I_{OVERSHOOT}$ of the conventional single-step gate driving and the proposed gate drive for comparison. In the turn-on of GaN FET (EPC2045, 100 V, 16 A rating) at 48 V and 8 A, compared with the conventional single-step gate driving, the proposed gate drive using DGD reduces E_{LOSS} from 3.9 µJ to 1.2 µJ by 69 % at the same $I_{OVERSHOOT}$ of 3.4 A and reduces $I_{OVERSHOOT}$ from 8.5 A to 3.4 A by 60 % at the same E_{LOSS} of 1.2 µJ, which clearly shows the advantage of DGD for GaN FETs.

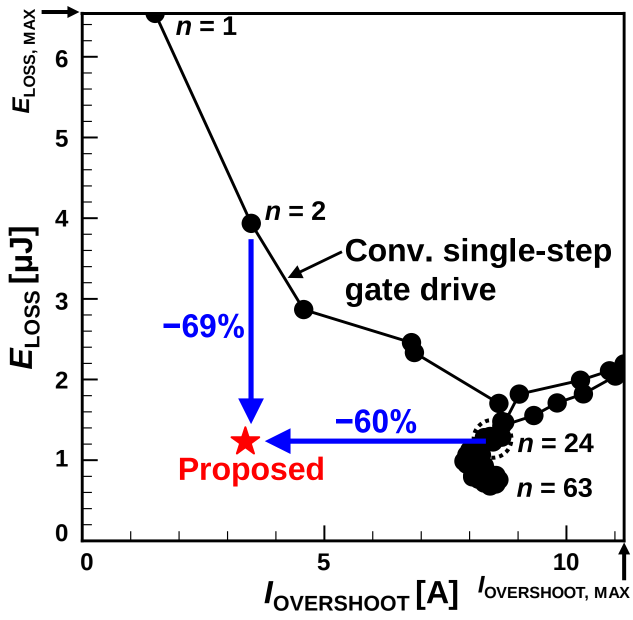

Fig. 5. Measured E_{LOSS} vs. $I_{OVERSHOOT}$ of conventional single-step gate driving and proposed gate drive.

4. Conclusions

Power Electronics 2.0, which is a combination of IoT, AI, and power electronics, is an essential technology for the power electronics industry to continue to grow in the future. In order to realize Power Electronics 2.0, however, a lot of technical issues in a wide range of fields, including AI, IoT, circuits, devices, sensors, ICs, and software, remain to be addressed and the researches that links these areas needs to be promoted in the future.

Acknowledgements

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References

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