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Introduction of New 650V Automotive Power Module with Latest Field Stop IGBT for an Excited Synchronous Motor Application

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Abstract

This paper introduces a 650V Automotive Power Module (APM) designed for automotive exciter motor applications. The module utilizes the newly developed Field Stop trench technology IGBT with an advanced softness freewheeling diode and features direct bonded copper substrates for high thermal performance. Specifically, this module offers high power density with low IGBT and Fast recovery freewheeling diode (FWD) losses tailored for automotive exciter applications. The paper provides a comprehensive description, including electrical characteristics and thermal performance analysis.

1 Introduction

Vehicle electrification has emerged as a pivotal megatrend within the automotive industry, with profound implications anticipated across various facets including the market, environment, infrastructure, and societal dynamics. One significant repercussion of this paradigm shift is the looming risk faced by automakers of forfeiting a fundamental competency: the development and construction of the combustion engine, traditionally considered the heart of automobiles [1]. Consequently, many major automotive OEM companies have heavily invested in engineering and production facilities to navigate the transition from combustion engine-powered cars to electric vehicles (EVs), while retaining the core competence of developing drive-train components. Due to significant advantages in terms of materials and safety, OEMs have opted to use AC induction synchronous motors instead of permanent magnet motors (brushless DC or synchronous), which are more commonly used in EVs as shown in Fig.1. Permanent magnets require rare earth materials for construction, the supply of which may soon be limited by law in several countries. Additionally, AC induction synchronous motors offer a safety advantage: in the event of an accident, the magnetic field generated by the exciter can be immediately shut down, instantly zeroing the motor's torque.

In response to these emerging needs, ON Semiconductor has successfully released the 650V Automotive Power Module (APM) for exciter applications. Specifically, the adopted Field Stop trench (FST) IGBT performance is optimized by its own characteristics for improved Electro-Magnetic Interference (EMI) performance. Additionally, the adapted fast recovery freewheeling diode (FWD) also exhibits superior softness characteristics. This paper provides a detailed description of the electrical performance of the IGBT and FWD, along with other important considerations for designing the system.

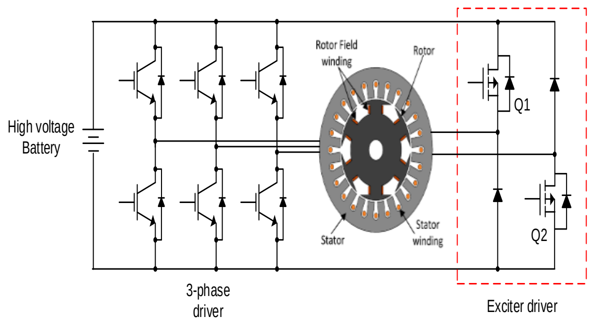

Fig. 1: Electrically Excited Synchronous Motor block diagram with traction inverter

2 Main features of design and electrical performance

Figure 2 illustrates the package and internal equivalent circuit of the new 650V Automotive Power Module.

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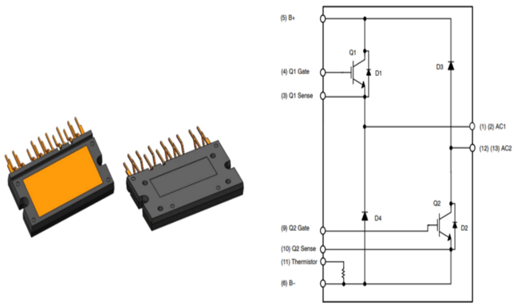
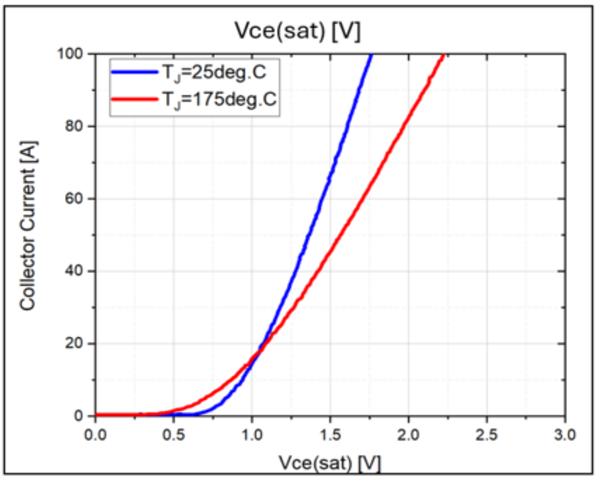


Fig. 2: Outline overview and Internal equipment circuit

This product comprises two latest Field Stop Technology (FST) IGBTs and Fast Recovery Freewheeling Diodes (FWD) in a two-phase inverter structure with a negative coefficient thermistor designed for general automotive exciter applications. The proposed FST IGBTs are fabricated using high-density trench IGBT cells to achieve the appropriate breakdown voltage level and lower conduction losses. Moreover, the n+ emitter area is optimized to adjust the maximum current level of the IGBTs, enhancing their short-circuit ruggedness. In this experiment, stripe-patterned trench cells are designed with dummy gates and a floating p-base region without emitter contact to reduce conduction losses by accumulating hole carriers near the cathode area. Additionally, multiple buffer layers are incorporated to optimize process variation and device performance. Consequently, the FST IGBTs exhibit key electrical characteristics such as low conduction and switching losses across all motor driving and exciter conditions [2]. Figures 3 and 4 depict the conduction and switching waveforms of the adapted FST IGBT and FWD for a 650V 75A exciter application. Particularly, the IGBT and FWD are optimized for soft turn-on switching without excessive ringing, facilitating easier design and cost-effectiveness to achieve better EMI performance.



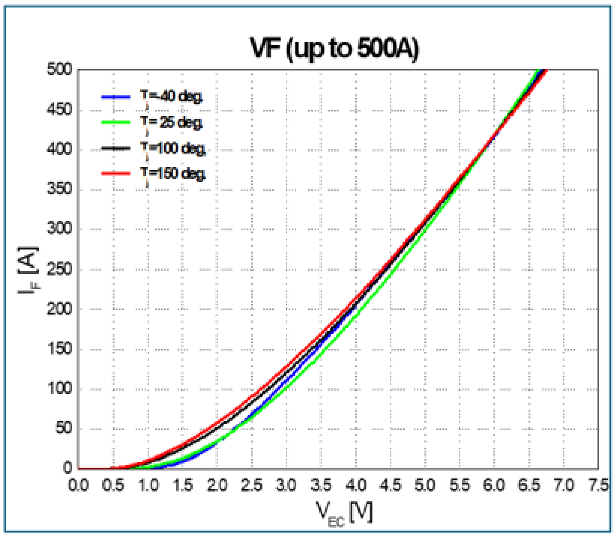


Fig. 3: I-V curve of IGBT and FWD for conduction

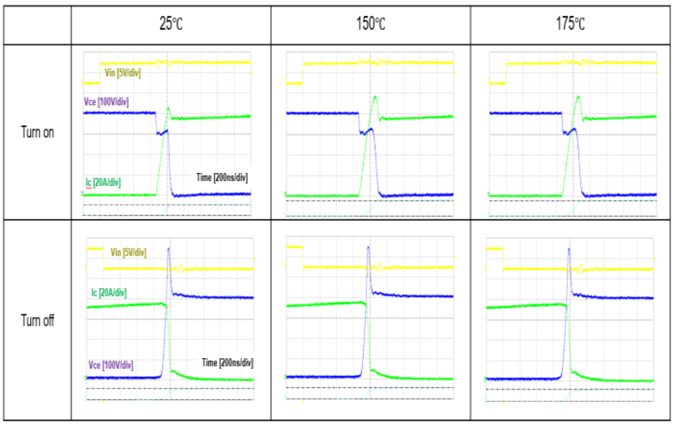


Fig. 4: Turn on/off switching characteristic at V_{DC}=400V, I_C=50A, V_{GE}=15V, Rg=8ohm

Based on the measurement results, Table 1 and Figure 5 illustrate total losses with favorable outcomes under typical exciter application conditions. Furthermore, the APM series is compliant with AEC-Q100 and AQG-324 standards.

DUT	Single IGBT		
	$P_{CON.}$	$P_{SWI.}$	$P_{TOT.}$
Power Loss @ $15A_{pk}$, 2KHz	3.5	0.5	4.0
Power Loss @ $15A_{pk}$, 12KHz	3.5	3.3	6.8
Power Loss @ $40A_{pk}$, 2KHz	12.3	1.4	13.7
Power Loss @ $40A_{pk}$, 12KHz	12.3	8.6	20.9

Table 1 : Single IGBT power loss table at V_{DC}=400V, I_C=50A, V_{GE}=15V, Rg=8ohm, T_C=80℃

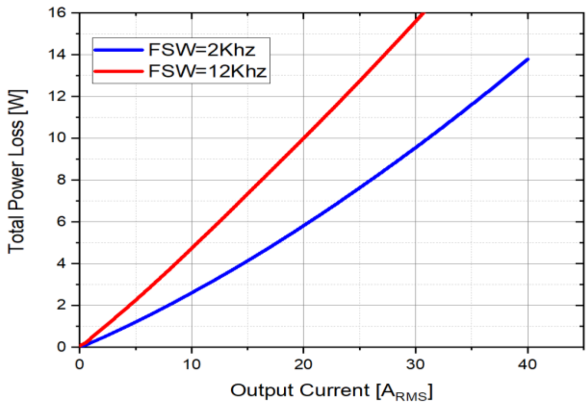


Fig. 5: Single IGBT total loss simulation graph at V_{DC}=400V, V_{GE}=15V, T_C=80℃

3 Conclusion

In this paper, we provide a comprehensive overview of the newly developed APM16 for 650V designed for automotive exciter application power stages. It offers several advantages, including enhanced reliability, straightforward construction, ease of assembly, and notably, outstanding cost-effectiveness tailored for exciter application power stages.

4 References

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