Low Cost Analog Basis Inverter Output Current Sensing Technology Practically Implementable inside IPM with Tiny PCB Coil

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Purpose of Work

As the key devices for electric vehicles, tractions, appliances and industrial motor drives, the intelligent power modules (IPMs) are becoming a trend, while getting miniature and high power density. Output current sensors for the inverter control, however, **remain bulky and costly with the magnetic cores.**

Recently, **PCB Rogowski coil approach** for current sensing has been demonstrated [LangMaak97, Takahara, Tabata, Hasegawa, JunWang,]. In those papers, however, FPGAs or digital processors are needed for waveform processing, as the result **the cost will becomes too high to integrate in IPMs**. A low cost analog basis demonstration with "Envelope Tracking" method has been proposed from the authors group [Otgon], however, tracking error cause **accuracy problem**.

In this paper, for the first time, tiny PCB coils are embedded inside the IGBT power module package to demonstrate noise immunity of the system, and applied new circuit to solve the accuracy problem. Only general purpose OP-amps and photo couplers are used in the demonstration circuit.

A simple structure with reduced cost PCB "Rogowski coil" current sensor has been developed to reduce the volume and cost of the systems as shown in figure 1. The authors of this study[1] have proposed new output current measurement method with tiny PCB sensor with analog amplifier circuits which enables an integration of current measurement inside the power semiconductor modules.

Although, an effect[2] of integrator circuit that leads to significant measurement error, had not been considered in the method. Thus, the usage of the integrated PCB current sensor is impossible in practice.

Approach

An analog approach has been proposed with new waveform reproduction method, named "envelope tracking", which uses two sets of sensors, integrator amplifiers and S/H circuits. The method detects and tracks the maximum point value of integrator amplifier signal at each switching (turn-on / turn-off) time of power semiconductors device.

During a narrow pulse part of sinusoidal pulse width modulation**,** the output signal of the integrator does not reach to its initial position before the next on/off event. This **event leads to an additional offset error value to integrator's next signal** as shown in Figure 3.

In this paper, we **estimated the error and showed the criteria of accurate envelope tracking**. Also, **modified analog circuit to eliminate the measurement error** under the narrow pulse width signals has been employed.

The PCB sensor placed inside the power module in our experimental setup, figure 2. Operational amplifiers have been used in the analog circuit which is also possible to put inside the power module.

[1] B. Bat-Ochir, et.al, "Envelop Tracking Based Embedded Current Measurement for Monitoring of IGBT and Power Converter System," Microelectronics Rel., Vol. 88–90, p.p 500-504, Sep. 2018.

[2] K. Hasegawa, et.al, "A New Output Current Measurement Method with Tiny PCB Sensors Capable of Being Embedded in an IGBT Module," in IEEE Trans. Power electronics, vol. 32, no. 3, pp. 1707-1712, Mar. 2017.

Results and Significance

By using 2 channels of proposed analog circuits and PCB sensors, we successfully measured output current of the inverter. Each channel output exactly follows upper or lower edges of the load current, as shown in figure 6.

Our result shows an excellent correspondence between conventional sensor output and proposed method output. Most importantly, PCB “Rogowski coil” sensor and modified, low cost analog circuits create practical possibility to integrate current measurement into a power module.

Supporting Materials (up to two additional pages)

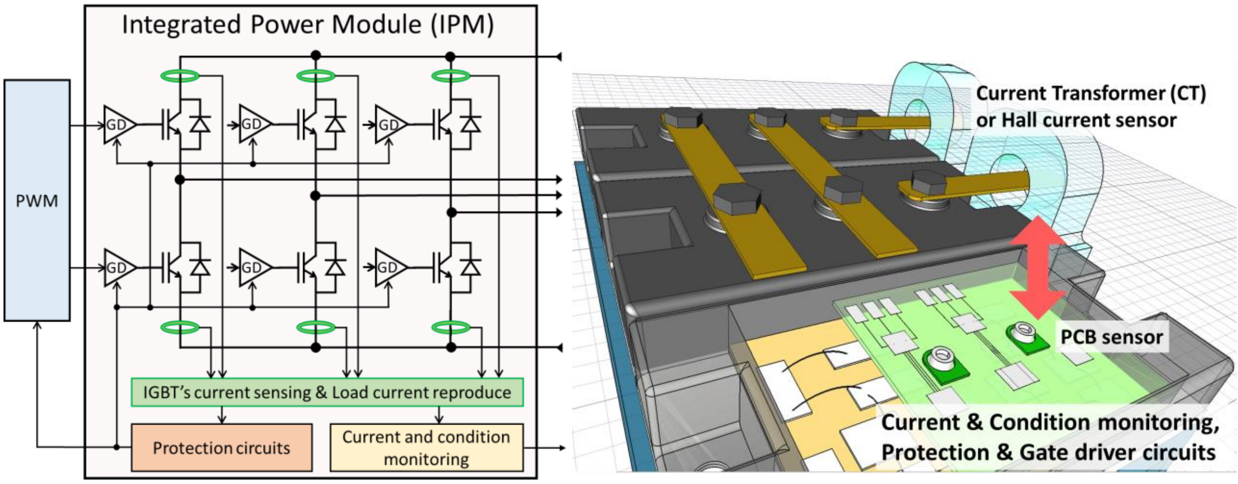

Fig. 1: Outlook on power modules, built-in current sensors, protection and gate driver circuits

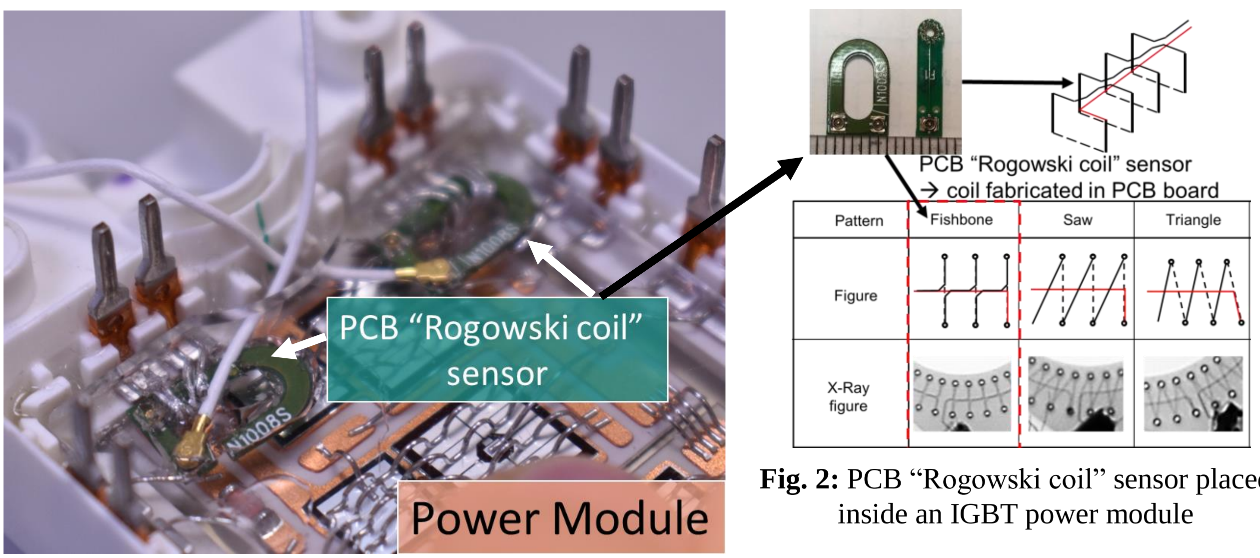

Fig. 2: PCB "Rogowski coil" sensor placed inside an IGBT power module

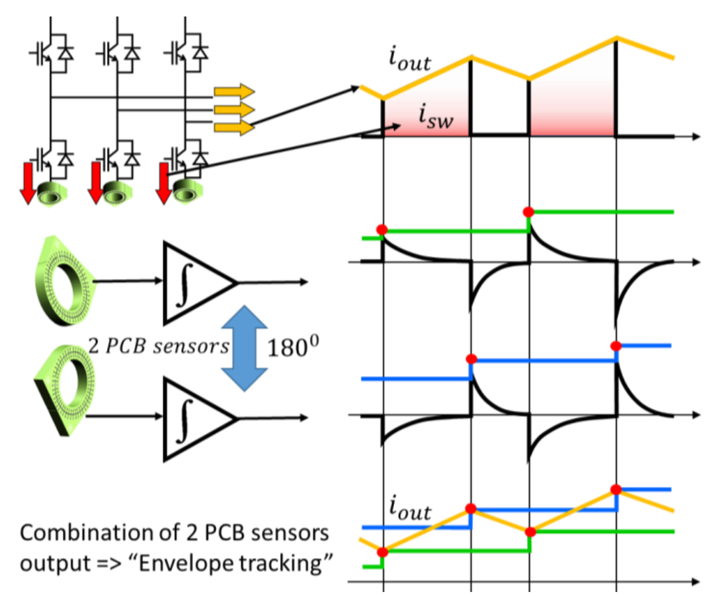

Fig. 3: Analog circuit based current measurement, "Envelope tracking" method.

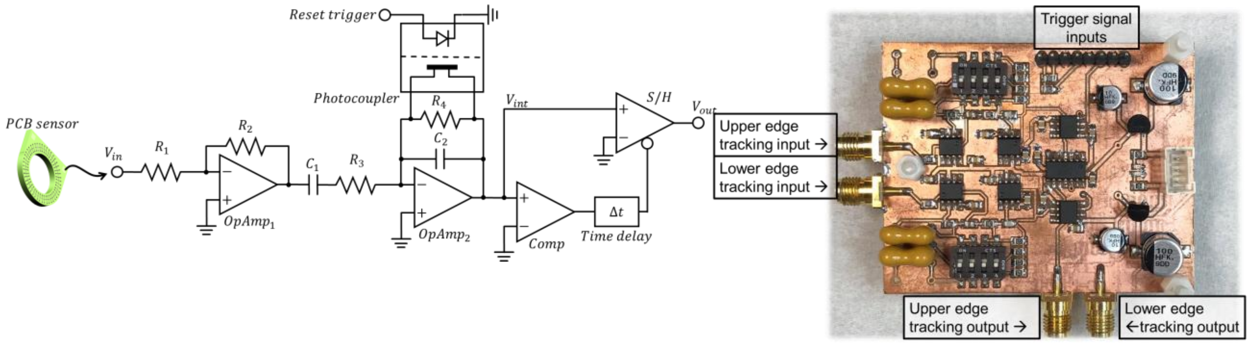

Fig. 4: The proposed analog circuit for current measurement, schematic and photo.

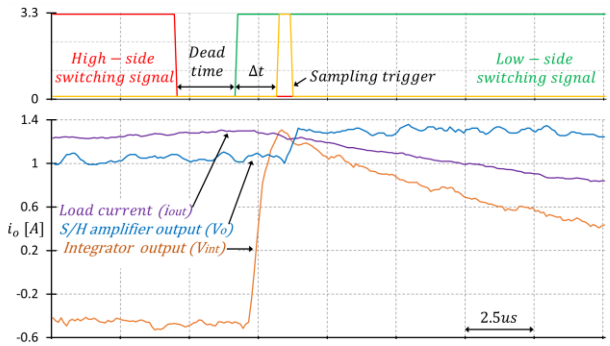

Fig. 5: Measurement waveforms of analog circuit

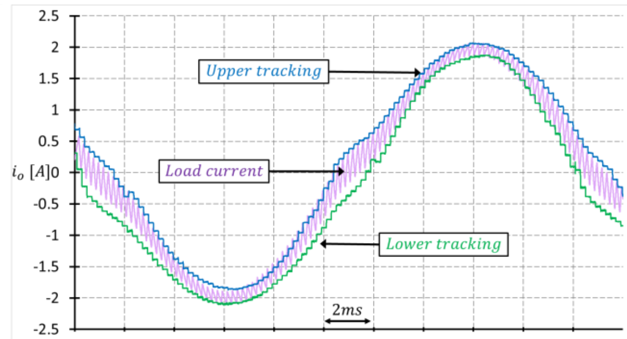

Fig. 6: H-bridge inverter output current measurement result, upper and lower edge tracking

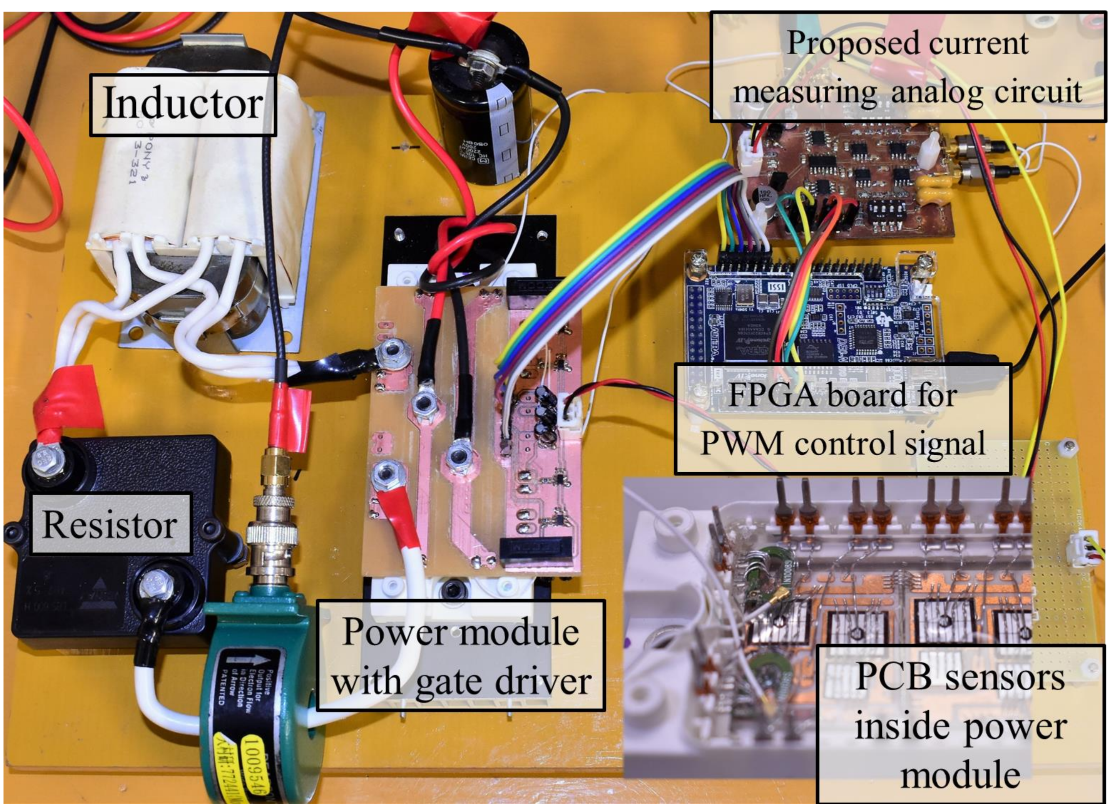

Fig. 7: Photo of the H-bridge inverter experimental setup. PCB sensors are placed inside the Infineon power module covered by connection and gate driver circuit board