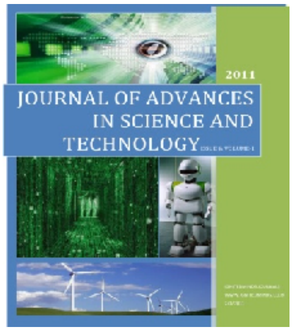

Study of Gate Drivers Techniques

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Abstract: With the uncompromising integration of IGBT drive and protection functions as well as DC/DC control and signal transition, a new generation of reliable and cost-effective IGBT driver solutions is born. The resulting smart IGBT gate driver construction helps to economize price-sensitive external components. The total system cost is thus significantly reduced. The IGBT gate driver cores 2SC0108T and 2SC0435T constitute a new standard in cost, functionality, reliability, and user-friendly design.

Keywords: 2SC0108T/2SC0435T, IGBT drivers, AAC

I. Introduction

It is well known that the number of individual components interacting in a system is important for its overall reliability. Fewer components mean higher reliability in non-redundant systems, as long as component failure rates are comparable. This principle is successfully applied to the monolithic integration of electronic functions into ICs for almost all aspects of everyday life, science and industry. In power electronics, however, design cycles are considerably slower and designers are more cautious in adopting technical advances. This risk-minimizing attitude has brought today's power systems to a very high level of reliability. However, as the number of electronic functions increases, the reliability limitation is becoming more and more severe due to the large number of discrete components and off-the-shelf ICs. The SCALE-2 ASIC platform has been specifically developed to address this problem. Custom integration shows its strength in the new IGBT gate driver cores 2SC0108T and 2SC0435T.

II. Reinforced insulation and high dv/ dt stability

The operating range of today's 1700V IGBT modules can be fully exploited with these drivers, as clearance and creepage are coordinated to EN50178 under pollution degree 2. Moreover, both the signal barrier and the DC/DC transformer between the primary and secondary sides provide reinforced insulation to EN50178, protection class 2. The combined coupling capacitance for DC/DC and pulse transformers between the primary and secondary sides is less than 18pF. Thanks to these outstanding performance figures, drive systems built with these cores withstand dv/dt transients as high as 75kV/µs.

III. Power and speed

The SCALE-2 ASIC chipset used in the 2SC0108T and 2SC0435T introduces a delay of less than 100ns in the turn- on and turn-off signal paths. This delay time is delivered at a superior repeatability of +/-4ns including jitter and ageing. A comparison with other technologies such as opto-couplers shows that the propagation delay time is typically as high as 500ns with a mismatch of several 100ns. Uneven ageing of separate drive channels is a common problem for fiber optics and opto coupler systems. In contrast, SCALE-2 drivers maintain symmetrical switching of the driver channels. The clear user advantage is constant IGBT losses over the lifetime of an inverter. Switching frequencies up to 100kHz are allowed with no derating for an ambient temperature up to +85°C. In the same environment, SCALE-2 IGBT driver cores provide a gate drive power of 1W and 4W per channel respectively (2SC0108T/2SC0435T). The associated gate drive current is 8A/35A. Any IGBT module ranging from 600V to 1700V in this voltage class can be easily used at an inverter output current of up to 2400A.

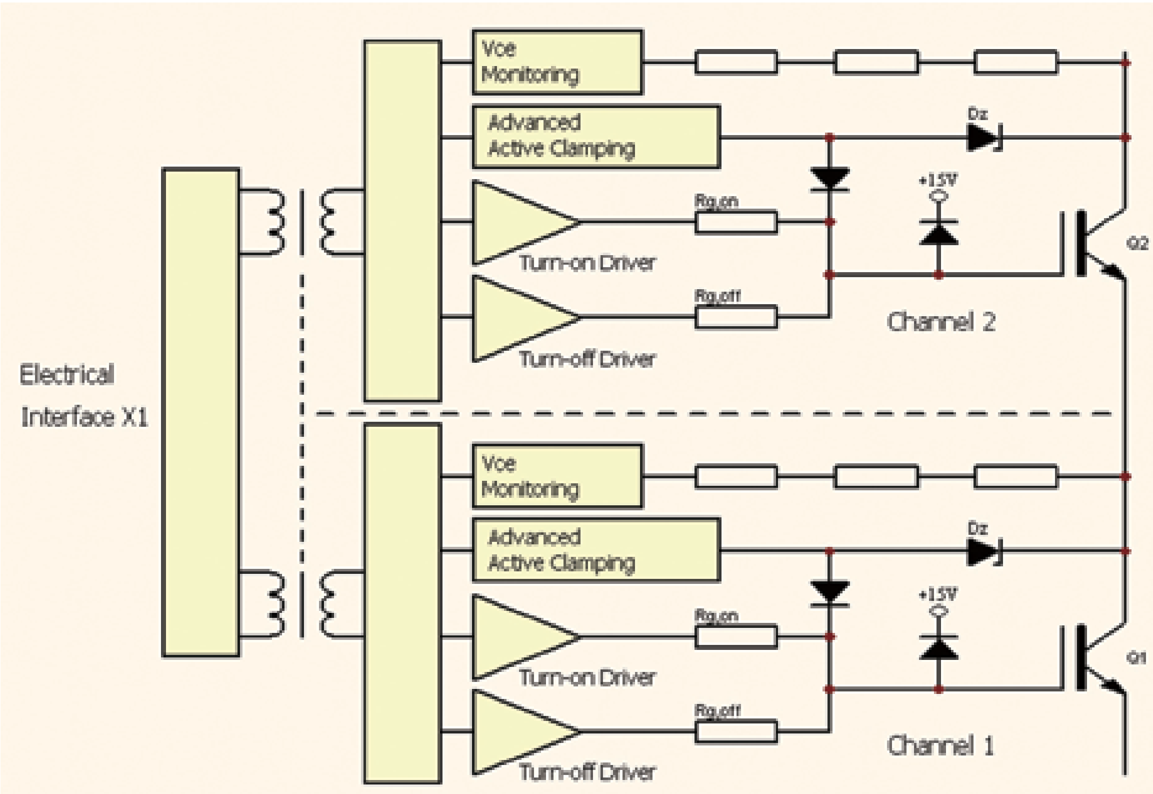

Figure 1: SCALE-2 drive and protection principle.

IV. Vce short circuit detection using no high voltage diodes

A new collector sense circuit featuring an externally configurable resistor network replaces the widespread high voltage sensing through diodes (Fig. 1). Its main advantage is precise, direct voltage measurement allowing any increase in IGBT saturation voltage to be detected. Direct Vce sensing is no longer influenced by parasitic capacitances of the high voltage diodes and their pronounced temperature dependence. Also, the cost of standard SMD 1206 resistors for the resistive divider is dramatically lower than for high voltage diodes. This benefit can be reaped immediately with the new SCALE-2 driver cores.

V. Regulated gate drive voltage

SCALE-2 drivers provide a gate voltage swing of +15V/–10V in IGBT mode. The turn-on voltage is tightly regulated to maintain a stable 15V regardless of the output power level. This feature is particularly appealing during short circuit of the IGBT. The high dv/dt values occurring in this failure mode inject considerable amounts of charge into the gate node (Miller feedback). This feedback causes the gate voltage to rise during a short circuit, resulting in excessively high levels of short-circuit current. This is a dangerous situation for the IGBT module. SCALE-2 drivers use a Schottky diode clamp to limit the gate voltage to safe values (see Fig. 1). The stable 15V supply easily absorbs the Miller feedback charge and safe operation of the IGBT is maintained.

VI. Under voltage lock-out

Both primary and secondary gate driver supplies are constantly monitored. If the supply voltage reaches a level of 12.5V or lower, a failure signal is generated and issued by the respective failure output SOx. During a primary side under-voltage event, the failure is shown as long as the voltage stays below the under-voltage level. The primary side ASIC then blocks all incoming PWM signals. During a secondary side under-voltage event, a signal pattern is transmitted from the secondary side ASIC to the primary side ASIC to provide an external error feedback on the respective primary side SOx output. This status is held for 10ms (adjustable). As long as the secondary side ASIC detects an under-voltage situation, the affected gate drive channel is disabled.

VII. Advanced active clamping (AAC)

In a standard active clamping circuit, the IGBT collector voltage is fed back to the IGBT gate via Transil diodes. As soon as the collector-emitter voltage exceeds the threshold voltage of the Transil chain, a current flows to the gate. This current is partly used to turn the IGBT 2SC0108T on again. The partly conductive IGBT effectively clamps transient over-voltage peaks during turn-off. The main drawback of this simple active clamping scheme is its speed and efficiency. The Transil chain tries to turn the IGBT on while the gate driver output stage simultaneously tries to keep the IGBT turned off. It takes some time and a lot of dissipated power for the Transil to overpower the output stage. The SCALE-2 advanced active clamping (AAC) feature is used in the 2SC0435T to overcome these limitations. Figure 2 shows the operating principle of AAC. The standard feedback path through the Transil diodes to the IGBT gate starts at the IGBT collector on the right. A second feedback path senses the collector voltage and supplies this signal to the SCALE-2 ASIC. The gate drive ASIC evaluates the collector voltage feedback and adapts the output strength of the gate drive to the situation. The closed-loop control maintains an optimized IGBT gate voltage to combine low switching losses and inherently safe IGBT protection. The switching and protection behavior can be easily adjusted by changing the external components Racl and Cacl in Fig. 2. More advanced options such as di/dt feedback and partial du/dt feedback are also supported. Once the active clamping behavior has been set, the AAC feedback loop automatically distinguishes between normal switching, where low losses are the primary focus, and short circuit turnoff, where the main emphasis is placed on keeping control of transient overvoltages and maintaining a soft turn-off with a limited current change rate di/dt. Figure 3 shows measurements of both normal switching and short circuit turnoff for the same AAC configuration. The soft turn-off of the short circuit can be clearly seen, as can the low-loss normal switching.

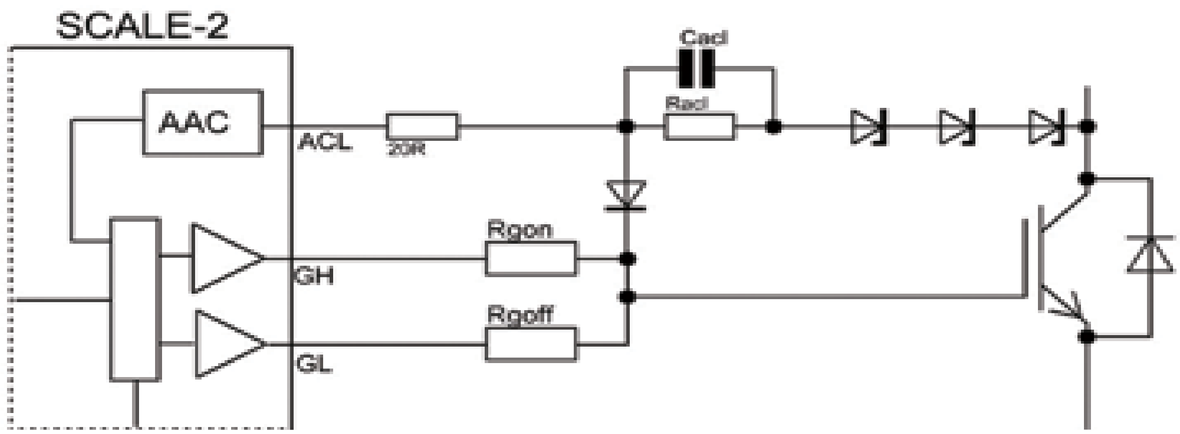

Figure 2: SCALE-2 advanced active clamping (AAC).

VIII. Separate gate turn-on/off outputs

The 2SC0108T and 2CS0435 feature two separate gate drive outputs for turning-on (GH) and turning-off (GL), as shown in Fig.1. Each output is connected to a dedicated turn-on and turnoff gate resistor respectively. A parallel diode is no longer needed in the gate drive path, thus reducing costs and increasing reliability.

IX. Flexible design with driver cores

Driver cores provide all necessary drive and protection functions with no limitation in flexibility. Any inverter design and IGBT module can be accommodated with little effort. It is easy to set different IGBT switching speeds, shortcircuit thresholds or other parameters simply by adjusting a few external devices. A whole range of inverter designs can be served by a single SCALE-2 driver core type. Mechanical construction also benefits from the high degree of freedom offered by these small and powerful cores. A dedicated half-bridge mode allows the implementation of a hardware-set dead time between the two half-bridge channels. The dead time is user programmable with a single external resistor for both channels.

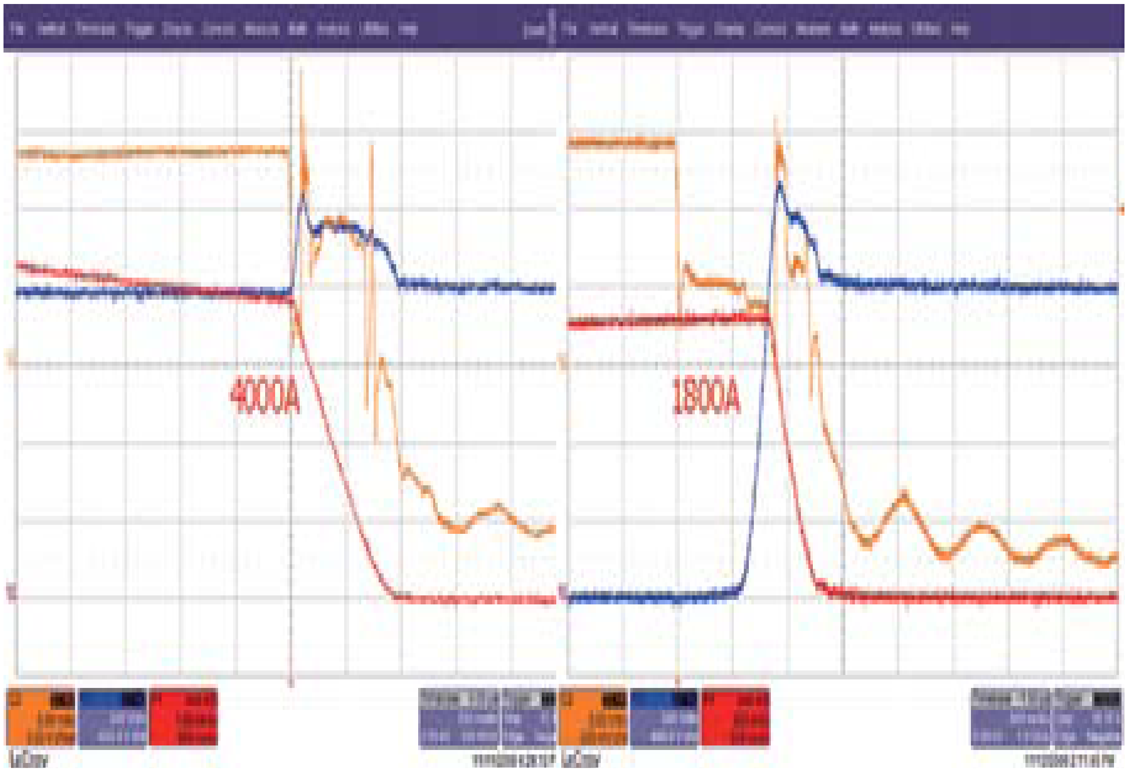

Figure 3: AAC performance.

X. Paralleling of IGBTs

Both the 2SC0108T and the 2SC0435T are particularly well suited for direct paralleling of IGBTs. This simple and very efficient paralleling topology is made possible by the extreme delay time repeatability in SCALE-2 driver cores. Figure 3 shows the system setup for direct paralleling. Two, three or more half-bridge legs are independently driven by a driver core. All driver cores receive the same input signal. The individual driver output signals on the secondary side show less than +/-4ns timing difference. This low value is negligible for the system. A major benefit is that there are no longer any offset currents between the parallel inverter legs, especially if the system is connected in an asymmetrical star-point configuration. Each IGBT module has its own driver with full galvanic isolation, thus blocking any offset currents. Easy scaling of the system output power by adding more parallel legs is another plus. The IGBTs are shown in Fig.3. When IGBT driver cores are paralleled, an electrically insulated auxiliary emitter avoids offset currents in them. Higher accuracy and uniform IGBT switching are simpler and more predictable. Thanks to the stable and fast driver core, a running time of less than 100ns and a jitter of 4ns, synchronization of the IGBT gate driver can be obviated. Offset currents in the auxiliary emitter due to an asymmetrical AC star point connection are inhibited. The low cost of these driver cores means that there is no economic limitation to this system topology.

XI. Low cost half-bridge driver

The cost-saving capability of ASIC integration is fully exploited towards the lower end of the driver power spectrum with the 2SC0108T low cost driver. The PCB is assembled with as few as 23 components, including transformer and ICs, to form a complete IGBT and MOSFET driver core with most of the functions familiar from the SCALE-2 platform. The output power rating is 1W per channel at up to 8A maximum output current within an ambient temperature range of –20°C and 85°C. Where there is a need for more power and current, the 2SC0435T provides the full set of SCALE-2 functions, highest power density and high output current together with advanced active clamping (AAC). The ambient temperature range of the 2SC0435T is –40°C to +85°C.

XII. IGBT gate driver for 10USD per channel

Available now, the pricing of the 2SC0108T is very competitive thanks to the low production cost of the SCALE-2 platform. At quantities of 10,000 items, the driver will be priced at US$20 (US$10-per channel). It thus compares very favorably with discrete solutions for bidirectional signal transmission,isolated DC-to-DC power and gate drive output. The benefits of high reliability and tried and tested SCALE technology are also included.

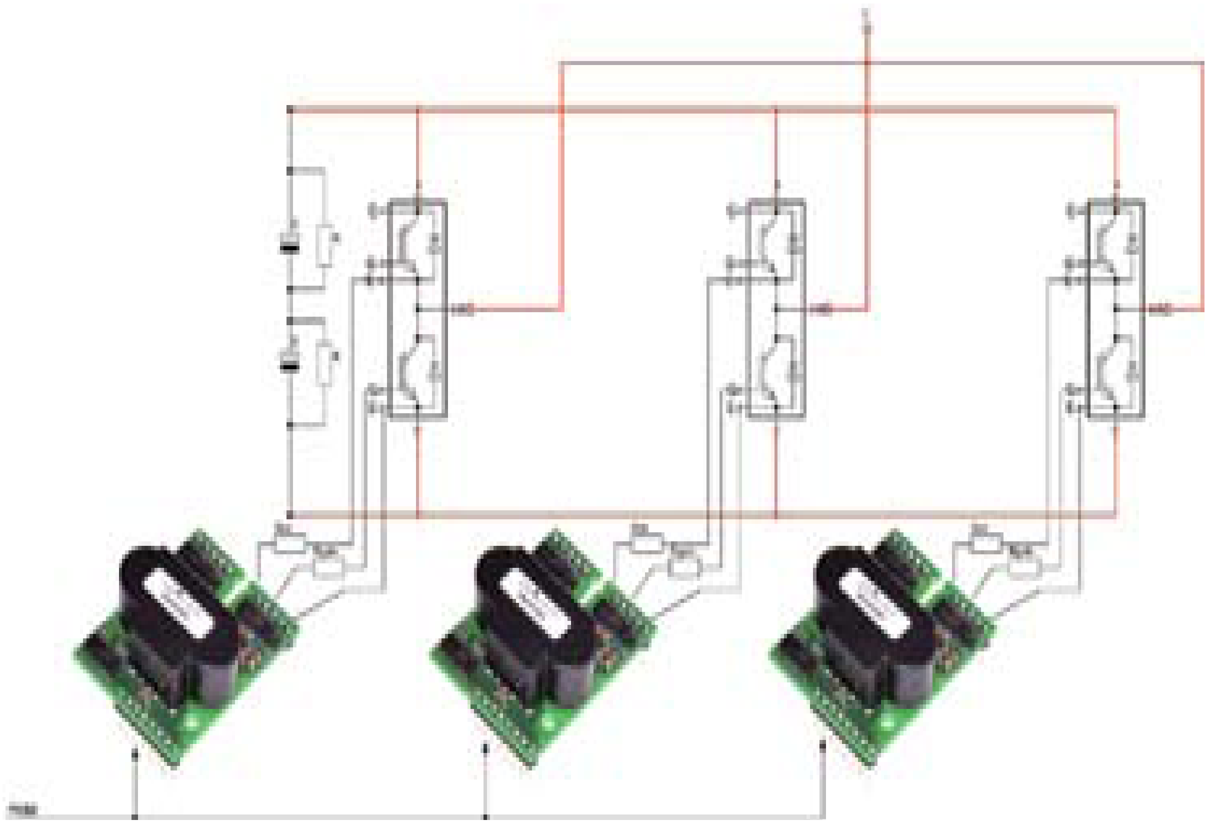

Figure 4: Direct paralleling of IGBT and gate driver core.

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