Direct Paralleling of SCALE-2 Gate Driver Cores

Introduction

Parallel-connected IGBTs are conventionally driven by a common driver, with individual gate and emitter resistors for each IGBT. An alternative approach to driving parallel-connected IGBT modules is to use an individual driver for each module. Figure 1 shows the difference between conventional parallel connection of IGBT modules with a common driver core and direct paralleling of SCALE-2 driver cores.
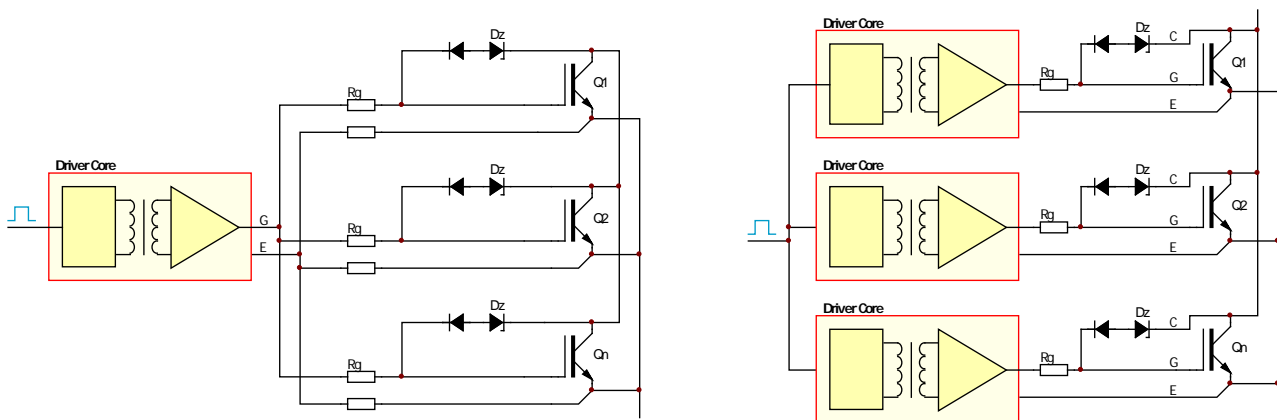

Fig. 1: Conventional parallel connection (left) and direct paralleling of three IGBT modules (right) using an individual SCALE-2 gate driver core with transformer interface

Direct paralleling of gate drivers has become possible with the SCALE-2 technology from CONCEPT as the signal propagation delays (typically 80ns ±4ns) and the delay jitter (typically $<\pm$1-3ns) are very small with narrow tolerances for SCALE-2 drivers with a transformer interface. The following SCALE-2 driver cores with a transformer interface can therefore be directly paralleled without producing an excessive current imbalance in paralleled IGBT modules:

- 2SC0108T
- 2SC0435T
- 2SC0650P
- 1SC2060P

2SD300C17 is not suitable for direct paralleling.

This application note describes the advantage of direct paralleling in brief and explains how to use SCALE-2 driver cores in direct paralleling operation.

Application note

Advantages of Direct Paralleling

Direct paralleling of IGBT drivers offers the following advantages compared to conventional parallel connection with a common driver for several paralleled IGBT modules:

- Optimal switching behavior, lowest switching losses

- A user-friendly, safe and reliable concept

- Simplest scaling of output: the usable switching frequency is not reduced with an increasing number of paralleled IGBT modules.

- No coupling of the gates, thus no mutual oscillations of the IGBTs possible

- No effects of the capacitive equalizing currents flowing away via the module baseplate

- No effects of inductive coupling on the gate cabling

- The equipment series can be simply extended to parallel connection, also subsequently

- Minimal derating and maximum utilization of the IGBT modules

- Simple set-up, no tangle of cables

How to Use SCALE-2 Driver Cores in Direct Paralleling

CONCEPT recommends the following procedure when using SCALE-2 driver cores in parallel operation:

- All drivers must be used with the same hardware configuration (gate resistors, desaturation protection, active clamping, blocking capacitors, ...)

- The supply voltages VCC and VDC (if available) of all parallel connected drivers must come from the same voltage source in order to ensure symmetrical operation of the drivers (see Fig. 2).

- Both input signals INA and INB of all parallel connected drivers must come from the same logic buffer (driver) in order to ensure very small delay differences (see Fig. 2).

- The slew rate of INA and INB must be high enough (> 0.25V/ns) in order to minimize the delay jitter. In particular, if the input signals INA and INB are filtered with an RC network (e.g. for short pulse suppression), a Schmitt trigger buffer must be used to generate a high slew rate at INA and INB.

- The length difference of the interface cables from the host board to the driver connectors should be less than 40cm for all parallel-connected drivers in order to keep the additional delay differences below about 2ns.

- All drivers must work in direct mode. Half-bridge mode (if available) is not suitable for parallel operation of SCALE-2 drivers.

- In case of fault turn-off, it is necessary to wait until the fault feedback of all paralleled drivers is reset in order to ensure that the blocking time of all paralleled drivers has elapsed. The corresponding circuit in Fig. 2 can be used to satisfy this requirement.

- The threshold level for desaturation protection must be set at such a high level that only IGBT short circuits are detected, but no overcurrents. Recommended value: Vth=10.2V (Rth=68kΩ). Moreover, the response time must be high enough (typically 6...9µs), so that no false fault turn-off is produced in the whole collector current range in a worst-case condition.

- The status outputs SO1 and SO2 of parallel-connected drivers can be evaluated individually to allow precise fault diagnosis, or they can be connected together.

System Behavior in Normal Operation

In normal switching operation (no fault feedback), the paralleled drivers can be used in the same way as without parallel connection. All paralleled IGBT modules are switched on and off synchronously. Laboratory measurements have shown that small signal delay differences (<5ns) as well as small differences of the negative gate voltage (<0.4V) lead to a small redistribution of the collector current at turn-off or turn-on as well as of the switching losses. However, this is a minor effect and asymmetry due to the mechanical construction of the converter will dominate in most cases.

System Behavior in The Short-circuit Condition

In case of a short circuit, it can be assumed that not all paralleled drivers will detect the short circuit exactly at the same time. The first driver that detects it sends a fault feedback back to the corresponding SOx output and switches off the corresponding IGBT. It is then recommended to send a turn-off command to all paralleled drivers immediately.

However, laboratory measurements have shown that asynchronous turn-off in the short-circuit condition with delay differences up to 2µs does not reveal any problems. Both low-inductance (~70nH) and high-inductance (>1.5µH) short circuits have been considered. However, CONCEPT recommends users to check this point in their specific application.

System Behavior in Case of Supply Undervoltage

In case of supply undervoltage, the corresponding driver will send a fault feedback back to the corresponding SOx output(s) and switch off the corresponding IGBT(s) immediately. It is then recommended to send a turn-off command to all paralleled drivers immediately. They will then switch off the corresponding IGBTs after a short delay.

The following primary-side circuit is recommended in case of two paralleled IGBT drivers (only one channel is shown). Furthermore, it is necessary to turn off the PWM signal at the latest 7µs after a fault condition has been detected by any driver.
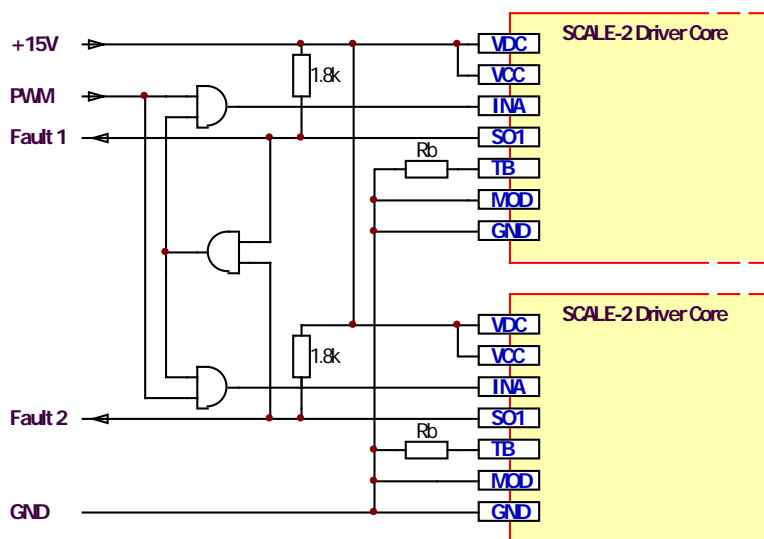

Fig. 2: Recommended primary-side interface for two paralleled gate drivers as an example

Application note

Converter Construction

When driving parallel-connected IGBT modules, it is important to ensure their symmetrical operation. Measurements in half-bridge topologies have shown that symmetrical operation of these modules can be reached when using a properly designed converter. The following points must especially be considered:

- The converter should be constructed as symmetrically as possible with respect to the paralleled IGBT modules in order to ensure symmetrical operation. In particular, the DC-link stray inductance of each paralleled IGBT module should be similar (Ls1 ≈ Ls2, Ls5 ≈ Ls6 in Fig. 3).

- It is important – except for the load terminals (Ls5 and Ls6) – to have a low-inductance connection between all paralleled IGBT modules (Ls4 small). Furthermore, it is also advantageous to minimize stray inductances Ls1, Ls2 and Ls3 in order to reduce the collector-emitter overvoltage at turn off.
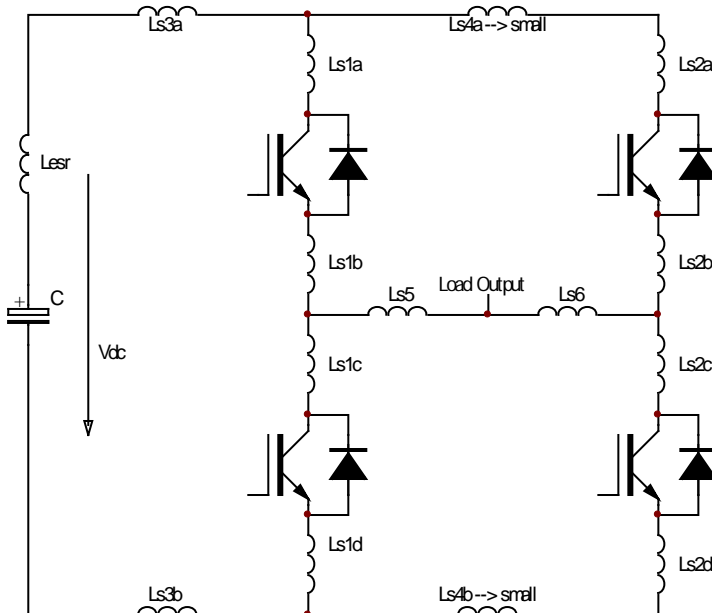

Fig. 3: Half-bridge topology with stray inductances

In any case it is recommended to measure the collector emitter voltage as well as the collector current of all paralleled IGBT modules to check the symmetry.

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Manufacturer

CT-Concept Technologie AG
Intelligent Power Electronics
Renferstrasse 15
CH-2504 Biel-Bienne
Switzerland

Tel.   +41 - 32 - 344 47 47
Fax   +41 - 32 - 344 47 40

E-mail   Info@IGBT-Driver.com
Internet   www.IGBT-Driver.com