PCIM'98 CONFERENCE PAPER

THE „**SCALE**" IGBT–DRIVER:

A NEW

SCALEABLE, **C**OMPACT, **A**LL PURPOSE, **L**OW COST, **E**ASY TO USE

DRIVER FOR IGBTS.

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Abstract

Integrated drive circuits have been used on a large scale for a number of years in power MOSFET and IGBT converters operating with low powers.

The requirements of converters with higher powers cannot be satisfied by one–chip solutions. Developers therefore make use of either bought–in or self–developed solutions based on standard components for these applications. The diversity of the resulting approaches is correspondingly large.

A chip set that can satisfy the requirements of these applications has now been developed for the power range from approximately 10kW to several megawatts: the "SCALE" driver chip set.

What is a "SCALE" driver?

SCALE drivers are based on a chip set consisting of two ICs and a pulse transformer for the electrical isolation.

"**SCALE**" stands for **S**caleable, **C**ompact, **A**ll–purpose, **L**ow–cost and **E**asy–to–use.

This is a concise enumeration of the most outstanding properties of SCALE drivers.

Scaleable

One of the most important properties of the SCALE driver chip set is its scaleability. In this context, the term scaleable means that the chip set — in contrast to all previous approaches to integrated drive circuits — can be used for a very large range of applications. The SCALE

driver chip set can be used to implement solutions for diverse drive currents (gate currents) and various drive powers. SCALE drivers are well suited for almost any switching frequency, any modulation mode and not least for isolation voltages of practically any magnitude.

SCALE drivers can be used to construct power sections from the kilowatt to the megawatt range.

Compact

SCALE drivers accommodate all the necessary components on a minimum surface area. They cover the following functions: driving, monitoring, status acknowledgement, isolated voltage supply (DC/DC converters) and electrical isolation of all signals between the control electronics and the power section.

SCALE drivers are currently the most compact driver solutions on the market with this range of functions.

All purpose

The SCALE driver chip set offers maximum flexibility of operation: by switching the mode accordingly, a choice can be made between half–bridge or direct–mode operation.

In half–bridge operation, the chip set can generate the required dead times directly.

In direct mode, there are no links between the individual channels of a multiple driver.

Low cost

SCALE drivers are high–quality driver circuits for IGBTs and power MOSFETs with an outstanding price/performance ratio. A SCALE driver contains all the components that can possibly be integrated. It encompasses the driver function itself, plus monitoring, acknowledgement, power supply (DC/DC converter) and electrical isolation of all signals.

SCALE drivers are the most inexpensive drivers on the market offering this performance.

Easy to use

The interface to the electronics is very simple: the SCALE driver chip set can handle all standard logic levels between 5V and 15V. The inputs have a Schmitt trigger characteristic and make no special demands on the input signals. The status acknowledgements are designed as open–collector outputs and are thus compatible with all the usual logic levels.

Application is extremely simple because a SCALE driver contains all the functions of an intelligent driver, and the drive signals, the status acknowledgement and the power supply are completely isolated from the power section.

Application of SCALE drivers with standard IGBT modules is in most cases simpler than an IPM, but without any loss in flexibility.

Description of the SCALE driver

Block diagram of a SCALE driver

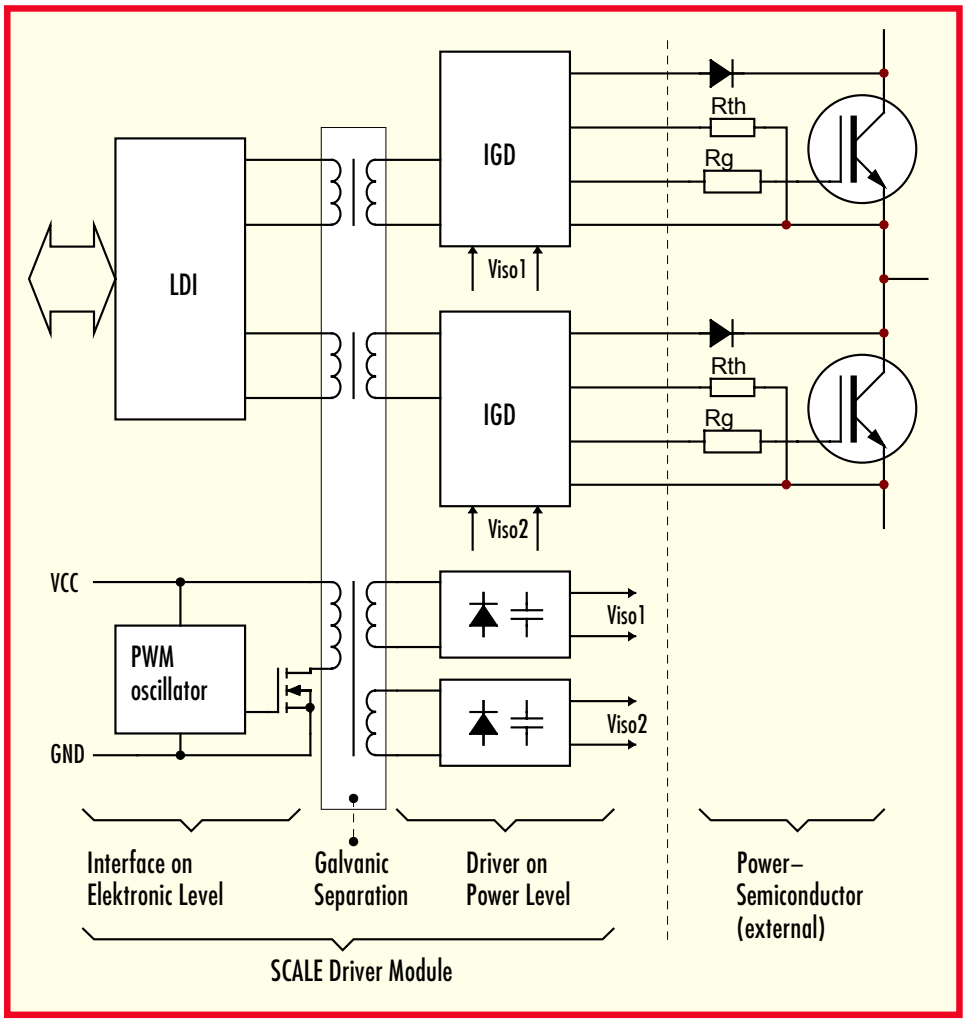

Fig. 1 Block diagram of a two–channel SCALE driver

The block diagram shows a two–channel driver based on the SCALE chip set. The three–phase design contains only one PWM oscillator, all other components are present in triplicate.

Product properties

Product Features

- Suitable for IGBTs and power MOSFETs
- Short–circuit and overcurrent protection
- Extremely reliable, long service life
- High gate current of ±5A to ±30A
- Electrical isolation from 500 V to >10kV
- Electrically isolated status acknowledgement
- Monitoring of power supply and self–monitoring
- Switching frequency DC to >100kHz
- Duty cycle: 0... 100%
- High dv/dt immunity, guaranteed >100,000V/µs
- Low cost
- Complete solution with integrated DC/DC converter
- Shorter development time

Reliable operation

Gate driving with a positive and negative control voltage (typically ±15V) allows the reliable operation of IGBT modules of any size from any manufacturer. Thanks to the high interference immunity attained by using a negative gate voltage, a number of power MOSFET or IGBT modules can be connected in parallel without having to worry about parasitic switching operations or oscillations.

The components of the SCALE driver series contain – for each of the two channels – an electrical isolation between the control and power sides, an overcurrent and short–circuit protection circuit for the power transistors, a supply–voltage monitoring circuit, a status acknowledgement circuit as well as an electrically–isolated supply for the drive electronics via an integrated DC/DC converter.

Genuine electrical isolation

SCALE drivers contain miniaturized transformers for the isolation of all channels. These offer outstanding isolation properties and low coupling capacities.

The SCALE driver can be used to obtain isolation voltages of practically any magnitude. Drive circuits with reliable isolation can be implemented that satisfy all relevant international standards and specifications.

The extremely high interference immunity of at least 100kV per microsecond predestines the SCALE driver to applications in which large potential differences and large potential jumps occur between the power section and the control electronics.

Reliable transformer principle

Pulse transformers were selected because they offer the following advantages over all other designs: minimum delay times, no degradation effects, maximum service life and the ability to obtain isolation voltages of any desired magnitude.

Delay times

The delay times through the complete driver circuit are around 350ns. The delays for the positive and the negative edges are symmetrical.

There are almost no differences in delay time between the different drivers, an important factor for ensuring operation without offset problems as well as for parallel circuits. Signal transfer is practically jitter–free.

Short–circuit and overcurrent protection

One of the important functions of the SCALE drivers is to ensure reliable protection of the power transistors against over–current and short circuit. The current measurement is based on the determination of the drain source or collector–emitter voltage at the activated transistor. If a threshold defined by the user is exceeded, the power transistor is turned off and remains blocked in this state for a defined minimum time. After this time has elapsed, the transistor is turned on again synchronously with the next turn–on edge of the drive signal.

Status acknowledgements

The pulse transformer is operated bi–directionally – for transferring both the drive information and the status acknowledgement.

LDI 001 logic–to–driver interface

PWM signals of the kind generated by the control electronics cannot simply be transferred via transformers. This is particularly difficult when a large frequency range and various duty cycle ratios are to be transmitted.

The LDI 001 logic–to–driver interface was developed for this reason. This IC has the following main functions:

1) Creation of a simple interface for the user
2) Matching to the logic level used in the electronics (5V...15V) with Schmitt trigger inputs
3) Coding of the PWM signals so that they can be transmitted via a pulse transformer

4) Evaluation of the status acknowledgement transmitted in coded form and its subsequent buffering so that a quasi–static acknowledgement signal is available to the user

5) Forming the dead times in a half bridge, where required. This function can also be deactivated

Block diagram of the LDI 001 logic–to–driver interface

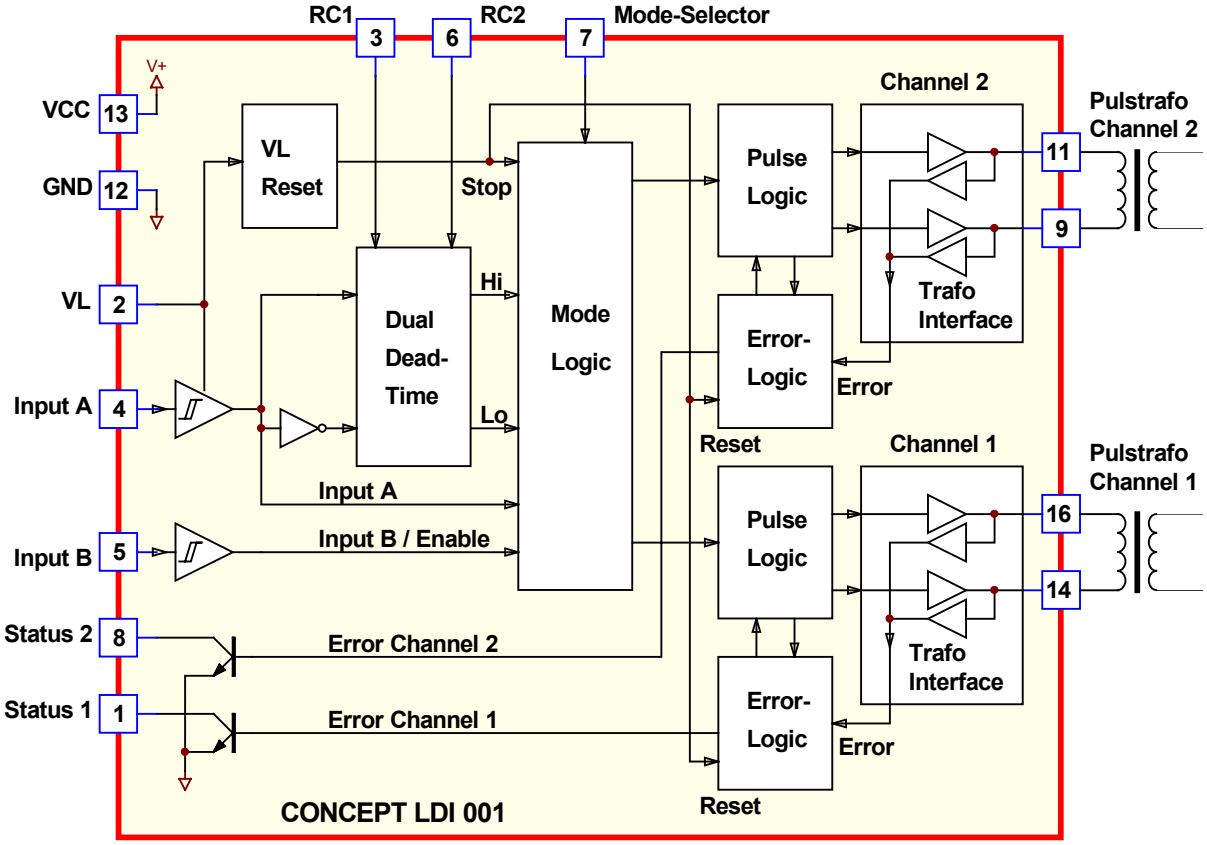

Fig. 2 Block diagram of the LDI 001 logic–to–driver interface

The functions shown within the block in Fig. 2 are integrated on a single chip. The entire signal processing function is completely integrated on the chip and no external components are required.

Inputs

The signal inputs have a Schmitt trigger characteristic. The switching thresholds are always 1/3 or 2/3 of the logic supply voltage respectively. This can be freely selected in the range between 5V...15V. This means that a SCALE driver can be connected directly and with no additional components to any logic circuits. But it also allows driving via longer cables: the noise–to–signal ratios at a 15V level are acceptable for these applications.

Coding the signals

The LDI 001 processes the signals so that each drive signal can be reliably transferred, irrespective of switching frequency and pulse width. The entire signal processing takes place on the chip – without external components.

But the short pulses that are otherwise critical for transformer solutions are also perfectly transmitted at all times.

Status acknowledgement

The status acknowledgements are available as open–collector signals. "High" status means "no error"; while "conductive" status indicates an error in this channel.

Several status outputs can also be connected directly in parallel if only a composite error message is required.

The status acknowledgements are buffered by an integrated flip–flop so that an error remains stored up to the next drive edge or until it is acknowledged.

Direct mode

In direct mode, there is no locking between different drive channels. This allows the use of controllers that already generate a dead time, for instance. But several channels can also switch–in simultaneously, a case that is required in applications such as asymmetrical half–bridges.

Half–bridge mode with dead time

In half–bridge mode, two channels are always operated as a half bridge. In this mode, the SCALE driver can directly generate the required dead times in the region of approximately 100ns to several microseconds. Only two external RC components are used. By deactivating the "Enable" input, all the power semiconductors are switched off.

IGD 001 intelligent gate driver

An IGD 001 intelligent gate driver is used for each drive channel. This IC has the following functions:

1) Decoding the PWM signals transferred via the pulse transformer
2) Amplifying the PWM signals to drive the final stage
3) Power Semiconductor desaturation monitoring (short circuit & overcurrent protection)

4) Under–voltage monitoring

5) Generating response and blocking times

6) Status acknowledgement to the controller (LDI 001)

Block diagram

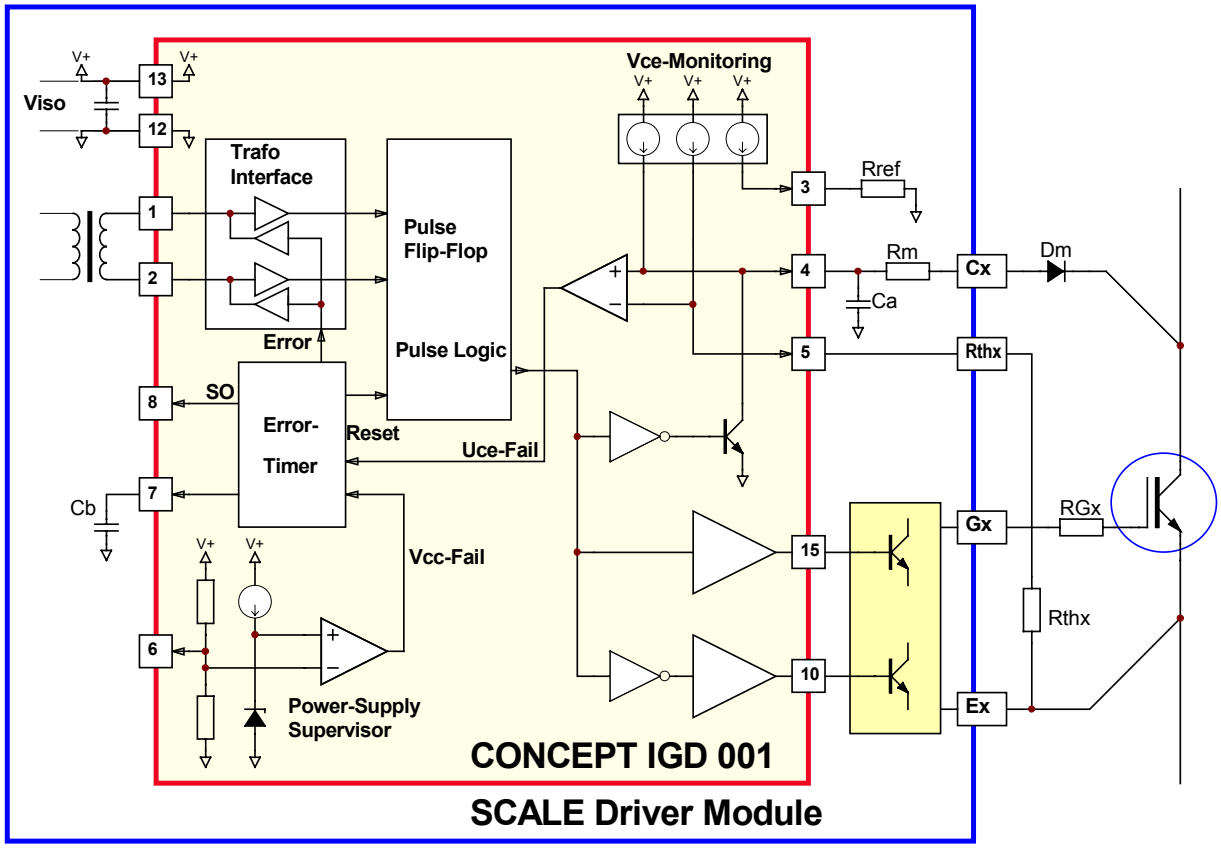

Fig. 3 Block diagram of IGD 001 intelligent gate driver with external wiring

All the functions shown in the inner block of Fig. 3 are integrated on the chip. The components shown in the outer block are contained in the SCALE driver modules. This means that practically no external components are required.

Short circuit and over–current protection

The IGD 001 is equipped with a Vce monitoring circuit. A resistor is used as the reference element for defining the turn–off threshold.

During the response time, the Vce monitoring circuit is inactive. The response time is the time that elapses after turn–on of the power semiconductor until the transistor is saturated.

When a Vce or under–voltage error occurs, the blocking time is initiated. During this time, the driver blocks the power semiconductor and does not accept any drive signals.

Power supply and monitoring

An under–voltage monitoring circuit blocks the driver in the event of insufficient supply voltages. n the case of under–voltage, the power semiconductor is driven by a negative gate voltage and an error is reported.

Example: application with a six–pack driver

To illustrate the product range of SCALE drivers, an application of the 6SD106E six–pack SCALE driver is shown here together with a six–pack IGBT module.

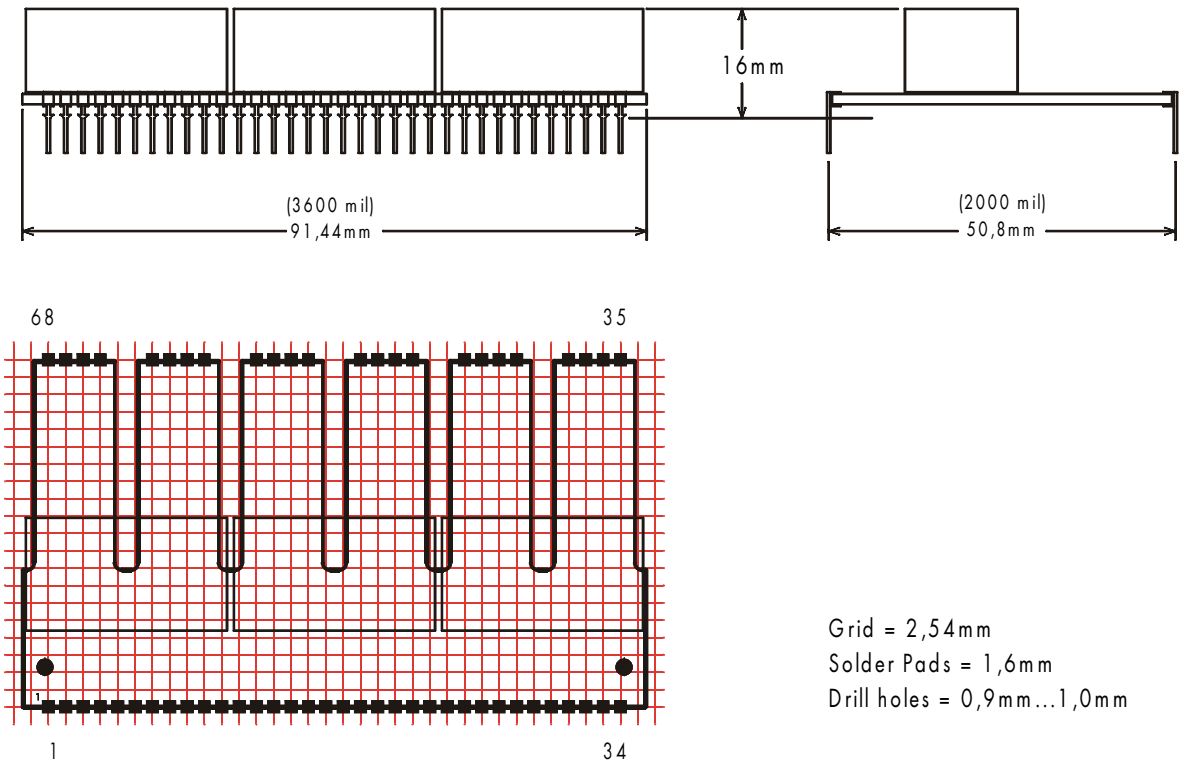

Fig.4 Mechanical layout of the 6SD106 six–pack driver for econopack

Circuit diagram of a 30kW inverter

In this application example, a six–pack IGBT module from eupec is shown together with the six–pack driver. The BSM100GD120DN2 module in an econopack is equipped with six IGBTs each of 100A/1200V. It attains an inverter output power of 20...35kW — depending on the switching frequency and heat sink. The driver power suffices to drive this IGBT module with switching frequencies to above 20kHz..

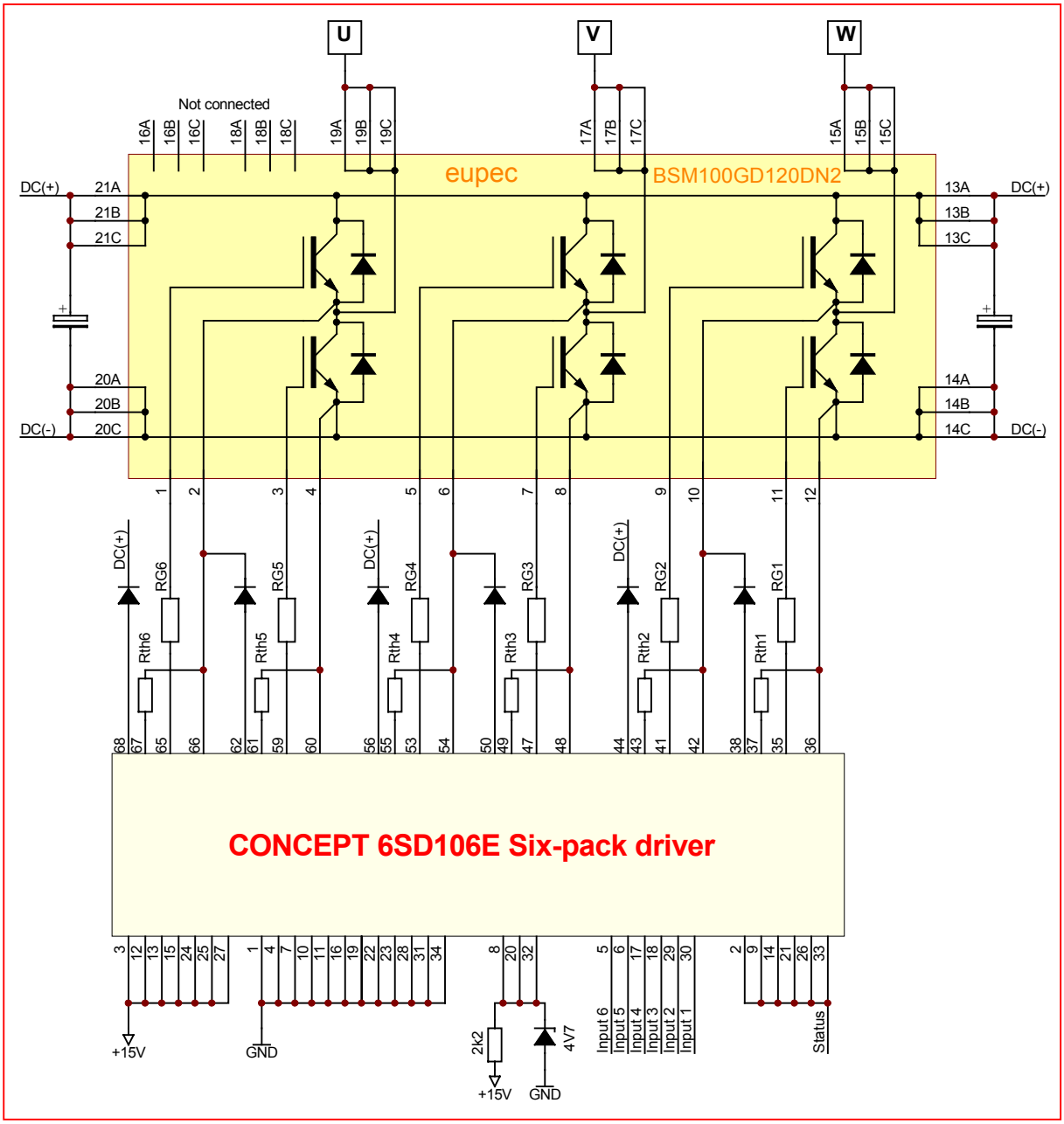

Fig. 5 Complete circuit diagram of the 30kW inverter

The circuit diagram shown in Fig. 5 shows all the components required for the inverter circuit. The diagram thus illustrates clearly the level of integration of the driver solution and its simplicity of application.

The SCALE driver solution has the advantage over IPM solutions — which require more external components but offer no greater flexibility in the choice of switching properties — that fewer additional components are needed to define the switching characteristics as required. In addition, the level of the protective turn–off (Vce monitoring) can be freely selected.

Outlook

The SCALE driver chip set can be used to develop a product range that includes drivers with different numbers of drive channels, drive powers, isolation properties etc. This product range can be used to cover a broad range of applications and powers — always with an equally simple interface to the electronics.

A driver chip with a fiber–optic interface is currently in preparation.

References

[1] "SCALE driver description", CT–Concept Technologie AG, 1998

[2] Data sheet "Six–pack IGBT driver 6SD106E", CT–Concept Technologie AG, 1998

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