TLE 6208-x
The universal Driver Family

by Frank Heinrichs
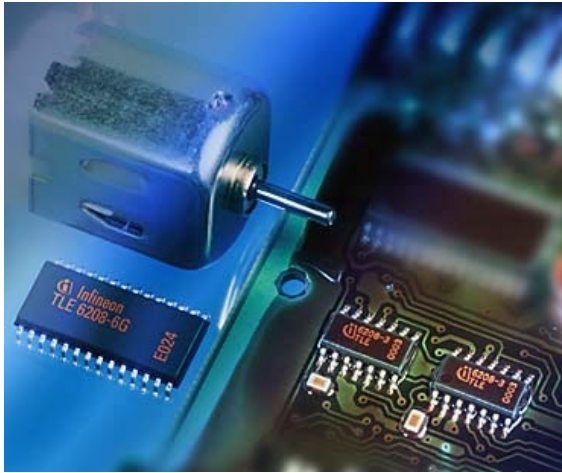
Automotive Power

Infineon technologies

N e v e r   s t o p   t h i n k i n g .

1. Abstract

This Application Note provides product specific application information on the TLE 6208-x driver family. It is intended to give the electronic design engineer a more detailed view of the product functionality and capabilities.

2. Introduction

In automotive body and convenience electronics, an increasing number of low power DC motors control such functions as exterior and interior mirror position and air flaps in climate control systems. The TLE 6208-x Multi Half-Bridge family provides a flexible, system-optimized solution for these and similar applications. Protection and diagnostic features in the TLE 6208-x satisfy the requirements of modern automotive ECUs. All diagnostic feedback and power stage control commands are transmitted via a serial interface (SPI).

The device is manufactured using Infineons Smart Power Technology (SPT) which combines DMOS power stages with bipolar analog and CMOS digital control circuits.

The ruggedness required in automotive applications is achieved by the robust technology, the dedicated protective circuits, and the high quality standards of the Infineon Automotive & Industrial business unit.

The TLE 6208-6G contains 6 high-side (HS) drivers and 6 low-side (LS) switches, which can be configured as required. These 12 switches are controlled via a 16-bit SPI interface. As a result, parallel or serial connections can be used to implement any switch applications required, and any motor controls in full-bridge or halfbridge configurations. This tristate functionality for motor halfbridges saves a complete halfbridge driver in the case of "multimotor applications", since the motors can simply be connected in series (see Figure 1).

The TLE 6208-3 is the "small brother" of the TLE 6208-6, it contains three instead of 6 half-bridges. In contrast to the six-fold driver, the high- and low-side transistors are configured to half-bridges internally to safe output pins. Due to the similarity in both output characteristics and control, it can also be used very easily as an extension to the TLE 6208-6 if additional outputs are required.

The ICs are protected against short-circuits and overtemperatures. The SPI interface allows full diagnosis of overload and underload, overvoltage and undervoltage. In the event of serious overheating, the IC sends an overtemperature warning signal, so that the intelligent control system can intervene to reduce the dissipated power accordingly.

It is also possible to mask the overload current cut-off threshold via software, so that power-on current spikes such as those occurring with motor and lighting loads can be managed. The overvoltage cut-off can likewise be disabled via software. This means that the IC can also be used for industrial electronics with supply voltages up to 40 V.

The TLE 6208-x devices have a separate inhibit input which switches the IC into sleep mode with an extremely low current consumption. The pin can also be used as a "safety disable"

All of these functions are incorporated in standard P-DSO packages, 28 pin for the six-fold driver and 14 pin for the three-fold driver.

On the packaging side, a special leadframe design ("enhanced standard") reduces thermal resistance to such an extent that intelligent distribution of dissipated power allows nearly all loads to be handled simultaneously on the driver chip.

In summary: Where there is a requirement to switch various loads, the TLE 6208-6 and -3 will often provide the most cost-effective and technically elegant solution.

3. Applications

The TLE 6208-x ICs are mainly used in Automotive body electronics, especially in HVAC controls and body control modules. The device is used for motor control, but due to the flexible pinout, it can also be used as single switch driving loads like LEDs, small lamps or relays.

Figure 1 shows how the TLE 6208-6 is used in a typical two-zone HVAC control system to drive 5 DC-motors.
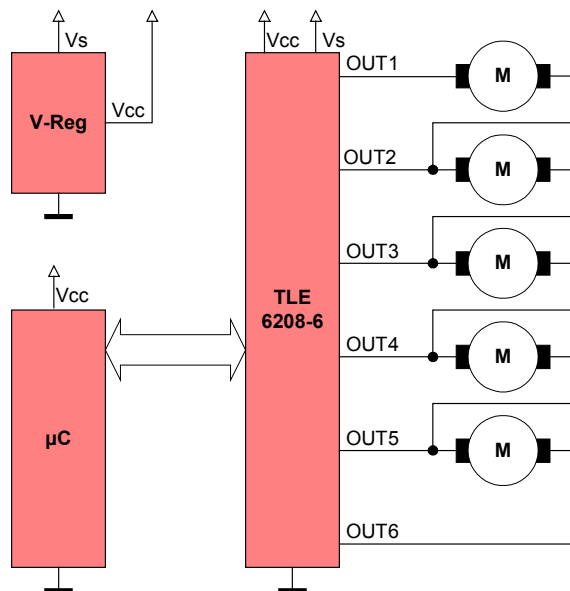

Figure 1: TLE 6208-6 used for driving 5 cascaded motors.

There also exists a "small brother" of this device, the TLE 6208-3G. This is a three-fold half-bridge, optimized for electric exterior mirror adjust in automotive door-modules. A very popular configuration for this application is shown in figure 2: One driver is used for mirror x-y control, the second one is used for mirror fold. As this feature is often only optional, this partitioning has the advantage that the additional driver can be depopulated, and only one, high-volume device is used.
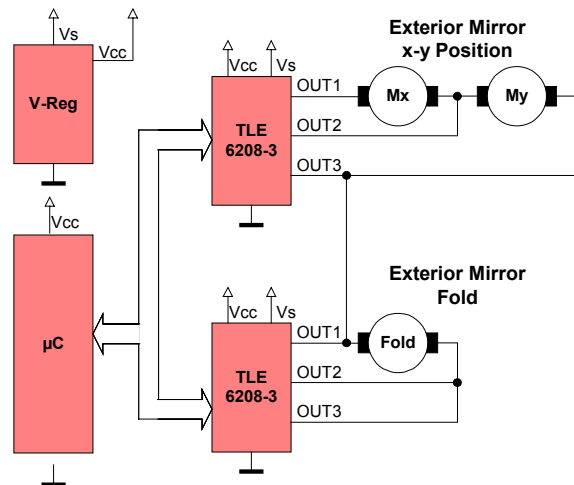

Figure 2: TLE 6208-3 used for Automotive exterior mirror adjust and fold

Both devices have a wide operating voltage of up to 40V. Due to this, they can be used not only in 12V automotive boardnet, but also in 24V truck or industrial applications.

4. Product description

4.1. Functionality Overview

Figure 3 shows the block-diagram of the TLE 6208-6. There are 6 halfbridge drivers on the right-hand side. An HS driver and a LS driver are combined to form a halfbridge driver in each case.
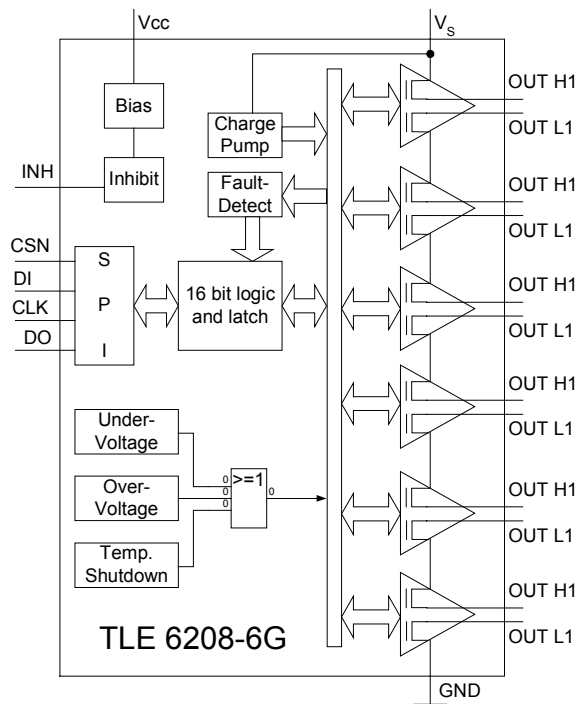

Figure 3: TLE 6208-6 functional block diagram

The drivers communicate via the internal data bus with the logic and the other control and monitoring functions: undervoltage (UV), overvoltage (OV), overtemperature (TSD), charge pump and fault detect.

Two pins are provided for supply to the IC: All power drivers are connected to the supply voltage VS. These are monitored by overvoltage and undervoltage comparators with hysteresis, so that the correct function can be checked in the application at any time.

The logic is supplied by the VCC voltage, typ. with 5V. The VCC voltage uses an internally generated Power-on Reset (POR) to initialize the IC at power-on. The advantage of this system is that information stored in the logic remains intact in the event of short-term failures

in the supply voltage VS. The system can therefore continue to operate following VS undervoltage, without having to be reprogrammed. The "undervoltage" information is stored, and can be read out via the interface. The same logically applies for overvoltage. "Interference spikes" on VS are therefore effectively suppressed.

The situation is different in the case of undervoltage on the Vcc connection pin. If this occurs, then the internally stored data is deleted, and the output transistors are switched to high-impedance status (tristate). The IC is initialized by Vcc following restart (Power-on Reset = POR)

The 16-bit wide programming word or control word is read in via the DI data input, and this is synchronized with the clock input CLK. The status word appears synchronously at the DO data output.

The transmission cycle begins when the chip is selected with the CSN input (H to L). If the CSN input changes from L to H, the word which has been read in becomes the control word. The DO output switches to tristate status at this point, thereby releasing the DO bus net for other uses.

The INH inhibit input can be used to cut off the complete IC. This reduces the current consumption to just a few µA, and results in the loss of any data stored. The output levels are switched to tristate. The IC is reinitialized with the internally generated POR (Power-on Reset) at restart.

This feature allows the use of this IC in battery-operated applications (vehicle body control applications), where low quiescent current is essential.

4.2. Chip Layout and package - thermal considerations

Figure 4 shows the chip layout of the TLE 6208-6. There are 6 power semiconductor switches on both the right-hand and left-hand sides. This represents the optimum power distribution across the chip. The analog blocks which are sensitive to temperature gradients (e.g. the bandgap reference) are located at the center of the chip, i.e. the farthest possible from the power transistors. These in turn can use the surface under the allocated driver transistors to

drain the dissipated heat. Optimum heat distribution on the chip was achieved using the Finite Element Method (FEM) for different cases.
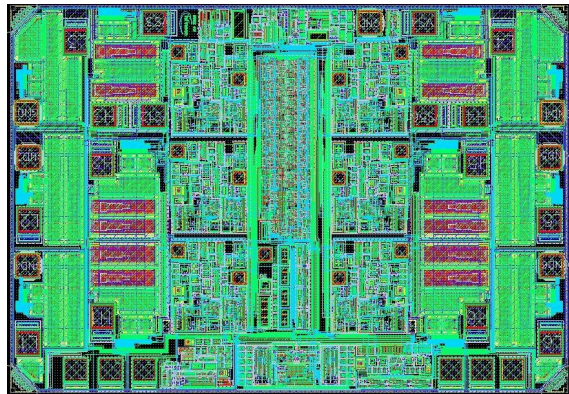

Figure 4 : Chip layout of the TLE 6208-6

4.2.1. FEM Simulations

The FEM model for the P-DSO-28-6 package, consisting of chip, glue, bonding wires, leadframes and molding compound, is shown in Figure 5.
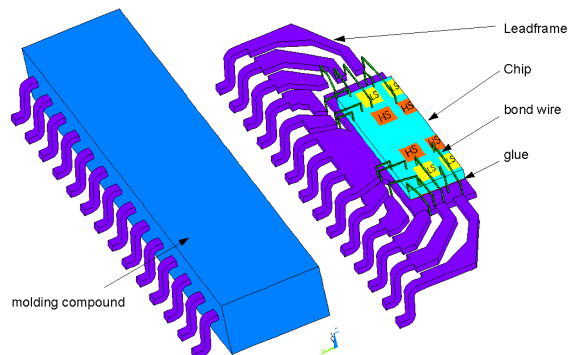

Figure 5: Finite Element Model setup (1/2 symmetry)

The "enhanced standard" leadframe is easy to identify, where the 4 central connections on each side (Pins 6 to 9 and 20 to 23) provide a metal bridge to the leadframe itself. These 8 pins on the leadframe therefore provide a very effective lateral heat drain.

The "worst-case" dissipated power occurs when all switches are loaded. Figure 6 shows the temperature distribution for this scenario. Only a quarter of the layout is shown, since the rest is symmetrical.
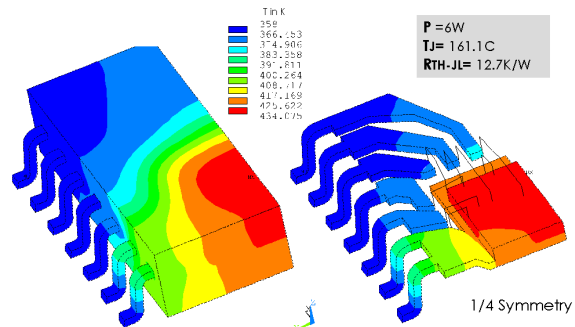

Figure 6: Temperature distribution with full load for all switches. T_{lead} = 85°C, P_{HS} = 6 x 0.5W, P_{LS} = 6 x 0.5W

The largest temperature difference in this case is approx. 75°C. The static thermal resistance Rthj-Lead- is therefore only approx. 13K/W.

Therefore: With a maximum permitted chip temperature of Tj=150°C, the TLE 6208-6G works up to an environmental temperature of 85°C. These values can be counted on for short periods, i.e. for applications with switching times of a few 100ms, since the startup time constants of motors and the power-on time constants (inrush) of lights are normally less than 100ms.

Since the thermal capacity of the PCB is not infinite, thermal resistance RthPCB-A for the PCB layout must be added to thermal resistance Rthj-Lead in order to ascertain the environment for continuous operation. In the case of assembly on a 1.5-mm thick FR4 PCB without cooling surfaces in addition to Pins 6 to 9 and 20 to 23, it can be assumed that RthPCB-A = 30K/W. This value can be reduced to approx. 20K/W with cooling areas on the PCB.

Figure 7 shows another, particularly interesting scenario. In this case, the chip is placed under maximum asymmetric thermal load. All of the switches on one side of the chip generate 0.5W dissipated power. Half-symmetry must therefore be used to illustrate this.
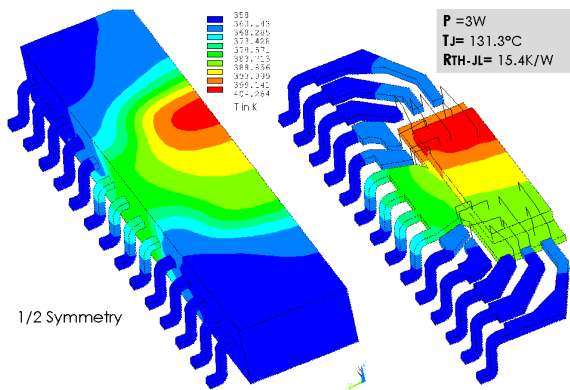
Figure 7: Temperature distribution for asymmetrical operation. T_{lead} = 85°C, P_{HS} = 3 x 0.5W, P_{LS} = 3 x 0.5W

The largest temperature difference is now only approx. 45°C. The static thermal resistance Rthj-Lead- has risen to an acceptable 15K/W. It is easy to see the lateral heat flow, firstly towards the center of the chip and then at right angles along the "cooling connections" out of the package.

As in the previous case, the temperature peaks are significantly lower for pulsed operation. For estimating purposes, the dyn. thermal resistance Zthj-Lead for single-pulse operation under load was calculated as per Figure 7 and shown in Figure 8.
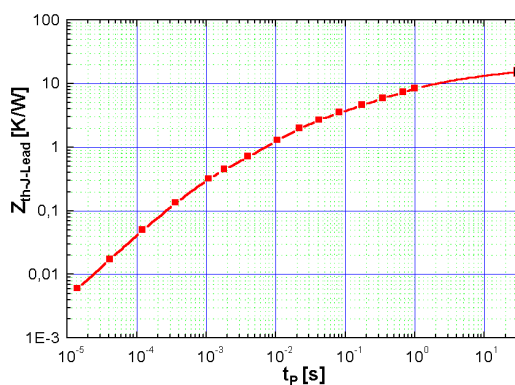

Figure 8: Transient thermal resistance of the TLE 6208-6G for single pulse operation.

4.3. Output stages

In the following, the TLE 6208-6 is discussed specifically. However, the identical circuits with the same functionality are also used in the TLE 6208-3.

Every driver block from DRV 1 to 6 contains a low-side driver and a high-side driver. The output pinning has been selected so that each HS driver and LS driver pair can be combined to form a half-bridge by short-circuiting adjacent pins. For the TLE 6208-3, this connection is done internally to save output pins and meet the constraints of the very small P-DSO-14 package. For the TLE 6208-6, the full flexibility of the configuration can be achieved by dissecting the half-bridges into "quarter-bridges". Figure 9 shows examples of possible applications.
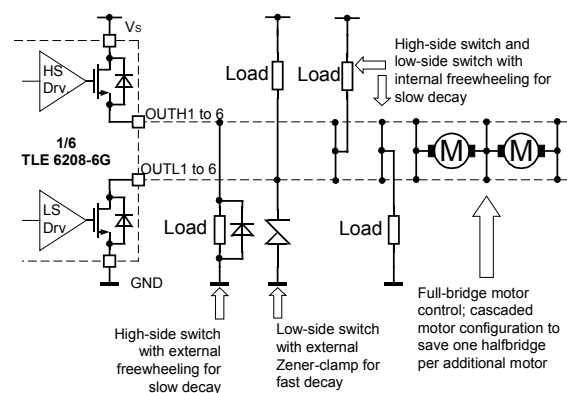

Figure 9: Configuration examples for "quarter"- bridges of the TLE 6208-6G

When demagnetizing inductive loads, the dissipated power peak can be significantly reduced by activating the transistor located parallel to the internal freewheeling diode. A special, integrated "timer" for power ON/OFF times ensures there is no crossover current at the half-bridge

in the following, detailed block schematic diagrams of the output stages are provided for further clarification.

4.3.1. Low-side switch circuit

The low-side driver circuit is shown in Figure 10. The output transistor MOUT, a power MOS (D-MOS) transistor, has an R_{DSON} of typ. 0.8Ω at 25°C.

Its source connection is linked to the Power-GND connection. The drain connection provides the output OUTL1 to OUTL6. Two sense devices (transistor, resistor and comparator) are used to detect overloads and underloads.

Figure 10: Simplified schematic of the low-side driver circuit
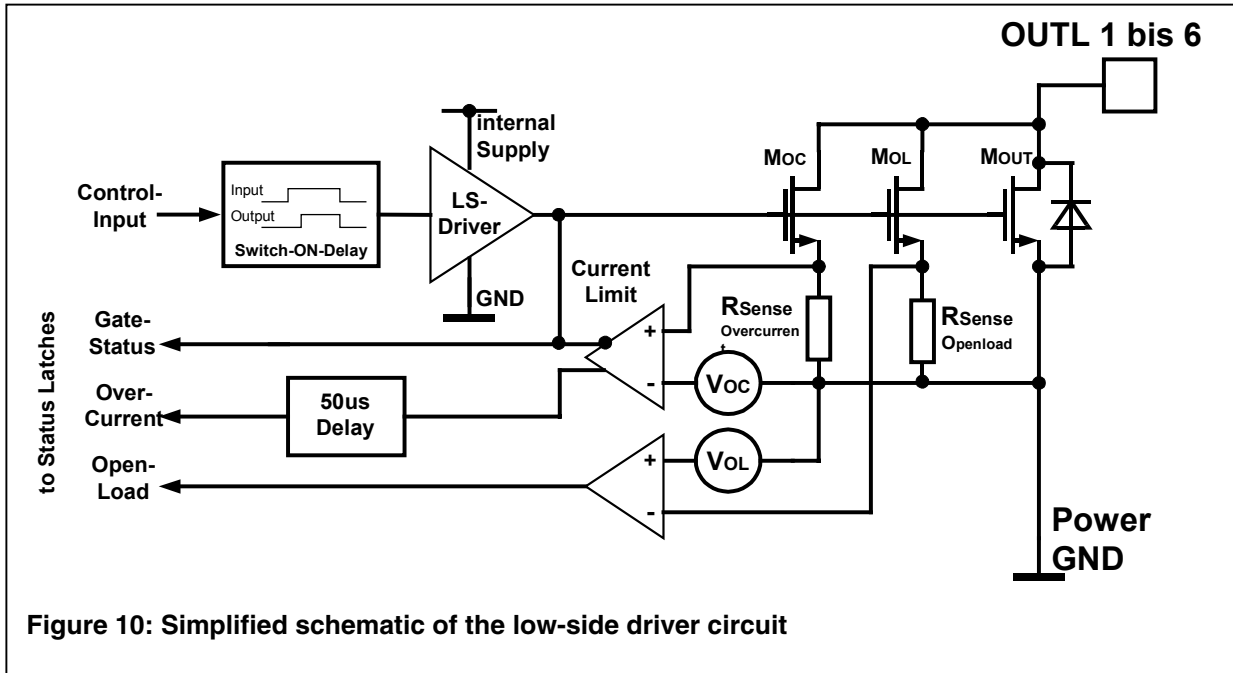
4.3.2. High-side switch circuit

Like the LS driver, the high-side driver circuit shown in Figure 11 contains an overcurrent read-out, an undercurrent read-out and a current limit. However, the sense resistors are now in the drain branch. The comparator inputs therefore have supply voltage V_S as a fixed reference potential.

Figure 11: Simplified schematic of the high-side driver circuit
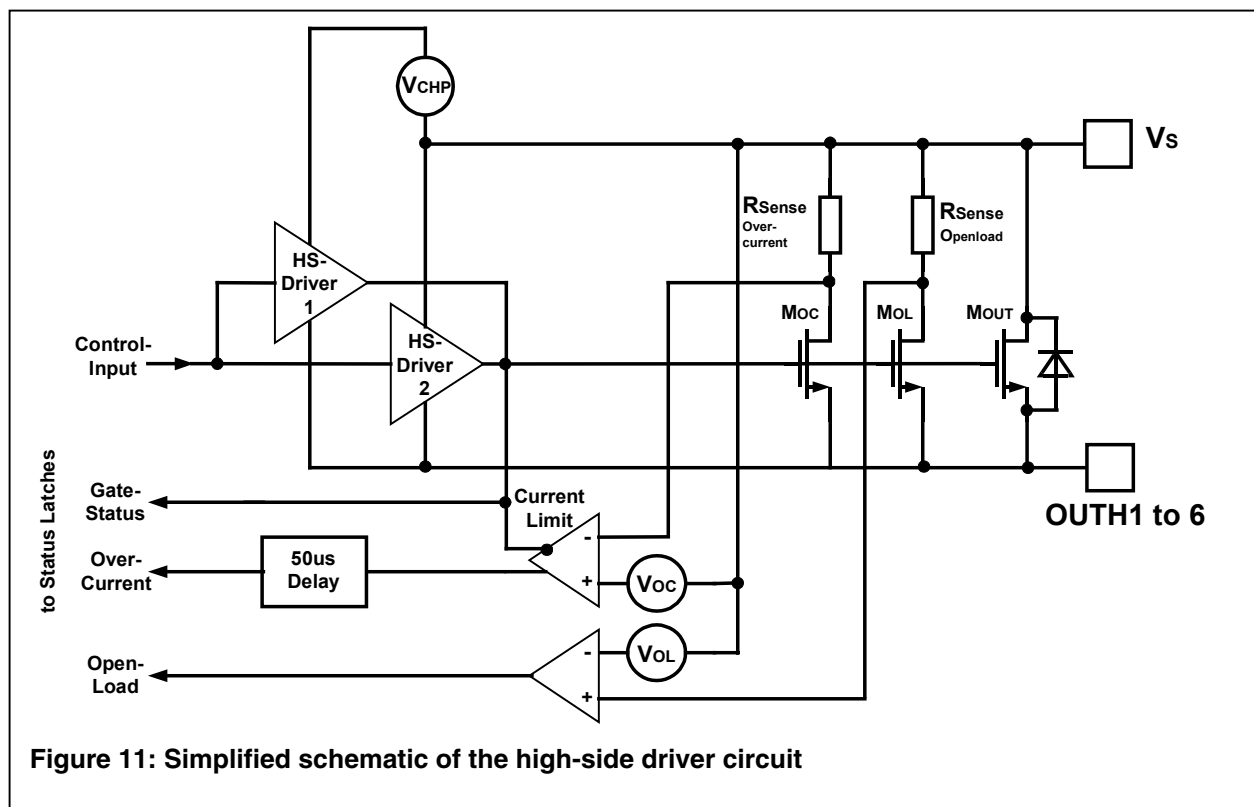
4.4. Protection and Diagnosis

4.4.1. Short circuit protection

In figure 12, the effect of the integrated short circuit protection is shown for the case of a low-side switch. The signals for high-side configuration look accordingly.
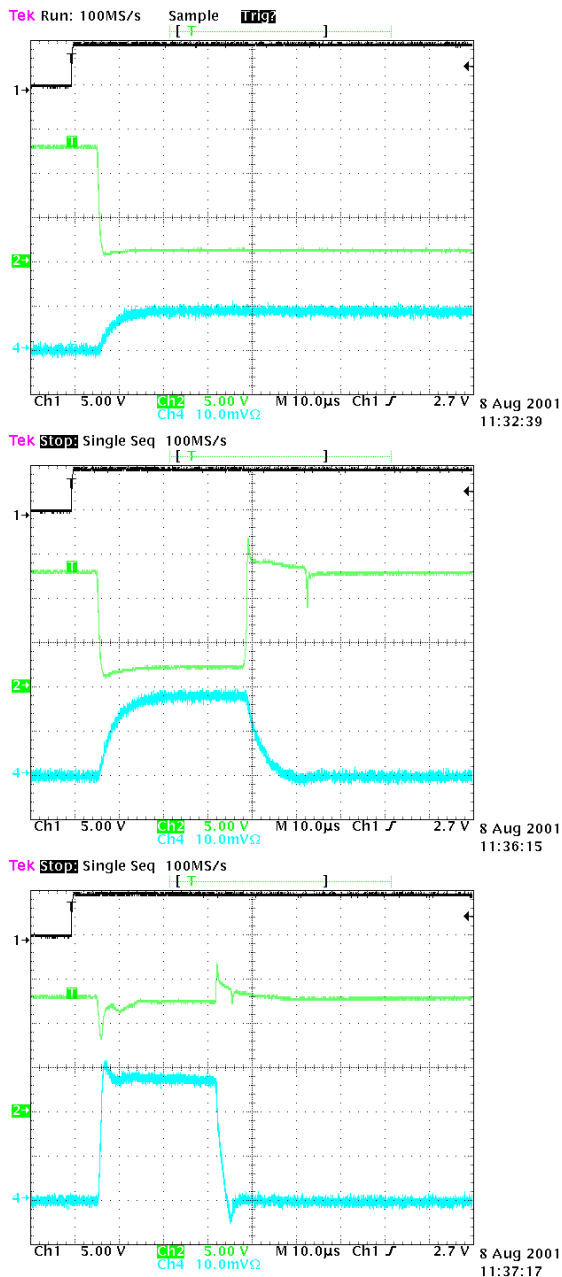

Figure 12: turn-on of low-side switch. Ch1 = CSN, Ch2 = OUT1, Ch4 = Iout@1A/div. Top: normal operation, middle: over-current shutdown, bottom: short circuit.

The first scope-screenshot shows normal operation. An SPI command with LS1 = H is sent. With the rising edge of the CLK signal the command is latched into the logic part of the TLE 6208. The low-side transistor is turned on, the output voltage is pulled to GND and the current rises. A load of 12Ω at Vs = 12V was used, so the current is below the shutdown limit of 1.5A.

The second screenshot shows the case for a load with a resistance of 6Ω, so the output current is above the over-current detection threshold. Accordingly, the output transistor is switched OFF after the shutdown delay time of 25µs. This overcurrent-shutdown is also reported in the SPI diagnostic register by Status LS-Switch 1 = L and Overload = H.

The third screenshot shows the behavior for a hard short of the output to Vs. In the case, the output current is no longer limited by the load. To protect itself, the TLE 6208 limits the output current in linear mode to 3A. Note that the voltage drops across the output transistor, not the load. Again, the fault is shown in the the diagnostic register.

It is possible to override the cut-off after 25µs by setting the overcurrent ON/OFF bit to L. However, the current continues to be restricted by the current limitation. This function allows the power-on of e.g. lights, motors, and heavy capacitive loads, which have high inrush currents and relatively short conducting periods.

4.4.2. Over-temperature protection

In addition to this output current based protection mechanisms, temperature sensors are placed in the power-transistor cell fields. At a temperature of typically 145°C, the pre-warnig flag (bit 0 of the diagnostic data protocol) is set to H. The device still operates at this temperature, but it is close to thermal shutdown. At a temperature of typically 175°C, the thermal shutdown takes place. All output drivers are switched of and the overload flag (bit 13 of the diagnostic data protocol) is set to H.

4.4.3. Open load detection

The TLE 6208-x drivers incorporate an open-circuit in ON-state detection (underload). If the switch is turned ON and the output current is

below the open-circuit detection threshold (typically 30mA), an internal open-load signal is generated. If this signal remains H for longer than the open-circuit delay time (typically 350µs), the under-load flag (bit 14 of the diagnostic data protocol) is set. This filter time ensures reliable open-circuit detection even with inductive loads with finite current rise times.

With the diagnostic scheme just described, it is not obvious from the diagnostic data which of the switches has caused the under-load message. The TLE 6208-6 has a new feature, the under-load shut-down control bit (bit 14 of the input data protocol). If this bit is set to H, the switch that generated the under-load message will be turned off. As the actual state of all 12 switches is given individually in the diagnostic protocol (bits 1 to 12), the failure channel can be identified by comparing the control- to the status word.

4.5. SPI control

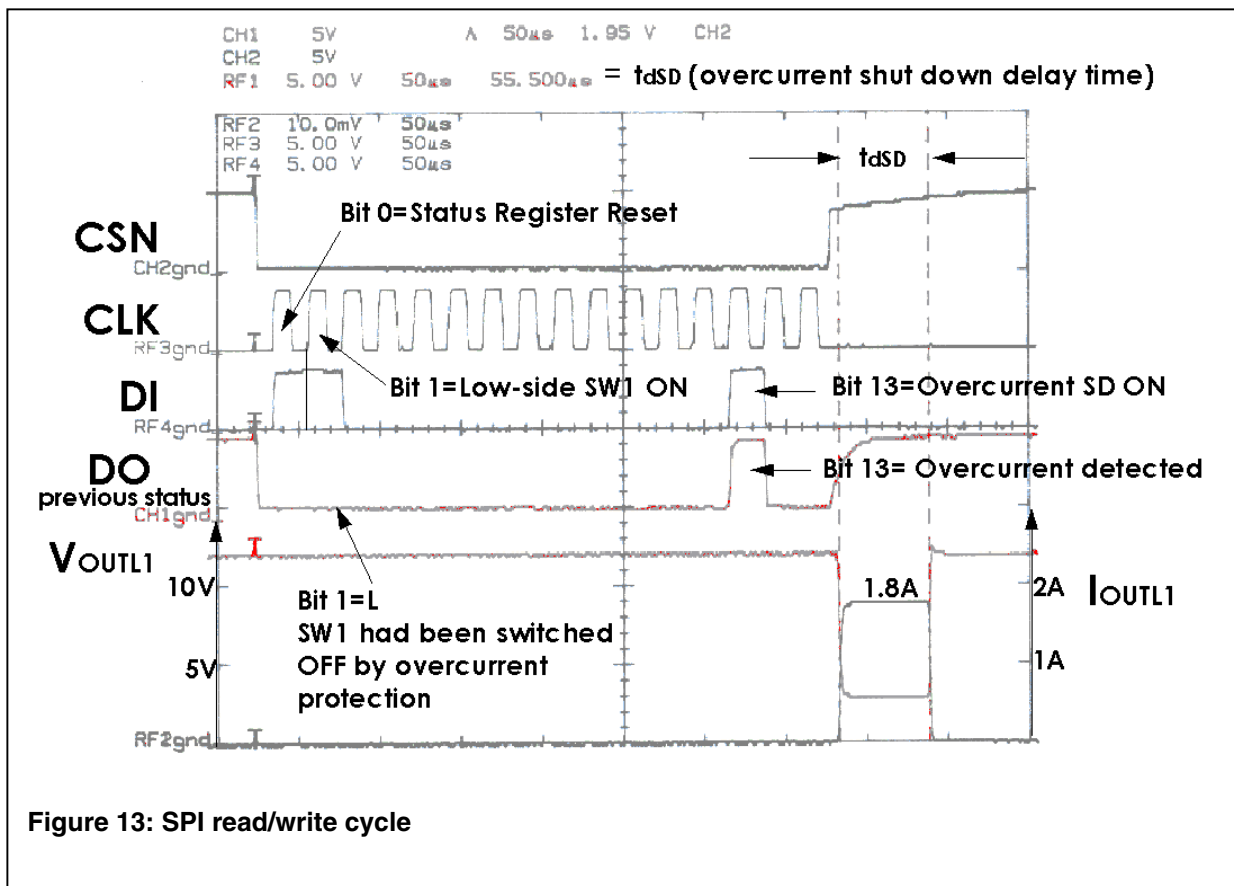The SPI interface is used to control the IC or read out the status word. Figure 13 shows a typical read/write cycle in the form of an scope screen-shot

Read-in of the 16-bit long control word begins after the H-L edge of the CSN signal. Read-in of the control word at the DI input is synchronized with the CLK clock. The status word for the previous control word appears at the data output DO. When the CSN signal changes from L to H, the data which has been read in takes effect. The IC is programmed. This is shown in Figure 13 where the two lower lines represent the voltage and the current of LS Switch 1 (was programmed with Bit 1=H at power-on; Bit 0=H has also been read in). After approx. 50us the IC cuts off the output because it is overloaded with more than 2A, and Bit 13=H (current cutoff active) was programmed at the same time.

The following two tables show the SPI input- and output data protocol with some additional explanations.

Figure 13: SPI read/write cycle

4.5.1. Input Data Protocol

Bit	Name	Explanation
15	OVLO on/off	L: Overvoltage lockout (OVLO) is not active. The IC can be operated up to V_S = 40V H: Overvoltage lockout is active. All outputs are cut off if V_S = min. 34V.
14	Under-load SD on/off	L: Switch remains ON after detection of under-current H: Switch is switched OFF if under-current is detected
13	Over-current SD on/off	L: Overcurrent lockout after 25µs is not active; the current is limited to typ. 3A. H: Overcurrent lockout after 25µs is active
12	HS-Switch 6	L: HS-switch 6 ON H: HS-switch 6 OFF
11	LS-Switch 6	L: LS-switch 6 OFF H: LS-switch 6 ON
10	HS-Switch 5	...
9	LS-Switch 5	...
8	HS-Switch 4	...
7	LS-Switch 4	...
6	HS-Switch 3	...
5	LS-Switch 3	...
4	HS-Switch 2	...
3	LS-Switch 2	...
2	HS-Switch 1	...
1	LS-Switch 1	...
0	Status Register Reset	L: All data remains stored in the status register H: The status register is reset with the rising edge of CNS

4.5.2. Output Data Protocol

Bit	Name	Explanation
15	Power supply fail	H: overvoltage or undervoltage has been or is still being detected at V_S. Overvoltage is also indicated if Bit 15 of the control word has been set to L (OVLO not active).
14	Under-load	H: underload has been detected on one or more of the 12 switches.
13	Over-load	H: one or more of the 12 switches is or was overloaded. Status Bits 1 to 12 can be used to identify the switch concerned.
12	Status HSS 6	L: Output transistor is inactive (high impedance) H: Output transistor is active (conducting)
11	Status LSS 6	...
10	Status HSS 5	...
9	Status LSS 5	...
8	Status HSS 4	...
7	Status LSS 4	...
6	Status HSS 3	...
5	Status LSS 3	...
4	Status HSS 2	...
3	Status LSS 2	...
2	Status HSS 1	...
1	Status LSS 1	...
0	Temp. Pre-warning	If the chip temperature rises above typ. T_j = 145°C, then Bit 0 is set to H. The information is stored in the status register.

At typ. T_j = 175°C, all output transistors are cut off (emergency off). The data remains stored in all registers. If the chip temperature drops below typ. T_j = 125°C, then Bit 0 is set to L. The

information in the status register is overwritten (all-clear).

All information is stored, unless Bit 0 of the control word is set and a new control cycle has been initiated (see Bit 0 of the control word). In the same way, the status register is deleted by turning VCC on or off, or by deactivating the IC via the inhibit input (INH=L).

4.6. Demo-Board

For the purposes of laboratory testing and as a development system, application boards for both the TLE 6208-6G and the TLE 6208-3G are available.together with Windows[R] control software.

4.6.1. Demo-Board Hardware

The boards include:

- The driver IC itself

- Voltage Regulator for Vcc 5V supply

- Power connectors for Vs and external loads

- Output status indication LEDs

- Parallel port connector for PC printer port

Figure 14 shows the schematic of the TLE 6208-6G demo-board

4.6.2. Demo-Board Software

The standard parallel interface on a PC is used to control and read the status word. Software running under Windows allows the simple definition of macros, which can be combined to create a sequence program. The standard screen masks are shown in Figure 15
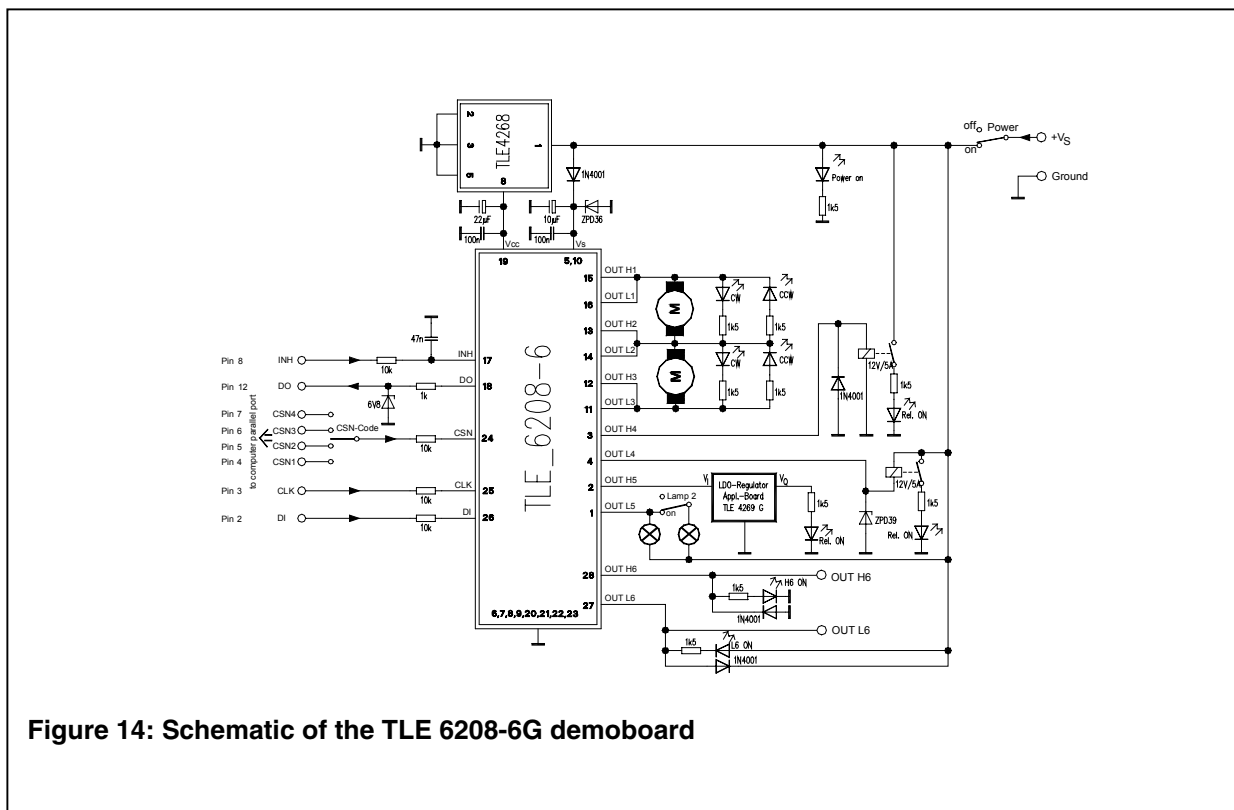
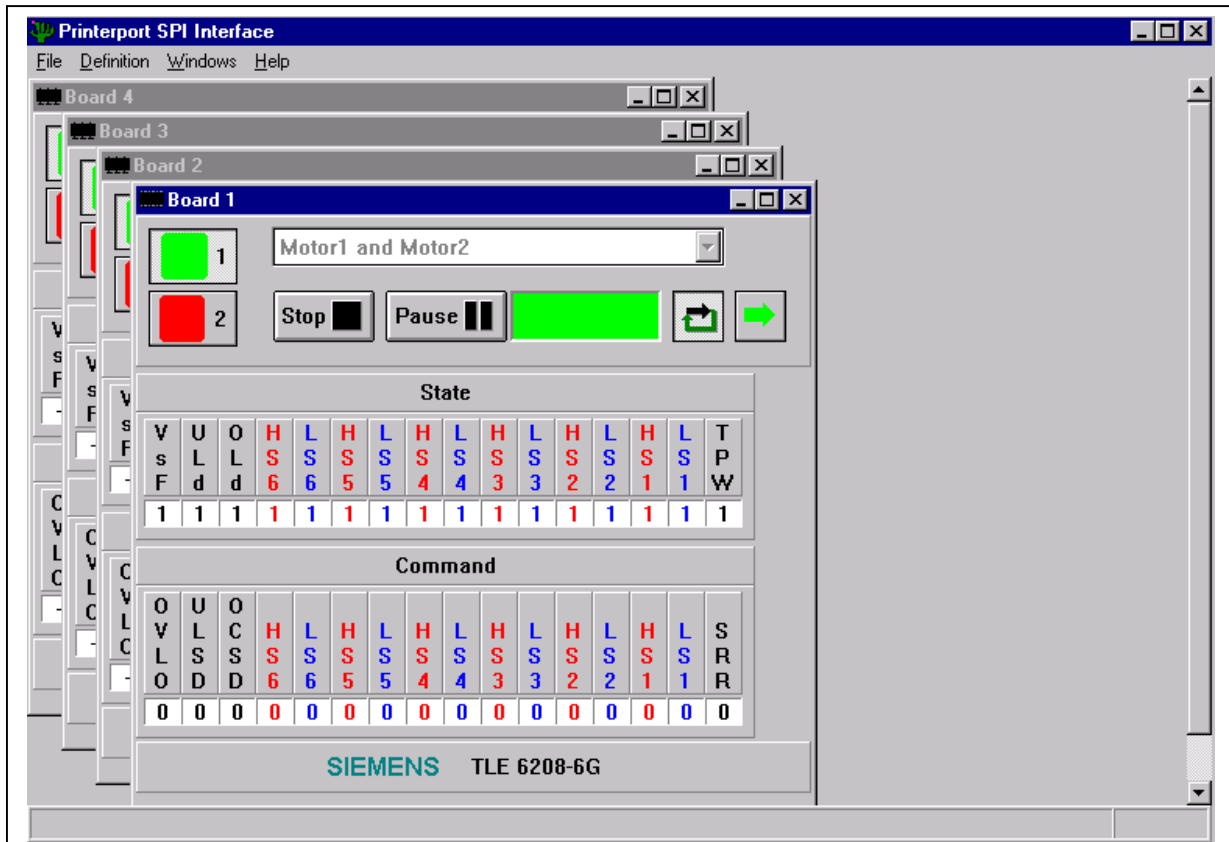**Figure 14: Schematic of the TLE 6208-6G demoboard**

Figure 15: Main window of SPIwin demoboard software

5. Conclusion

The TLE 6208-xG family has successfully bridged the gap between single switches and motor bridge applications.

This unique combination allows all possible loads to be controlled easily, and therefore sets a new standard in the field of power electronics.

These ICs are also the first step towards so-called Application Specific Standard Products (ASSPs), where a specific combination of output stages, optimized for a target application is integrated.

This ASSP-approach gets even more important in combination with new bus systems like CAN and LIN and high logic-density power technologies, which allow the integration of complex state-machines with physical layer bus transceivers and power stages.

6. Additional information

More information can by found in the internet under the following URLs:

www.infineon.com	general info
www.infoneon.com\bridges	product information about bridge products

Other documents:

System Engineering Application Note and Software SE_1199 (Details and code examples about SPI programming with Infineons C164 µController, available on request)

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"Business excellence means intelligent approaches and clearly defined processes, which are both constantly under review and ultimately lead to good operating results.

Better operating results and business excellence mean less idleness and wastefulness for all of us, more professional success, more accurate information, a better overview and, thereby, less frustration and more satisfaction."

Dr. Ulrich Schuhmacher