SPIDER+

More than a relay driver

About this document

Scope and purpose

This application note describes the main features and system level benefits that SPIDER+ brings to automotive applications, with practical application examples and partitioning hints in order to maximize the value while allowing flexibility and scalability.

Intended audience

This application note is intended for anyone who wants to know more about the SPIDER+ family.

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1 Introduction

Infineon Technologies' SPIDER family of products (SPI Drivers for enhanced relay control) has been successful driving off-board relays in automotive applications for several years, particularly in the body electronics area, enabling integration, scalability, flexibility and robustness for the application.

The automotive industry is highly demanding in time-to-market requirements, reliability and cost; to satisfy these requirements, vehicle manufacturers standardize architectures and consolidate requirements across different vehicle platforms. On the other hand, the electronic content in vehicles is rapidly increasing and the number of features and options is very widespread, therefore flexibility and scalability is also required. The electronic module design is a key factor to support the demands of the industry.

This application note describes the main features and system level benefits that SPIDER+ contributes to automotive applications, with practical application examples and partitioning hints in order to maximize the value while allowing flexibility and scalability.

2 SPIDER+ at a glance

SPIDER+ is the newest generation of Infineon Technologies SPIDER product family. With a broad portfolio offering different driver topologies (high-side, low-side and configurable switches), a standardized SPI register set, pin-out compatibility among some of the family members, and an optional LED package optimized for applications with LED and bulbs; SPIDER+ enables scalability on vehicle platforms and architectures.

In this chapter, the new features of the SPIDER+ family, and more importantly, on how to maximize their value in the application are described.

2.1 What is a SPIDER?

Most people know the definition of a spider in biology as an eight-legged arthropod, but its definition in electronics is that SPIDER stands for ***SPI-D****R*I*VER*. Originally, SPIDERs were designed for driving relays in automotive and industrial applications, today SPIDERs include additional features that enable driving additional loads, for example LEDs or small bulbs. The main characteristics of SPIDERs are summarized below:

- SPIDERs are multi-channel drivers. Integration into multi-channel drivers helps reduce board space and component count, reducing cost in materials, logistics and manufacturability.
- SPIDERs are high-side, low-side and configurable solid-state switches. With different combinations of high-side, low-side and configurable drivers in the same package, different topologies of switching power to a load, are supported.
- SPIDERs have SPI (serial peripheral interface). By the addition of a serial communication protocol, the number of microcontroller inputs and outputs (I/O) required for control and diagnosis is significantly reduced compared to a discrete solution. A quick comparison is shown in Figure 1.
- SPIDERs are protected switches with diagnosis. Protection against overcurrent, over temperature and short circuit are implemented for each individual channel, the device is also protected against electrostatic discharge (*ESD*). Diagnostics for open load and over load (either overcurrent or over temperature) are reported via SPI.

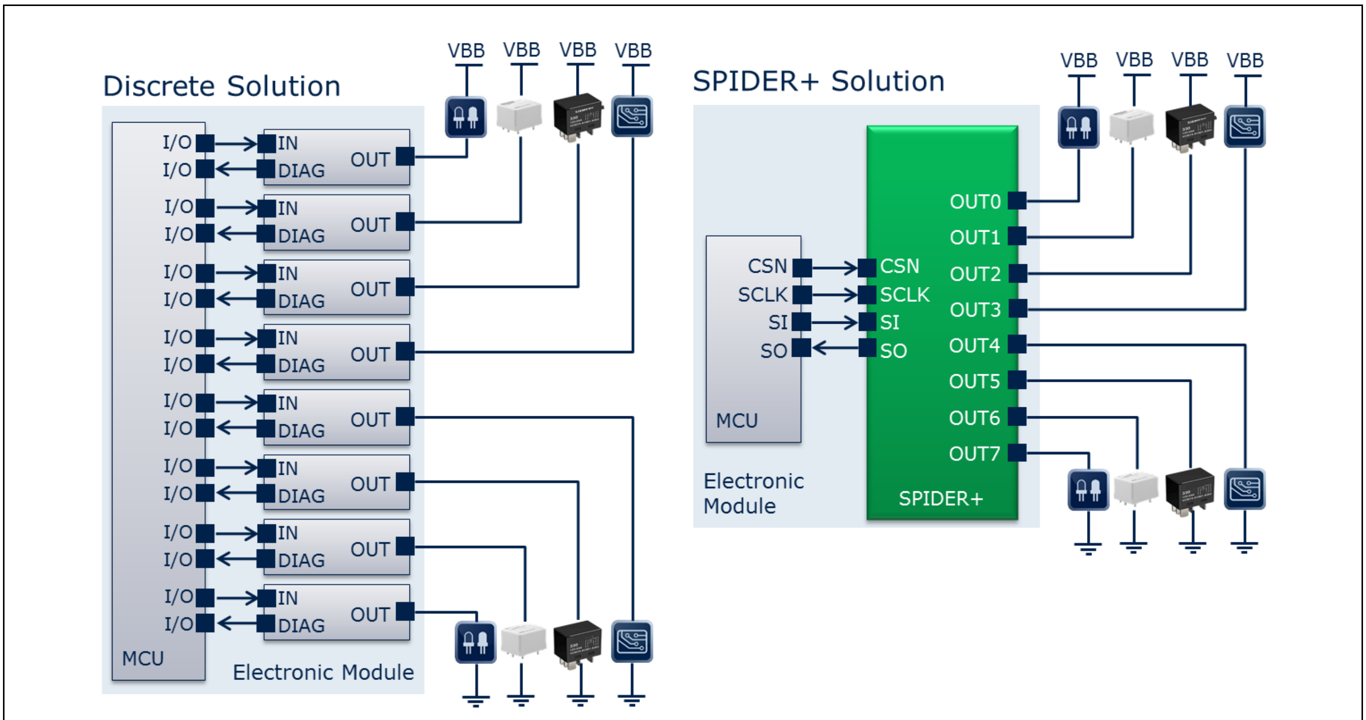

Figure 1 SPIDER+ solution versus discrete solution

2.2 What is NEW with the SPIDER+ family?

SPIDER+ is the newest generation of SPIDER products. In addition to characteristics already listed in Chapter 2.1, "What is a SPIDER?", the new family has the following characteristics:

- Standardized R_{DSON} per channel, typically 1 Ω with identical parameters for each channel
- Protection against overvoltage, over temperature, and short circuit.
- Standard open load diagnostics in off state
- Digital supply voltage compatible with 3.3 V and 5.0 V microcontrollers
- 16-bit SPI daisy chain capable of up to 5 MHz CLK frequency, with standardized register set for the entire family
- Improved fail-safe mode (limp home) supplied by supply voltage (V_S) for increased reliability
- Cranking (supply down to 3.0 V)
- 2 direct inputs with input mapping functionality enabling a direct input pin to control any output
- Optional LED package available including:
    - 2 On-chip PWM generators
    - Open load detection in the on state
    - Bulb inrush mode (BIM)
- 150 mil pitch packages with exposed pad that reduce board space and enable better thermal performance.
- Very low current consumption in sleep mode
- Enhanced diagnosis via SPI (i.e. input status register, output status monitor, operational mode, etc.) to support ISO26262 requirements

For a more detailed description of the functionality and the electrical parameters, please refer to device datasheet [2]. Figure 2 shows the internal block diagram of one member of the SPIDER+ family, TLE75602-ESH (6 configurable channels and 2 low-side channels with LED package).

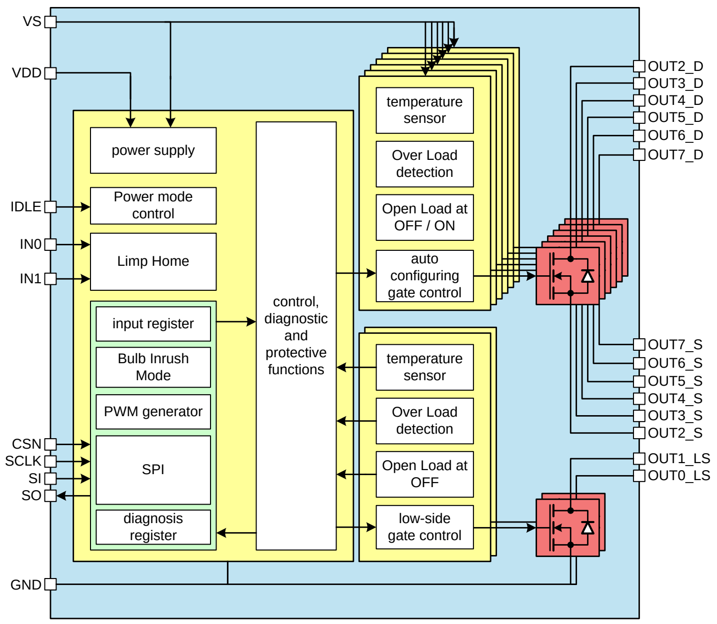

Figure 2 TLE75602-ESH block diagram

Table 1 lists SPIDER+ portfolio; 9 products are offered with different output driver configurations, from purely fixed low-side channels to purely high-side channels with different combinations of fixed with configurable channels and an optional LED package.

Table 1 SPIDER+ Portfolio

Number of channels	Configurable channels	High-side channels	Low-side channels	LED package	Part number
4	-	-	4	-	TLE75004-EPD
8	-	-	8	-	TLE75008-ESD
8	-	8	-	-	TLE75080-ESD
8	-	8	-	YES	TLE75080-ESH
8	6	-	2	-	TLE75602-ESD
8	6	-	2	YES	TLE75602-ESH
8	6	2	-	YES	TLE75620-EST
8	2	4	2	-	TLE75242-ESD
8	2	4	2	YES	TLE75242-ESH

SPIDER+ offers drop-in compatibility among some members of the family, more details will be explained subsequently in this application note in Chapter 3.3.1, “Hardware compatibility”.

2.2.1 The LED pack

SPIDER+ offers an optional LED pack for various members of the family. Members with LED pack are pin-to-pin compatible with the standard version.

In addition to the standard features already described, the LED pack enables the next functionality:

- **Open Load diagnosis in the on state** – With open load diagnosis in the on state, undesirable LED glowing in the off state is removed. A diagnosis loop is also available so each channel is diagnosed automatically in synchronization with its control signal, including PWM, reducing the workload of the microcontroller to a simple SPI command.
- **Two internal PWM generators** – In addition to the 2 direct input pins, with the 2 internal PWM generators, up to 4 different PWM frequency and duty cycle combinations can be used by the output drivers.
- **Bulb Inrush mode** – The bulb inrush mode or BIM is an auto-retry feature that enables the device to handle inrush currents that would normally latch the output off. With the BIM, driving small bulbs up to 5 W or other capacitive loads is also possible.

The LED pack is available for all parts containing fixed high-side channels or configurable channels, in this case TLE75080-ESH, TLE75242-ESH, TLE75602-ESH and TLE75620-EST. It is very easy to distinguish a part including the LED package from a standard part by simply looking at the last letter on the part number. Parts ending in “**D**” have a standard feature set, for example TLE75602-ES**D**; If the part number finishes with an “**H**” or “**T**” instead, it means the part includes the LED package, for example TLE75602-ES**H**.

2.2.2 SPIDER+ target applications

The most common automotive application for SPIDER+ is in the body control module (BCM) arena, where a high number of relays, indicators and actuators distributed throughout the vehicle are controlled and diagnosed. However, SPIDER+ serves almost any automotive electronic control unit or ECU, for example Smart-PDB (power distribution box), HVAC flap control, smart mirror control, E-shift and many others.

In Chapter 4, “Partitioning example with SPIDER+”, several topologies and driver examples with SPIDER+ are described.

3 System benefits of SPIDER+

SPIDER+ includes several features and characteristics designed to bring benefits and savings at a system level, supporting the premise of “lowest cost per channel”.

Some of the system level benefits when using SPIDER+ are briefly described in this chapter.

3.1 Reduction of board space and microcontroller resources

SPIDER+ family is not only implemented in the smallest package of its kind, integrating several channels in the smallest footprint, 4 channels in a PG-TSDSO-14 and 8 channels in a PG-TSDSO-24, but also uses serial communication (SPI) for control and diagnosis, reducing the required number of inputs and outputs required from the microcontroller. In addition to this, several devices within the SPIDER+ family are pin-to-pin compatible, enabling a standardized and scalable design that supports different production population variants while minimizing board space.

3.1.1 Multi-channel integration

As previously described, SPIDER+ is a multi-channel device, integrating up to eight drivers in the same package. Not only is integration cheaper than the sum of the parts, additional savings are obtained by reducing board space and external circuitry associated to each device, for example, decoupling capacitors. There are also additional savings in manufacturing, as the assembly time is reduced, less testing is required and logistics complexity is reduced.

Special attention is required in the thermal performance of the device when multiple channels are integrated in the same package, as each channel will be a source of power that has to be dissipated by the same package. Additional details on power dissipation calculations and other functional requirements are described in more detail in Chapter 4, “Partitioning example with SPIDER+”.

3.1.2 SPI communication

One of the main benefits of SPIDER is the implementation of serial peripheral interface or SPI. Serial communication reduces the number of required input and output pins from the microcontroller, usually called “master”, to control and diagnose the output drivers, usually called “slave”.

SPI is a synchronous and multi-slave protocol; therefore, multiple devices can be controlled by the same SPI bus in either parallel or daisy-chain configuration. When several devices share the same SPI, the resources from the microcontroller in terms of I/O are significantly reduced.

With a parallel SPI, also known as cascaded SPI, in addition to the SCLK, SI and SO, one output from the microcontroller (chip select, CSN) is required for each slave in the bus, in order to address the message to a specific slave. With this configuration, standard 16-bit word messages are used in the communication between the microcontroller and the SPI slave.

Using a daisy-chain configuration, the number of pins required from the microcontroller is reduced to a minimum of 4 (SO, SI, CLK and CSN) regardless of the number of “slaves” in the chain. The drawback of the daisy-chain topology is that the SPI message length is proportional to the number “n” of devices in the chain by n*16-bit. For example, if 4 SPIDER+ devices are controlled in a SPI daisy chain configuration, the message length would be 64-bit. It is important to evaluate the impact of the additional latency in the communication given by extended bit length messages.

SPIDER+ uses a standard 16-bit SPI message concept for the entire family. The structure of the SPI registers enables a single software development valid for every member of the family.

For more detailed information on the registers and electrical characteristics, please refer to device datasheet [2].

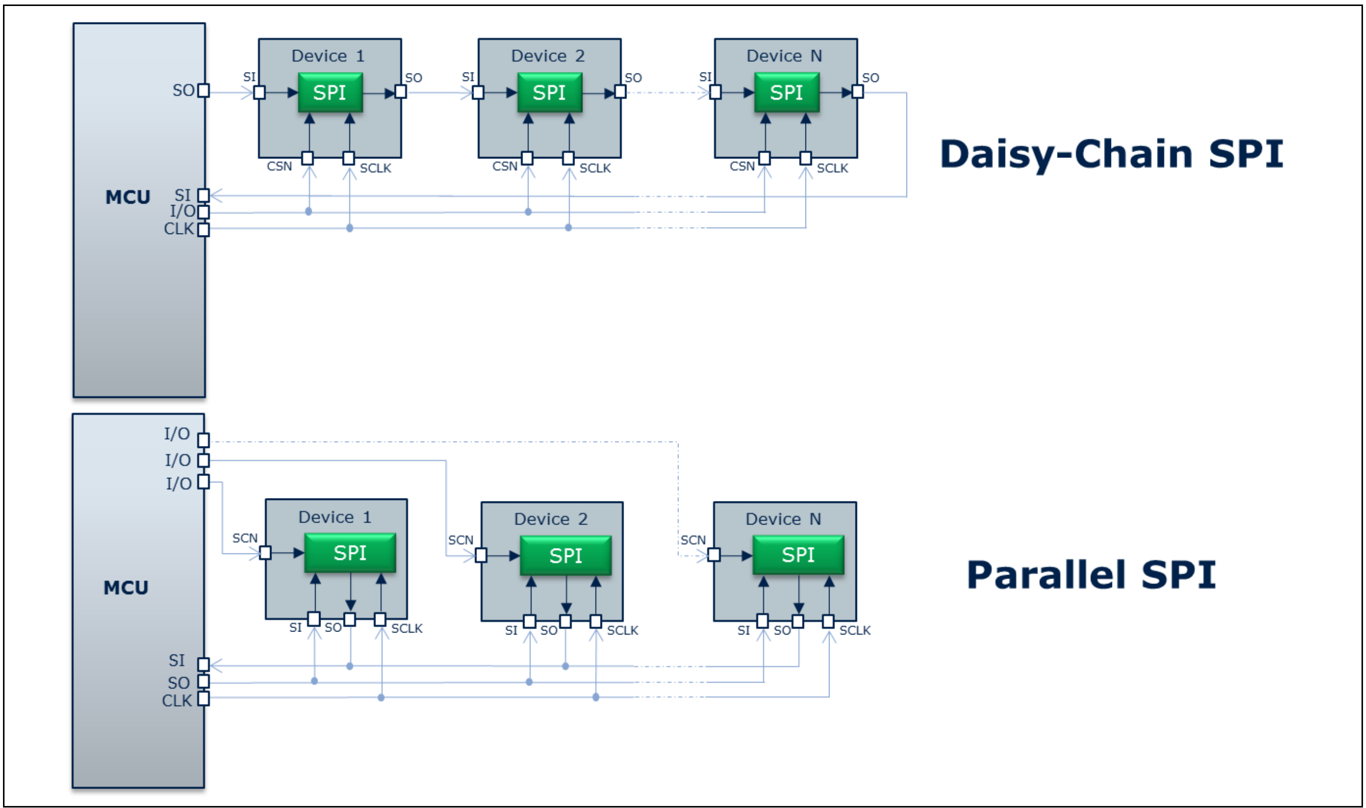

Figure 3 Parallel versus daisy-chain SPI

3.2 Flexibility

As seen in SPIDER+ Portfolio, SPIDER+ family offers different combinations of high-side switches, low-side switches and configurable switches in the same package, ranging from pure fixed low-side channel devices to pure fixed high-side channel devices and offers different combinations of fixed high-side, fixed low-side and configurable channels. SPIDER+ product portfolio enables different topologies and design flexibility within its portfolio.

The power stage also supports different types of loads such as relays, LEDs, small bulbs, solenoids; most resistive, inductive, or capacitive load in the current rage of SPIDERs, typically 330 mA per channel for octal drivers. It is also important to highlight that the products are compatible with 3.0 V and 5.0 V microcontrollers.

3.2.1 Low-side, high-side and configurable switch topologies

SPIDER+ is a family of multi-channel drivers integrating a variety of high-side, low-side and configurable channels in the same device. Within the numerous members of the family, there are several part numbers to choose from, ranging from fixed low-side channel devices (TLE75004-EPD, TLE75008-ESD) to a device with fixed high-side channels (TLE75080-ESD, TLE75080-ESH), please refer to SPIDER+ Portfolio, for a summary of all family members.

Figure 4 illustrates the basic topology of a low-side switch and a high-side switch.

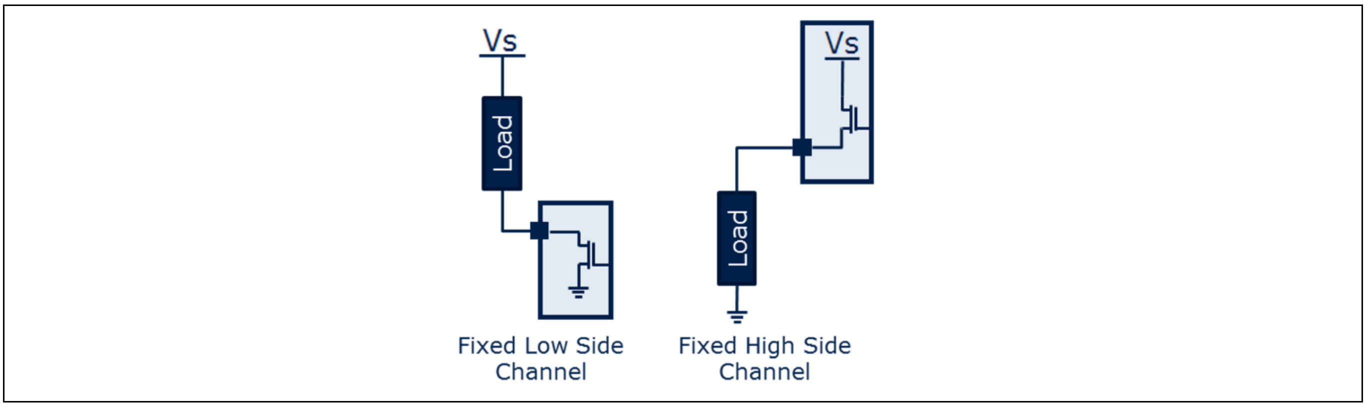

Figure 4 Driver topologies supported by SPIDER+ fixed channels

In a fixed low-side switch, only the drain of the NMOS is accessible. The low-side driver connects ground (GND) to the load, and the load is always connected to a higher potential (V_S), for example the battery, on the other end. When the low-side switch is activated, the circuit is closed and current flows throughout the load. The low-side switch is the easiest and cheapest topology to implement but has two main disadvantages at a system level. Firstly, it requires two wires per load (assuming off board load), one for the switch and one for battery (V_S). Secondly, the disadvantage is that in case of a short circuit to ground, the most common failure mode in the vehicle, the load is inadvertently activated.

In the fixed high-side channels, only the source of NMOS is accessible. The high-side driver connects the power or battery (V_S) to the load, and the load is always connected to a lower potential on the other end, in this case ground (GND). The advantages at a system level is wiring reduction, as only one wire is required for the switch and the other end of the load is connected to ground (GND) directly on the chassis; also, in case of short circuit to ground on the output, the load is not inadvertently activated. A high-side channel is more expensive than a low-side channel, as a charge pump is required to provide a gate to source voltage higher than battery (V_S) to ensure the gate of the NMOS has enough voltage to activate the switch (V_{GSth}, Voltage Gate-Source threshold).

In the configurable channels, both the Drain and the Source of the NMOS are accessible. These channels provide the flexibility not only to drive the load either from the high-side or low-side, but also enables design flexibility in case of future requirements change in the design. With configurable channels several other topologies can be implemented, for example an H-bridge configuration, please refer to Figure 5. An additional system level benefit using the configurable channels is that different battery or fuse feeds can be supported within the same device (more information to come in Chapter 4.5, “Battery feeds”). Configurable channels are the most expensive driver topology as it requires, in addition to the charge pump, access to the drain and the source of the NMOS.

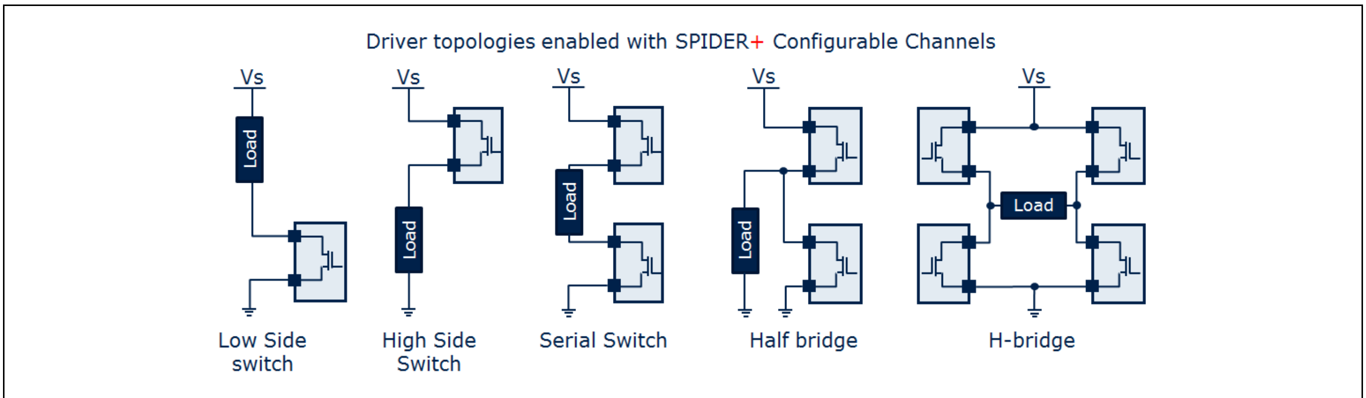

Figure 5 Driver topologies supported by SPIDER+ configurable channels

3.2.2 Enabling resistive, inductive and capacitive loads

There are a significant number of loads that can be driven by SPIDER+. The standard power stage is capable of driving resistive loads and inductive loads without the need for any external protection in most common cases. For capacitive modeled loads such as small bulbs or power feeds the optional LED package is also available to satisfy some of the inrush requirements.

- **Resistive loads** – The only limiting factors for driving resistive loads with SPIDER+ are the current capability and power dissipation. Some of the most typical resistive loads targeted for SPIDER+ are sensors, reference voltages (without inrush) and indicator LEDs. Additional details can be found in Chapter 4.9, “Considerations for driving LEDs”.
- **Inductive loads** – The typical inductive load for SPIDER+ is a relay coil. In addition to the power dissipation and current capability of the power stage, a critical consideration with these types of loads is the dissipated inductive energy when the load is switched off. SPIDER+ implements an active clamping circuit that is able to repetitively absorb the inductive energy for most automotive relays without the need for additional external protection circuitry (i.e. recirculation diode). However, it is important to analyze each individual relay or inductive load driven by SPIDER+ to make sure it does not exceed the maximum rating given in the specification for turn-off energy. Additional details can be found in Chapter 4.8, “Considerations for driving relays and inductive loads”.
- **Capacitive loads** – Capacitive loads are simplistically defined as any electronic load that has an initial peak current or inrush greater than the steady state current. The standard power stage of SPIDER+ would normally latch-off due to overcurrent protection under this circumstance. However, with the optional LED package, the power stage also has the capability of driving small bulbs (5 W with two channels in parallel or 2 W single channel) and other capacitive loads by implementing an automatic retry strategy called Bulb Inrush Mode or BIM. Additional details can be found in Chapter 4.8.2, “Considerations for driving bulbs and capacitive loads (LED package only)”.

3.3 Scalability

To enable simpler and faster designs, SPIDER+ offers drop-in compatibility among some members of the family; the standard part is always pin to pin compatible with its correspondent part with LED package. It also has a standardized 16-bit SPI structure that enables the same software to be used with all members of the family; these two topics will be explained below in more detail.

3.3.1 Hardware compatibility

There are two packages available within the family; PG-TSDSO-24 is used for all 8-channel products and PG-TSDSO-14 for the 4-channel product. All members of the family share the same logic pinout, with different levels of pin-pin compatibility offered among similar devices. The following levels of scalability and pin-compatibility are offered in SPIDER+:

Standard feature set and LED package drop in compatibility – Parts with and without LED package share the same footprint and pinout. A part with standard feature set has termination “D” while the part with LED package has the termination “H” or “T”:

TLE75602-ESD and TLE75602-ESH are pin-to-pin compatible.

TLE75080-ESD and TLE75080-ESH are pin-to-pin compatible.

TLE75242-ESD and TLE75242-ESH are pin-to-pin compatible.

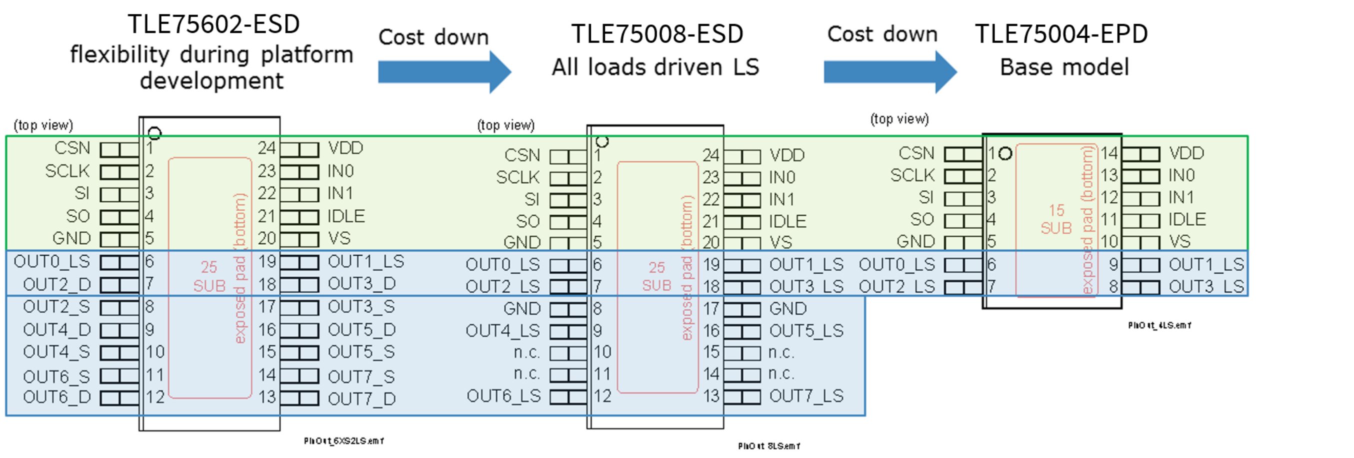

Figure 6 Hardware compatibility example, low-side dominated architectures

In low-side dominated architectures, it is also possible to scale up and down with numbers of channels; TLE75004-EPD can be used as a drop-in cost down to TLE75008-ESD, TLE75602-ESD and TLE75602-ESH. Please note that TLE75602-ESD and TLE75602-ESH are also drop in compatible with TLE75008-ESD, enabling flexibility during development with possibility for choosing a lower cost part in production, as an example Figure 6.

3.3.2 Software compatibility

SPIDER+ uses a 16-bit standard message concept for the whole family. The structure of the SPI messages enables one software development valid for the entire family. Bits related to family functions not present in the device are defaulted to logic "0". As an example, Figure 7 shows the standard diagnosis register of TLE75004-EPD (4 channels low-side) and TLE75080-ESH (8 channels high-side with open load at on, PWM generation and bulb inrush mode). Error diagnosis for channels 4 to 7 in TLE75004-EPD (ERRn) and open load in the on-state (OL_ON), which are not available in the 4-channel device, are reported as logic "0".

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Default	
0	UVR VS	LOP VDD	MODE		TER	0	OL OFF	0	0	0	0	ERR				7800_H	← TLE75004-EPD
0	UVR VS	LOP VDD	MODE		TER	OL ON	OL OFF	ERR								7800_H	← TLE75080-ESH

Figure 7 Software compatibility example, SPI standard register

3.4 Fail-safe functionality

SPIDER+ has several provisions for fail-safe functionality including limp home mode and cranking down to 3.0 V, also included is a set of diagnosis functions for overtemperature, overcurrent and open load in the off and on-states. Below, additional details are given.

3.4.1 Limp home mode

Limp home mode is fail-safe mechanism used in automotive electronics to ensure certain safety critical loads in the vehicle remain functional even in cases where something fails in the electronic module, including errors in software execution, a corruption in the SPI messaging or an improper voltage in the digital supply. Commonly, limp home mode functionality implies redundant paths for controlling the safety critical loads; for example, a

monitoring IC that can take control over the status of a safety-critical relay when the microcontroller generates an internal reset.

All SPIDER+ devices support limp home functionality by means of using the IDLE pin in combination with the input pins IN0 and IN1. With this functionality, one or two of the channels in the SPIDER+ can be controlled directly by the input pins while "ignoring" SPI control commands whenever the IDLE pin is set to a logic "low" (typically from a monitoring IC or a system basis chip, SBC).

In normal operation or active mode, with IDLE = "high", IN0 and IN1 control any selected output channel via SPI registers MAPIN0 and MAPIN1. In limp home mode, with IDLE = "low", IN0 and IN1 will have direct control over channel 2 and channel 3 respectively, while all other channels are switched off. If both IN0 and IN1 are low while IDLE is also set to low the device will enter IDLE mode, where the quiescent current of the part is significantly reduced. In case of loss of V_{DD}, the device can still enter limp home mode.

During limp home mode, not only control of CH2 and CH3 is possible but also real time protection and diagnosis are available to these channels. Overtemperature and over load protection are functional with an internal timer that will automatically perform output channel retry, activating the correspondent output as long as the input pin remains high and the fail condition continues to exist. The status of the input pins IN0 and IN1 can be monitored via the input status monitor register (INST). In limp home mode the SPI communication is still active as read-only, which means that all SPI registers can still be read but cannot be written.

The application example in Chapter 4 of this application note includes some functional safety requirements that will be also analyzed in more detail in Chapter 4.7, "Functional safety and limp home mode".

3.4.2 Functional safety

SPIDER+ includes an enhanced diagnosis scheme via SPI where the whole path from the microcontroller to load is traceable. In other words, input pins, power stages, communication and load can all be diagnosed; these features support the functional safety requirements of the safety standard for automotive electronics, ISO26262.

ISO26262 supporting documentation will be available upon request, including the device Failure in Time (FIT) rate as well as the chip area estimation grouped by function and block.

With SPIDER+ features it is easier to diagnose the complete path from microcontroller to load. Input status, supply status, device status and output status can all be diagnosed via SPI as indicated in Figure 8.

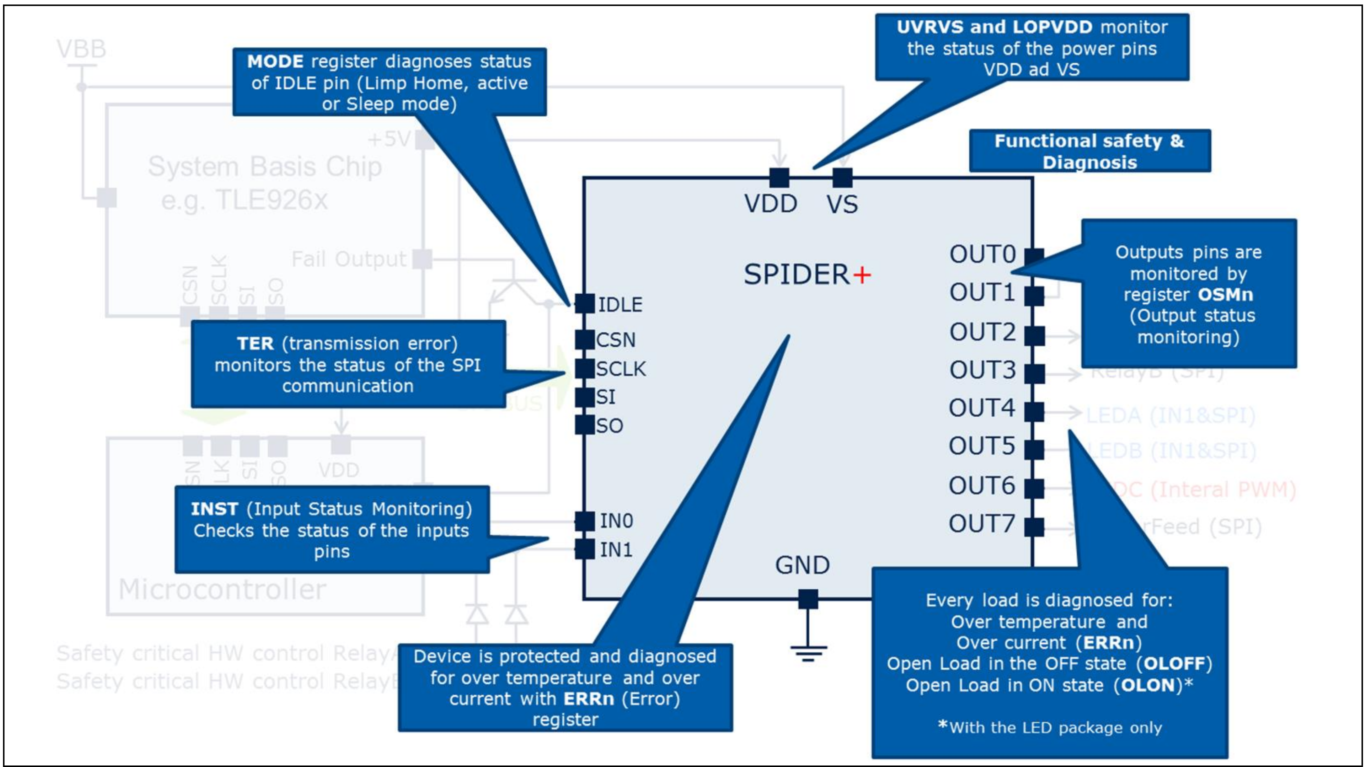

Figure 8 SPIDER+ diagnosis supporting functional safety.

3.4.3 Cranking functionality

All members of SPIDER+ family can operate down to a battery level of 3.0 V, which ensure not only that loads can be activated or deactivated during a cranking pulse; SPI communication and register values remain operational down to this voltage as long as the logic supply V_{DD} is also operational (above 3.0 V).

It is important to consider the possible additional current consumption in the digital power supply V_{DD} during cranking operative range (COR), this additional current is specified and described in more detail in device datasheet [2].

3.5 Low quiescent current consumption

As described earlier, there are 4 operational modes in any SPIDER+ device, Sleep mode, Idle mode, Active mode and limp home mode. The first two are intended to reduce the power consumption of the device when the loads are off. Sleep mode is the lowest current consumption mode, as low as I_{SLEEP} = 5 µA worst-case at 85°C for the whole device; I_{IDLE} is as low as 2.5 mA worst-case.

3.6 Robustness

All devices include protection against ESD, short circuit, overcurrent, reverse battery, overvoltage and open load.

4 Partitioning example with SPIDER+

Partitioning is one of the most important processes in the design cycle of electronic modules, the system is analyzed in smaller pieces called “building blocks”, the connection and interaction between the different building blocks is also analyzed making sure that all requirements are met.

The partitioning is also the process where the optimal driver for each load is determined; a good partitioning will lead to a reliable and cost optimized design. This section of the application note provides some examples on how to partition with SPIDER+, and guides through the device selection towards a reliable, flexible and cost optimized design.

4.1 Start with a useful load-list

To optimize a design by means of integration into multi-channel drivers, it is important to start with a clear understanding of the application requirements, including electrical, mechanical and functional requirements; it is also important to consider vehicle variant information and any other special requirements that might be relevant to the application, for example fail-safe requirements such as limp home mode and cranking.

A load-list with proper and relevant information is a very simple tool that enables having a clear picture of all the requirements at the same time and it is key to ensure that all requirements are met while having a reliable and cost optimized design.

As can be seen in Table 2, a useful load-list includes information on vehicle variants; functional requirements as required driver topology and fuse feed; electrical requirements in terms of voltage, currents and switching frequencies and functional requirements for limp home, cranking functionality, among others.

Table 2 Load-list example

Vehicle variant			Functional requirements			Electrical requirements			Special requirements			
Low end	Mid end	High end	Load name	Driver topology [HS/LS]	Battery/ fuse feed	Current max. @ 16 V [mA]	Operational voltage max [V]	PWM requirement [Hz]	Limp home mode	Crank	Inrush	Other
Y	Y	Y	Relay A	Low-side	GND	250	18	–	Y	Y	–	Safety critical/ direct drive req.
Y	Y	Y	Relay B	Low-side	GND	250	18	–	Y	Y	–	–
Y	Y	Y	Relay C/D	Low-side	GND	600	14	–	–	–	–	Dual coil relay
–	Y	Y	LED A	High-side	V_{BAT1}	100	16	200	–	–	–	PWM at same frequency and duty cycle
–	Y	Y	LED B	High-side	V_{BAT1}	100	16	200	–	–	–	
–	–	Y	LED C	High-side	V_{BAT1}	300	16	400	–	–	–	–
–	–	Y	Power feed	High-side	V_{BAT2}	100	18	–	–	–	Y	1 µF capacitor at load

The load-list for a centralized body control module (BCM) of a modern automobile could have hundreds of loads; for simplification purposes, Table 2 shows a load-list example with only 7 low current loads (less than one ampere) as an extract out of a much larger load-list, this example load-list is used to illustrate some of the design considerations when using SPIDER+ in the following sections.

4.2 Choosing the right driver topology – low-side, high-side and configurable switches

In most cases, the carmaker or OEM (Original Equipment Manufacturer) specifies the driver topology required for each load. In our specific example from Table 2, there are 7 loads of which 3 require a low-side driver and 4 require a high-side driver. Several devices in SPIDER+ portfolio, like TLE75602-ESD, TLE75602-ESH, TLE75242-ESD or TLE75242-ESH support the topologies requested. To narrow down the device selection and find the most cost optimized solution, other variables need to be considered as explained in the following sections of this application note.

4.3 Enabling production variants

As described in Chapter 3.3.1, “Hardware compatibility”, several members of SPIDER+ family are drop-in compatible which is extremely useful when several production variants have to be supported.

For the specific partitioning example fromTable 2, we have partitioned the 7 loads with SPIDER+ using a different part number for each variant optimizing cost while keeping a single footprint in the PCB and with no changes in electrical design.

In this example, for the low-end variant, only 4 low-side channels are required to drive relay A, relay B and relay C/D, therefore TLE75004-EPD, 4-channel low-side device in the smallest package PG-TSDSO-14 can be used. Please note that two of the SPIDER+ channels are used in parallel to drive the dual coil relay C/D, more details on paralleling outputs can be found in Chapter 4.8 Considerations for driving relays and inductive loads.

For the mid end variant, the application requires 6 channels only, 4 low-side and 2 high-side; as there is no 6-channel device available in the SPIDER+ family, we are scaling to the lowest cost octal driver available TLE75242-ESD (2 low-side channels, 4 high-side channels and 2 configurable channels with standard feature set) that enables using two of the configurable channels as low-side, and using two of the 4 available fixed high-side for driving LED A and LED B.

In high end variant 8 channels are required for the seven loads (remember that relay C/D is partitioned using two channels in parallel) with two different battery feeds for the high-side loads (V_{BAT1} and V_{BAT2}), a load with inrush requirements for power feed, two different frequencies and duty cycles for the LEDs and a dedicated direct drive requirement for relay A. For the high-end variant, the highest level of flexibility and the LED package is required to meet all requirements and therefore TLE75602-ESH (6 configurable channels, 2 low-side channels, LED package that includes bulb inrush mode, open load in on-state and internal PWM generation) is proposed as the solution.

In summary for our example, TLE75004-EPD gives the best cost per channel and utilization for the low-end variant, TLE75242-ESD can be populated in the mid end variant to support the additional loads required and TLE75602-ESH provides all the flexibility and the features to support all the requirements in the high-end variant. Please note that the three devices can be populated using the same PCB footprint with no changes in the electrical design as illustrated in Figure 9.

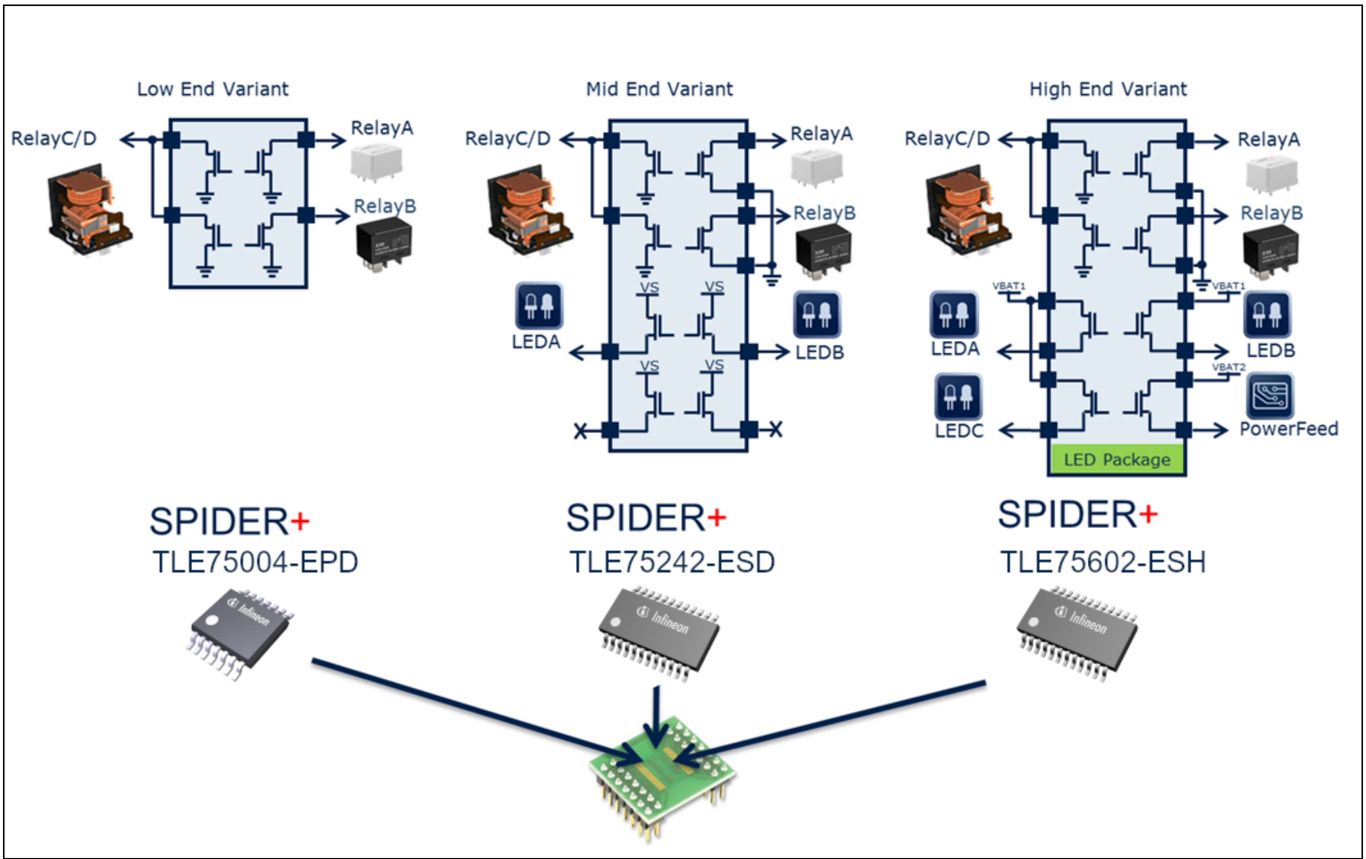

Figure 9 Partitioning example with SPIDER+ supporting production variants

4.4 SPIDER+ power stage and power dissipation considerations

The power stage is standard across SPIDER+ family; with a typical $R_{DS(ON)}$ of 1 Ω at 25°C and a maximum of 2.2 Ω guaranteed across temperature and operational voltage. The power stage is protected for overcurrent, over temperature, overvoltage, loss of ground, loss of battery and electrostatic discharge ESD and it can also be diagnosed for over temperature, overcurrent and open load.

As SPIDER+ integrates multiple channels in the same package, it is important to consider the power dissipation for the whole device at each usage profile to ensure that maximum junction temperature T_J is kept below its maximum rating of 150°C and the current for each individual channel does not reach the over load threshold $I_{L(OVL)}$ under any circumstance. Even though each individual channel has overcurrent and over temperature protection as a safety mechanism, it is important to keep the device within operational ratings to ensure long term reliability.

Power dissipation calculations should encompass static characteristics or conduction losses, given by the $R_{DS(ON)}$ of the output stage and the current flowing through it by the following formula:

$$P_{conduction} = \sum_{CH1}^{CHN} I^2 \cdot R_{DS(ON)} \qquad (1)$$

Worst-case $R_{DS(ON)}$ at hot temperature (150°C) is 2.2 Ω for all members of SPIDER+ family.

For channels using PWM, switching losses also have to be considered, calculated by:

$$P_{switching} = \sum_{n=0}^{7} \frac{1}{2} \cdot I_{CHn} \cdot V_S \cdot f_{PWM} \cdot (t_{rise} + t_{fall}) \quad (2)$$

Where t_{rise} and t_{fall} are obtained from the slew rate values given in device datasheet [2] dV/dt_{ON} and dV/dt_{OFF}; using the worst-case rating of 0.7 V/µs given in the specification, t_{rise} equals t_{fall} to 20 µs at 14 V and 22.9 µs at 16 V.

The evaluation of equation (1) and equation (2) for specific load-list example of Table 2 is shown in Table 3. The load-list also indicates that at higher voltages some of the loads are turned OFF, the calculation is done considering the different usage profiles at 14 V, 16 V and 18 V to understand the real worst-case condition, which might not necessarily happen at the highest operational voltage. Please note that the calculation is done only for the high-end variant using TLE75602-ESH, being the worst-case condition integrating all the loads into the device.

Also note that the currents ratings must be scaled to the specific voltage required by the use profile, for example, relay A was defined as 250 mA at 16 V in the load-list, but it is scaled linearly to 219 mA at 14 V and 281 mA for the 18 V profile.

Table 3 Conduction and switching losses calculations example

		Current [mA]			**Conduction losses per channel [mW]**			**Switching losses per channel [mW]**		
TLE75602-ESH	**Load**	**14 V**	**16 V**	**18 V**	**14 V**	**16 V**	**18 V**	**14 V**	**16 V**	**18 V**
OUT0	(1/2) Relay C/D	300	-	-	198	-	-	-	-	-
OUT1	(1/2) Relay C/D	300	-	-	198	-	-	-	-	-
OUT2	Relay A	219	250	281	106	138	174	-	-	-
OUT3	Relay B	219	250	281	106	138	174	-	-	-
OUT4	LED A	88	100	-	17	22	-	5	7	-
OUT5	LED B	88	100	-	17	22	-	5	7	-
OUT6	LED C	263	300	-	152	198	-	29	44	-
OUT7	Power feed	88	100	113	17	22	28	-	-	-
Total conduction losses, Pconduction [mW]					**811**	**540**	**376**			
Total switching losses, Pswitching [mW]								**39**	**58**	**0**

The operational current, required for the whole device to operate, is usually neglected in the power calculations, but it can also be a significant contributor to the total power dissipation of the device, the maximum supply current in active mode with all channels on, $I_{VS(ACTIVE)}$, is defined as 8.7 mA in the TLE75602-ESH datasheet [2]. The operational power, $P_{operational}$, is simply defined as:

$$P_{operational} = V_S \cdot I_{VS(ACTIVE)} \quad (3)$$

Evaluating equation (3) for the different usage profiles:

$P_{operational}$ @ 14 V = 122 mW

$P_{operational}$ @ 16 V = 140 mW

$P_{operational}$ @ 18 V = 157 mW

The total power dissipation for the device is given by the sum of the different sources of power dissipation from equations (1), (2) and (3), in other words:

$$P_{total} = P_{conduction} + P_{switching} + P_{operational} \quad (4)$$

Solving equation (4) for each usage profile:

Table 4 Device power dissipation calculations example

		Usage profile		
Power dissipation	**Unit**	**14 V**	**16 V**	**18 V**
$P_{conduction}$	[mW]	811	540	376
$P_{switching}$	[mW]	39	58	0
$P_{operational}$	[mW]	122	140	157
P_{total}	[mW]	**972**	**738**	**533**

For this specific example, the power dissipation is the largest at 14 V (972 mW) compared to the one at 16 V or 18 V as a result of some of the loads not being operational at higher voltages.

To estimate the maximum junction temperature of the device, the maximum ambient temperature $T_{A(MAX)}$ has to be considered, in this specific example assume 85°C outside the electronic module, however, the temperature "inside the module" could be 10°C to 15°C degrees higher for the actual device mounted in the PCB, given the influence of other drivers generating heat in the board. Simultaneously, this additional temperature has to be considered in the real application. In this example assume $T_{A(MAX)}$ = 100°C.

$$T_{J(MAX)} = P_{total} \cdot R_{thJA} + T_{A(MAX)} \tag{5}$$

Assuming the thermal resistance junction to ambient, R_{thJA}, given in the device specification of 28 K/W for a 2s2p type board (for further information please refer to the corresponding product datasheet [2]) and evaluating equation (5), the maximum device temperature $T_{J(MAX)}$ at 14 V (worst-case) is 127.2°C, which is well below the 150°C maximum specified for the device.

4.5 Battery feeds

The different fuse feeds or battery feeds associated with each specific load have to be considered and might affect the device selection and consequently the partitioning cost.

Flexible channels can be used as high-side or low-side drivers, and as the drain and source are both available externally to the part, different battery feeds can be also supported.

In our specific example from Table 2, the high-end variant requires 4 low-side channels and 4 high-side channels (3 on V_{BAT1} and 1 on V_{BAT2}) therefore, a part with enough flexible channels is required, in this case TLE75602-ESH. As two battery feeds are only required in the high-end population version, the number of flexible channels required can be downgraded for the mid end variant. By using TLE75242-ESD with 4 fixed high-side channels, the cost is reduced for the mid end variant. See Figure 10.

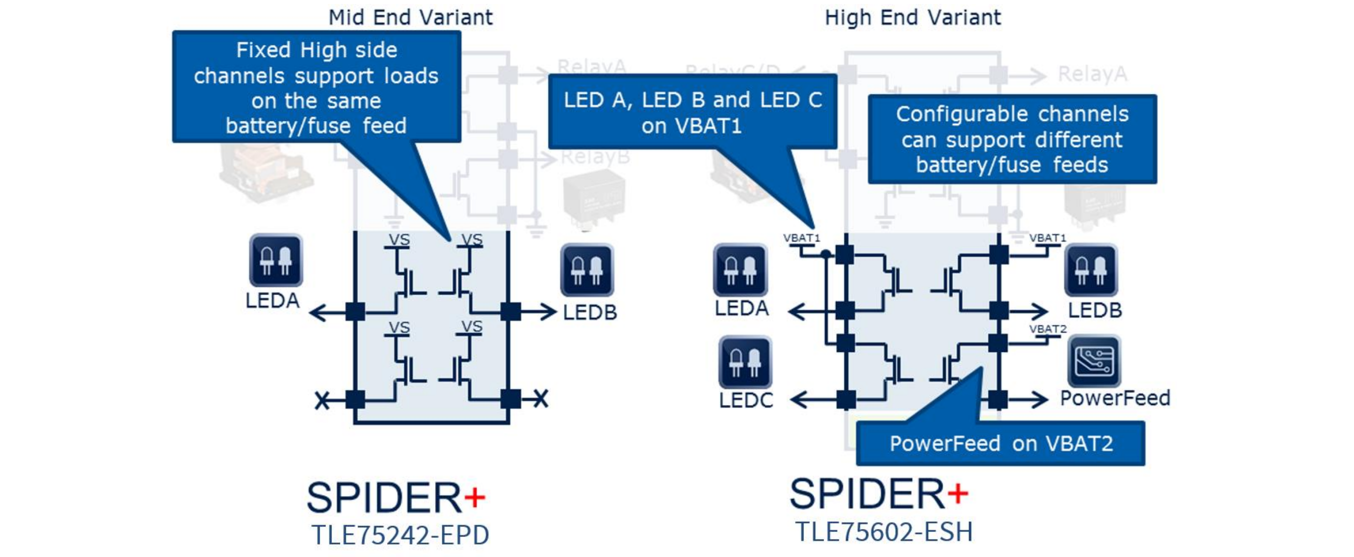

Figure 10 Configurable channels support multiple battery or fuse feeds, example

4.6 Low voltage operation – Cranking, start stop

All members of SPIDER+ family can operate down to a battery level of 3.0 V, which ensure not only that loads can be activated or deactivated during a cranking pulse but also that the full diagnosis capability remains; SPI communication and register values remain operational down to this voltage as long as the logic supply V_{DD} is also operational (above 3.0 V).

It is important to consider the possible additional current consumption in the digital power supply V_{DD} during cranking operative range (COR), this additional current is specified and described in more detail in the device datasheet [2].

4.7 Functional safety and limp home mode

Limp home mode is a fail-safe mechanism. In automotive electronics limp home mode ensures that certain functionalities remain available in cases where something goes wrong in the electronic module. For example, the SPI communication between the microcontroller and any of the output drivers could be corrupted, meaning that responses to sent messages don't match the expectations. The microcontroller can diagnose a fail-safe mode and generate a reset.

All SPIDER+ devices include limp home functionality by means of using the IDLE pin and the IN pins; with this functionality, one or two output channels (limited by the number of IN pins) can be controlled directly by safety hardware, ignoring SPI communication, in case of a module failure.

It is important to note that IN0 will have control of output Channel 2 (OUT2) and IN1 will have control of output Channel 3 (OUT3) always during limp home mode regardless of any SPI configuration. When the device is not in limp home mode (normal mode), the IN0 and IN1 can be used for controlling any output channel in the device, programmable by SPI using the MAPIN0 and MAPIN1 registers.

In the specific partitioning example corresponding to the Table 2 load-list, two of the loads, relay A and relay B require limp home mode functionality, meaning that they must have a way to be controlled even when there is an error in SPI communication or in case the +5V (V_{DD}) is out of regulation. In addition to this, according to the load-list, relay A also requires a direct drive or dedicated pin, meaning that its control cannot be made via SPI and has to be done via hardware as a redundant path to the microcontroller.

Assume that the safety concept for this example application uses a system basis chip or SBC (e.g. Infineon-TLE926x) for monitoring the status of the microcontroller, the SPI communication and the +5V (V_{DD}) supply as illustrated in Figure 11; when the SBC detects a problem it will trigger the "Fail output" that is connected to the IDLE pin of the SPIDER+.

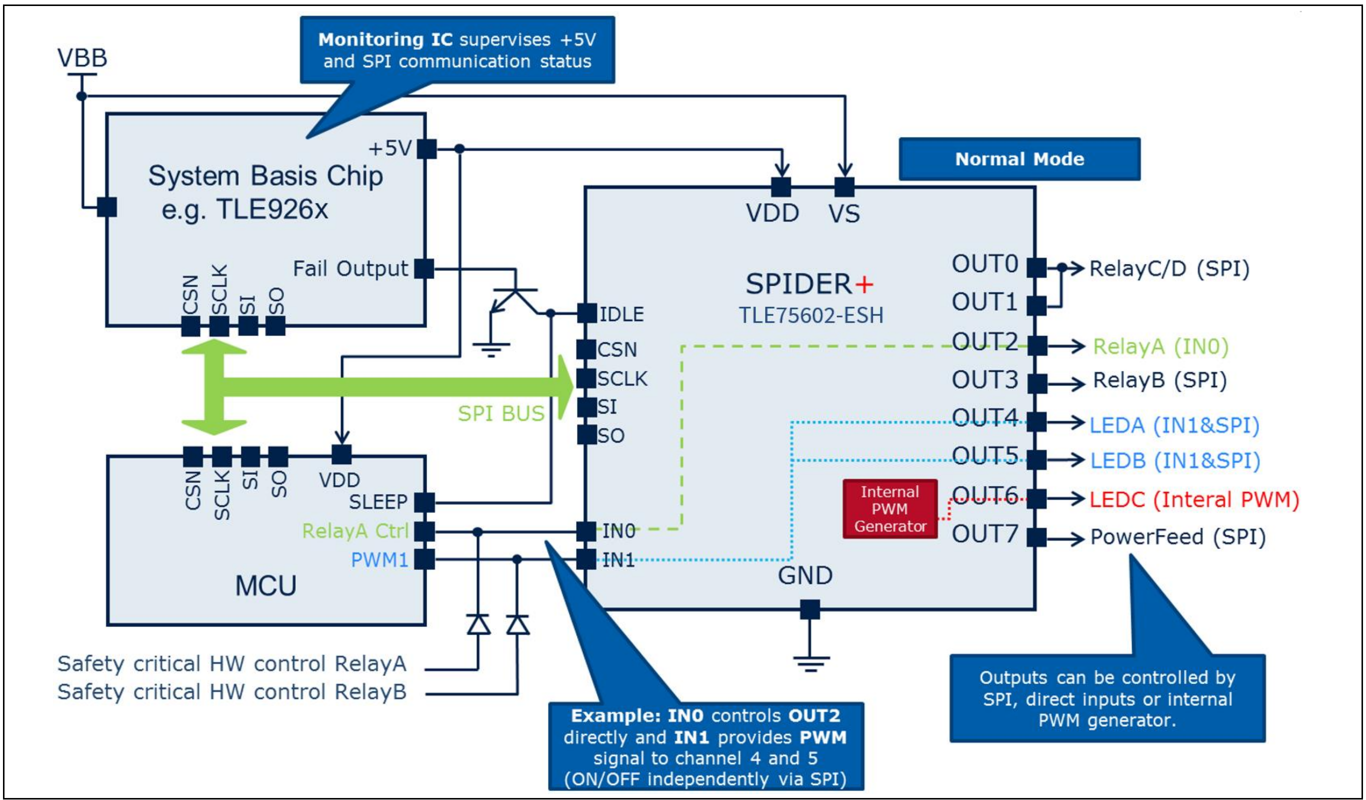

Figure 11 SPIDER+ Safety concept in normal operation

In the example, relay A and relay B are assigned to OUT2 and OUT3 as these channels can be controlled directly by IN0 and IN1 during limp home mode, see Figure 12. As relay A, assigned to OUT2 requires direct control at all times, IN0 is dedicated to control the status of this load, an optional I/O from the microcontroller (relay A ctrl) is also used as redundant path along with the external safety hardware (safety critical HW control relay A). Relay B, on the other hand is only controlled by the IN1 during limp home mode. In normal operation IN1 could be assigned to other functions, in this case, to provide the PWM1 signal used by LED A and LED B.

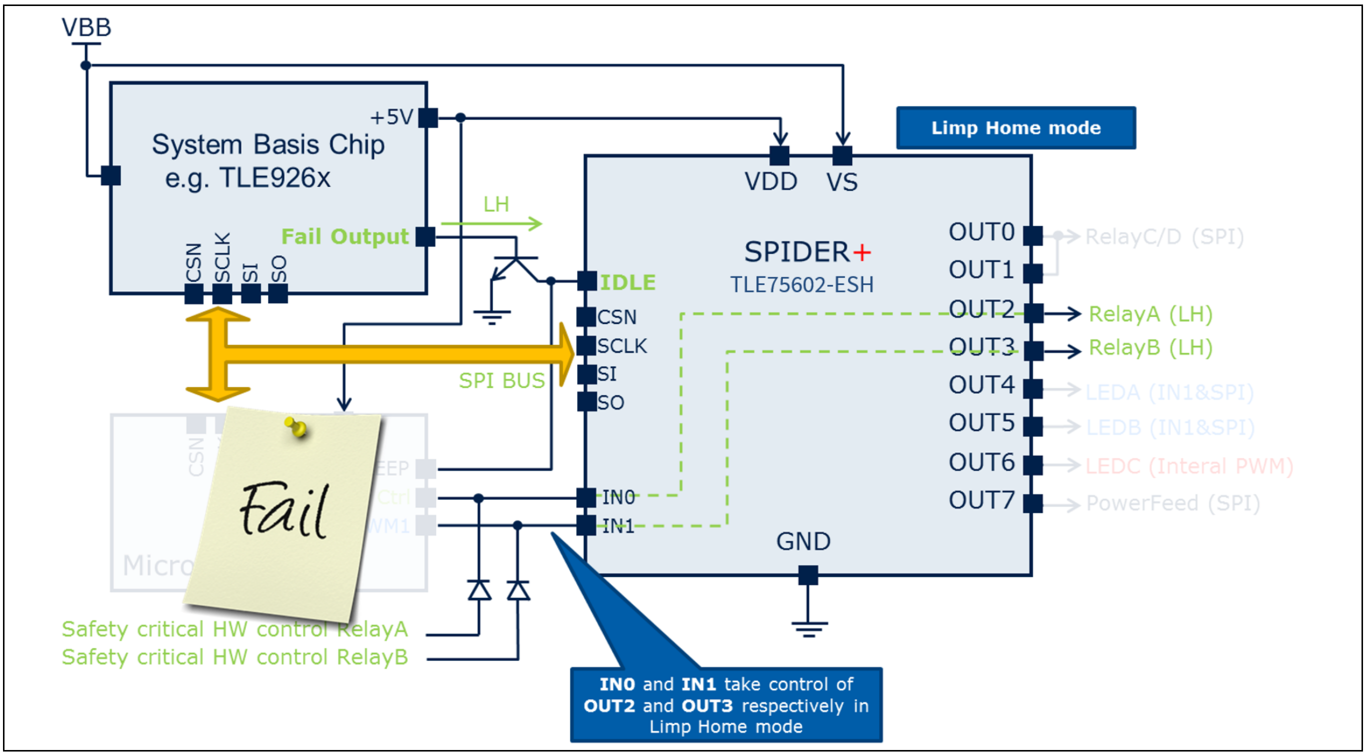

Figure 12 SPIDER+ safety concept in limp home mode

4.8 Considerations for driving relays and inductive loads

Special attention has to be paid when driving any inductive load, for example a relay coil, using any semiconductor solution including SPIDER+. When an inductive load is switched off, it generates a voltage across its terminals to oppose the reduction in current (the Lenz law) whose amplitude depends on the current slope and the inductance value; this might cause the drain-source voltage of the driver to exceed its maximum voltage and avalanche.

SPIDER+ implements an active clamping circuit that is able to repetitively absorb the inductive energy for most automotive relays without the need for additional external protection circuitry (e.g. a recirculation diode). However, it is important to analyze each individual relay or inductive load driven by SPIDER+ to make sure it does not exceed the maximum rating given in the specification E_{AR} = 10 mJ for up to a 2 M cycles.

The inductive energy E_L stored in an inductive load is defined by the following equation:

$$E_L = \frac{1}{2} \cdot L \cdot I_L^2 \quad (6)$$

Where L is the inductance of the load and I_L is the load current.

The application note “Switching inductive loads” [1] gives additional details in Chapter 2.2, page 6 on how to calculate the inductive energy to be dissipated in the power stage of the device during an output clamping event. This is summarized by equation (7) for a high-side channel and equation (8) for a low-side channel.

$$E_{HS} = (V_S - V_{OUT(CL)}) \cdot \left[\frac{V_{OUT(CL)}}{R_L} \cdot ln\left(1 - \frac{R_L \cdot I_L}{V_{OUT(CL)}}\right) + I_L\right] \cdot \frac{L}{R_L} \quad (7)$$

$$E_{LS} = V_{DS(CL)} \cdot \left[\frac{V_S - V_{DS(CL)}}{R_L} \cdot \ln\left(1 - \frac{R_L \cdot I_L}{V_S - V_{DS(CL)}}\right) + I_L\right] \cdot \frac{L}{R_L} \quad (8)$$

Where:
V_S = supply voltage [V]
$V_{OUT(CL)}$ = Source to ground clamping voltage, typ. -19 V
R_L = Load resistance [Ω]
I_L = Load current [A]
$V_{DS(CL)}$ = Drain to source clamping voltage [V], typ. 46 V
L = load inductance [H]

As an example, the specification of a relay states a coil current (I_L) of 170 mA at 13.5 V and 25°C, with an inductance of 740 mH. The coil resistance R_L can be calculated by Ohms law using the current I_L = 170 mA and the voltage V_S = 13.5 V, resulting in 79.4 Ω. Evaluating equation (7) for a high-side driver topology, the calculated energy to be dissipated by the device results in 18.4 mJ, which exceeds the maximum ratings for the device given in the specification (E_{AR} = 10 mJ for up to a 2 M cycles). It would seem that external protection circuitry, like a recirculation diode at the output power stage, would be required to protect the SPIDER+ output stage due to inductive energy coming from this specific relay.

However, the inductance of a relay decreases as the coil current is increased when activated with typical automotive supply voltages due to magnetic field saturation of the coil. Relay manufacturers usually specify the inductance measured at low current and at a given frequency (i.e. 1 mA and 100 kHz), resulting in in a much greater inductance than actual inductance of the coil at switch off, when the coil is already saturated in actual automotive applications.

If the inductance is alternatively extracted from lab measurements, by applying a voltage step to the relay coil and measuring the time constant $\tau = L/R$ for example, a more realistic value can be estimated. The time constant τ is considered the time that will take the current to reach 62.3% of its steady state value.

Figure 13 shows an actual lab measurement made for the relay used in the previous calculation, specified as 170 mA at 13.5 V, with an inductance of 740 mH. As can be seen in the graph, the steady state current (C2, purple) is 165.8 mA to a step response of approximately 13.5 V (C1, yellow) which results in a coil resistance that is very close to that specified by the relay supplier, with a quick calculation, the coil resistance results in 81.2 Ω.

In the same Figure 13, it can also be seen that it takes approximately 4.07 ms to reach the 62.3% of the steady state value, resulting in an inductance of 330.4 mH, which is less than half the inductance of 740 mH specified by the relay supplier. Reevaluating equation (7) with the updated inductance value, the resultant inductive energy is 8.2 mJ, which is now within device specification; it is important to note that the worst-case inductive energy event will occur at higher voltages and lower temperatures; therefore, it is recommended to perform this testing at different operational voltages and temperatures.

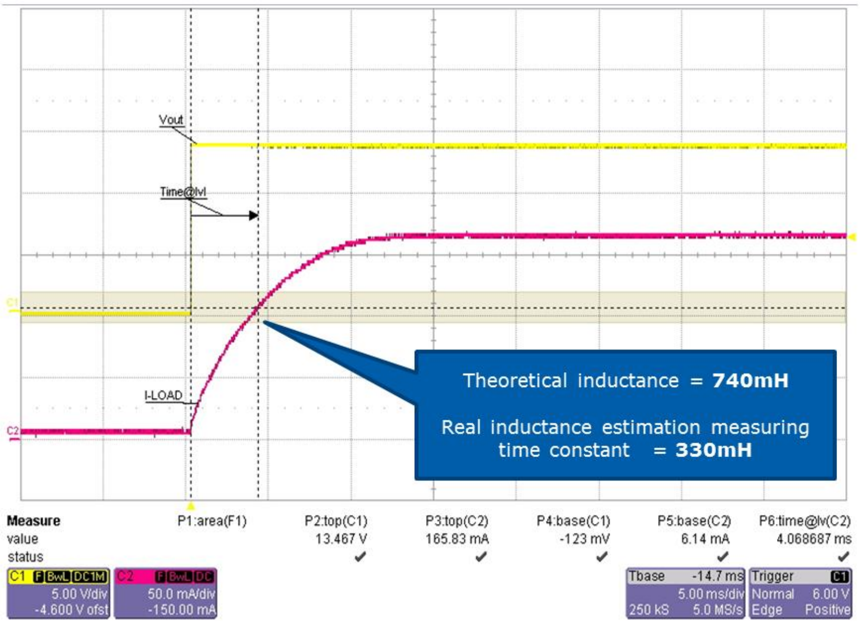

Figure 13 Estimation of relay coil inductance by lab measurments

In addition to the calculations shown above, the inductive energy dissipated in the driver output stage can also be measured in the lab, by monitoring the output voltage (V_{OUT}), output current (I_L), battery voltage (V_S) and using the math functions available in most digital oscilloscopes by the following formula:

$$E_{measured} = \int_{t0}^{t_{clamp}} I_L(t) \cdot [V_S(t) - V_{OUT}(t)] \cdot dt \quad (9)$$

This measurement is shown in Figure 14, where the resultant measured energy for the same relay is 2.93 mJ, which is only 16% of the theoretical energy calculated using the parameters given in relay specification (18.4 mJ). Clearly, the SPIDER+ device is able to withstand the inductive energy of this particular relay in a repetitive manner.

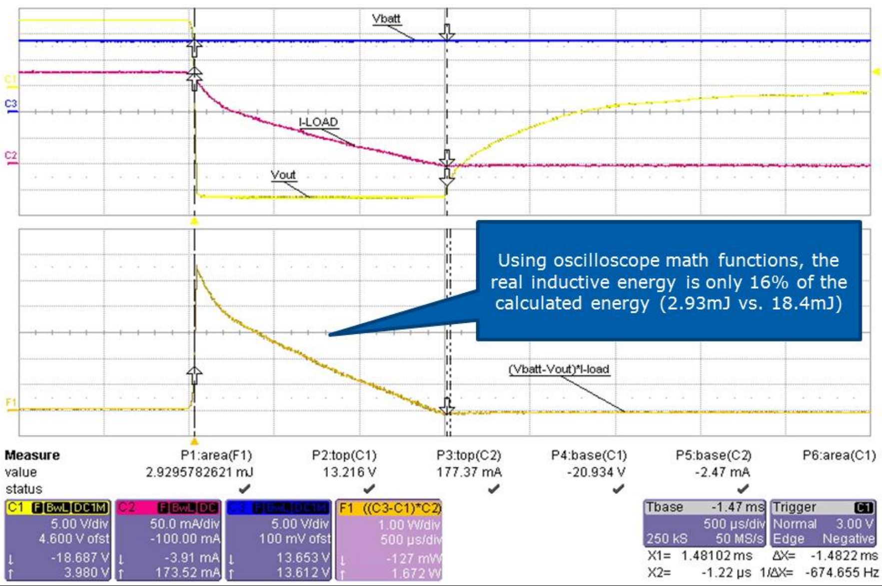

Figure 14 Real inductive switch off energy measurement

Where:
C1 (yellow) = V_{OUT} [V] (SPIDER+ pin OUTn_HS for fixed high-side or OUTn_S for configurable device)
C2 (purple) = I_{Load} [A]
C3 (blue) = V_{BATT} [V] (SPIDER+ pin VS)
F1 (orange) = P_{switch} [W], $P_{switch} = (V_{BATT} - V_{OUT}) \cdot I_{Load}$
P1: area (measurement) = $E_{measured}$ [J], integral (area) of P_{switch} between cursors (clamping event duration)

4.8.1 Driving channels in parallel

Going back to our partitioning of Table 2 , dual coil relay relay C/D is partitioned using two SPIDER+ output channels in parallel as the current definition of the load (600 mA at 16 V) is greater than the overcurrent limit $I_{L(OVL1)}$ defined for a single channel (500 mA worst-case at hot temperature according to the device specification).

In addition to the overcurrent limitation, the power stage of a SPIDER+ is designed and capable for driving almost any automotive relay coil; however, in the case of dual coil relay the repetitive energy ratings are most likely to be exceeded.

Whenever a relay or any other inductive load exceeds SPIDER+ energy, power dissipation or overcurrent limits for a single channel, two or more channels can be used in parallel to provide the desired current and energy capability for the load. SPIDER+ enables configuring pairs of channels in parallel via SPI, so that whenever a channel is commanded to be off, the other channel associated to this load is also turned off, even in cases of overcurrent or overtemperature shutdown conditions. With this feature, the inductive energy is split equally among the channels when turning off. Additional details can also be found within device datasheet [2] Chapter 7.3, “Switching channels in parallel”.

4.8.2 Considerations for driving bulbs and capacitive loads (LED package only)

SPIDER+ family offers an optional LED package for various members of the family; members with LED package are drop-in replaceable with the standard version. With the LED package, the power stage also has the capability of driving small bulbs (typically 5 W bulbs with 2 channels in parallel or 2 W single channel) and other capacitive loads. This feature is called bulb inrush mode or BIM. The LED package feature is available in TLE75242-ESH, TLE75602-ESH, TLE75620-EST and TLE75080-ESH.

A capacitive load shall be categorized as any electrical load that has a transient peak current greater than the steady state current. This peak current is usually referred to as inrush current. For example, a 500-mA steady state with an initial peak current of 5 A is considered as a 500-mA load with a 10X inrush ($I_{INRUSH} = 10*I_{SS}$). Inrush conditions usually last less than 100 ms and therefore have no effect on the power dissipation of the channel in the steady state; however, this initial peak current could be interpreted as a short circuit or overcurrent condition by the driver and thus resulting in shutting the output off.

The bulb inrush mode, available with the LED package, is an auto-retry feature that enables the device to handle inrush currents that would normally latch the output off. With the bulb inrush mode (BIM) activated for a specific channel (SPI bit BIM.OUTn set to logic “1”), if the load is turned on and an initial overcurrent threshold is exceeded, the output will latch off immediately and restart automatically after 40 µs, switching on and off as many times as required to overcome the inrush; to distinguish the inrush from a real overcurrent condition, an internal timer will automatically disable the restart feature 40 ms after the first activation. If the 40 ms are exceeded, an overcurrent condition will cause the output to latch-off.

In the partitioning example in Table 2, a switched battery feed (power feed) is required to supply power to an external module with a nominal current requirement of 100 mA in steady state with an input capacitance of 1 µF. With a standard part, like TLE75602-ESD, the peak current generated by charging the capacitor will trigger an overcurrent condition, automatically turning the channel off; using the TLE75602-ESH instead, which includes the LED package with bulb inrush mode. The inrush generated by the capacitor can be overcome in

less than 4 ms by means of automatically restarting the output every 40 µs. The behavior is exemplified in Figure 15.

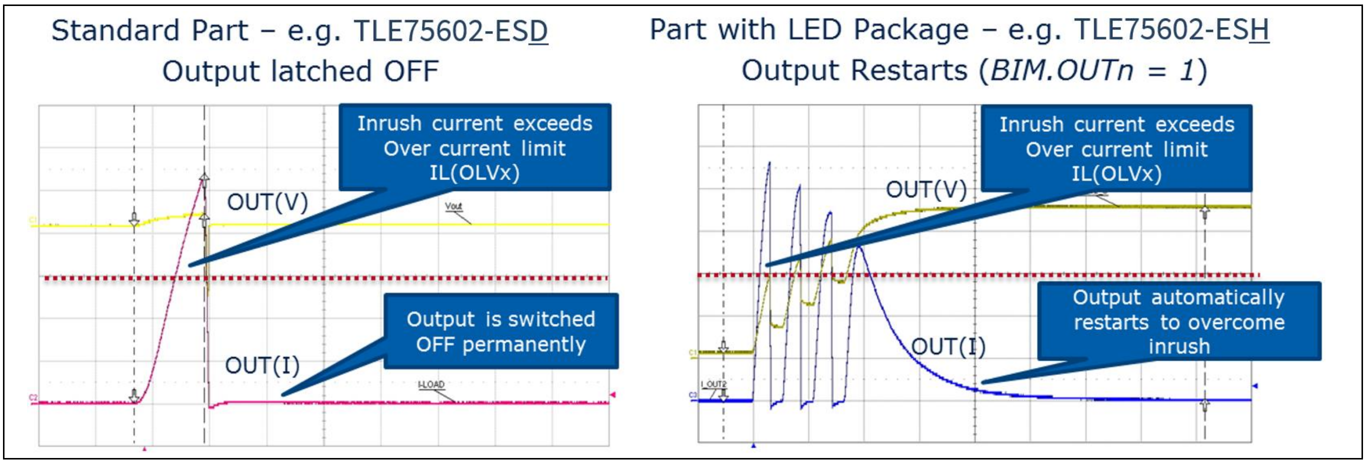

Figure 15 Capacitive loads inrush with and without LED package

Please note that the recommended ESD caps connected to each output channel, typically 47 nF, are not considered capacitive loads as the inrush is not high enough to touch the overcurrent limits for a standard part.

4.9 Considerations for driving LEDs

SPIDER+ power stage is commonly used to drive LEDs that do not require constant current control, for example signal indicators less than 500 mA of current. Typically driving the LEDs is not a concern from the electrical point of view, as long as the power dissipation and current capability is within the limits of the power stage, there are no issues with the inductive energy or inrush. The main challenges when driving LEDs are usually diagnosis for open load and supporting different PWM and duty cycle combinations.

The optional LED package available in TLE75242-ESH, TLE75602-ESH, TLE75620-EST and TLE75080-ESH include additional features designed for driving LEDs, like open load in the on-state and the internal PWM generator. Depending on the application requirements, the optional LED package may or may not be required. In other words, most LEDs can be driven with the power state of any SPIDER+ device but if the application requires additional functionality with regard to open load diagnostics and PWM flexibility, then a drop-in part with LED package can be used instead.

4.9.1 Open load diagnosis in the off and on state

All channels of any SPIDER+ device include open load diagnosis in the off-state, the status is reported via SPI by the Output Status Monitoring register DIAG_OSM.OUTn. This feature is implemented with a small current source I_{OL}, typically 85 µA, across the drain and the source of the internal N-MOS, intended to create a low voltage drop when the load is present, this voltage is compared with an internal reference $V_{OUT(OL)}$.

This diagnosis current I_{OL} has the disadvantage of potentially making LEDs glow, which can be noticeable in the dark and might not be accepted by the application requirements. A common practice to reduce the glow is to disable the diagnosis current via SPI and only activate it for short periods of time, for example 10 ms every second, controlled by the application software, to perform the proper LED diagnosis. For some safety critical LEDs this instantaneous activation of the load is not accepted either.

With the LED package, open load in the on-state is possible; this is done by means of monitoring the current flowing through the LED during the on-state, which completely removes any LED glow during the off-state. To enable operation at very low duty cycles, while ensuring enough time to perform the open load at on diagnosis, an automatic diagnosis loop is also available, where each channel is diagnosed in synchronization with the

rising edge of the PWM control signal, avoiding the need for the software to synchronize the SPI diagnosis messages with the PWM control signals.

4.9.2 Direct drive and the internal PWM generator (LED package only)

As previously described, all members of SPIDER+ have two input pins, IN0 and IN1, that can be configured to control any output in combination with the SPI message using a logic "OR" or "AND" combination. A typical use of input pins IN0 and IN1 is to provide the PWM signal (frequency and duty cycle) used by the channels required to do PWM, via SPI each channel can be commanded to be fully on, off or to PWM at the frequency and duty indicated by either IN0 or IN1. For example, all eight channels of a SPIDER+ could PWM at the same time using a maximum of two different frequency and duty cycle combinations given by signals tied to IN0 and IN1.

In case more than two different frequencies and duty cycle combinations are required to run simultaneously, the LED package is available. This feature offers two in-chip PWM generators. The number of PWM frequencies and duty cycle combinations is doubled. In other words, a standard part without LED package (for example, TLE75602-ESD) can PWM all output channels with two different frequency or duty cycle combinations; the same part with LED package, TLE75602-ESH, can PWM all output channels with up to 4 different frequency and duty cycle combinations.

Please be aware that IN0 or IN1 might be also required for other functions, for example a safety critical load requiring direct drive, which might limit the maximum number of PWM signals possible. This is the case with our example on partitioning in Table 2, where relay A uses IN0 as dedicated direct drive pin. As two different PWM signals are required for LED A, LED B and LED C the internal PWM generator is used to provide the second PWM signal required by LED C. LED A and LED B use the PWM signal directly from IN1, as shown in Figure 16.

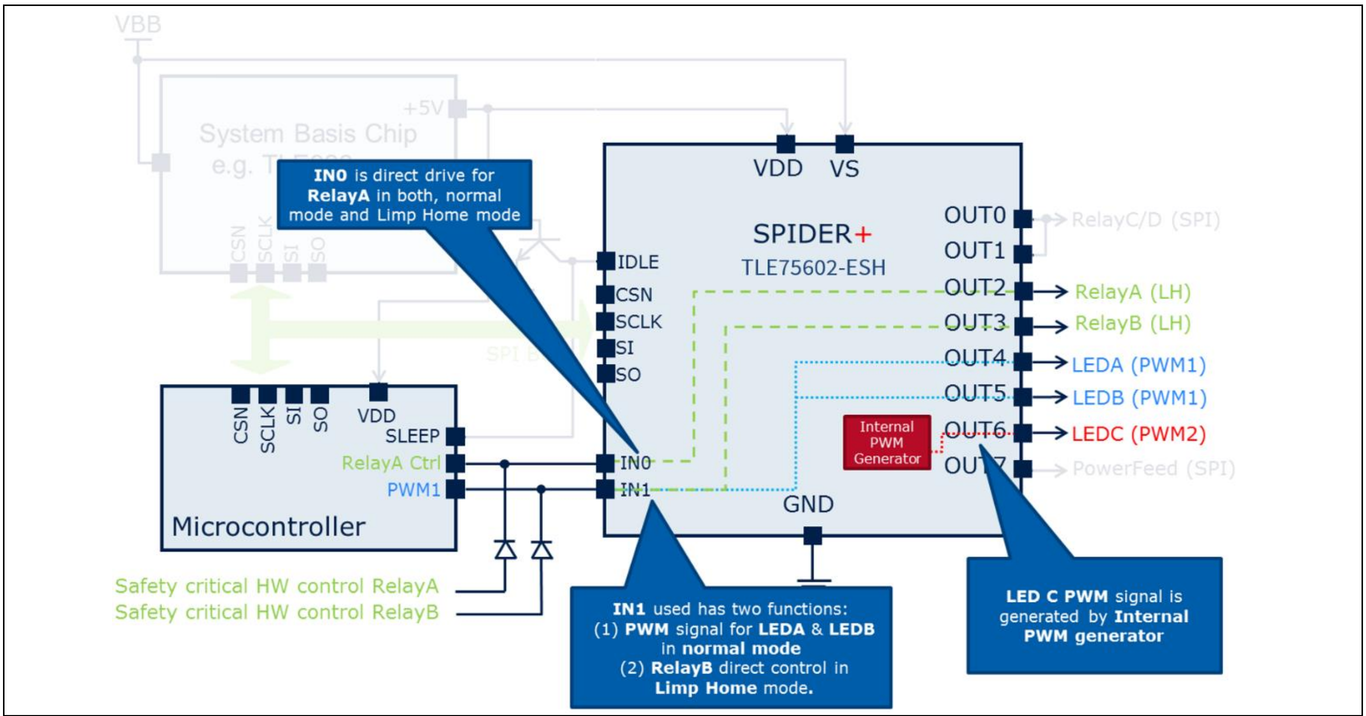

Figure 16 Input pins in combination with internal PWM generator

5 Conclusion

This application note exemplifies some of the system level benefits that the SPIDER+ family of products brings to automotive applications, including:

- **Flexibility** – by having a portfolio supporting from purely low-side architectures to purely high-side architectures, with different combinations of low-side, high-side and configurable drivers available. By supporting different kinds of loads including relays, LEDs, small bulbs, solenoids and most resistive, inductive and capacitive loads within the current range of integrated multichannel drivers, SPIDER+ is also compatible to interface with 3.0 V and 5.0 V microcontrollers.
- **Scalability** – by having drop-in compatibility among different members of the family and with versions including LED package and by having a 16-bit SPI structure that enables one software development for all members of the family.
- **Functional Safety** – with provisions for limp home mode and cranking down to 3.0 V and including a set of diagnosis functions for overtemperature, overcurrent and open load in the off and on state.
- **Robustness** – by having protection against ESD, short circuit, overcurrent, reverse battery, overvoltage and open load.
- **Board space reductions** – by integrating several channels with the smallest package of its kind, using SPI to communicate with the microcontroller, reducing the required number of inputs and outputs required for control and diagnosis, having devices pin-to-pin compatible save the need for additional footprints to support platforms and population options, and by the reduction of external components required.

Infineon Technologies SPIDER+ Family is “more than a relay driver” designed to support the automotive requirements in a safe, reliable and cost-effective manner.

6 References

[1] Infineon Technologies AG, www.infineon.com 2011-04-19. [Online] Application Note: Multichannel Low-Side Switches - Switching Inductive Loads Rev.1.00

[2] Infineon Technologies AG, www.infineon.com 2019-06-25. [Online] Datasheet, *SPIDER+ | Multichannel SPI Driver Enhanced Relay Control - Product List*

Revision history

Document version	Date of release	Description of changes
Rev.2.00	2020-07-02	• Editorial changes • Changed package types: PG-SSOP-14 → PG-TSDSO-14 and PG-SSOP-24 → PG-TSDSO-24 • Device name change: TLE75xxx-EMy → TLE75xxx-ESy and TLE75xxx-ELy → TLE75xxx-EPy • Corrected power calculations and updated thermal calcuations according to thermal resistance of new package • Changed device names according to new packages • Corrected units in Table 2: kHz → Hz
Rev.1.01	2015-10-26	• Conversion to latest template

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