FAQ application note for TLE956x and TLE9185

Frequently asked questions and application hints

Application Note

About this document

Scope and purpose

This application note is intended to provide helpful suggestions and hints on how to set up and handle specific modules and functionalities which are not subject of the datasheet and might be interesting for end users. It is organized in a frequently asked question style and doesn't follow any specific order.

Note: The following information is given as a hint for the implementation of the device only and shall not be regarded as a description or warranty of a certain functionality, condition or quality of the device.

Intended audience

This document is intended for customer and field application engineers working with TLE956x and TLE9185 families.

This document compiles frequently asked questions for the TLE956x and TLE9185 and provides solutions to common problems which might occur during the development using these devices. This document must be used in conjunction with the device datasheets, which contain full technical details, specifications and description of operation.

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1 Collection of questions and topics

This chapter gives an overview of the collected Questions and Topics.

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2 Topics common to TLE956x and TLE9185

2.1 What is the purpose of the separate VS and VSINT pins?

VSINT is the supply for the voltage regulator VCC1

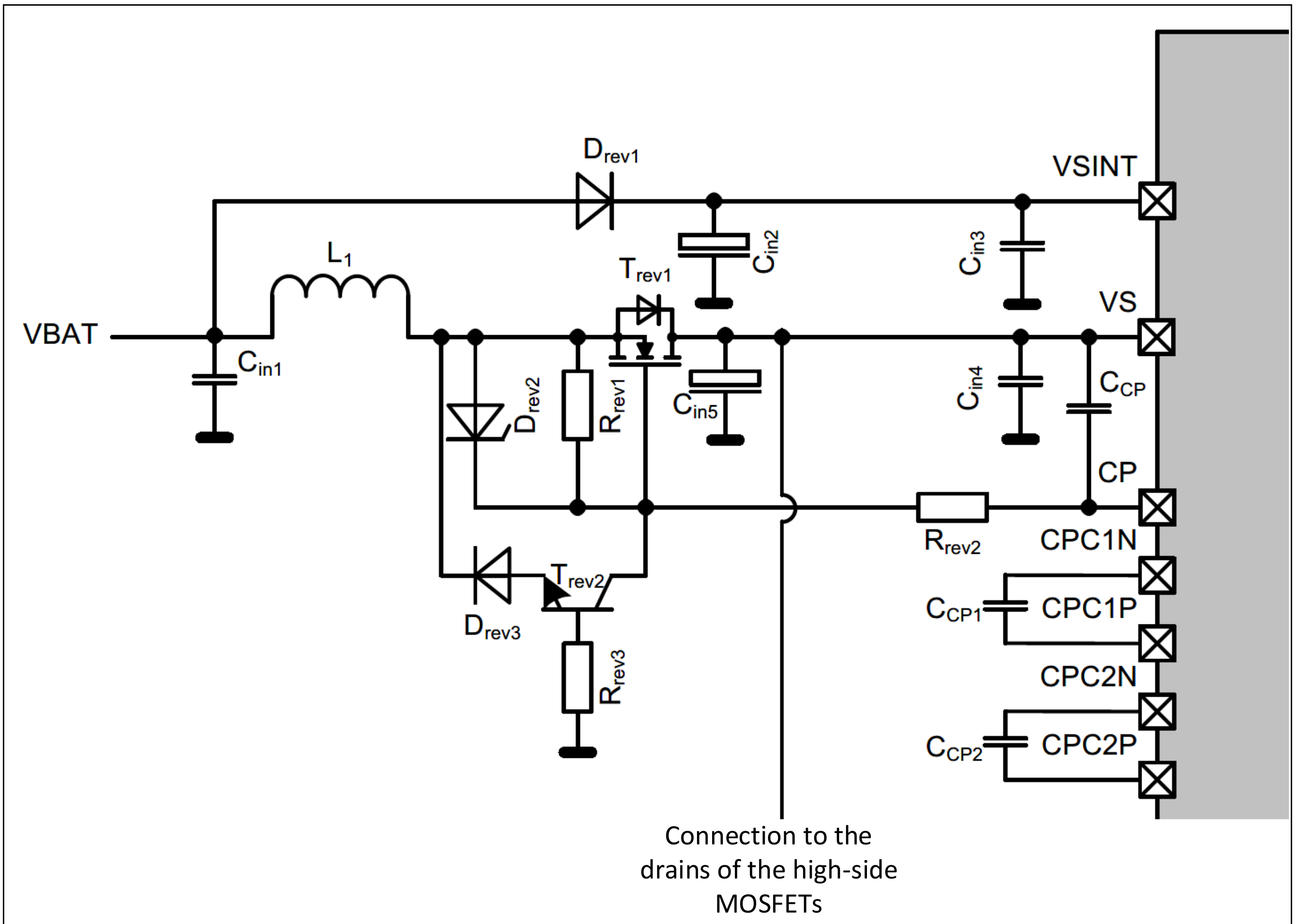
VS is the supply for the charge pump and for the gate drivers.

Having two separate inputs for VS and VSINT enables to buffer more easily VSINT, in order to maintain VCC1 in case of a drop of the battery voltage.

Indeed, the possible high load current drawn by the half-bridges does not discharge C_{in2}, which is the buffer capacitor for VSINT, thanks to the decoupling diode D_{rev1}.

Note: D_{rev1} is also used as reverse battery protection for VSINT.

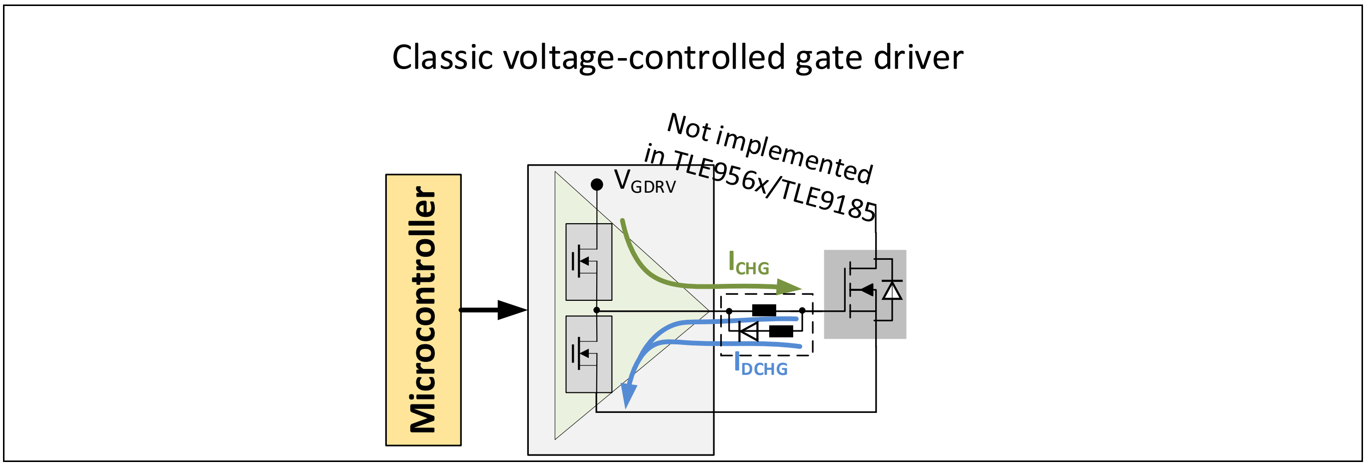
Figure 1 Separate supply for VS and VSINT



2.2 Are series resistor at the gate of the MOSFETs required?

With classic voltage-controlled gate driver, **series resistors** or a network of resistors / diode at the gate of the external MOSFETs **are required** to control the gate charge and the discharge currents, and therefore the MOSFET switching times.

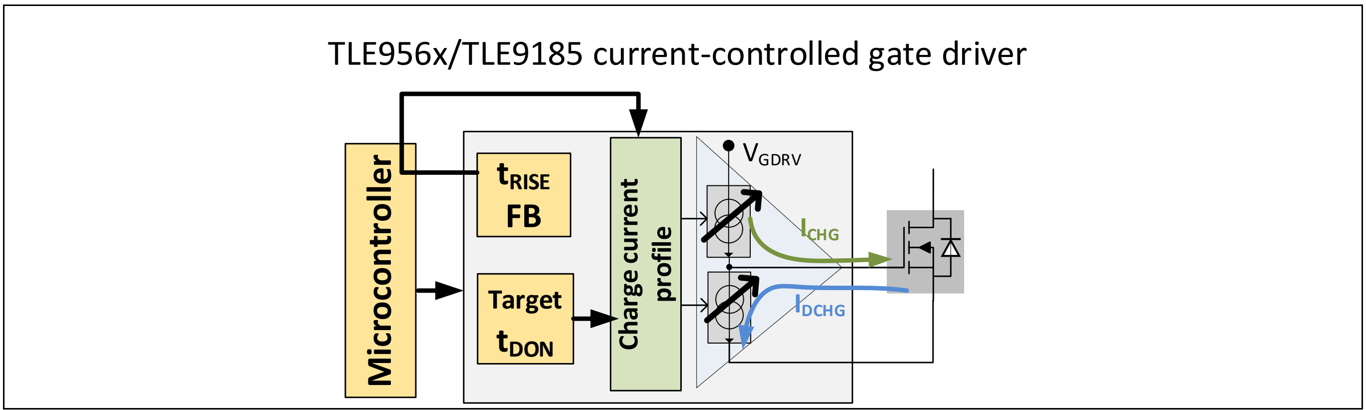
Figure 2 Classic gate driver requiring series resistor or resistor/diode network for the control of the switching times



With the current-controlled gate drivers of the TLE956x/TLE9185, series resistors at the gate of the external MOSFETs **are not required**.This reduces the bill of material and the required PCB area.

For more information, refer to the elearning about the advanced motor control solutions, Link.

Figure 3 TLE956x/TLE9185 current controlled gate driver without series gate resistors



A series resistor might be used in order damp eventual oscillations (not observed so far in Infineon evaluations). For this purpose, it is recommended to test first with a 0 Ω resistor. If no oscillations are observed, then the gate resistors can be removed for an updated board version.

If nevertheless, gate series resistors are used, it is recommended to keep the resistance below 10 Ω. A too high resistance causes a large voltage drop during the turn-on/off of the MOSFET, and charge/discharge current might be significantly lower than the expected value without resistance.

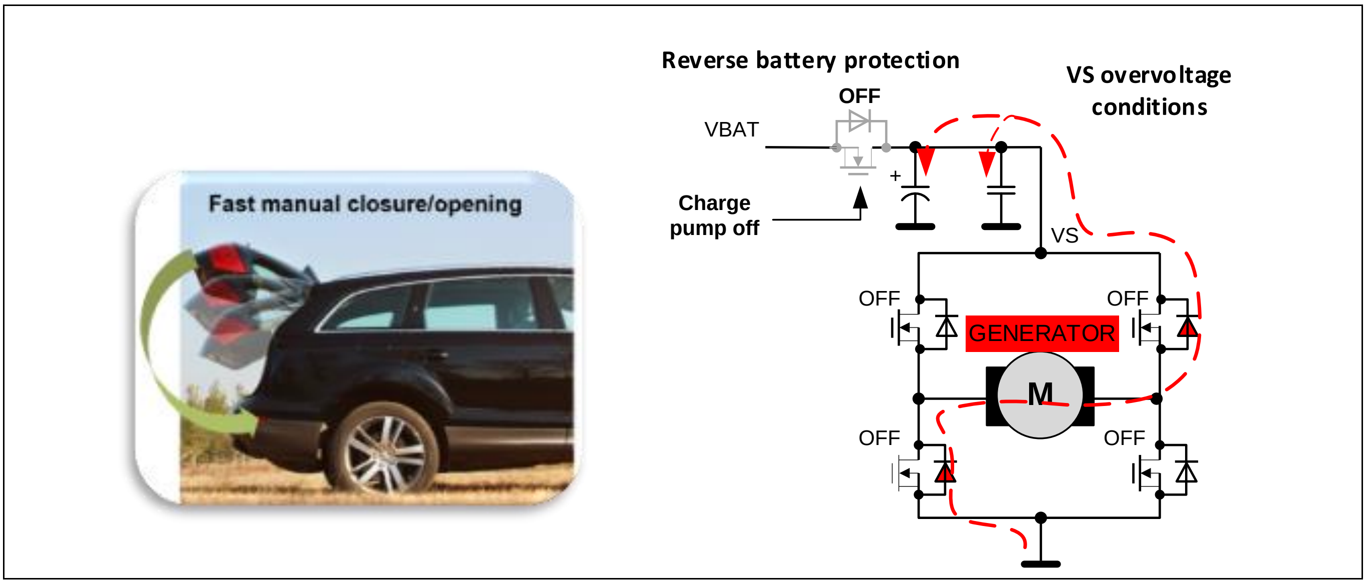
2.3 What is the purpose of the VS/VSINT overvoltage brake feature?

The VS/VSINT overvoltage brake is intended to protect the application, when a motor operates in generator mode.

The operation in generator mode can occur in several cases such as:

- The motor rotation is caused by the application of an external torque, such as the manual closure of the trunk lid or of a sliding door
- While the motor is activated by the half-bridges, then the MOSFETs are turned off without any active brake

Figure 4 Example of a manually closed trunk lid causing VS overvoltage conditions



In both cases, a current flows through the motor while the external half-bridges are off.

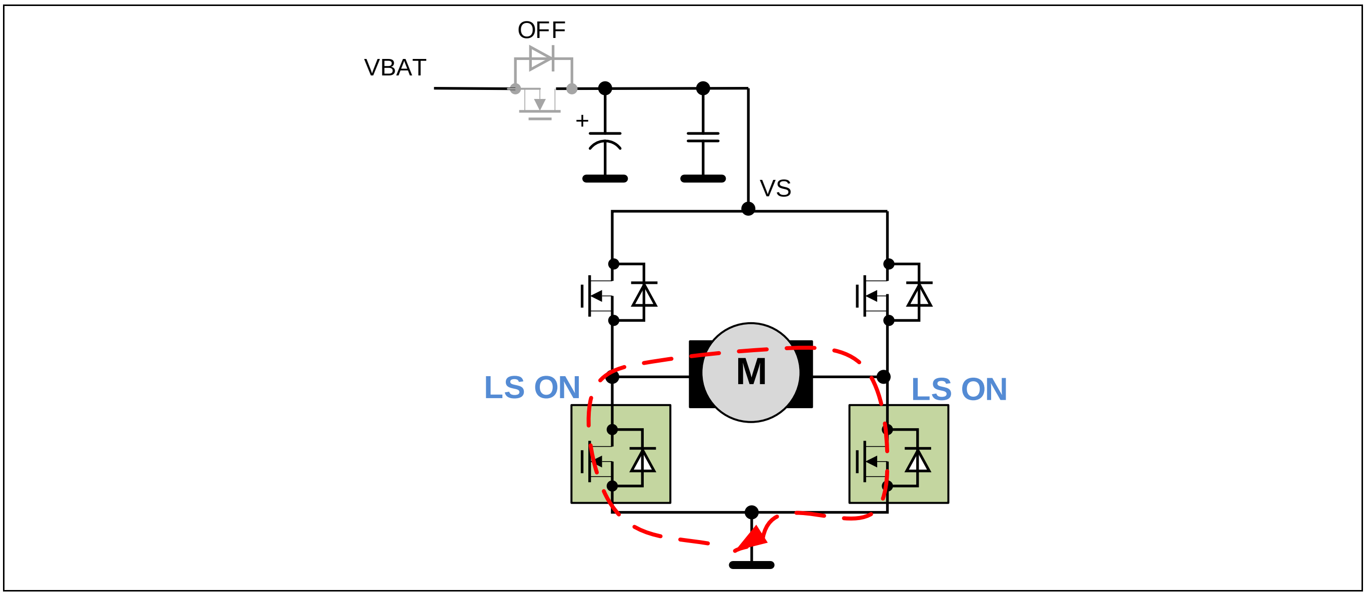
The motor current flows through the body diode of the external MOSFETs (refer to Figure 4).

If the charge pump is off, then the current cannot flow back to the battery. Instead, it charges the DC link capacitor, causing an increase of the VS voltage.

If no measures are taken, VS can exceed the absolute maximum rating of some components, causing a damage of the module.

The VS/VSINT overvoltage brake feature monitors VS/VSINT, and turns on the low-side MOSFETs, even if the device is in sleep mode or if the charge pump is off. This action actively brakes the motor and stops the increase of the supply voltage, protecting the module.

Figure 5 Turn-on of the low-side MOSFETs during a VS/VSINT overvoltage brake event



2.4 Does the VS/VSINT overvoltage brake protect the application when the module is unpowered?

The following situation might happen:

- The module is unpowered during the assembly process of the vehicle
- At the same time the trunk lid is manually closed

Even if the battery is disconnected, the motor actually operates as a generator, causing VS/VSINT to increase.

When the supply voltage is above the power-on reset threshold, the device wakes up and the VS/VSINT overvoltage brake feature is enabled by default. When the VS/VSINT overvoltage brake threshold is reached, the low-sides MOSFETs are turned on, stopping the increase of the supply voltage.

Therefore, **the VS/VSINT overvoltage brake is available, even if the module is unpowered**.

2.5 How to treat unused gate drivers when the parking brake mode or the VS overvoltage brake are used?

SHx must be connected to GND if the following conditions are met:

- The half-bridge is not used
- And the corresponding external MOSFETs are not populated on the board
- And the VS overvoltage brake or the parking brake mode are used
- And the passive drain-source overvoltage detection is activated

The SHx of the half-bridges without populated MOSFETs must be connected GND to avoid a wrong drain-source overvoltage detection.

Indeed, the device activates all low-sides MOSFETs during a VS/VSINT overvoltage brake event or when the parking brake mode is activated.

If an unused SHx is not connected to GND, then SHx is not pulled to low because of the unpopulated MOSFET.

The floating SHx can result in $V_{SHx} - V_{SL} > V_{VDSMONTHx\_BRAKE}$ and a drain-source overvoltage for the half-bridge HBx is detected. Then **the device turns off all low-side MOSFETs** because of the error detection.

GHx and GLx can be left open.

2.6 What is the purpose of the static activation?

The static charge current I_{CHGST} and the static discharge current I_{DCHGST} for static activation are used for two purposes:

1. I_{CHGST} and I_{DCHGST} charge and discharge the gate of the external MOSFETs, which are not controlled in PWM. These MOSFETs can be turned on and turned off faster than the MOSFET controlled in PWM, because the single activation is not relevant for the EMC characterization
2. I_{DCHGST} discharges the gate of the MOSFETs in case of failure

Two criteria must be considered for the configuration of I_{DCHGST} for a short circuit of the MOSFETs:

1. the MOSFETs must be turned off fast enough in order to stay within the safe operating area, considering the possible high drain-source current
2. the MOSFETs may not be turned off too fast, because a high current in combination with stray inductances and a fast turn off can trigger a MOSFET avalanche

That is the reason why I_{DCHGST} is individually configurable for each half-bridge driver, so that these two criteria can be fulfilled for the considered MOSFET type.

2.7 What are the benefits of the active free-wheeling?

The active free-wheeling reduces the power losses in the free-wheeling MOSFET during the PWM operation (pulse width modulation), therefore reducing costs at system level:

- allowing the usage of smaller MOSFETs and/or smaller MOSFET packages
- reducing the required PCB cooling surface of the free-wheeling MOSFET

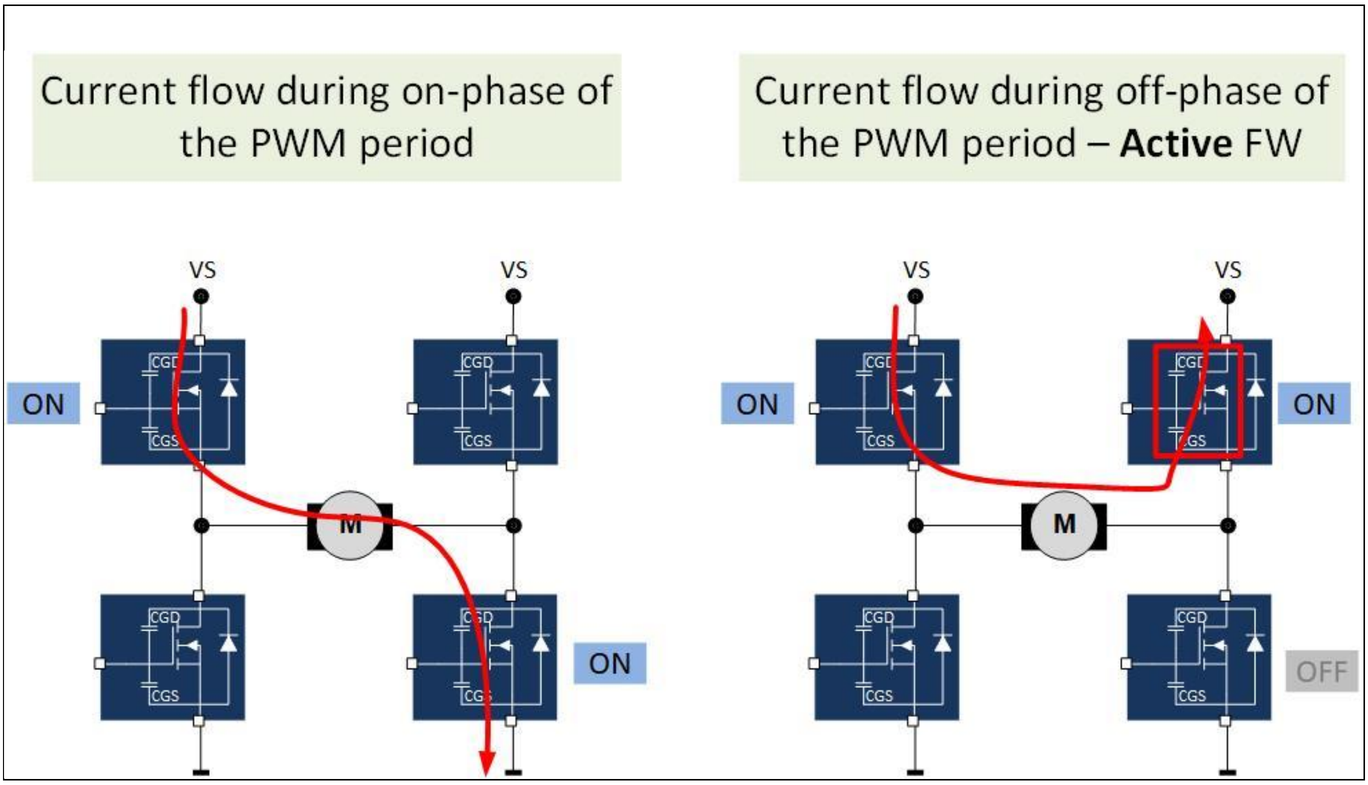
2.7.1 Active free-wheeling

During the off-phase of the PWM period, the free-wheeling (FW) MOSFET is turned on.

Therefore the current flows through FW MOSFET instead of flowing through the MOSFET body diode.

Note that the current of the FW MOSFET flows from the source to the drain, due to the load inductance.

Figure 6 Current flow during off-phase of the PWM period – Active free-wheeling (with low-side PWM)



The peak power dissipation in the FW MOSFET during the PWM off-phase is given by (1):

(1) $P_{DISS\_FW\_MOSFET\_INST} = R_{DSON} \times I_{LOAD}^{2}$

The peak power disspation in the FW MOSFET is present only during the PWM off-phase, therefore, the average power dissipation in the free-wheeling MOSFET over a PWM period is:

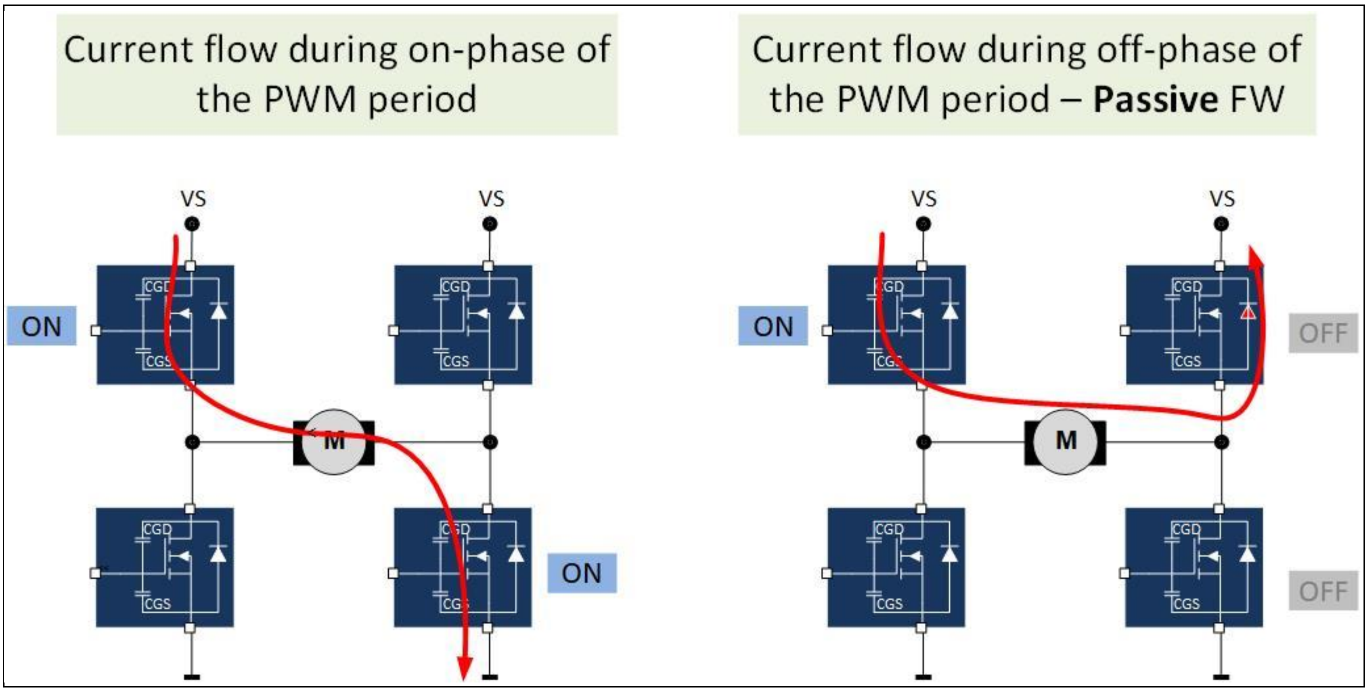
(2) $P_{DISS\_FW\_MOSFET\_AVR} = R_{DSON} \times I_{LOAD}^{2} \times (1\text{-Duty})$ where Duty designates is the duty cycle (Ton / (Ton + Toff))

Note: The current ripple during the FW phase is neflected, in other words, it is assumed that the load current is constant over a PWM period

Note: For the sake of clarity, the passive FW during to avoid cross-currents is neglected, due to the short duration of this phase.

2.7.2 Passive free-wheeling

Figure 7 Current flow during off-phase of the PWM period – Passive free-wheeling (with low-side PWM)



The peak power dissipation in the free-wheeling diode during the PWM off-phase and the average power dissipation over a PWM period are given respectively by (3) and (4).

(3) $P_{DISS\_FW\_PEAK} = V_F \times I_{LOAD}$

(4) $P_{DISS\_FW\_AVR} = V_F \times I_{LOAD} \times (1 - Duty)$

V_F designates the forward voltage of the MOSFET body diode

2.7.3 Example

Example: I_{LOAD} @70 % duty cycle = 15A, V_F = 1V, R_{DSON} = 7 mΩ

Power dispation	Active free-wheeling	Passive free-wheeling
Peak power dissipation[1] [W]	1.58 ☑	15 ☒
Average power dissipation [W]	0.47 ☑	4.5 ☒

[1] during the PWM off-phase

In this example, the active free-wheeling decreases the average power dissipation in the free-wheeling MOSFET by 4 W.

Assuming a junction-to-ambient thermal resistance ($R_{TH-JAMB}$) of 25 K/W, the active free-wheeling control scheme reduces the average FW MOSFET temperature by 100 K, compared to a passive free-wheeling scheme.

2.8 Why is the gate of the high-side MOSFETs at the VS potential while the MOSFETs are off?

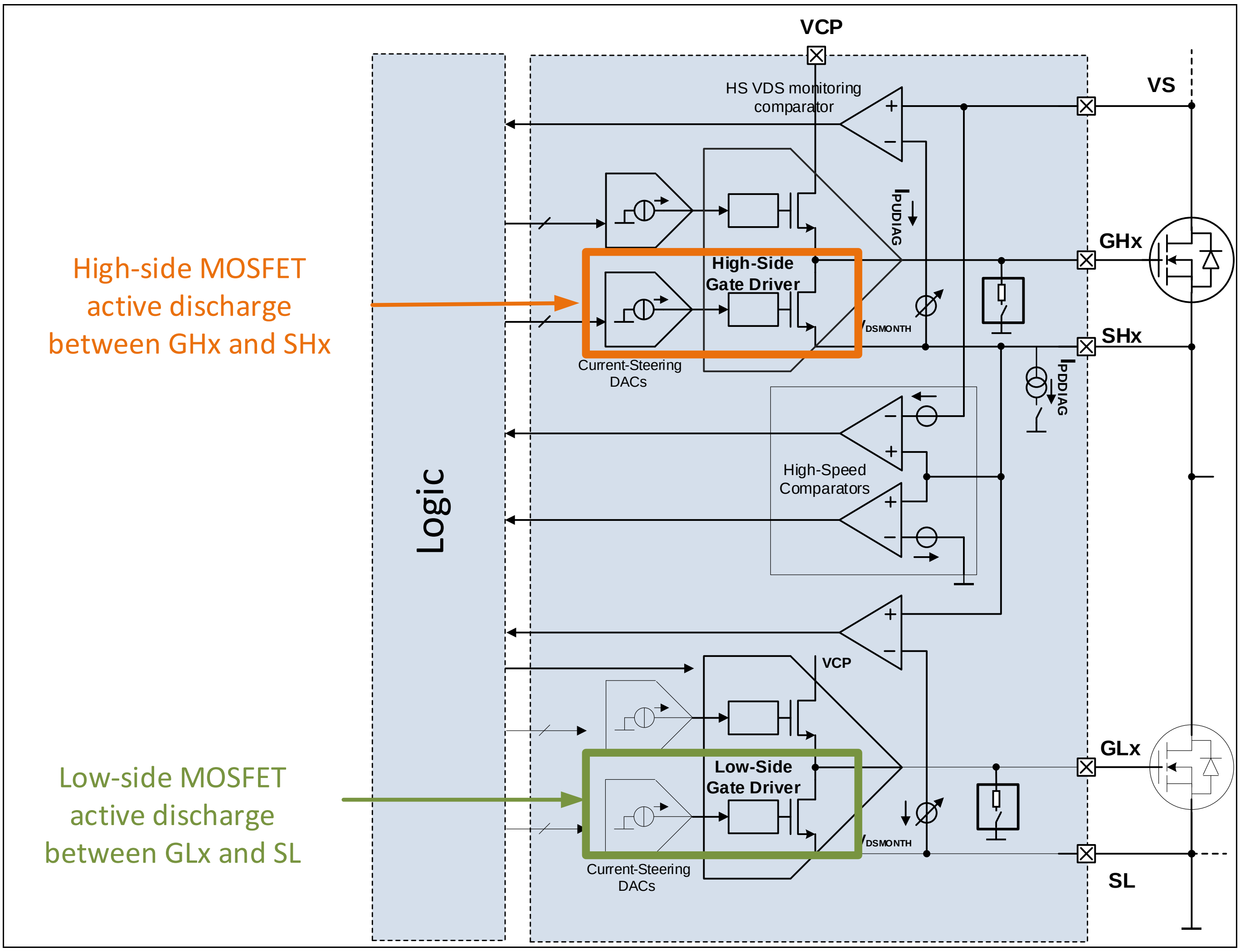
When a half-bridge is configured as Active OFF (HBxMODE[1:0] = 11_B while the charge pump is enabled), then the MOSFETs of HBx are indeed **actively turned off** by the current sinks of the **floating gate drivers** (Refer to Figure 8) .

Indeed, the current sink between GHx (gate of high-side x) and SHx (source of high-side x) keeps the gate of the high-side MOSFETs discharged, therefore $\mathbf{V_{GHx} = V_{SHx}}$.

If no short circuit is present at SHx and the pull-up diagnostic currents are deactivated, then SHx is pulled up to VS by I_{PUDIAG} (which is also enabled if the bridge driver is in active mode):

$\mathbf{V_{GHx} = V_{SHx} = VS}$, theferore $V_{GHx} \neq 0$ V.

Figure 8 Gate driver active discharge for one half-bridge



Although $V_{GHx} \neq 0$ V, the high-side MOSFET is off because $\mathbf{V_{GHSx} = V_{GHx} - V_{SH} \sim 0\ V}$

Note: If SHx is pulled down e.g. by a pull-down diagnostic current, then $V_{GHx} = V_{SH}$ = GND. Likewise, a current sink between the GLx and SL pins keeps the gate of the low-side MOSFETs discharged. As V_{SL} is connected to GND, then V_{GLx} = GND.

2.9 What is the difference between active and passive discharge?

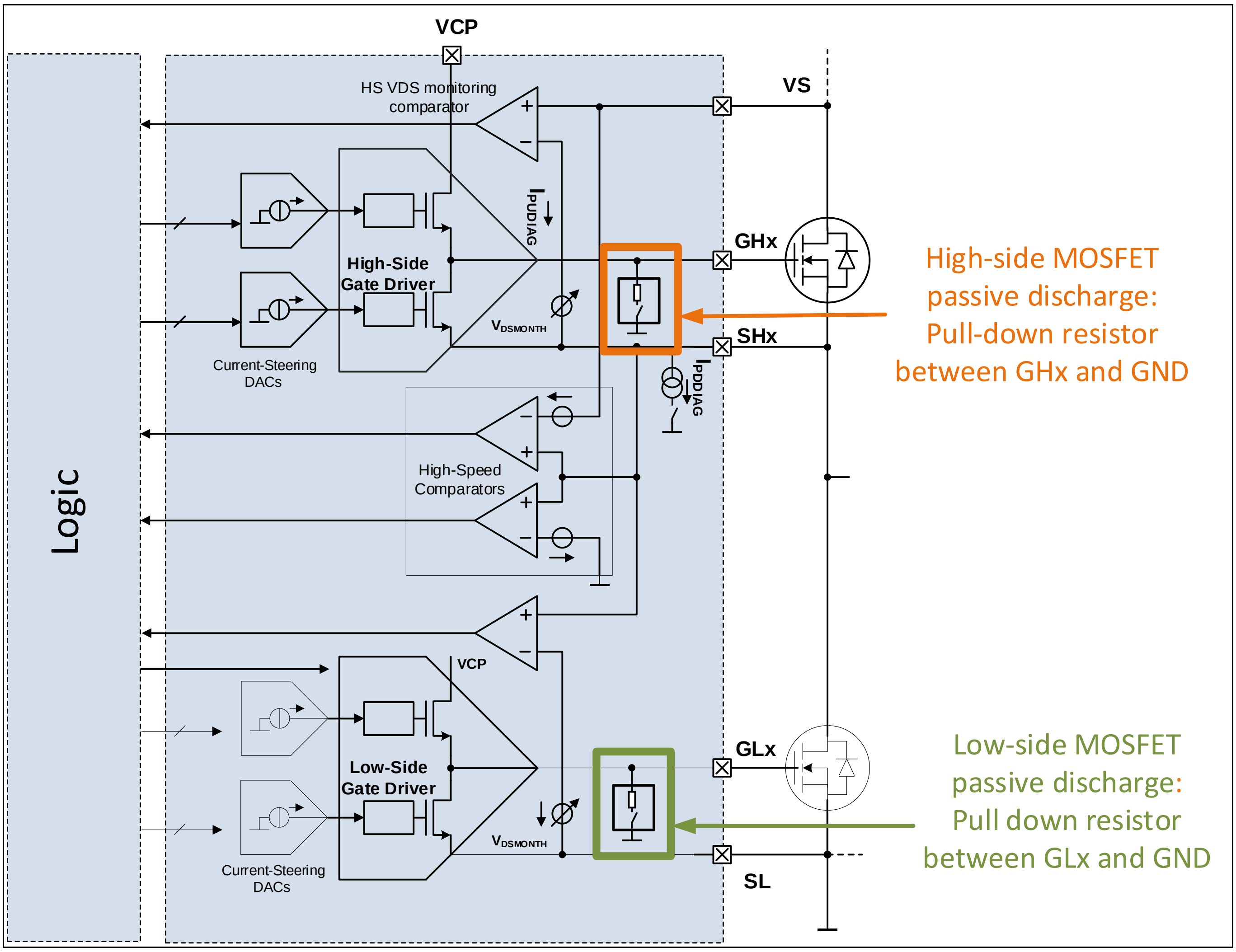
The active discharge for the high-side and low-side MOSFETs is described in the chapter 2.8 and highlighted in Figure 8).

In normal mode, a half-bridge is in **passive discharge if HBxMODE[1:0] = 00$_B$**.

The passive discharge consists of a pull-down resistor:

- Between GHx and GND to keep the high-side MOSFETs off
- Between GLx and GND to keep the low-side MOSFETs off

Figure 9 Gate driver passive discharge for one half-bridge



The passive discharge is enabled for example:

- in Sleep Mode and in Stop Mode, in order to reduce the current consumption of the device
- in Normal Mode when the charge pump is on and HBxMODE[1:0]= 00_B, in order to reduce the current consumption
- to ensure the termination of GHx and GLx when an active discharge is not possible (e.g. when the charge pump is deactivated or in case of charge pump undervoltage):
    - Overtemperature event
    - VS undervoltage / overvoltage event
    - Charge pump undervoltage
    - Fail safe mode
    - CPEN bit = 0

2.10 When are the external high-sides / low-sides turned on after a drain-source overvoltage detection?

When the status bits HSxDSOV or LSxDSOV are cleared, the half-bridge follows the content of HBxMODE.

Example 1:

1. HB1MODE = 01_B: HS MOSFET is on
2. Then a VDS overvoltage is detected
    - The half-bridge is turned off and the HS1DSOV status bit is set
    - Note: the device keeps the content of HB1MODE unchanged to 01_B, even if the HS1 is turned off
3. The DSOV status register is cleared
4. Since HB1MODE = 01_B, then the external high-side MOSFET 1 is turned back on, following the content of HB1MODE

Example 2:

1. HB1MODE = 01_B, HS MOSFET is on
2. Then a VDS overvoltage is detected
    - The half-bridge is turned off and the HS1DSOV status bit is set
    - The device keeps HB1MODE = 01_B
3. The microcontroller sends a SPI frame which resets HB1MODE = 00_B
4. Then the µC clears DSOV status register
5. Since HB1MODE = 00_B, the external high-side and low-side MOSFETs stay off, following the content of HB1MODE, even if HS1DSOV is reset

3 Topics specific to TLE956x

3.1 How to treat unused wake inputs

In general, it is recommended to connect unused WKx pins to GND.

However, it is possible to leave the unused WKx pins floating, as long as the internal pull-down resistors are enabled by SPI command.

If a WKx pins are unused and routed to the connector, it is recommended to keep the corresponding ESD capacitors populated on the board.

Important note:

If a WKx function is disabled and the device goes to Fail-Safe Mode, the WKx is automatically enabled as one of the wake-up sources. If an unused WKx input is left open without activated pull-down, this input can trigger a wake event, sending the device back to normal mode.

4 Revision history

Document version	Date of release	Description of changes
1.0	2021-07-29	First release

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Edition 2021-07-29

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference
Z8F80164896