AN12226

Diagnostic application note for MC33813; MC33814

Rev. 2 — 11 June 2020
Application note

Document information

Information	Content
Keywords	AN12226, MC33813, MC33814, diagnostic, automotive, small engine, EFI
Abstract	This document details the different diagnosis available on MC33813; MC33814 low-side drivers and pre-drivers, their conditions and actions taken when a fault occurs.

Revision history

Rev	Date	Description
2	20200611	• Figure 3, Figure 4, Figure 5, and Figure 8: updated the low-side driver block diagram (the external components remain unchanged) • Section 3.1: updated the output voltage description
1	20181012	initial version

1 Introduction

1.1 Purpose

The main aim of this application note is to explain the different diagnosis and their behavior on the MC33813 and MC33814.

1.2 Application scope

The MC33813; MC33814 is a cost-optimized IC solution for managing one and two-cylinder engines for two-wheelers market or the general engine market (such as power generators). With a high level of integration and flexibility, the IC offers an ideal response to contemporary market requirements. For example, Euro 4/5 and onboard diagnostic (OBD) I/II requirement for two-wheelers segment. Diagnostic and protection features present on all outputs allow applications to operate with greater safety.

There is no restriction in using MC33813; MC33814 for a specific application scenario. The low-side drivers can drive any loads, so care must be taken to avoid any false diagnosis.

1.3 Related documents

This section lists all the documentation mentioned in this application note. Use the application note in combination with the data sheet.

Table 1. Related documents

Document name	Description
http://www.nxp.com/MC33813	data sheet
http://www.nxp.com/MC33814	data sheet

2 Introduction to MC33813; MC33814

With six drivers (MC33814) or five drivers (MC33813), three pre-drivers (MC33814) or two pre-drivers (MC33813), a 5.0 V regulator for the microcontroller unit (MCU), a protected external sensor supply, and a high level of integration, the IC offers an ideal response to contemporary market requirements. This high level of flexibility on drivers and pre-drivers allows different type of applications to be addressed (one or two cylinders, two wheelers, or general engine).

The innovative variable reluctance sensor (VRS) system optimizes noise immunity under cranking conditions. Diagnostic and protection features present on all outputs allow applications to operate with greater safety.

2.1 Main functions

- Operates over a functional supply voltage range of 4.5 V < V_{BAT} < 36 V
- Start-up/shutdown control and power sequence logic with KEYSW input and SPI bit PWREN
- MCU supply: V_{CC} is a 5.0 V (±2.0 %, 200 mA) regulated supply
- Sensor supply: V_{prot} (100 mA) is a V_{CC} tracking protected sensor supply

- Three (MC33814) or two (MC33813) configurable pre-drivers for insulated gate bipolar transistor (IGBT) or general-purpose metal-oxide-semiconductor field-effect transistors (MOSFETs) for ignition and O_2 sensor [heated exhaust gas oxygen (HEGO)] heater:
  - Pulse width modulation (PWM)
  - Overcurrent shutdown
  - Short-circuit to battery shutdown
- Six (MC33814) or five (MC33813) low-side drivers with full diagnostics, self-protection, and PWM control:
  - Two (MC33814) or one (MC33813) fuel injector drivers, $R_{DS(on)}$ = 0.6 Ω, I_{lim} = 1.8 A, to drive typical 12 Ω high-impedance injectors
  - Relay 1 driver, $R_{DS(on)}$ = 0.4 Ω, I_{lim} = 3.0 A, to drive fuel pump
  - Relay 2 driver, $R_{DS(on)}$ = 1.5 Ω, I_{lim} = 1.2 A, to drive power relay
  - Lamp driver, $R_{DS(on)}$ = 1.5 Ω, I_{lim} = 1.2 A, to drive warning lamp or an LED
  - Programmable tachometer driver, $R_{DS(on)}$ = 20 Ω, I_{sd} = 60 mA, to drive a tachometer display
- Innovative configurable VRS conditioning circuit, with two different parameter settings for engine cranking and running mode; optional automatic mode to improve noise immunity in cranking conditions
- K-line (ISO 9141)
- MCU reset generator and programmable watchdog
- MCU interface: 16-bit serial peripheral interface (SPI) and parallel interface with 5.0 V IO capability

2.2 Embedded diagnostics

The MC33813; MC33814 has several embedded diagnostics features, including:

- A system fault SPI register with an *Any System Fault* bit which is an OR of all fault reported by the IC. This system fault is a simple way for the user to monitor the IC.
- Power-on self-test (POST): routine to ensure that the SPI is working correctly and the status registers in the MC33813; MC33814 are viable
- SPI integrity check with SPI error flag if failure
- Power supply failure monitoring with V_{CC} undervoltage detection and V_{BAT} overvoltage detection
- Diagnostic feature on V_{prot} (external sensor supply) allowing to detect short-circuit to battery, short-circuit to ground, and overtemperature conditions. Events are flagged in corresponding SPI registers.
- Diagnostic feature on power stages (INJOUT1/2, ROUT1/2, LAMPOUT, TACHOUT) allowing to detect overcurrent, short-circuit to ground (except TACHOUT), open load, and overtemperature conditions. Events are flagged in corresponding SPI registers.
- Diagnostic feature on pre-driver stages (IGNOUT1/2, O2HOUT) allowing to detect overcurrent, short-circuit to battery, and open load conditions. Events are flagged in corresponding SPI registers.
- Two current measurement circuits are available for more accurate current control and better protection for pre-drivers.
- Overtemperature protection feature on the ISO 9141 bus

2.3 Embedded protections

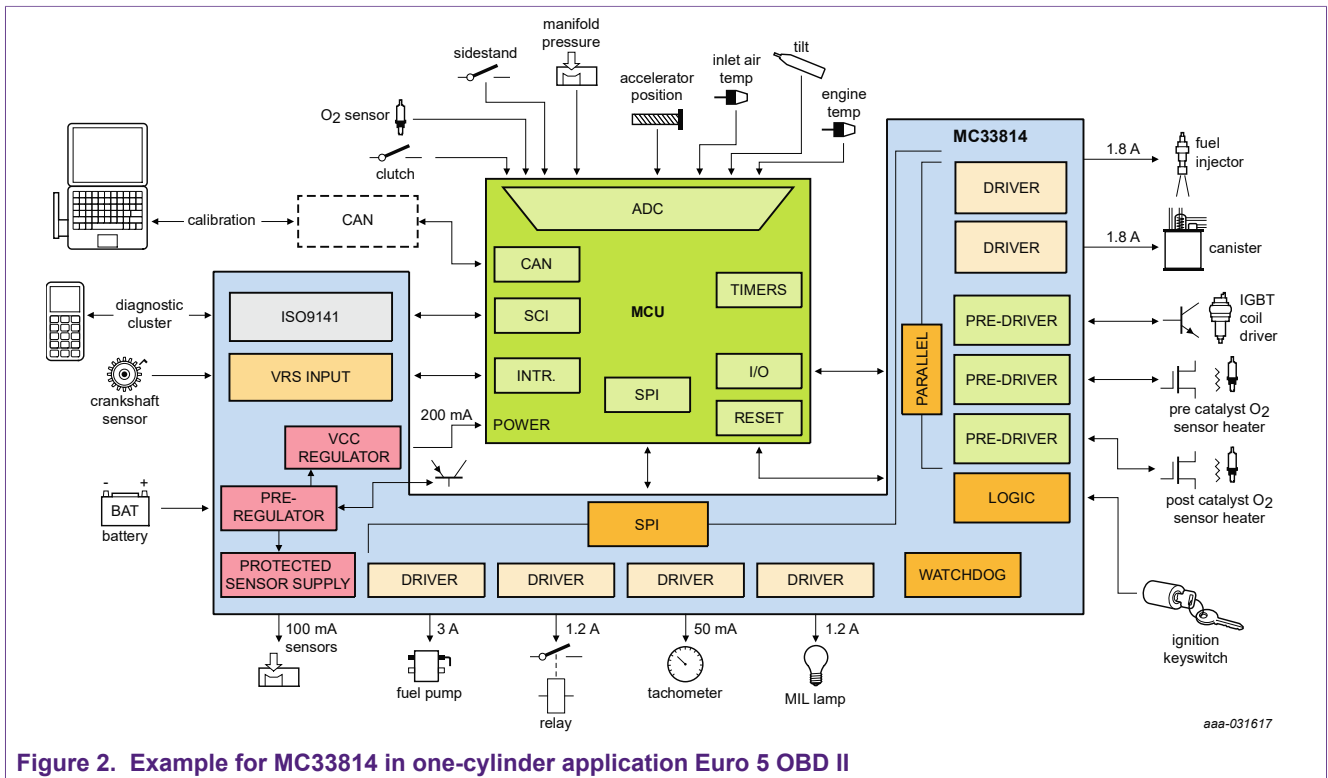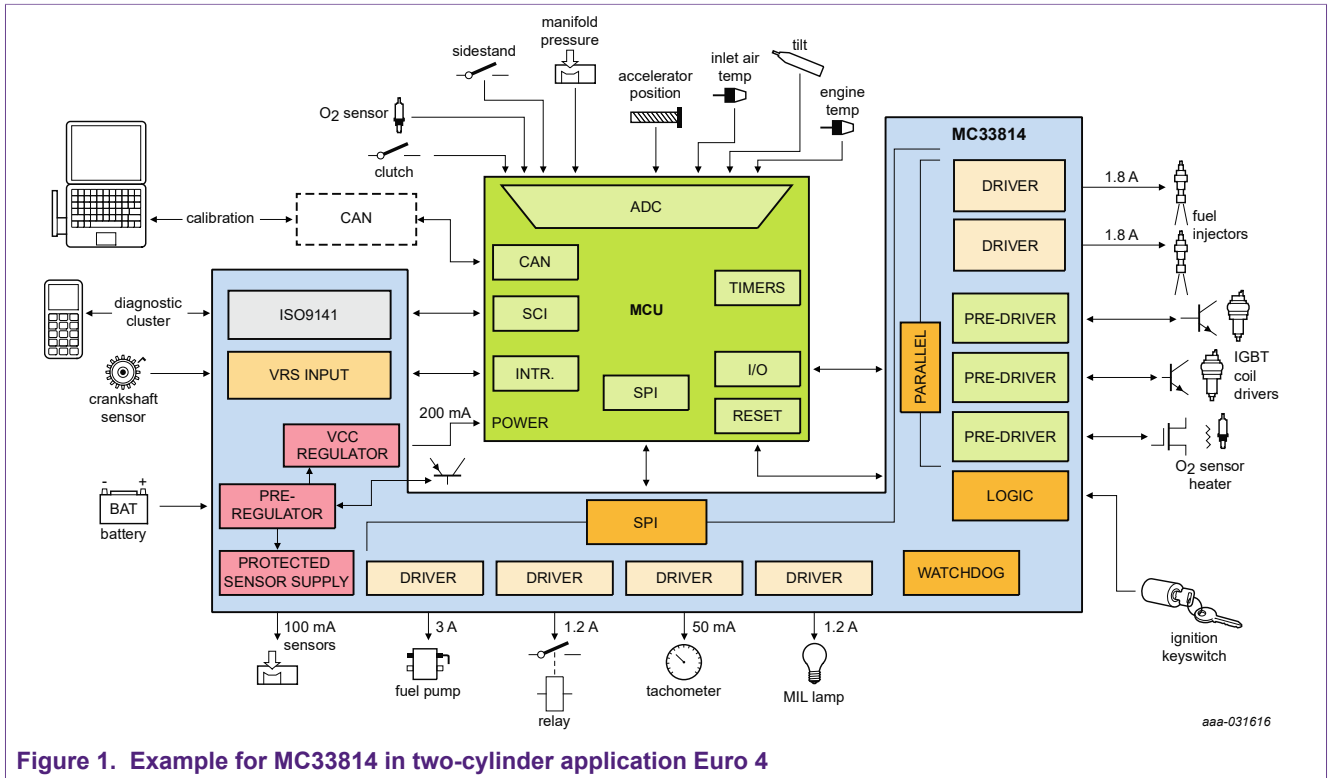The MC33813; MC33814 has several embedded protections features, including:

- Power-on reset (POR) ensuring proper logic operation
- Power supply failure protection by generating reset event to the MCU if V_{CC} undervoltage or V_{BAT} overvoltage condition
- Overcurrent limitation protection feature on power stages INJOUT1/2, ROUT1/2, and LAMPOUT
- Overcurrent shutdown protection feature on TACHOUT power stage
- Thermal shutdown protection on power stages (INJOUT1/2, ROUT1/2, LAMPOUT, TACHOUT) and other features such as V_{prot} and ISO 9141 bus
- Overcurrent shutdown protection feature on pre-driver
- Safety switch on/off for power stage and pre-drivers: using the AND bit, switch on/off of power stage can be enabled only if switch on/off bit and the direct input are in the appropriate state
- Internal reset bit allowing to reset completely the device to its default state, without toggling the RESETB output pin

2.4 Flags mapping relevant for diagnosis and fault

Table 2. SPI status registers

Reg #	Hex	Description	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	injector 1 driver faults	faults	X	X	X	OL	OC	OT	SG
1	1	injector 2 driver faults	faults	X	X	X	OL	OC	OT	SG
2	2	relay 1 driver faults	faults	X	X	X	OL	OC	OT	SG
3	3	relay 2 driver faults	faults	X	X	X	OL	OC	OT	SG
4	4	tachometer driver faults	faults	X	X	X	OL	OC	OT	X
5	5	lamp driver faults	faults	X	X	X	OL	OC	OT	SG
7	7	O_2 heater pre-driver faults	faults	X	X	X	OL	OC	X	X
8	8	injection 1 pre-driver faults	faults	X	X	X	OL	OC	X	X
9	9	injection 2 pre-driver faults	faults	X	X	X	OL	OC	X	X
10	A	watchdog state	enable/ disable	WD timer bit 6	WD timer bit 5	WD timer bit 4	WD timer bit 3	WD timer bit 2	WD timer bit 1	WD timer bit 0
11	B	VRS conditioner and ISO 9141 faults	peak 8	peak 4	peak 2	peak 1	X	clamp active VRSP	clamp active VRSN	ISO OT
13	D	power supply and any system faults	any system faults	KEYSW	PWREN	BATSW	SPI error	V_{prot} short-circuit to battery	V_{prot} OT	V_{prot} SG
14	E	system on/off indicators	INJ1 off/on	INJ2 off/on	REL1 off/on	REL2 off/on	LAMP off/on	IGN1 off/on	IGN2 off/on	O2H off/on
15	F	model code/ revision number	model code 2	model code 1	model code 0	revision number	revision number	revision number	revision number	revision number

2.5 Target applications

Figure 1. Example for MC33814 in two-cylinder application Euro 4

Figure 2. Example for MC33814 in one-cylinder application Euro 5 OBD II

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3 Diagnostics

This application note covers only the diagnostics relevant for low-side drivers (LSDs) and pre-drivers which are:

- Short-circuit to ground (SG)
- Overtemperature (OT)
- Overcurrent (OC)
- Open load (OL)

3.1 Short-circuit to ground

The SG diagnosis is only valid for:

- Injector 1
- Injector 2 (only for MC33814)
- Relay 1 driver
- Relay 2 driver
- Lamp driver

The aim of this function (also known as open load in on state) is to check if relevant current is flowing through the low side when on. If too low current is detected, the corresponding bit SG is set. It can happen if a resistive short-circuit to ground happens on the load; see Figure 3.
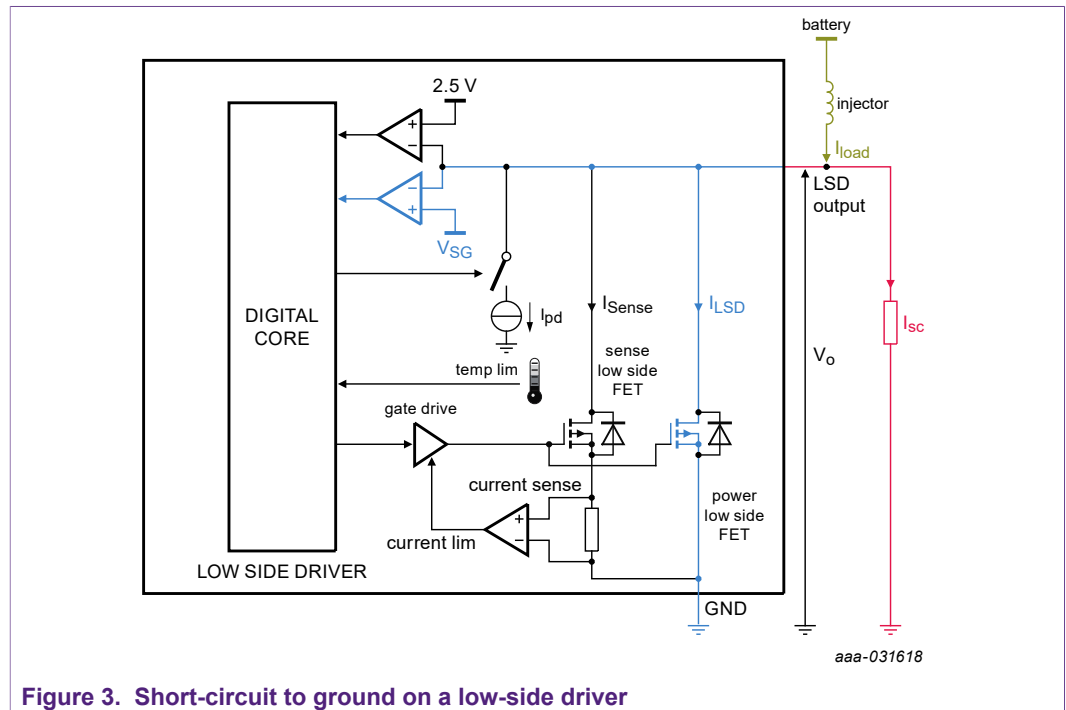
Figure 3. Short-circuit to ground on a low-side driver

- In normal condition (when there is no short-circuit to ground and I_{sc} = 0 A), the output voltage is $V_o = I_{load} \times R_{DS(on)}$. This voltage is compared to a reference V_{SG} (typically 30 mV, maximum value is 75 mV). If $V_o > V_{SG}$, the digital core detects no short-circuit to ground (no open load on).

- If there is a load short-circuit to ground, the short-circuit resistance decreases the equivalent resistance seen on the LSD output and so V_o. In this case, $V_o = I_{load} \times R_{DS(on)} // R_{sc}$. If $V_o < V_{SG}$, the digital core detects a short-circuit to ground (open load on). In this case, the bit SG of status register is set.

If the load drives too low current (e.g. by an LED), the SG diagnosis can be disabled by clearing the OL current sink enable bit of configuration register. In this case, the current source I_{pd} is disabled and no SG diagnosis can be set.

When the bit is set, the fault must disappear and the bit must be manually set to logic 0 to be cleared.

3.2 Overtemperature

The SG diagnosis is only valid for:

- Injector 1
- Injector 2 (only for MC33814)
- Relay 1 driver
- Relay 2 driver
- Tachometer driver
- Lamp driver

Each driver above has an independent temperature limitation sensor to be protected from overheating.
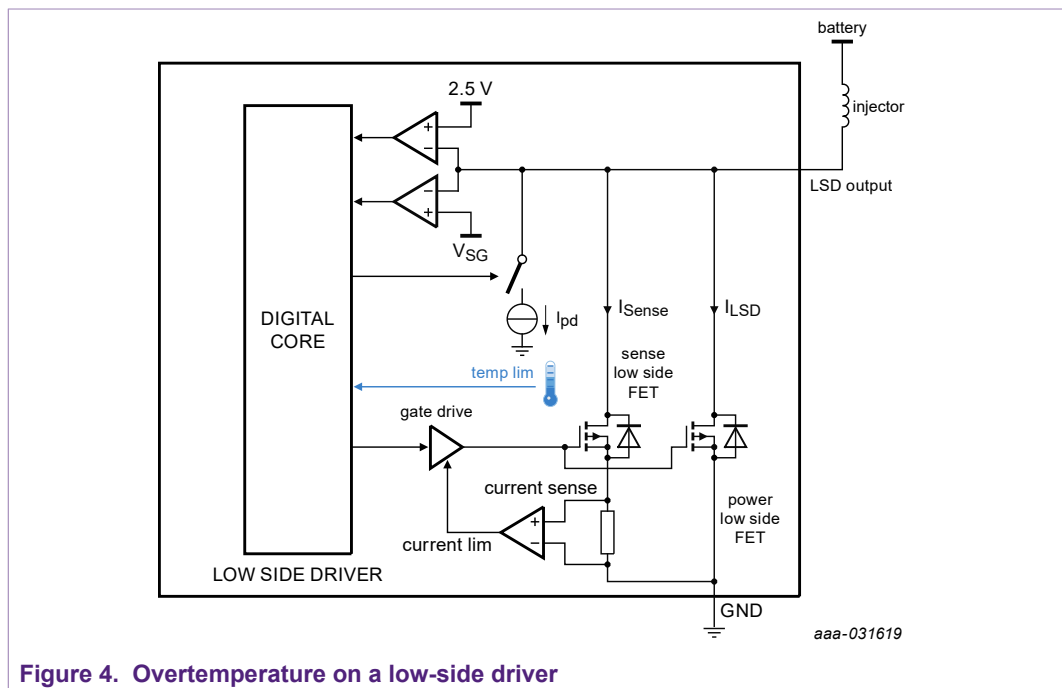
Figure 4. Overtemperature on a low-side driver

If the temperature on the LSD goes over 175 °C (typical), the output is switched off, the OT bit is set and no other driver is affected. When the bit is set, the fault must disappear and the bit must be manually set to logic 0 to be cleared.

When the temperature goes below 175 °C again (with hysteresis), the output automatically switches on again as long as it is driven on.

3.3 Overcurrent

The overcurrent (short-circuit to battery) diagnostic is valid for all low-side drivers and pre-drivers and is detected in the on state.

3.3.1 Low-side drivers

When an additional load is added to the application, like a short-circuit to the battery, an overcurrent can happen.

The short-circuit to battery is detected thanks to the internal LSD drain voltage and compared to a fixed reference (2.5 V typical). If the voltage is above this reference, the gate is automatically switched off.
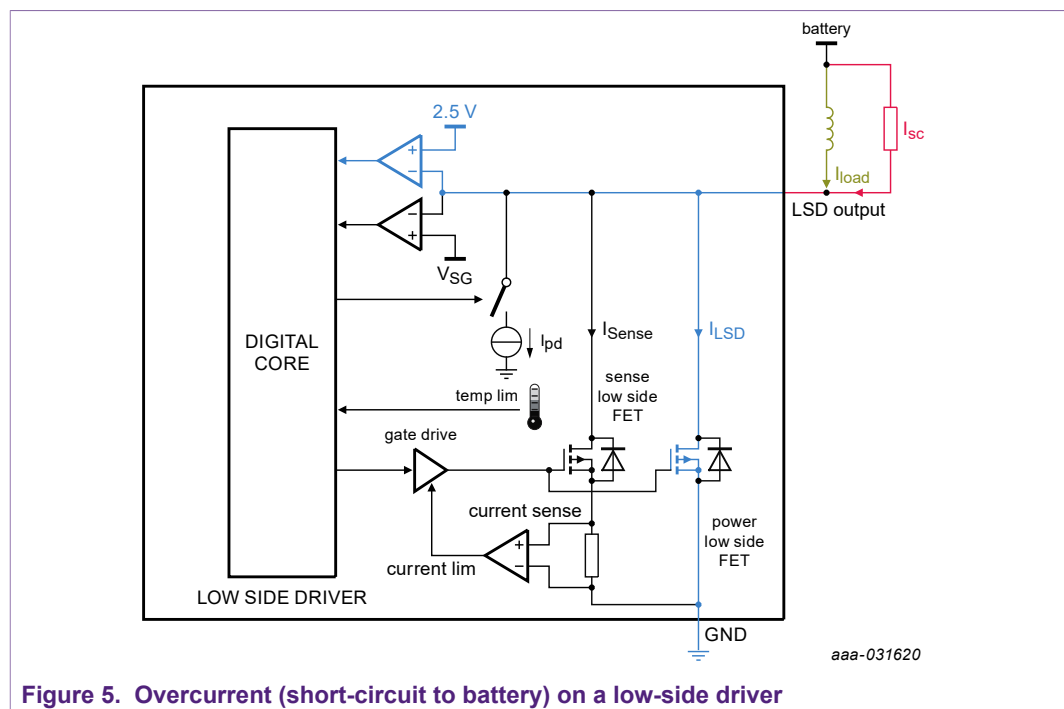
Figure 5. Overcurrent (short-circuit to battery) on a low-side driver

In addition, the corresponding bit OC in the status register is set. When the bit is set, the fault must disappear and the bit must be manually set to logic 0 to be cleared.

To switch the output on again, the overcurrent must be gone. The output must be driven off and on again (by direct input or by SPI). If the retry enable bit is set in the configuration register, there is no need to send switch off and switch on commands. The driver tries to switch on again until the overcurrent is gone.
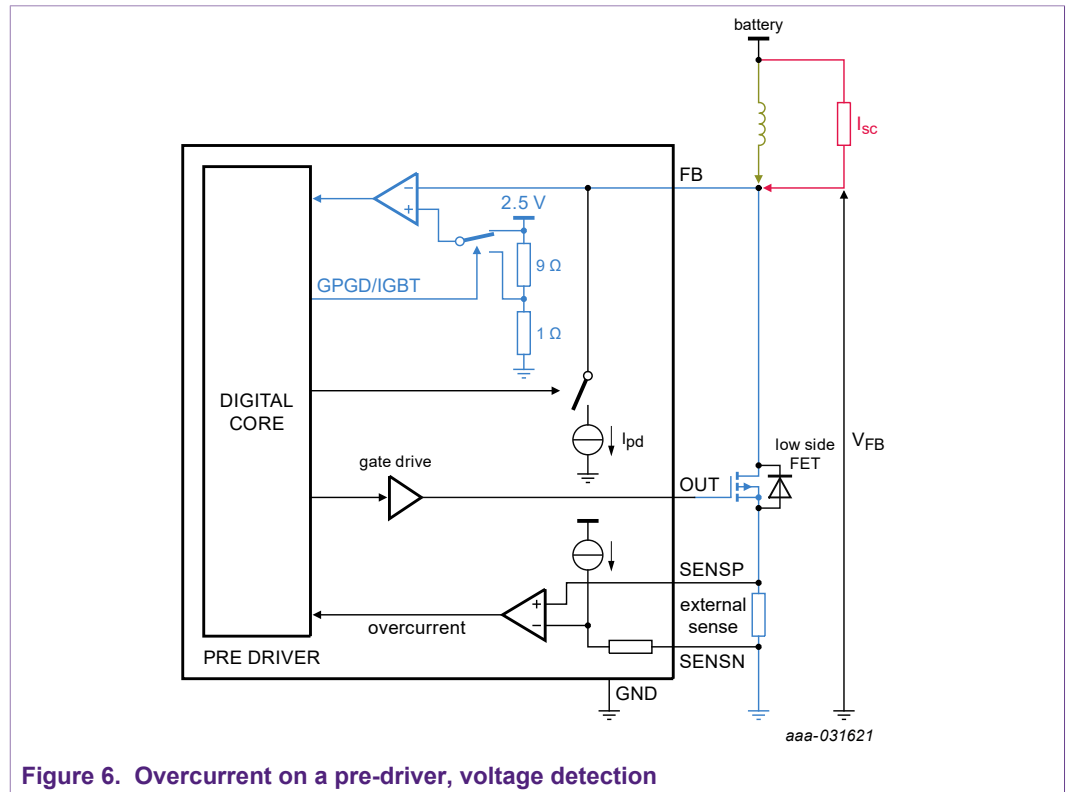
3.3.2 Pre-drivers

For pre-drivers, there are two events that can set the overcurrent flag:

1. Voltage detection

In this case, the voltage on the feedback pin (FB), is compared to 2.5 V for a general purpose gate driver (GPGD) configuration or to 250 mV for an IGBT configuration. If the voltage is higher than 2.5 V (when configured as GPGD) or 250 mV (when configured as IGBT) when the pre-driver is on, a short-circuit to battery is detected. The OC bit is set,

and the pre-driver turns off. When the bit is set, the fault must disappear and the bit must be manually set to logic 0 to be cleared.

To switch the output on again, the overcurrent must be gone and the output must be driven off and on again (by direct input or by SPI). If the retry enable bit is set in the configuration register, there is no need to send switch off and switch on commands. The driver tries to switch on again until the overcurrent is gone.
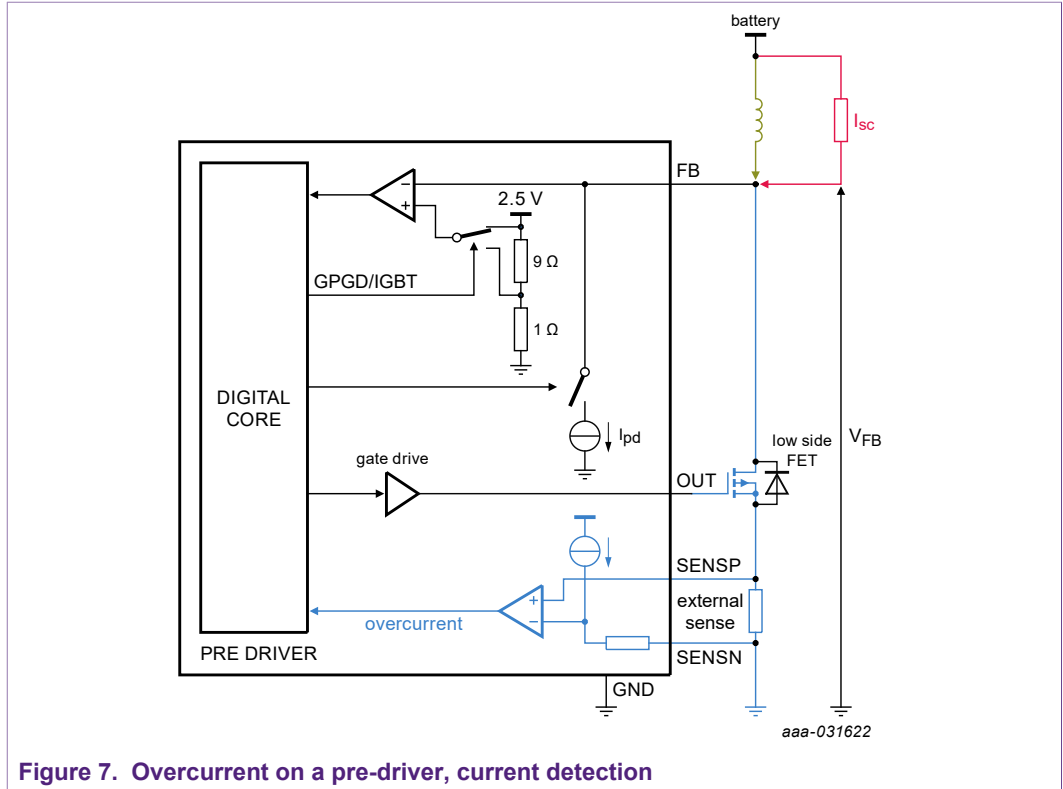

Figure 6. Overcurrent on a pre-driver, voltage detection

2. Current detection

In this case, an external sense resistor is used. It is connected to pins IGNSENSP and IGNSENSEN for IGNOUT1 and IGNOUT2 (IGNOUT2 only valid for MC33814) and pins O2HSENSP and O2HSENSN. If the voltage between SENSP and SENSN is higher than 200 mV, an overcurrent is detected, the OC bit is set, and the pre-driver turns off. For MC33814, the threshold goes to 400 mV when both IGNOUT1 and IGNOUT2 are configured as IGBT and both are on at the same time. When the bit is set, the fault must disappear and the bit must be manually set to logic 0 to be cleared.

To switch the output on again, the overcurrent must be gone. The output must be driven off and on again (by direct input or by SPI). If the retry enable bit is set in the configuration register, there is no need to send switch off and switch on commands. The driver tries to switch on again until the overcurrent is gone.

Figure 7. Overcurrent on a pre-driver, current detection

3.4 Open load

The open load (open load off state) diagnosis is valid for all low-side drivers and pre-drivers and is detected in the off state.

For both pre-drivers and LSDs, the open load detection uses an internal pull-down current source. The OL current sink bit in the configuration register controls the internal pull-down current source.

3.4.1 Low-side drivers

If the OL current sink bit is enabled, 75 µA is sunk from the GND through the LSD. If no load is connected to the battery and the output is off, the voltage on the LSD output pin is close to 0 V.
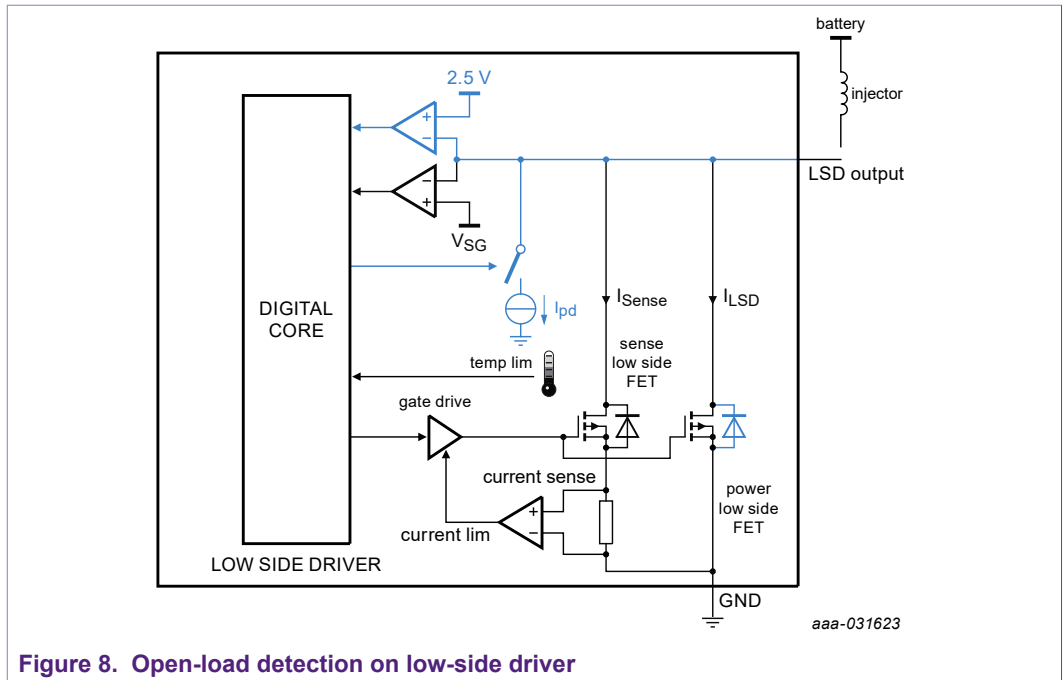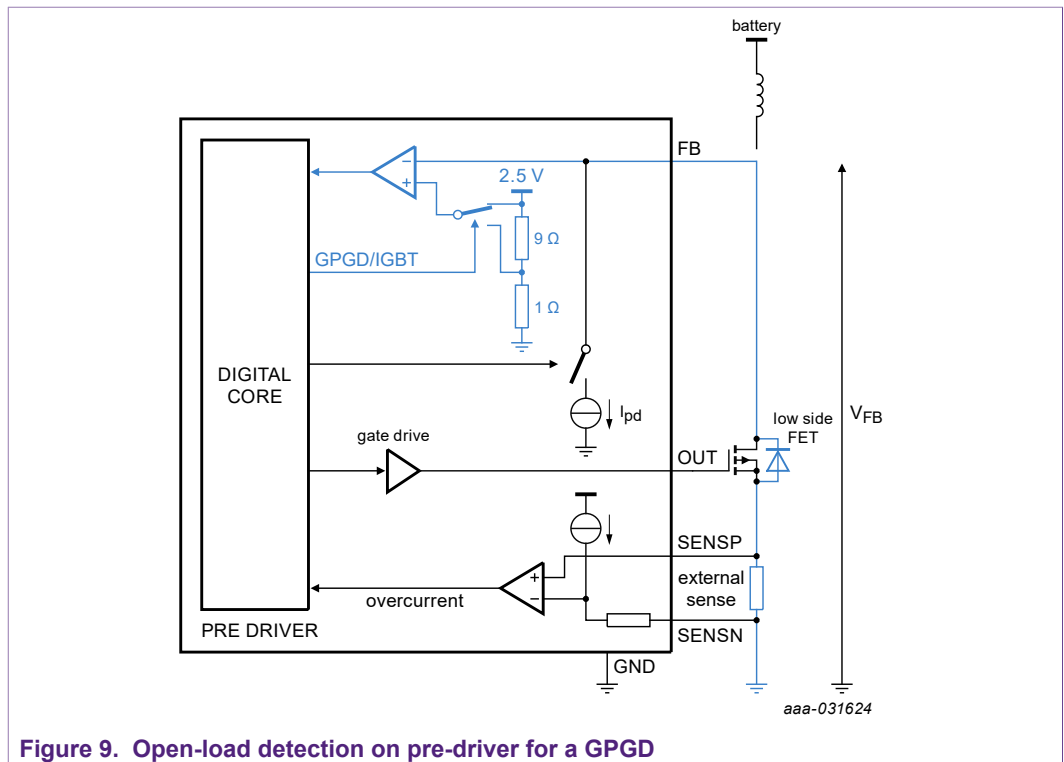
Figure 8. Open-load detection on low-side driver

If a load is connected, the voltage on the LSD output pin is close to V_{BAT}. This voltage is compared to a 2.5 V comparator.

Depending on the comparator output OL bit in the status register is set. When the bit is set, the fault must disappear and the bit must be manually set to logic 0 to be cleared.

3.4.2 Pre-drivers

If the OL current sink bit is enabled, 75 µA is sunk from the feedback pin to the GND. If no load is connected to the battery and the output is off, the voltage on the FB pin is close to 0 V.

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Figure 9. Open-load detection on pre-driver for a GPGD

If the load is connected, the voltage seen on the FB pin is close to the battery voltage.

The voltage is compared to a 2.5 V or 250 mV reference (respectively for GPGD configuration and IGBT).

Depending on the comparator output OL bit in the status register is set. When the bit is set, the fault must disappear and the bit must be manually set to logic 0 to be cleared.

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Figures

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