AN5386

Safety application notes for MC12XS6 family

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Document information

Information	Content
Keywords	AN5386
Abstract	This document discusses the safety requirements for the use of an NXP product and in functional safety relevant applications requiring high functional safety integrity levels.

1 Introduction

This document discusses the safety requirements for the use of an NXP product and in functional safety relevant applications requiring high functional safety integrity levels. This safety manual is provided to support the MC12XS6 12 V eXtreme Switch family. This family has nine products:

- MC07XS6517
- MC08XS6421
- MC10XS6200
- MC10XS6225
- MC10XS6325
- MC17XS6400
- MC17XS6500
- MC25XS6300
- MC40XS6500

This document is intended to support system and software engineers using the available features, as well as achieving additional diagnostic coverage by software measures.

Several measures are prescribed as safety requirements whereby the measure described was assumed to be in place when analyzing the functional safety. In this sense, requirements in the Safety Manual (SM) are driven by assumptions concerning the functional safety of the system.

- **Assumption:** An assumption being relevant for functional safety in the specific application under consideration (condition of use). It is assumed that the user fulfills an assumption in his design.

Example:

Assumption: The recommended operating conditions given in the datasheet are maintained.

This document also contains guidelines on how to configure and operate the NXP device for functional safety relevant applications requiring high functional safety integrity levels.

These guidelines are considered to be useful approaches for the specific topics under discussion. The user will need to use discretion in deciding whether these measures are appropriate for their applications.

It is assumed the user of this document is generally familiar with the NXP device, ISO 26262 and IEC 61508.

1.1 Related documents

This section lists all the documentation mentioned in this application note.

The application note is to be used in combination with the datasheet.

Table 1. Related Documents

Document Name	Description
IEC 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems, international standard, ed. 2.0, April 2010
ISO 26262:2011	Road vehicles – Functional safety, first edition

Document Name	Description
MC12XS6D1, MC12XS6D2, MC12XS6D3, MC12XS6D4	Data Sheet

1.2 Vocabulary

The following terms, defined in ISO 26262-1 and IEC 61508-4, apply to this document:

- **System:** Functional safety-related system, both implements the required functional safety goals necessary to achieve or maintain a safe state system for the equipment under control (control system), and is intended to achieve on its own or with other Electrical/Electronic/Programmable Electronic functional safety-related systems, and other risk reduction measures, the necessary functional safety integrity for the required safety functions.
- **System integrator:** The person who is responsible for the system integration.
- **Element:** Part of a subsystem comprising of a single component or any group of components (for example, hardware, software, hardware parts, software units) performing one or more element safety functions (functional safety requirements).

2 General information

These devices are designed to be used in automotive or industrial applications which need to be integrated in a system that fulfill functional safety requirements, as defined by functional safety integrity levels, such as ASIL D of ISO 26262 or SIL 3 of IEC 61508.

2.1 Assumed conditions of operation

Assumption: The recommended operating conditions given in the NXP Data Sheet are maintained.

Assumption: The latest device errata is taken into account during system design, implementation, and maintenance.

Assumption: All field failures of the devices are reported to silicon supplier.

2.2 Safety function

Given the application independent nature of the NXP device, no general safety function can be specified. Therefore, this document specifies a safety function being application independent for the majority of applications. This application independent safety function would have to be integrated into a complete (application dependent) system.

2.3 Safety goals

The safety goals at application level are to:

- Prevent unintended turn-off and turn-on of the channel outputs
- Prevent application damage due to load misfunctioning

3 Assumptions of use

Figure 1 shows a generic safety system architecture example. The primary feature of the MC12XS6 family is to be the main switch to turn on and turn off lights in a vehicle. The device will also turn on and turn off other loads, such as DC motors, solenoids and power modules.

All devices embed internal fault-detection mechanisms and diagnostics. SPI communication pins report fault and diagnostics back to the MCU.

MC12XS6 is also self-protected against overload and overheating.

At the system level, the MC12XS6 family is compliant for integration in an ASIL B system.

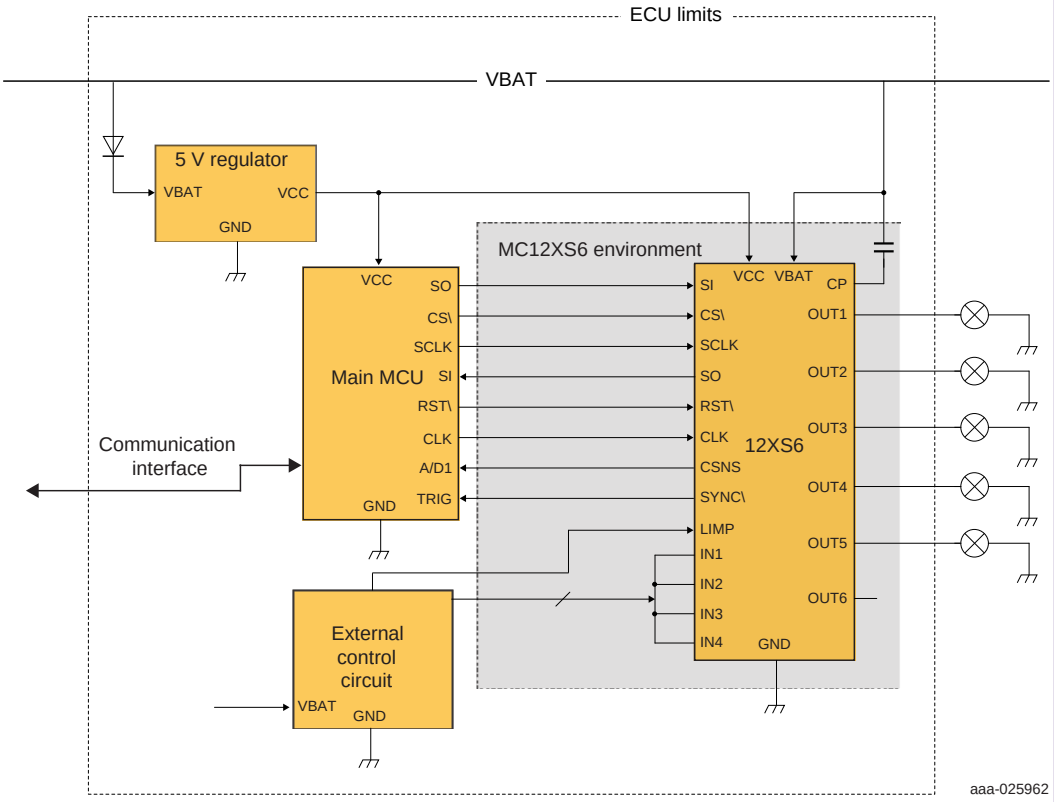


Figure 1. Generic safety system architecture example

Table 2. Pin descriptions

Pin	Description	Safety monitored
V_{CC}	Digital core and interface supply	Yes
V_{BAT}	Power supply	Yes
RST\	Reset of device, active low to high	No
CLK	External PWM clock	Yes
LIMP	Fail mode digital input	Yes
IN1...4	Direct input drive	Yes

Pin	Description	Safety monitored
SPI (4)	Serial peripheral interface between MCU and MC12XS6 device	Yes
SYNC\	Current sense synchronization	No
CSNS	Analog sense output	No
CP	Charge pump	Yes
OUT1...5	Power outputs	Yes
OUT6	External output pin	No

3.1 Targeted applications

The MC12XS6 family is developed to control different type of loads (bulb lamps, HID ballast, xenon or LED modules) with low $R_{DS(on)}$ in high-side drive mode. It is designed for car, trailers and industrial applications.

Applications:

- Lighting: High beam, low beam, turn indicators, side indicators, fog lamp, brake indicators, rear indicators, parking lights
- Industrial: motor control, heaters, water pump, solenoids

Figure 2 shows an example of an application with external components.

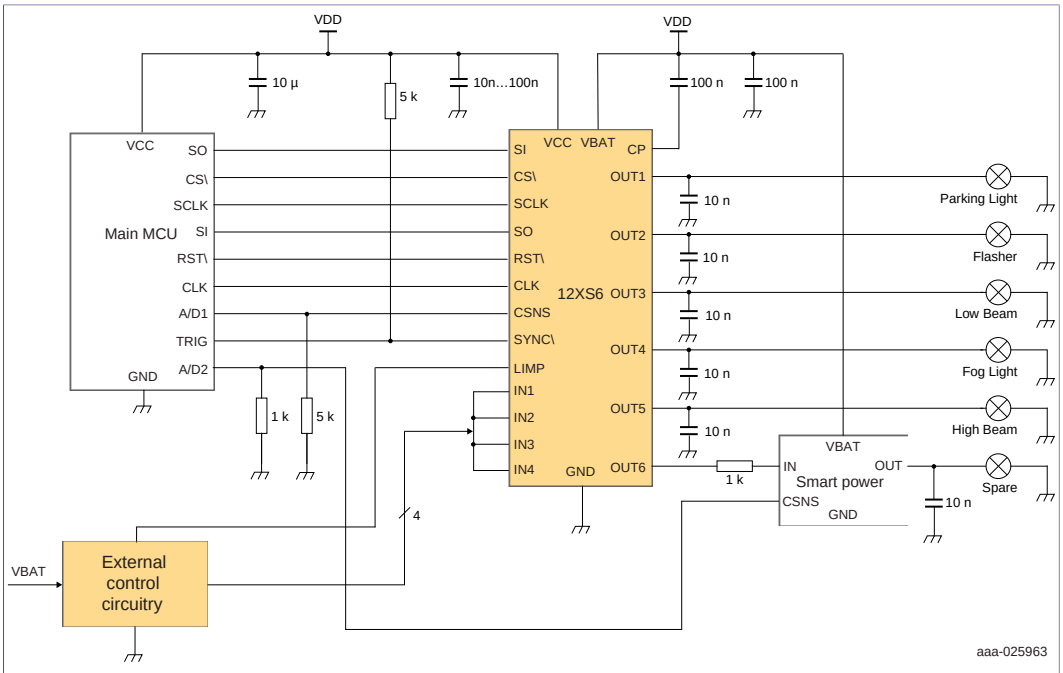


Figure 2. Example of an application with external components

3.2 Main functions of the MC12XS6 family

The MC12XS6 is a 12 V device family, composed by dual/triple/quad and penta high side switches with integrated control, and a high number of protection and diagnostic functions. It has been designed especially for automotive applications. The low $R_{DS(on)}$

channels can control different load types; bulbs, solenoids, or DC motors. Control, device configuration, and diagnostics are performed through a 16-bit serial peripheral interface (SPI), allowing easy integration into existing applications. This device is powered by SMARTMOS technology.

Power channels can be controlled individually by external clock signals using SPI, or by direct inputs in fail-safe mode. Programmable output voltage slew- rates (individually programmable) such as setting the phasing between outputs helps to improve electromagnetic compatibility (EMC) performance. To avoid shutting off the device upon inrush current, while still being able to closely track the load current, a dynamic overcurrent threshold profile is featured. Switching current of each channel can be sensed with a programmable sensing ratio. Whenever communication with the external microcontroller is lost, the device enters a Fail-safe operation mode, but remains operational, controllable, and protected.

Main functions:

- Turn OFF and ON the main power to the load
- Control of the turn-on/off either with communication bus or direct inputs
- Control the slew rate when turning-on/off
- Control the duty cycle when in PWM mode
- Adjust the output frequency based on internal clock thanks to internal prescaler
- Control delays between channels when turning-on/off
- Control the transient overcurrent profile timing window and the continuous current level threshold
- Turn-off the output when an overcurrent, overtemperature, undervoltage, overvoltage are detected
- Control re-activation of the output when overcurrent, overtemperature, undervoltage are detected
- Control output state when external clock is out of range
- Control of an external MOSFET or smart power switch with OUT6
- Report an image of the current in the power switch (MOSFET)
- Report an image of the temperature
- Report an image of the voltage of V_{PWR} pin

Embedded protections:

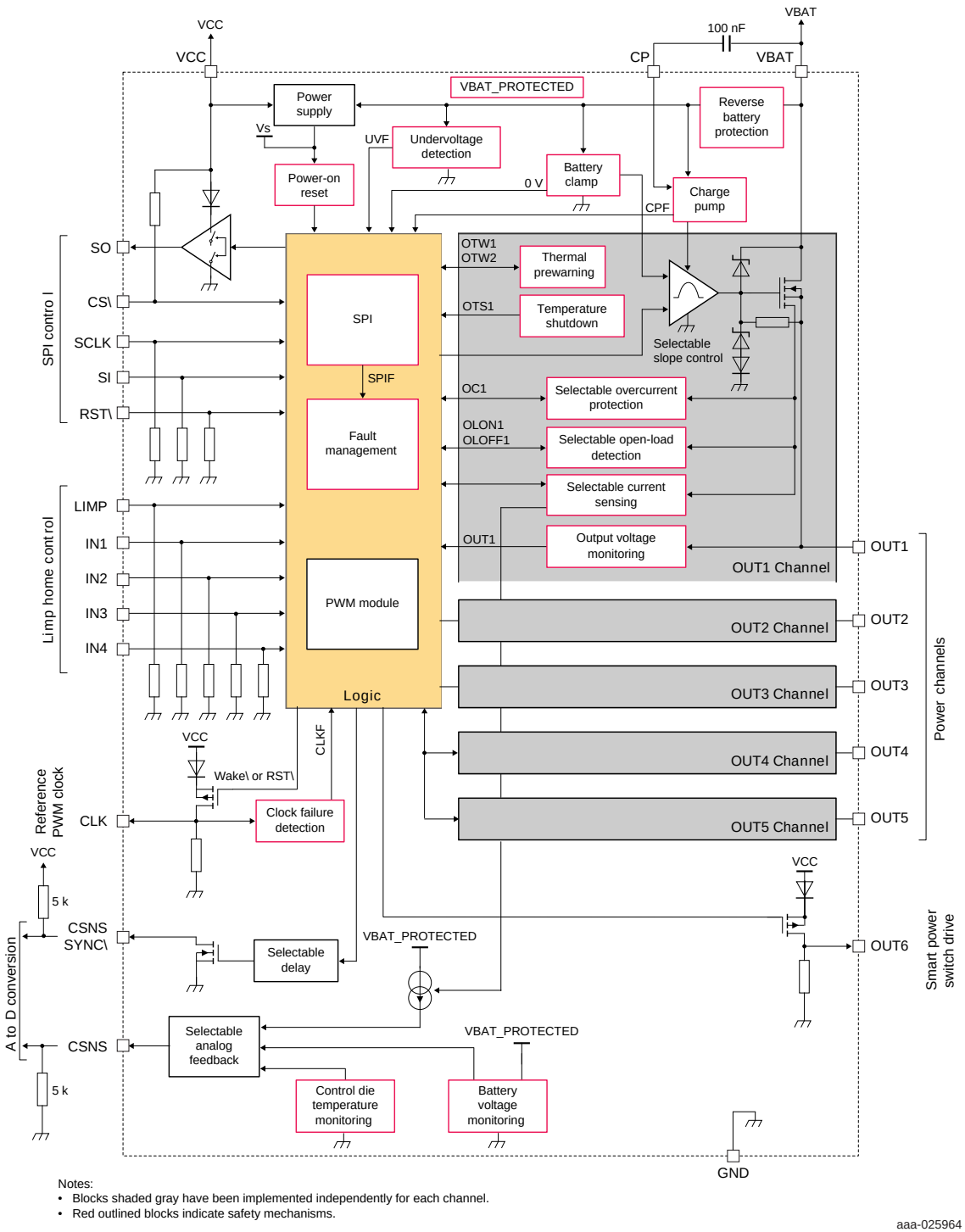
- Overload
- Severe short circuit
- V_{PWR} overvoltage over maximum ratings
- V_{PWR} undervoltage
- Overtemperature

Embedded diagnostics:

- Open load detection when in ON mode
- Open load detection when in OFF mode
- V_{PWR} overvoltage
- Short to Battery detection / output channel states
- Warning on temperature level detection
- Output current value
- Device temperature value
- Supply voltage value
- I/O’s logic state

- Register read

A block diagram of a device from MC12XS6 family is shown in Figure 3. All devices in this family have the same block diagram. All safety mechanisms in Figure 3 are identified in red.



Notes:
- Blocks shaded gray have been implemented independently for each channel.
- Red outlined blocks indicate safety mechanisms.

aaa-025964

Figure 3. Internal block diagram

4 Safety states

This section describes all the safe states of MC12XS6 that will be further identified in Section 6 "Device fault and device diagnostics management".

In Figure 4, the states applied for the safe state are illustrated in red while unchanged states are illustrated in black.

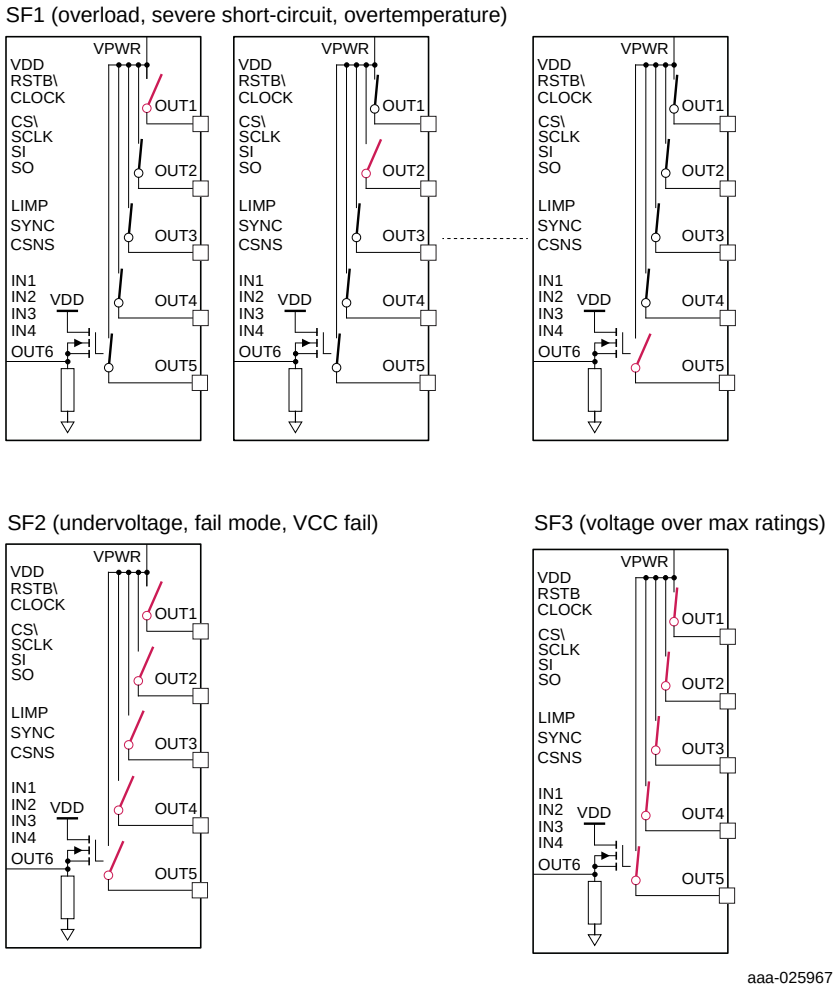


Figure 4. Safety states

5 Flags mapping relevant for diagnosis and faults

This section describes all flags of MC12XS6 that will be further identified in Section 6 "Device fault and device diagnostics management". The register and labelling method use an “x” extension to refer to each channel. A register name or bit name without the “x” extension means the register (or the bit) is common to all channels.

The following tables relate to MCU SPI commands to retrieve flags in the relevant device register.

Table 3. Quick status register and flags

READ	Quick status register read command															
	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
MOSI	0	0	0	0	WD	–	–	–	–	–	–	–	0	0	0	1
MISO	SOA3	SOA2	SOA1	SOA0	FM	DSF	OVLF	OLF	CPF	RCF	CLKF	QSF5	QSF4	QSF3	QSF2	QSF1
Flags					**FG5**	**FGC**[1]	**FGB**[1]	**FGA**[1]	**FG4**	**FG3**	**FG2**	**FG1**				

[1] FGA, FGB and FGC are logic OR of several faults that is available on all status registers except I/O status register.

Table 4. Channel (x) status register and flags

READ	CHx status register read command															
	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
MOSI	0	0	0	0	WD	–	–	–	–	–	–	–	0	*Output selection*[1]		
MISO	SOA3	SOA2	SOA1	SOA0	FM	DSF	OVLF	OLF	*res*	OTSx	OTWx	OC2x	OC1x	OC0x	OLONx	OLOFFx
Flags					**FG5**	**FGC**	**FGB**	**FGA**		**FG10**	**FG9**	**FG8**			**FG7**	**FG6**

[1] Output selection using D0...2 where 010 is the combination for channel 1, 110 for channel 5.

Table 5. Device status register and flag

READ	Device status register read command															
	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
MOSI	0	0	0	0	WD	–	–	–	–	–	–	–	0	1	1	1
MISO	SOA3	SOA2	SOA1	SOA0	FM	DSF	OVLF	OLF	*res*	*res*	*res*	TMF	OVF	UVF	SPIF	iLIMP
Flags					**FG5**	**FGC**	**FGB**	**FGA**					**FG14**	**FG13**	**FG12**	**FG11**

Table 6. I/O status register and flag

READ	I/O status register read command															
	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
MOSI	0	0	0	0	WD	–	–	–	–	–	–	–	1	0	0	0
MISO	SOA3	SOA2	SOA1	SOA0	FM	*res*	TOGGLE	iIN4	iIN3	iIN2	iIN1	OUT5	OUT4	OUT3	OUT2	OUT1
Flags					**FG5**		**FGD**	**FG16**				**FG15**				

6 Device fault and device diagnostics management

MC12XS6 family embeds internal fault detection leading to internal reactions on device operations.

In addition, MC12XS6 family embeds internal diagnostics that do not lead to internal reaction on device operations, only reporting none-regular operations. Both faults and diagnostics will be detailed separately.

6.1 Internal device faults detection

MC12XS6 family embeds internal fault detection leading to internal reactions on device operations. The detected faults are:

- Overload (OC)
- Severe short-circuit (SC)
- V_{PWR} Overvoltage over maximum ratings
- V_{PWR} Undervoltage (UV)
- Overtemperature (OT)
- Charge pump failure (CPF)

Two additional detections, not classified as faults in the device datasheets, have internal reactions and are similar to the previously mentioned faults. These detections are:

- SPI protocol failure (SPIF)
- Register clear flag (RCF)

Table 7. Summary table of device fault and device diagnostics management

ID	Name	Description	Module or function covered
SM1	Overload detection	On each channel, detect the current in the load is over specified range either in transit or in DC operation	Load fault (short circuit at end of harness, overloaded channel…)
SM2	Severe short circuit detection	On each channel, detect the short circuit at device output (on PCB)	Output channel pin shorted to GND, PCB fault, load fault if connected close to output channel
SM3	Voltage over max ratings detection	On V_{PWR}, voltage is over the maximum specified between V_{PWR} & GND	Battery line fault
SM4	Undervoltage detection Case 1	On V_{PWR}, voltage is under the specified range: $V_{PWR} < V_{PWR(UV)}$ Case 1: $V_{CC} > V_{CC(FAIL)}$ with device in normal mode	Battery line fault
SM5	Undervoltage detection Case 2	On V_{PWR}, voltage is under the specified range: $V_{PWR} < V_{PWR(UV)}$ Case 2: Device in Fail-safe mode or $V_{CC} < V_{CC(FAIL)}$	Battery line fault and system V_{CC} fault
SM6	Overtemperature detection	For each channel, detection of temperature is over 175 °C (typ)	Module temperature, board overheating, power overload faults
SM7	V_{CC} out of range detection	Monitoring of V_{CC} low voltage threshold with conditions $V_{CC} < V_{CC\_FAIL}$: enter in Fail-safe mode The SO data are not available	System VDD fault
SM8	Loss of communication detection	Monitoring of the SPI frame integrity through Watchdog, timeout or protocol length error	SPI communication fault, MCU SPI pin fault

ID	Name	Description	Module or function covered
SM9	Charge pump failure detection	Monitor charge pump voltage value within the normal range	PCB fault
SM10	Open load ON mode detection	On each channel, detection of current below I_{OL} or I_{OLLED} (of LED mode activated) when channel is ON	Load disconnection, filament cut, channel output pin disconnection
SM11	Open load OFF mode detection	On each channel, detection of current below I_{OLOFF} when the channel is OFF and OLOFFx request is sent	Load disconnection, filament cut, channel output pin disconnection
SM12	Overvoltage detection	On V_{PWR}, voltage is over the range specified for overvoltage	Battery line fault
SM13	Clock fail detection	When the device operates in PWM, if external clock is disconnected or out of the f_{CLK} frequency range	MCU clock pin fault, MCU to device line fault, channel input clock disconnection
SM14	Overtemperature warning detection	For each channel, detection of temperature over T_{OTW1} or T_{OTW2} (depending on OTW SEL configuration)	Board overheating, power overload faults
SM15	Output channel state detection	On each channel, detection of channel output state and report into register. Allows diagnosis if channel is short circuited to V_{PWR} when channel is off state	Load short to battery
SM16	Input channel state detection	Each device input state (INx or LIMP) is monitored and reported into register after t_{IN_DGL} permanent state on signal	Monitor a possible wrong GPIO event on master/slave MCU
SM17	Output current value & SYNC detection	For each channel, current recopy of output channel current can be multiplexed on CSNS pin, SYNCB pin allows user to trig the measurement when output is running in PWM	Load dysfunction, degradation or partial disconnection detection
SM18	Device temperature detection	Control die temperature (not Power die temperature) is reported through the CSNS pin	Module temperature monitoring, board overheating
SM19	Device supply voltage detection	The analog supply voltage of the device can be reflected in the CSNS pin	Battery line fault monitoring
SM20	Register read	Register read reports data register and SO state	Any fault or diagnostic in the application covered by above SM-x

6.1.1 Overload

Overcurrent detection and conditions are depicted in datasheet.

Table 8. Overload detection

Overload detection	Description of safety mechanism	On each channel, detect the current in the load is over specified range either in transit or in DC operation	SM1
	Device reaction	Turn-off faulty channel	SF1
		OVLF bit raised on Quick status register for corresponding output (x) and the detail can be seen on *OC0...2x* bits from CHx status register	FG8 / FG1 & FGB
	MCU reaction	Integrator to decide action	
	Reset conditions	After fault disappeared, de-latch sequence + CHx status register read	

6.1.2 Severe Short Circuit (SC)

Table 9. Severe short circuit detection

Severe short circuit detection	Description of safety mechanism	On each channel, detect the short circuit at device output (on PCB)	SM2
	Device reaction	Turn-off faulty channel	SF1
		OVLF bit raised on quick status register for corresponding output (x) and the detail can be seen on *OC0...2x* bits from CHx status register (combination 110 for SC)	FG8 / FG1 & FGB
	MCU reaction	Integrator to decide action	
	Reset conditions	After fault disappeared, de-latch sequence + CHx status register read	

6.1.3 Voltage over maximum ratings

Table 10. Voltage over maximum ratings

Voltage over max ratings detection	Description of safety mechanism	On V_{PWR}, voltage is over the maximum specified between V_{PWR} & GND	SM3
	Device reaction	Turn-on all channels	SF3
		OV bit raised in Device status and quick status register	FG14 & FGC
	MCU reaction	Integrator to decide action	
	Reset conditions	After fault disappeared, flag will be removed	

6.1.4 Undervoltage (UV) with $V_{CC} > V_{CC(FAIL)}$ and device in normal mode (with Watchdog)

Table 11. Undervoltage detection in normal mode and no $V_{CC(FAIL)}$

Undervoltage detection Case 1	Description of safety mechanism	On V_{PWR}, voltage is under the specified range: $V_{PWR} < V_{PWR(UV)}$ Case 1: $V_{CC} > V_{CC(FAIL)}$ with device in normal mode	SM4
	Device reaction	Turn-off all channels	SF2
		UV bit raised in Device status and in the quick status register. The ON/OFF of the outputs is cleared except for OUT6. Other registers configuration are not cleared	FG13 & FGC
	MCU reaction	Integrator to decide action	
	Reset conditions	Undervoltage condition disappeared, then UV bit is cleared upon a reading of Device status register	

6.1.5 Undervoltage (UV) and device in fail-safe mode (or $V_{CC} < V_{CC(FAIL)}$)

Table 12. Undervoltage detection in fail mode

Undervoltage detection Case 2	Description of safety mechanism	On V_{PWR}, voltage is under the specified range: $V_{PWR} < V_{PWR(UV)}$ Case 2: Device in Fail-safe mode or $V_{CC} < V_{CC(FAIL)}$	SM5
	Device reaction	Turn-off all channels as long as $V_{PWR} < V_{PWR}(UV)$	SF2
		All register are cleared	FG13, FG5 & FGC

	MCU reaction	Integrator to decide action
	Reset conditions	Undervoltage condition disappeared and, the restart of the outputs is controlled by the autorestart feature

6.1.6 Overtemperature (OT)

Table 13. Overtemperature detection

Overtemperature detection	Description of safety mechanism	For each channel, detection of temperature is over 175 °C (typ)	SM6
	Device reaction	If faulty channel is ON, channel is turned OFF	SF1
		If channels are OFF and Tj>TSD there is no way to Turn On	
		OT bit raised in Channel status register of faulty channel and on quick status register	FG10 & FGB
	MCU reaction	Integrator to decide action	
	Reset conditions	After temperature < TSD , de-latch sequence , read Channel status register	

6.1.7 V_{CC} out of range

Table 14. V_{CC} out of range detection

V_{CC} out of range detection	Description of safety mechanism	Monitoring of V_{CC} low voltage threshold with conditions V_{CC} <V_{CC_FAIL} : enter in Fail-safe mode The SO data are not available	SM7
	Device reaction	Turn-off all channels	SF2
		All register contents are reset	FG3, FG5
	MCU reaction	Integrator to decide action Channels can be turned ON by direct inputs pins	
	Reset conditions	None	

6.1.8 Loss of SPI communication fault when device in normal mode (with watchdog toggle)

Table 15. Loss of communication detection

Loss of communication detection	Description of safety mechanism	Monitoring of the SPI frame integrity through Watchdog, timeout or protocol length error	SM8
	Device reaction	Channels state configuration is lost and outputs are set according to the Fail mode configuration state	SF2
		All register contents are reset (register clear flag) and the SPI fault flag can be read out in Fail mode	FG3, FG5 & FG12
	MCU reaction	Integrator to decide action Reload device configuration after wake up sequence	
	Reset conditions	Once communication and watchdog recovers, SPIF and FM flags are automatically unlatched. Read Quick status register to unlatch RCF	

6.1.9 Charge pump failure (CPF)

Table 16. Charge pump failure detection

Charge pump failure detection	Description of safety mechanism	Monitor Charge Pump voltage value within the normal range	SM9
	Device reaction	Turn-off all channel with no possibility to turn On	SF2
		Charge Pump flag raised inside Quick status register	FG4
	MCU reaction	Integrator to decide action	
	Reset conditions	None	

6.2 External fault diagnostics

MC12XS6 family does embed internal diagnostics leading to non-internal reactions on device operations. Those diagnostics are:

- Open load in ON mode for incandescent and LED (OLON)
- Open load in OFF mode (OLOFF)
- V_{PWR} overvoltage (OV)
- External clock fail (CLOCK_fail)
- Overtemperature warning (OTW)
- Output channel state (OUTx)
- Direct input state (INx)
- Analog supply voltage value (CSNS)
- Output current value (CSNS)
- Device temperature value (CSNS)

6.2.1 Open load in ON mode (OLON)

Table 17. Open load ON detection

Open load ON mode detection	Description of safety mechanism	On each channel, detection of current below I_{OL} or I_{OLLED} (of LED mode activated) when channel is ON	SM10
	Device reaction	OLF raised in Quick status register for output x and OLONx bit raised in corresponding channel status register	FGA / FG1 & FG7
	MCU reaction	Integrator to decide action	
	Reset conditions	After fault disappeared, channel status must be read to clear the fault	

6.2.2 Open load in OFF mode (OLOFF)

Table 18. Open load OFF detection

Open load OFF mode detection	Description of safety mechanism	On each channel, detection of current below I_{OLOFF} when the channel is OFF and OLOFFx request is sent	SM11
	Device reaction	OLF raised in Quick status register for output x and OLOFFx bit raised in corresponding channel status register	FGA / FG1 & FG6
	MCU reaction	Integrator to decide action	
	Reset conditions	After fault disappeared, FAULTR register read for OLOFF bit clearance	

6.2.3 Overvoltage (OV)

Table 19. Overvoltage detection

Overvoltage detection	Description of safety mechanism	On V_{PWR}, voltage is over the range specified for overvoltage	SM12
	Device reaction	Device status flag raised on Quick status register and overvoltage flag raised on device status register	FG14
	MCU reaction	Integrator to decide action	
	Reset conditions	After fault disappeared, a read command of the device status register must be performed	

6.2.4 External clock fail (CLOCK_Fail)

Table 20. Clock fail detection

Clock fail detection	Description of safety mechanism	When the device operates in PWM, if external clock is disconnected or out of the f_{CLK} frequency range	SM13
	Device reaction	If Output channel ON bit is set to 1, the output will be turned 100 % ON	
		If Output channel ON bit is set to 0, the output will be kept OFF	
		CLKF bit raised in Device status register	FG2
	MCU reaction	Integrator to decide action	
	Reset conditions	After fault disappeared, read device status register for CLKF bit clearance	

6.2.5 Overtemperature warning (OTW)

Table 21. Overtemperature warning detection

Overtemperature warning detection	Description of safety mechanism	For each channel, detection of temperature over T_{OTW1} or T_{OTW2} (depending on OTW SEL configuration)	SM14
	Device reaction	QSFx bit raised on Device status register for corresponding output channel and OTW bit raised Output status register	FG1 & FG9
	MCU reaction	Integrator to decide action	
	Reset conditions	After temperature < $T_{OT}x$, Channel status read for bit clearance	

6.2.6 Output channel state

Table 22. Output channel state detection

Output channel state detection	Description of safety mechanism	On each channel, detection of channel output state and report into register. Allows diagnosis if channel is short circuited to V_{PWR} when channel is off state	SM15
	Device reaction	OUTx bit raised into I/O status register	FG15
	MCU reaction	Integrator to decide action	
	Reset conditions	None	

6.2.7 Input channel state

Table 23. Input channel state detection

Input channel state detection	Description of safety mechanism	Each device input (INx or LIMP) is monitored and reported into register after t_{IN_DGL} permanent state on signal	SM16
	Device reaction	INx or iLIMP bit raised into I/O status register. TOGGLE bit is a logic OR of INx pins	FGD, FG11 & FG16
	MCU reaction	Integrator to decide action	
	Reset conditions	None	

6.2.8 Output current value and SYNCB

Table 24. Output current value & SYNCB detection

Output current value & SYNCB detection	Description of safety mechanism	For each channel, current recopy of output channel current can be multiplexed on CSNS pin, SYNCB pin allows user to trig the measurement when output is running in PWM	SM17
	Device reaction	None	None
	MCU reaction	Integrator to decide action	
	Reset conditions	None	

6.2.9 Device temperature

Table 25. Device temperature detection

Device temperature detection	Description of safety mechanism	Control die temperature (not Power die temperature) is reported through the CSNS pin	SM18
	Device reaction	None	None
	MCU reaction	Integrator to decide action	
	Reset conditions	None	

6.2.10 Supply voltage

Table 26. Supply voltage detection

Device supply voltage detection	Description of safety mechanism	The analog supply voltage of the device can be reflected in the CSNS pin	SM19
	Device reaction	None	None
	MCU reaction	Integrator to decide action	
	Reset conditions	None	

6.2.11 Register read

Table 27. Register read

Register read	Description of safety mechanism	Register read reports data register and SO state	SM20
	Device reaction	Reports on SO in register contents upon register read request	
	MCU reaction	Integrator to decide action	
	Reset conditions	None	

6.3 Detection time and reaction time

The *fault detection time* is the maximum deglitch time for detection of a fault or a diagnostic and its report into the SPI registers. After this timing, the device will activate the reaction.

The *fault detection time* is the maximum time needed to put the device in a safe configuration with outputs turned off.

The Turn Off in case of fault is not achieved through a regular turn off with edge shaping but with the fast turn off (FTO) feature.

6.3.1 Detection and shutdown time along with the different fault types

The fault detection time varies according to the type of fault:

- Overtemperature shutdown
- Charge pump failure
- Overcurrent, short-circuit, severe short-circuit and overcurrent On demand
- Open load in ON (with configurable deglitch time) and OFF state

The following table details the fault detection times for the different fault types.

Table 28. Fault detection times along with the different fault types

Characteristic	Min.	Typ.	Max.	Unit
Fault detection time				
OCLO and OCHI OD	1.0	2.0	3.0	µs
OCHI1:3 and SSC	1.0	2.0	3.0	
OTS	2.0	5.0	10	
UV and OV	2.0	3.5	5.5	µs
CPF	–	4.0	6.0	µs
OLOFF	2.0	3.3	5.0	
OLON with OLON DGL = 0	48	64	80	
OLON with OLON DGL = 1	1.5	2.0	2.5	ms

The fault detection time is a deglitch time required for detection to report the fault to the SPI registers and start the safety mechanisms for critical faults: Overcurrent, Overload, Overtemperature, undervoltage, charge pump failure, Open load in Off state. This fault

detection time is same for all devices of MC12XS6 family. This time is depicted in the datasheet as $t_{FAULT\ SD}$.

For these listed critical faults, the channel output is turned-off starting when fault detection time is completed. The channel output is turned off with the fast turn Off feature. This time is depicted as t_{OUTPUT} in the datasheet, t_{OUTPUT} is 4.5 µs maximum.

Figure 5 shows the total maximum time to get the MC12XS6 part into a safe condition after a fault occurs.

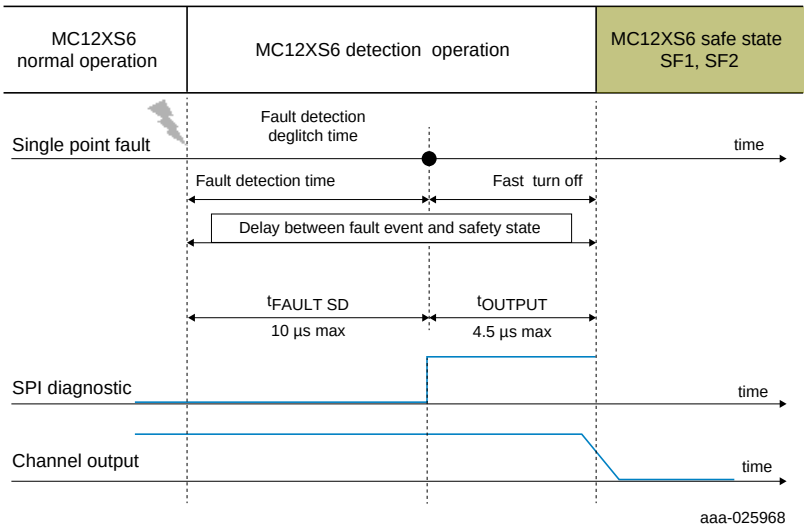


Figure 5. Reaction time to get IC in safe condition after a fault occurs

7 Operation of use and mission profile

The MC12XS6 family is used in application for which the mission profile is described in Table 29. This document is based on this mission profile, although use of MC12XS6 is not limited to these values. Mission profile may slightly differ application to application but the one used is representative of a typical automotive profile.

Table 29. Mission profile

Mission parameters	Mission profile
Junction temperature	-40 °C to 150 °C
Lifetime	15 years
Total operation time (ON)	12000 hrs.
Total sleep time (Standby)	119400 hrs.

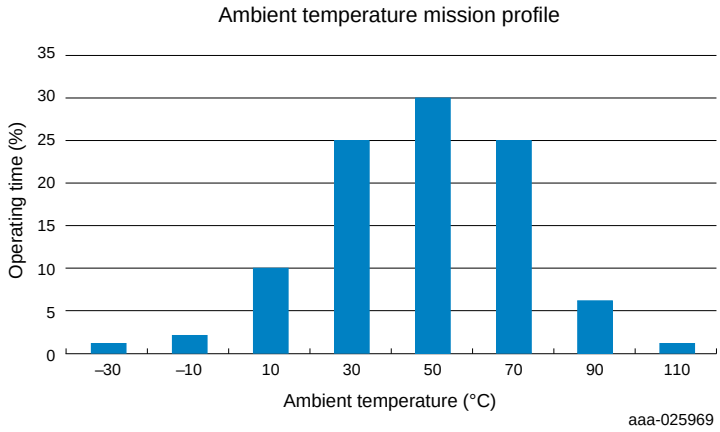


Figure 6. Temperature profile

The temperature cycles taken into account in the calculation are:

Table 30. Thermal cycling

Cycle Definition	Start temp. Of the cycle	Numb. of cycles
Night	20	670
Day	25	1340
Non Used	10	30

Global FIT rate calculation for reference MC07XS6517 (SOIC54) & MC17XS6500 (SOIC32):

The global FIT rate calculation (λ) is in accordance to the IEC/TR 62380. The standard considers the failure rate model for permanent faults in a semiconductor device to be the sum of three subcomponents:

- **Die** predictive failure rate
- **Package** predictive failure rate
- **Interface electrical overstress** predictive failure.

Table 31. FIT rate

λ	FIT
$\Lambda_{component}$ SOIC54	34.9
$\Lambda_{component}$ SOIC32	32.2

8 Revision history

Table 32. Revision history

Revision	Date	Description of changes
1.0	1/2017	Initial release

9 Legal information

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