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Dual 24 V, 20 mOhm High Side Switch

The 20XS4200 device is part of a 24 V dual high side switch product family with integrated control, and a high number of protective and diagnostic functions. It has been designed for truck, bus, and industrial applications. The low $R_{DS(ON)}$ channels (<20 m Ω) 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.

Both channels can be controlled individually by external/internal clock signals, or by direct inputs. Using the internal clock allows fully autonomous device operation. Programmable output voltage slew-rates (individually programmable) helps 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 over-current 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.

Features

- Two fully-protected 20 m Ω (@ 25 °C) high side switches
- Up to 3.0 A steady-state current per channel
- Separate bulb and DC motor latched over-current handling
- Individually programmable internal/external PWM clock signals
- Over-current, short-circuit, and over-temperature protection with programmable autoretry functions
- Accurate temperature and current sensing
- Open-load detection (channel in OFF and ON state), also for LED applications (7.0 mA typ.)
- Normal operating range: 8.0 - 36 V, extended range: 6.0 - 58 V
- 3.3 V and 5.0 V compatible 16-bit SPI port for device control, configuration and diagnostics at rates up to 8.0 MHz

20XS4200

HIGH SIDE SWITCH



ORDERING INFORMATION		
Device	Temperature Range (T _A)	Package
MC20XS4200FK	-40 to 125 °C	23 PQFN

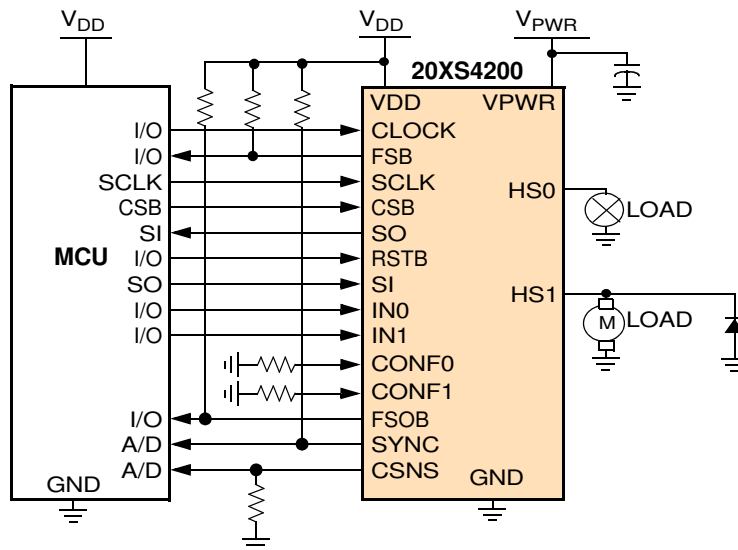


Figure 1. Simplified Application Diagram

* This document contains certain information on a new product. Specifications and information herein are subject to change without notice.

INTERNAL BLOCK DIAGRAM

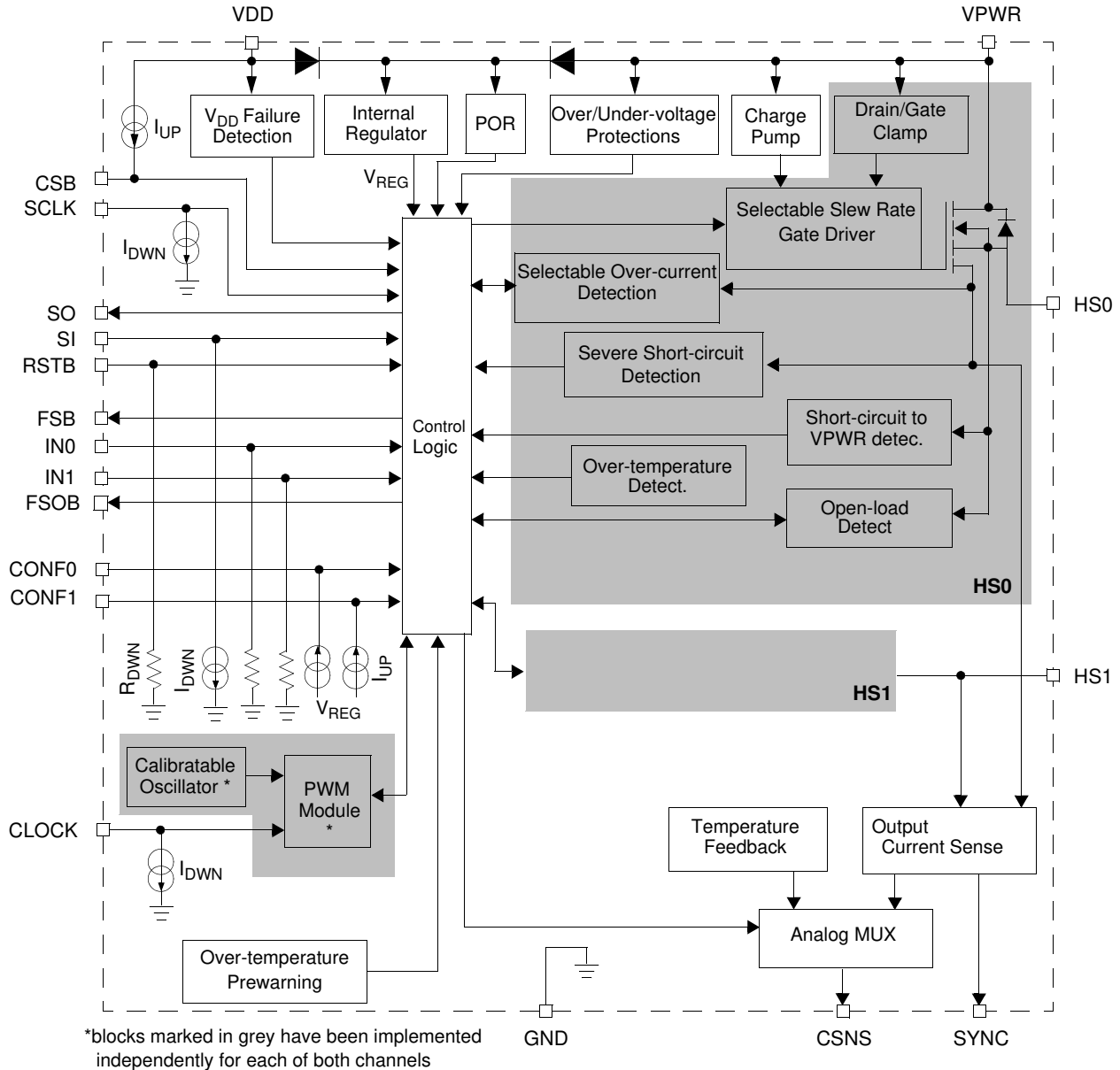


Figure 2. Internal Block Diagram

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PIN ASSIGNMENT

Transparent Top View

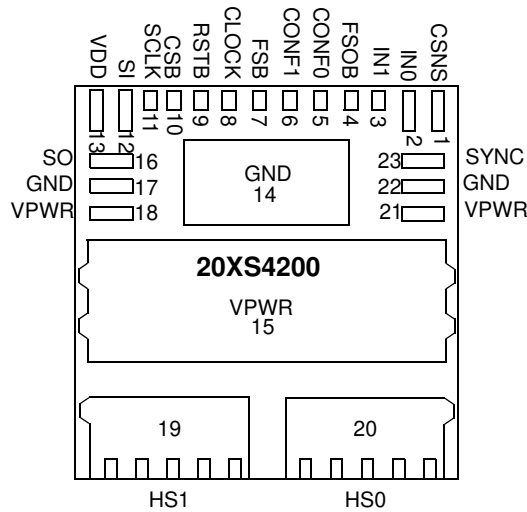


Figure 3. Device Pin Assignments

Table 1. 20XS4200 Pin Description

The function of each pin is described in the section [Functional Description](#)

Pin Number	Pin Name	Function	Formal Name	Definition
1	CSNS	Output	Output Current/ Temperature Monitoring	This pin either outputs a current proportional to the channel's output current or a voltage proportional to the temperature of the GND pin (pin 14). Selection between current and temperature sensing, as well as setting the current sensing sensitivity are performed through the SPI interface. An external pull-down resistor must be connected between CSNS and GND.
2 3	IN0 IN1	Input	Direct Inputs	The IN[0:1] input pins are used to directly control the switching state of both switches and consequently the voltage on the HS0:HS1 output pins. The pins are connected to GND by internal pull-down resistors
4	FSOB	Output	Fail-safe Output (Active Low)	FSOB is asserted (active-low) upon entering Fail-safe mode (see Functional Description) This open-drain output requires an external pull-up resistor to VPWR
5 6	CONF0 CONF1	Input	Configuration Input	The CONF[0:1] input pins are used to select the appropriate over-current detection profile (bulb/DC motor) for each of both channels. CONF requires a pull-down resistor to GND.
7	FSB	Output	Fault Status (Active Low)	This open-drain output pin (external pull-up resistor to VDD required) is set when the device enters Fault mode (see Fault Mode)
8	CLOCK	Input	PWM Clock	The clock input gives the time-base when the device is operated in external clock/internal PWM mode. This pin has an internal pull-down current source.
9	RSTB	Input	Reset	This input pin is used to initialize the device's configuration - and fault registers. Reset will put the device in Sleep mode (low current consumption) provided it is not stimulated by direct input signals. This pin is connected to GND by an internal pull-down resistor.
10	CSB	Input	Chip Select (Active Low)	This input pin is connected to the SPI chip-select output of an external micro-controller. CSB is internally pulled up to VDD by a current source I _{UP} .

Table 1. 20XS4200 Pin Description (continued)

The function of each pin is described in the section [Functional Description](#)

Pin Number	Pin Name	Function	Formal Name	Definition
11	SCLK	Input	Serial Clock	This input pin is to be connected to an external SPI Clock signal. The SCLK pin is internally connected to a pull-down current source I_{DWN}
12	SI	Input	Serial Input	This input pin receives the SPI input data from an external device (micro-controller or another extreme switch device in case of daisy-chaining). The SI pin is internally connected to a pull-down current source I_{DWN}
13	VDD	Power	Digital Drain Voltage	This is the positive supply pin of the SPI interface.
16	SO	Output	Serial Output	This output pin transmits SPI data to an external device (external micro-controller or the SI pin of the next SPI device in case of daisy-chaining). The pin doesn't require external pull-up or pull-down resistors, but a series resistor is recommended to limit current consumption in case of GND disconnection
14, 17, 22	GND	Ground	Ground	These pins, internally connected, are the ground pins for the logic - and analog circuitry. It is recommended to also connect these pins on the PCB.
15,18,21	VPWR	Power	Positive Power Supply	These pins, internally connected, supply both the device's power and control circuitry (except the SPI port). The drain of both internal MOSFET switches is connected to them. Pin 15 is the device's primary thermal pad.
19 20	HS1 HS0	Output	Power Switch Outputs	Output pins of the switches, to be connected to the load.
23	SYNC	Output	Output Current Monitoring Synchronization	This output pin is asserted (active low) when the Current Sense (CS) output signal is within the specified accuracy range. Reading the SYNC pin allows the external micro-processor to synchronize to the device when operating in autonomous operating mode. SYNC is open-drain and requires a pull-up resistor to VDD.

ELECTRICAL CHARACTERISTICS

MAXIMUM RATINGS

Table 2. Maximum Ratings

All voltages are relative to ground unless mentioned otherwise. Exceeding these ratings may cause permanent damage.

Parameter	Symbol	Maximum ratings	Unit
ELECTRICAL RATINGS			
VPWR Supply Voltage Range Load Dump at 25 °C (500 ms) Reverse Battery at 25 °C (2 min.) Fast Negative Transient Pulses (ISO 7637-2 pulse #1, V _{PWR} =14 V & Ri=10 Ω)	V _{PWR}	58 -28 -60	V
VDD Supply Voltage Range	V _{DD}	-0.3 to 5.5	V
Voltage on Input pins ⁽⁶⁾ (except IN[0:1]) and Output pins ⁽⁷⁾ (except HS[0:1])	V _{MAX,LOGIC} ⁽⁶⁾	-0.3 to 5.5	V
Voltage on Fail-safe Output (FSOB)	V _{FSO}	-0.3 to 58	V
Voltage on SO pin	V _{SO}	-0.3 to V _{DD} +0.3	V
Voltage (continuous, max. allowable) on IN[0:1] Inputs	V _{IN,MAX}	58	V
Voltage (continuous, max. allowable) on output pins (HS [0:1]),	V _{HS[0:1]}	-28 to 58	V
Rated Continuous Output Current per channel ⁽¹⁾	I _{HS[0:1]}	3.0	A
Maximum allowable energy dissipation per channel and two parallel channels, single-pulse method ⁽²⁾	E _{CL[0:1]_SING}	90	mJ
Maximum allowable energy dissipation per channel and two parallel channels, repetitive-pulses condition. 1 ⁽³⁾	E _{CL[0:1]_REP1}	> 65	mJ
Maximum allowable energy dissipation per channel and two parallel channels, repetitive-pulses condition. 2 ⁽⁴⁾	E _{CL[0:1]_REP2}	> 65	mJ
ESD Voltage ⁽⁵⁾ Human Body Model (HBM) for HS[0:1], VPWR and GND Human Body Model (HBM) for other pins Charge Device Model (CDM) Package Corner pins (1, 13, 19, 20) All Other pins	V _{ESD1} V _{ESD2} V _{ESD3} V _{ESD4}	±8000 ±2000 ±750 ±500	V

Notes:

- Output current rating valid as long as maximum junction temperature is not exceeded. For computation of the maximum allowable output current, the thermal resistance of the package & the underlying heatsink must be taken into account
- Single pulse Energy dissipation, Single-pulse short-circuit method (L_L = 2.0 mH, R = 30 mΩ V_{PWR} = 28 V, T_J = 150°C initial).
- Dissipation during repetitive cycles: switch off upon short-circuit (L_L = 20 μH, R = 200 mΩ, V_{PWR} = 28 V, T_J = 125 °C initial, f_S<2.0 Hz).
- Dissipation during repetitive cycles: switch off upon short-circuit (L_L = 40 μH, R = 400 mΩ, V_{PWR} = 28 V, T_J = 125 °C initial, f_S<2.0 Hz).
- ESD testing is performed in accordance with the Human Body Model (HBM) (C_{ZAP} = 100 pF, R_{ZAP} = 1500 Ω), and the Charge Device Model (CDM), Robotic (C_{ZAP} = 4.0 pF).
- Concerned Input pins are: CONF[0:1], RSTB, SI, SCLK, Clock, and CSB.
- Concerned Output pins are: CSNS, SYNC, and FSB.

Table 2. Maximum Ratings (continued)

All voltages are relative to ground unless mentioned otherwise. Exceeding these ratings may cause permanent damage.

Parameter	Symbol	Maximum ratings	Unit
THERMAL RATINGS			
Operating Temperature			°C
Ambient	T_A	-40 to 125	
Junction	T_J	-40 to 150	
Storage Temperature	T_{STG}	-55 to 150	°C
Thermal Resistance Junction to Case Bottom / VPWR Flag Surface	$R_{\theta JC}$	0.32	°C/W
Peak package reflow temperature during reflow ^{(8),(9)}	T_{PPRT}	Note 9	°C

Notes:

- Pin soldering temperature limit is for 40 seconds maximum duration. Not designed for immersion soldering. Exceeding these limits may cause malfunction or permanent damage to the device.
- Freescale's Package Reflow capability meets Pb-free requirements for JEDEC standard J-STD-020. For Peak Package Reflow Temperature and Moisture Sensitivity Levels (MSL), Go to www.freescale.com, search by part number [e.g. remove prefixes/suffixes and enter the core ID to view all orderable parts. (i.e. MC33xxx enter 33xxx), and review parametrics.

STATIC ELECTRICAL CHARACTERISTICS

Table 3. Static Electrical Characteristics

Unless specified otherwise: $8.0\text{ V} \leq V_{PWR} \leq 36\text{ V}$, $3.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$, $-40\text{ }^\circ\text{C} \leq T_A \leq 125\text{ }^\circ\text{C}$, $\text{GND} = 0\text{ V}$. Typical values are average values evaluated under nominal conditions $T_A = 25\text{ }^\circ\text{C}$, $V_{PWR} = 28\text{ V}$ & $V_{DD} = 5.0\text{ V}$, unless specified otherwise.

Parameter	Symbol	Min	Typ	Max	Unit
SUPPLY ELECTRICAL CHARACTERISTICS					
Supply Voltage Range: Full Specification compliant Extended Mode ⁽¹⁰⁾	V_{PWR}	8.0 6.0	24 –	36 58	V
V_{PWR} Supply Current, device in wake-up mode, channel On, open-load Outputs in ON-state, HS[0:1] open, IN[0:1] > V_{IH}	$I_{PWR(ON)}$	–	6.5	8.0	mA
V_{PWR} Supply Current, device in wake-up mode (Standby), channel Off open-load in OFF-state detection disabled, HS[0:1] shorted to ground with $V_{DD} = 5.5\text{ V}$ and $\text{RSTB} > V_{WAKE}$	$I_{PWR(SBY)}$	–	6.5	8.0	mA
Sleep State Supply Current $V_{PWR} = 24\text{ V}$, $\text{RSTB} = \text{IN}[0:1] < V_{WAKE}$, HS[0:1] connected to ground $T_A = 25\text{ }^\circ\text{C}$ $T_A = 125\text{ }^\circ\text{C}$	$I_{PWR(SLEEP)}$	– –	3.0 –	10.0 60.0	μA
V_{DD} Supply Voltage	$V_{DD(ON)}$	3.0	–	5.5	V
V_{DD} Supply Current at $V_{DD} = 5.5\text{ V}$ No SPI Communication 8.0 MHz SPI Communication ⁽¹¹⁾	$I_{DD(ON)}$	– –	– 5.0	2.2 –	mA
V_{DD} Sleep State Current at $V_{DD} = 5.5\text{ V}$ with or without V_{PWR}	$I_{DD(SLEEP)}$	–	–	5.0	μA
Over-voltage Shutdown Threshold	$V_{PWR(OV)}$	39	42	45.5	V
Over-voltage Shutdown Hysteresis	$V_{PWR(OVHYS)}$	0.2	0.8	1.5	V
Under-voltage Shutdown Threshold ⁽¹²⁾	$V_{PWR(UV)}$	5.0	–	6.0	V
V_{PWR} Power-On-Reset (POR) Voltage Threshold ⁽¹²⁾	$V_{PWR(POR)}$	2.2	2.6	4.0	V
V_{DD} Power-On-Reset (POR) Voltage Threshold ⁽¹²⁾	$V_{DD(POR)}$	1.5	2.0	2.5	V
V_{DD} Supply Failure Voltage Threshold (assumed $V_{PWR} > V_{PWR(UV)}$)	$V_{DD(FAIL)}$	2.2	2.5	2.8	V

Notes

- In extended mode, availability of several device functions (channel control, value of $R_{DS(ON)}$, over-temperature protection) is guaranteed, but compliance with the specified values in this document is not. Below 6.0 V, the device is only protected from overheating (thermal shutdown). Above $V_{PWR(OV)}$, the channels can only be turned ON when the over-voltage detection function has been disabled.
- Typical value guaranteed per design.
- When the device recovers from under-voltage and returns to normal mode ($6.0\text{ V} < V_{PWR} < 58\text{ V}$) before the end of the auto-retry period (see [Auto-retry](#)), the device will perform normally. When V_{PWR} drops below $V_{PWR(UV)}$, under-voltage is detected (see [Under-voltage Fault \(Latchable Fault\)](#) and [EMC Performances](#)).

Table 3. Static Electrical Characteristics (continued)

Unless specified otherwise: $8.0\text{ V} \leq V_{PWR} \leq 36\text{ V}$, $3.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$, $-40\text{ }^\circ\text{C} \leq T_A \leq 125\text{ }^\circ\text{C}$, $\text{GND} = 0\text{ V}$. Typical values are average values evaluated under nominal conditions $T_A = 25\text{ }^\circ\text{C}$, $V_{PWR} = 28\text{ V}$ & $V_{DD} = 5.0\text{ V}$, unless specified otherwise.

Parameter	Symbol	Min	Typ	Max	Unit
ELECTRICAL CHARACTERISTICS OF THE OUTPUT STAGE (HS0 AND HS1)					
ON-Resistance, Drain-to-Source ($I_{HS} = 3.0\text{ A}$, $T_J = 25\text{ }^\circ\text{C}$) CSNS_ratio = 0 $V_{PWR} = 8.0\text{ V}$ $V_{PWR} = 28\text{ V}$ $V_{PWR} = 36\text{ V}$	$R_{DS(ON)25_0}$	– – –	– – –	20 20 20	m Ω
ON-Resistance, Drain-to-Source ($I_{HS} = 1.0\text{ A}$, $T_J = 25\text{ }^\circ\text{C}$) CSNS_ratio = 1 $V_{PWR} = 8.0\text{ V}$ $V_{PWR} = 28\text{ V}$ $V_{PWR} = 36\text{ V}$	$R_{DS(ON)25_1}$	– – –	– – –	20 20 20	m Ω
ON-Resistance, Drain-to-Source ($I_{HS} = 3.0\text{ A}$, $T_J = 150\text{ }^\circ\text{C}$) CSNS_ratio = 0 $V_{PWR} = 8.0\text{ V}$ $V_{PWR} = 28\text{ V}$ $V_{PWR} = 36\text{ V}$	$R_{DS(ON)150_0}$	– – –	– – –	36 36 36	m Ω
ON-Resistance, Drain-to-Source ($I_{HS} = 1.0\text{ A}$, $T_J = 150\text{ }^\circ\text{C}$) CSNS_ratio = 1 $V_{PWR} = 8.0\text{ V}$ $V_{PWR} = 28\text{ V}$ $V_{PWR} = 36\text{ V}$	$R_{DS(ON)150_1}$	– – –	– – –	36 36 36	m Ω
ON-Resistance, Drain-to-Source difference from one channel to the other in parallel mode ($I_{HS} = 1.0\text{ A}$, $T_J = 150\text{ }^\circ\text{C}$) CSNS_ratio = X	$\Delta R_{DS(ON)150}$	-0.9	–	+0.9	m Ω
ON-Resistance, Source-Drain ($I_{HS} = -3.0\text{ A}$, $T_J = 150\text{ }^\circ\text{C}$, $V_{PWR} = -24\text{ V}$)	$R_{SD(ON)150}$	–	–	36	m Ω
Max. detectable wiring length (2.5 mm ²) for severe short-circuit detection (see Severe Short-circuit Fault (latchable fault)): High slew rate selected Medium slew rate selected: Low slew rate selected:	L_{SHORT}	50 100 200	130 260 500	300 600 1200	cm
Over-current Detection thresholds with CSNS_ratio bit = 0 (CSR0)	I_{OCH1_0} I_{OCH2_0} I_{OCM1_0} I_{OCM2_0} I_{OCL1_0} I_{OCL2_0} I_{OCL3_0}	27.5 17.5 10.8 6.7 4.5 3.0 1.5	33.0 21.0 13.0 8.0 5.4 3.6 1.8	38.5 24.5 15.2 9.3 6.3 4.2 2.1	A

Table 3. Static Electrical Characteristics (continued)

Unless specified otherwise: $8.0\text{ V} \leq V_{PWR} \leq 36\text{ V}$, $3.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$, $-40\text{ }^\circ\text{C} \leq T_A \leq 125\text{ }^\circ\text{C}$, $\text{GND} = 0\text{ V}$. Typical values are average values evaluated under nominal conditions $T_A = 25\text{ }^\circ\text{C}$, $V_{PWR} = 28\text{ V}$ & $V_{DD} = 5.0\text{ V}$, unless specified otherwise.

Parameter	Symbol	Min	Typ	Max	Unit
ELECTRICAL CHARACTERISTICS OF THE OUTPUT STAGE (HS0 AND HS1) (CONTINUED)					
Over-current Detection thresholds with CSNS_ratio bit = 1(CSR1)	I_{OCH1_1}	9.2	11.0	12.8	A
	I_{OCH2_1}	5.8	7.0	8.2	
	I_{OCM1_1}	3.6	4.3	5.1	
	I_{OCM2_1}	2.2	2.7	3.1	
	I_{OCL1_1}	1.5	1.8	2.1	
	I_{OCL2_1}	1.0	1.2	1.4	
	I_{OCL3_1}	0.48	0.6	0.72	
Output (HS[x]) leakage Current in sleep state (positive value = outgoing) $V_{HS,OFF} = 0\text{ V}$ ($V_{HS,OFF}$ = output voltage in OFF state) $V_{HS,OFF} = V_{PWR}$, device in sleep state ($V_{PWR} = 24\text{ V max.}$)	I_{OUT_LEAK}	–	–	+5.0	μA
		-40.0	–	+5.0	
Switch Turn-on threshold for Supply over-voltage (V_{PWR} -GND)	$V_{D_GND(CLAMP)}$	58	–	66	V
Switch turn-on threshold for Drain-Source over-voltage (measured at $I_{OUT} = 500\text{ mA}$)	$V_{DS(CLAMP)}$	58	–	66	V
Switch turn-on threshold for Drain-Source over-voltage difference from one channel to the other in parallel mode (@ $I_{HS} = 500\text{ mA}$)	$\Delta V_{DS(CLAMP)}$	-2.0	–	+2.0	V
Current Sensing Ratio ⁽¹³⁾ CSNS_ratio bit = 0 (high current mode) CSNS_ratio bit = 1 (low current mode)	C_{SR0} C_{SR1}	– –	1/1500 1/500	– –	–
Minimum measurable load current with compensated error ⁽¹⁴⁾	I_{LOAD_MIN}	–	–	50	mA
CSNS leakage current in OFF state ($\text{CSNS}_x\text{_en} = 0$, $\text{CSNS_ratio_bit}_x = 0$)	I_{CSR_LEAK}	-4.0	–	+4.0	μA
Systematic offset error (see Current Sense Errors)	$I_{LOAD_ERR_SYS}$	–	5.5	–	mA
Random offset error	$I_{LOAD_ERR_RAND}$	-125	–	125	mA

Notes:

- Current Sense Ratio $C_{SRx} = I_{CSNS} / (I_{HS[x]} + I_{LOAD_ERR_SYS})$
- See note ⁽¹⁵⁾, but with I_{CSNS_MEAS} obtained after compensation of $I_{LOAD_ERR_RAND}$ (see [Activation and Use of Offset Compensation](#)). Further accuracy improvements can be obtained by performing a 1- or 2 point calibration (see Application Note)
- $E_{SRx_ERR} = (I_{CSNS_MEAS} / I_{CSNS_MODEL}) - 1$, with $I_{CSNS_MODEL} = (I_{HS[x]} + I_{LOAD_ERR_SYS}) * C_{SRx}$, ($I_{LOAD_ERR_SYS}$ defined above, see section [Current Sense Error Model](#)). With this model, load current becomes: $I_{HS[x]} = I_{CSNS} / C_{SRx} - I_{LOAD_ERR_SYS}$

Table 3. Static Electrical Characteristics (continued)

Unless specified otherwise: $8.0\text{ V} \leq V_{PWR} \leq 36\text{ V}$, $3.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$, $-40\text{ }^\circ\text{C} \leq T_A \leq 125\text{ }^\circ\text{C}$, $\text{GND} = 0\text{ V}$. Typical values are average values evaluated under nominal conditions $T_A = 25\text{ }^\circ\text{C}$, $V_{PWR} = 28\text{ V}$ & $V_{DD} = 5.0\text{ V}$, unless specified otherwise.

Parameter	Symbol	Min	Typ	Max	Unit
ELECTRICAL CHARACTERISTICS OF THE OUTPUT STAGE (HS0 AND HS1) (CONTINUED)					
E_{SR0} Output Current Sensing Error (% , uncompensated ⁽¹⁶⁾) at output Current level (Sense ratio C_{SR0} selected):	E_{SR0_ERR}				%
$T_J = -40\text{ }^\circ\text{C}$					
3.0 A		-13	–	13	
1.5 A		-12	–	12	
0.75 A		-17	–	17	
0.375 A		-31	–	31	
$T_J = 125\text{ }^\circ\text{C}$					
3.0 A		-10	–	10	
1.5 A		-9.0	–	9.0	
0.75 A		-12	–	12	
0.375 A		-19	–	19	
$T_J = 25\text{ to }125\text{ }^\circ\text{C}$					
3.0 A		-10	–	10	
1.5 A		-9.0	–	9.0	
0.75 A		-12	–	12	
0.375 A		-22	–	22	
E_{SR0} Output Current Sensing Error (% after offset compensation ⁽¹⁶⁾) at output Current level (Sense ratio C_{SR0} selected):	$E_{SR0_ERR(Comp)}$				%
$T_J = -40\text{ }^\circ\text{C}$					
3.0 A		-10	–	10	
1.5 A		-10	–	10	
0.75 A		-10	–	10	
0.375 A		-10	–	10	
$T_J = 125\text{ }^\circ\text{C}$					
3.0 A		-9.0	–	9.0	
1.5 A		-8.0	–	8.0	
0.75 A		-8.0	–	8.0	
0.375 A		-9.0	–	9.0	
$T_J = 25\text{ to }125\text{ }^\circ\text{C}$					
3.0 A		-9.0	–	9.0	
1.5 A		-8.0	–	8.0	
0.75 A		-8.0	–	8.0	
0.375 A		-9.0	–	9.0	

Notes:

16. $E_{SRx_ERR} = (I_{CSNS_MEAS} / I_{CSNS_MODEL}) - 1$, with $I_{CSNS_MODEL} = (I(HS[x]) + I_{LOAD_ERR_SYS}) * C_{SRx}$, ($I_{LOAD_ERR_SYS}$ defined above, see section [Current Sense Error Model](#)). With this model, load current becomes: $I(HS[x]) = I_{CSNS} / C_{SRx} - I_{LOAD_ERR_SYS}$

Table 3. Static Electrical Characteristics (continued)

Unless specified otherwise: $8.0\text{ V} \leq V_{PWR} \leq 36\text{ V}$, $3.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$, $-40\text{ }^\circ\text{C} \leq T_A \leq 125\text{ }^\circ\text{C}$, $\text{GND} = 0\text{ V}$. Typical values are average values evaluated under nominal conditions $T_A = 25\text{ }^\circ\text{C}$, $V_{PWR} = 28\text{ V}$ & $V_{DD} = 5.0\text{ V}$, unless specified otherwise.

Parameter	Symbol	Min	Typ	Max	Unit
ELECTRICAL CHARACTERISTICS OF THE OUTPUT STAGE (HS0 AND HS1) (CONTINUED)					
E_{SR1} Output Current Sensing Error (% , uncompensated ⁽¹⁷⁾) at output Current level (Sense ratio C_{SR1} selected): $T_J = -40\text{ }^\circ\text{C}$ 0.75 A $T_J = 125\text{ }^\circ\text{C}$ 0.75 A $T_J = 25\text{ to }125\text{ }^\circ\text{C}$ 0.75 A	E_{SR1_ERR}	-15 -12 -12	- - -	15 12 12	%
E_{SR1} Output Current Sensing Error (% after offset compensation ⁽¹⁸⁾) at output Current level (Sense ratio C_{SR1} selected): $T_J = -40\text{ }^\circ\text{C}$ 0.75 A 0.25 A 0.125 A 0.075 A $T_J = 125\text{ }^\circ\text{C}$ 0.75 A 0.25 A 0.125 A 0.075 A $T_J = 25\text{ to }125\text{ }^\circ\text{C}$ 0.75 A 0.25 A 0.125 A 0.075 A	$E_{SR1_ERR(Comp)}$	-10 -11 -18 -29 -8.0 -10 -12 -16 -8.0 -10 -13 -21	- - - - - - - - - - - -	10 11 18 29 8.0 10 12 16 8.0 10 13 21	%
E_{SR0} Output Current Sensing Error in parallel mode (% , uncompensated ⁽¹⁹⁾) at outputs Current level (Sense ratio C_{SR0} selected): $T_J = -40\text{ }^\circ\text{C}$ 6.0 A 3.0 A $T_J = 125\text{ }^\circ\text{C}$ 6.0 A 3.0 A $T_J = 25\text{ to }125\text{ }^\circ\text{C}$ 6.0 A 3.0 A	$E_{SR0_ERR_PAR}$	-10 -11 -8.0 -8.0 -8.0 -8.0	- - - - - -	10 11 8.0 8.0 8.0 8.0	%

Notes:

- $E_{SRx_ERR} = (I_{CSNS_MEAS} / I_{CSNS_MODEL}) - 1$, with $I_{CSNS_MODEL} = (I(HS[x]) + I_{LOAD_ERR_SYS}) * C_{SRx}$, ($I_{LOAD_ERR_SYS}$ defined above, see section [Current Sense Error Model](#)). With this model, load current becomes: $I(HS[x]) = I_{CSNS} / C_{SRx} - I_{LOAD_ERR_SYS}$
- See note ⁽²⁰⁾, but with I_{CSNS_MEAS} obtained after compensation of $I_{LOAD_ERR_RAND}$ (see [Activation and Use of Offset Compensation](#)). Further accuracy improvements can be obtained by performing a 1- or 2 point calibration
- Minimum required value of Open-load impedance for detection of Open-load in OFF-state: $200\text{ k}\Omega$. ($V_{OLD(THRES)} = V_{HS} @ I_{OLD(OFF)}$)

Table 3. Static Electrical Characteristics (continued)

Unless specified otherwise: $8.0\text{ V} \leq V_{PWR} \leq 36\text{ V}$, $3.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$, $-40\text{ }^\circ\text{C} \leq T_A \leq 125\text{ }^\circ\text{C}$, $\text{GND} = 0\text{ V}$. Typical values are average values evaluated under nominal conditions $T_A = 25\text{ }^\circ\text{C}$, $V_{PWR} = 28\text{ V}$ & $V_{DD} = 5.0\text{ V}$, unless specified otherwise.

Parameter	Symbol	Min	Typ	Max	Unit
ELECTRICAL CHARACTERISTICS OF THE OUTPUT STAGE (HS0 AND HS1) (CONTINUED)					
Current Sense Clamping Voltage (condition: $R(\text{CSNS}) > 10\text{ k}\Omega$)	$V_{CL(\text{CSNS})}$	5.5	–	7.5	V
Open-load detection Current threshold in OFF state ⁽²⁰⁾	$I_{\text{OLD}(\text{OFF})}$	30	–	100	μA
Open-load Fault Detection Voltage Threshold ⁽²⁰⁾	$V_{\text{OLD}(\text{THRES})}$	4.0	–	5.5	V
Open-load detection Current threshold in ON state (see Open-Load Detection In On State (OL_ON)): CSNS_ratio bit = 0 CSNS_ratio bit = 1 (fast slew rate $\text{SR}[1:0] = 10$ mandatory for this function)	$I_{\text{OLD}(\text{ON})}$	60 5.0	150 7.0	300 10	mA
Time period of the periodically activated open-load in ON state detection for CSNS_ratio bit = 1	t_{OLLED}	105	150	195	ms
Output Shorted-to- V_{PWR} Detection Voltage Threshold (channel in OFF state)	$V_{\text{OSD}(\text{THRES})}$	$V_{PWR}-1.2$	$V_{PWR}-0.8$	$V_{PWR}-0.4$	V
Switch turn-on threshold for Negative Output Voltages (protects against negative transients) - (measured at $I_{\text{OUT}} = 100\text{mA}$, Channel in OFF state)	V_{CL}	-35	–	-24	V
Switch turn-on threshold for Negative Output Voltages difference from one channel to the other in parallel mode - (measured at $I_{\text{OUT}} = 100\text{mA}$, Channel in OFF state)	ΔV_{CL}	-2.0	–	+2.0	V
Switching State (On/Off) discrimination thresholds	$V_{\text{HS_TH}}$	$0.45 \cdot V_{PWR}$	$0.5 \cdot V_{PWR}$	$0.55 \cdot V_{PWR}$	V
Shutdown temperature (Power MOSFET junction; $6.0\text{ V} < V_{PWR} < 58\text{ V}$)	T_{SD}	160	175	190	$^\circ\text{C}$

Notes:

20. Minimum required value of Open-load impedance for detection of Open-load in OFF-state: $200\text{ k}\Omega$. ($V_{\text{OLD}(\text{THRES})} = V_{\text{HS}} @ I_{\text{OLD}(\text{OFF})}$)

Table 3. Static Electrical Characteristics (continued)

Unless specified otherwise: $8.0\text{ V} \leq V_{PWR} \leq 36\text{ V}$, $3.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$, $-40\text{ }^\circ\text{C} \leq T_A \leq 125\text{ }^\circ\text{C}$, $\text{GND} = 0\text{ V}$. Typical values are average values evaluated under nominal conditions $T_A = 25\text{ }^\circ\text{C}$, $V_{PWR} = 28\text{ V}$ & $V_{DD} = 5.0\text{ V}$, unless specified otherwise.

Parameter	Symbol	Min	Typ	Max	Unit
ELECTRICAL CHARACTERISTICS OF THE CONTROL INTERFACE PINS					
Logic Input Voltage, High ⁽²¹⁾	V_{IH}	2.0	–	5.5	V
Logic Input Voltage, Low ⁽²¹⁾	V_{IL}	-0.3	–	0.8	V
Wake-up Threshold Voltage (IN[0:1] and RSTB) ⁽²²⁾	V_{WAKE}	1.0	–	2.2	V
Internal Pull-down Current Source (on Inputs: CLOCK, SCLK and SI) ⁽²³⁾	I_{DWN}	5.0	–	20	μA
Internal Pull-up Current Source (input CSB) ⁽²⁴⁾	I_{UP_CSB}	5.0	–	20	μA
Internal Pull-up Current Source (input CONF[0:1]) ⁽²⁵⁾	I_{UP_CONF}	25	–	100	μA
Capacitance of SO, FSB and FSOB pins in Tri-state	C_{SO}	–	–	20	pF
Internal Pull-down Resistance (RSTB and IN[0:1])	R_{DWN}	125	250	500	$\text{k}\Omega$
Input Capacitance ⁽²⁶⁾	C_{IN}	–	4.0	12	pF
SO High-state Output Voltage ($I_{OH} = 1.0\text{ mA}$)	V_{SOH}	$V_{DD}-0.4$	–	–	V
SYNC, SO, FSOB and FSB Low-state Output Voltage ($I_{OL} = -1.0\text{ mA}$)	V_{SOL}	–	–	0.4	V
SYNC, SO, CSNS, FSOB and FSB Tri-state Leakage Current: $\bar{I}_{SO(LEAK)}$ ($0.0\text{ V} < V(\text{SO}) < V_{DD}$, or $V(\text{FS})$ or $V(\text{SYNC}) = 5.5\text{ V}$, or $V(\text{FSO}) = 36\text{ V}$ or $V(\text{CSNS}) = 0.0\text{ V}$)	$I_{SO(LEAK)}$	-2.0	0.0	2.0	μA
CONF[0:1]: Required values of the External Pull-down Resistor - Lighting applications - DC motor applications	R_{CONF}	1.0 50	– –	10 Infinite	$\text{k}\Omega$

Notes

21. High and low voltage ranges apply to SI, CSB, SCLK, RSTB, IN[0:1] and CLOCK input signals. The IN[0:1] signals may be derived from V_{PWR} and can tolerate voltages up to 58 V.
22. Voltage above which the device will wake-up
23. Valid for $V_{SI} \geq 0.8\text{ V}$ and $V_{SCLK} \geq 0.8\text{ V}$ and $V_{CLOCK} \geq 0.8\text{ V}$.
24. Valid for $V_{CSB} \leq 2.0\text{ V}$. CSB has an internal pull-up current source derived from V_{DD}
25. Pins CONF[0:1] are connected to an internal current source, derived from an internal voltage regulator ($V_{REG} \sim 3.0\text{ V}$).
26. Input capacitance of SI, CSB, SCLK, RSTB, IN[0:1], CONF[0:1], and CLOCK pins. This parameter is guaranteed by the manufacturing process but is not tested in production.

DYNAMIC ELECTRICAL CHARACTERISTICS

Table 4. Dynamic Electrical Characteristics

Unless specified otherwise: $8.0\text{ V} \leq V_{PWR} \leq 36\text{ V}$, $3.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$, $-40\text{ }^\circ\text{C} \leq T_A \leq 125\text{ }^\circ\text{C}$, $\text{GND} = 0\text{ V}$. Typical values are average values evaluated under nominal conditions $T_A = 25\text{ }^\circ\text{C}$, $V_{PWR} = 28\text{ V}$ & $V_{DD} = 5.0\text{ V}$, unless specified otherwise.

Parameter	Symbol	Min	Typ	Max	Unit
OUTPUT VOLTAGE SWITCHING CHARACTERISTICS					
Rising and Falling edges medium slew rate (SR[1:0] = 00) ⁽²⁷⁾ $V_{PWR} = 16\text{ V}$ $V_{PWR} = 28\text{ V}$ $V_{PWR} = 36\text{ V}$	SR _{R_00} SR _{F_00}	0.164 0.28 0.34	– – –	0.65 0.79 0.90	V/μs
Rising and Falling edges low slew rate (SR[1:0] = 01) ⁽²⁷⁾ $V_{PWR} = 16\text{ V}$ $V_{PWR} = 28\text{ V}$ $V_{PWR} = 36\text{ V}$	SR _{R_01} SR _{F_01}	0.081 0.14 0.17	– – –	0.32 0.395 0.45	V/μs
Rising and Falling edges high slew rate / SR[1:0] = 10) ⁽²⁷⁾ $V_{PWR} = 16\text{ V}$ $V_{PWR} = 28\text{ V}$ $V_{PWR} = 36\text{ V}$	SR _{R_10} SR _{F_10}	0.29 0.55 0.68	– – –	1.30 1.58 1.80	V/μs
Rising/Falling edge slew rate matching (SR _R /SR _F) $16\text{ V} < V_{PWR} < 36\text{ V}$	ΔSR	0.75	1.0	1.2	
Edge slew rate difference from one channel to the other in parallel mode ⁽²⁷⁾ $16\text{ V} < V_{PWR} < 36\text{ V}$ SR[1:0] = 00 SR[1:0] = 01 SR[1:0] = 10	ΔSR	-0.1 -0.06 -0.14	0.0 0.0 0.0	+0.1 +0.06 +0.14	V/μs
Output Turn-ON and Turn-OFF Delays (medium slew rate: SR[1:0] = 00) ⁽²⁸⁾ $16\text{ V} < V_{PWR} < 36\text{ V}$	t _{DLY_00}	32	–	128	μs
Output Turn-ON and Turn-OFF Delays (low slew rate / SR[1:0] = 01) ⁽²⁸⁾ $16\text{ V} < V_{PWR} < 36\text{ V}$	t _{DLY_01}	59	–	245	μs
Output Turn-ON and Turn-OFF Delays (high slew rate / SR[1:0] = 10) ⁽²⁸⁾ $16\text{ V} < V_{PWR} < 36\text{ V}$	t _{DLY_10}	18	–	68	μs
Turn-ON and Turn-OFF Delay time matching (t _{DLY(ON)} - t _{DLY(OFF)}) f _{PWM} = 400 Hz, $16\text{ V} < V_{PWR} < 36\text{ V}$, duty cycle on IN[x] = 50 %, SR[1:0] = 00	Δt _{RF_00}	-25	0.0	25	μs
Turn-ON and Turn-OFF Delay time matching (t _{DLY(ON)} - t _{DLY(OFF)}) f _{PWM} = 200 Hz, $16\text{ V} < V_{PWR} < 36\text{ V}$, duty cycle on IN[x] = 50 %, SR[1:0] = 01	Δt _{RF_01}	-50	0.0	50	μs

Notes

- Rising and Falling edge slew rates specified for a 20% to 80% voltage variation on a 10.0 Ω resistive load (see [Output Voltage Slew Rate and Delay](#)).
- Turn-on delay time measured as delay between a rising edge of the channel control signal (IN[0:1] = 1) and the associated rising edge of the output voltage up to: $V_{HS[0:1]} = V_{PWR} / 2$ (where $R_L = 10.0\text{ }^\circ\Omega$). Turn-OFF delay time is measured as time between a falling edge of the channel control signal (IN[0:1] = 0) and the associated falling edge of the output voltage up to the instant at which: $V_{HS[0:1]} = V_{PWR} / 2$ ($R_L = 10.0\text{ }^\circ\Omega$)

Table 4. Dynamic Electrical Characteristics (continued)

Unless specified otherwise: $8.0\text{ V} \leq V_{PWR} \leq 36\text{ V}$, $3.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$, $-40\text{ }^\circ\text{C} \leq T_A \leq 125\text{ }^\circ\text{C}$, $\text{GND} = 0\text{ V}$. Typical values are average values evaluated under nominal conditions $T_A = 25\text{ }^\circ\text{C}$, $V_{PWR} = 28\text{ V}$ & $V_{DD} = 5.0\text{ V}$, unless specified otherwise.

Parameter	Symbol	Min	Typ	Max	Unit
Turn-ON and Turn-OFF Delay time matching ($t_{DLY(ON)} - t_{DLY(OFF)}$) $f_{PWM} = 1.0\text{ kHz}$, $16\text{ V} < V_{PWR} < 36\text{ V}$, duty cycle on IN[X] = 50%, SR[1:0] = 10	Δt_{RF_10}	-13	0.0	13	μs
Delay time difference from one channel to the other in parallel mode ⁽²⁹⁾ $16\text{ V} < V_{PWR} < 36\text{ V}$ SR[1:0] = 00 SR[1:0] = 01 SR[1:0] = 10	$\Delta t_{(DLY)}$	-40 -21 -11	0.0 0.0 0.0	40 21 11	μs
Fault Detection Delay Time ⁽³⁰⁾	t_{FAULT}	–	5.0	8.0	μs
Output Shutdown Delay Time ⁽³¹⁾	t_{DETECT}	–	10.0	15.0	μs
Current sense output settling Time for SR[1:0] = 00 (medium slew rate) ⁽²⁹⁾ $16\text{ V} < V_{PWR} < 36\text{ V}$	$t_{CSNSVAL_00}$	0.0	118	235	μs
Current sense output settling Time for SR[1:0] = 01 (low slew rate) ⁽²⁹⁾ $16\text{ V} < V_{PWR} < 36\text{ V}$	$t_{CSNSVAL_01}$	0.0	185	355	μs
Current sense output settling Time for SR[1:0] = 10 (high slew rate) ⁽²⁹⁾ $16\text{ V} < V_{PWR} < 36\text{ V}$	$t_{CSNSVAL_10}$	0.0	108	205	μs
SYNC output signal delay for SR[1:0] = 00 (medium SR) ⁽²⁹⁾	$t_{SYNCVAL_00}$	50	–	150	μs
SYNC output signal delay for SR[1:0] = 01 (low SR) ⁽²⁹⁾	$t_{SYNCVAL_01}$	80	–	290	μs
SYNC output signal delay for SR[1:0] = 10 (high SR) ⁽³²⁾	$t_{SYNCVAL_10}$	24	–	80	μs
Recommended sync_to_read delay SR[1:0] = 00 (medium slew rate) ⁽²⁹⁾	$t_{SYNREAD_00}$	0.0	–	200	μs
Recommended sync_to_read delay SR[1:0] = 01 (low slew rate) ⁽²⁹⁾	$t_{SYNREAD_01}$	0.0	–	200	μs
Recommended sync_to_read delay SR[1:0] = 10 (high slew rate) ⁽²⁹⁾	$t_{SYNREAD_10}$	0.0	–	200	μs
Upper over-current threshold duration	t_{OCH1} t_{OCH2}	6.0 12.0	8.6 17.2	11.2 22.4	ms
Medium over-current threshold duration (CONF = 0; Lighting Profile)	t_{OCM1_L} t_{OCM2_L}	48 96	67 137	87 178	ms
Medium over-current threshold duration (CONF = 1; DC motor Profile)	t_{OCM1_M} t_{OCM2_M}	48 96	67 137	87 178	ms

Notes

29. Rising and Falling edge slew rates specified for a 20% to 80% voltage variation on a 10.0 Ω resistive load (see [Output Voltage Slew Rate and Delay](#)).
30. Time required to detect and report the fault to the FSB pin.
31. Time required to switch off the channel after detection of over-temperature (OT), over-current (OC), SC or UV error (time measured between start of the negative edge on the FSB pin and the falling edge on the output voltage until $V(\text{HS}[0:1]) = 50\%$ of V_{PWR}).
32. Settling time ($= t_{CSNSVAL_XX}$), SYNC output signal delay ($= t_{SYNCVAL_XX}$) and Read-out delay ($= t_{SYNREAD_XX}$) are defined for a stepped load current ($100\text{ mA} < I(\text{LOAD}) < I(\text{OCLX A FOR CSNS_RATIO_S} = 1, \text{ AND } 300\text{ mA} < I(\text{LOAD}) < I(\text{OCLX A}_0 \text{ FOR CSNS_RATIO_S} = 0)$). (see [Figure 8](#) and [Output Current Monitoring \(CSNS\)](#))

Table 4. Dynamic Electrical Characteristics (continued)

Unless specified otherwise: $8.0\text{ V} \leq V_{PWR} \leq 36\text{ V}$, $3.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$, $-40\text{ }^\circ\text{C} \leq T_A \leq 125\text{ }^\circ\text{C}$, $\text{GND} = 0\text{ V}$. Typical values are average values evaluated under nominal conditions $T_A = 25\text{ }^\circ\text{C}$, $V_{PWR} = 28\text{ V}$ & $V_{DD} = 5.0\text{ V}$, unless specified otherwise.

Parameter	Symbol	Min	Typ	Max	Unit
FREQUENCY & PWM DUTY CYCLE RANGES ⁽³⁴⁾ (protections fully operational, see Protective Functions)					
Switching Frequency range - Direct Inputs	f_{CONTROL}	0.0	–	1000	Hz
Switching Frequency range - External clock with internal PWM (recommended)	$f_{\text{PWM_EXT}}$	20	–	1000	Hz
Switching Frequency range - Internal clock with internal PWM (recommended)	$f_{\text{PWM_INT}}$	60	–	1000	Hz
Duty Cycle range	R_{CONTROL}	0.0	–	100	%
AVAILABILITY DIAGNOSTIC FUNCTIONS OVER DUTY CYCLE AND SWITCHING FREQUENCY (protections & diagnostics both fully operational, see Diagnostic Features for the exact boundary values)					
Available Duty Cycle Range, $f_{\text{PWM}} = 1.0\text{ kHz}$ high slew rate, PWM mode ⁽³⁵⁾ OL_OFF OL_ON OS	$R_{\text{PWM_1K_H}}$	0.0 35 0.0	– – –	62 100 90	%
Available Duty Cycle Range, $f_{\text{PWM}} = 400\text{ Hz}$, medium slew rate, PWM mode ⁽³⁵⁾ OL_OFF OL_ON OS	$R_{\text{PWM_400_M}}$	0.0 21 0.0	– – –	81 100 88	%
Available Duty Cycle Range, $f_{\text{PWM}} = 400\text{ Hz}$, high slew rate, PWM mode ⁽³⁵⁾ OL_OFF OL_ON OS	$R_{\text{PWM_400_H}}$	0.0 14 0.0	– – –	84 100 95	%
Available Duty Cycle Range, $f_{\text{PWM}} = 200\text{ Hz}$, low slew rate mode, PWM mode ⁽³⁵⁾ OL_OFF OL_ON OS	$R_{\text{PWM_200_L}}$	0.0 15 0.0	– – –	86 100 93	%
Available Duty Cycle Range, $f_{\text{PWM}} = 200\text{ Hz}$, medium slew rate, PWM mode ⁽³⁵⁾ OL_OFF OL_ON OS	$R_{\text{PWM_200_M}}$	0.0 11 0.0	– – –	90 100 94	%
Available Duty Cycle Range, $f_{\text{PWM}} = 100\text{ Hz}$ in low slew rate, PWM mode ⁽³⁵⁾ OL_OFF OL_ON OS	$R_{\text{PWM_100_L}}$	0.0 8.0 0.0	– – –	93 100 96	%
Deviation of the internal clock PWM frequency after Calibration ⁽³⁶⁾	$A_{\text{FPWM(CAL)}}$	-10	–	+10	%
Default output frequency when using an uncalibrated oscillator	$f_{\text{PWM(0)}}$	280	400	520	Hz
Minimal required Low Time during Calibration of the Internal Clock through CSB	$t_{\text{CSB(MIN)}}$	1.0	1.5	2.0	μs
Maximal allowed Low Time during Calibration of the Internal Clock through CSB	$t_{\text{CSB(MAX)}}$	70	100	130	μs
Recommended external Clock Frequency Range (external clock/PWM Module)	f_{CLOCK}	15	–	512	kHz
Upper detection threshold for external Clock frequency monitoring	$f_{\text{CLOCK(MAX)}}$	512	730	930	kHz
Lower detection threshold for external Clock frequency monitoring	$f_{\text{CLOCK(MIN)}}$	5.0	7.0	10	kHz

Table 4. Dynamic Electrical Characteristics (continued)

Unless specified otherwise: $8.0\text{ V} \leq V_{PWR} \leq 36\text{ V}$, $3.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$, $-40\text{ }^\circ\text{C} \leq T_A \leq 125\text{ }^\circ\text{C}$, $\text{GND} = 0\text{ V}$. Typical values are average values evaluated under nominal conditions $T_A = 25\text{ }^\circ\text{C}$, $V_{PWR} = 28\text{ V}$ & $V_{DD} = 5.0\text{ V}$, unless specified otherwise.

Parameter	Symbol	Min	Typ	Max	Unit
TIMING: SPI PORT, IN[0]/ IN[1] SIGNALS & AUTORETRY					
Required Low time allowing delatching or triggering sleep mode (direct input mode)	t_{IN}	175	250	325	ms
Watchdog Timeout for entering Fail-safe Mode due to loss of SPI contact ⁽³³⁾	t_{WDTO}	217	310	400	ms
Auto-Retry Repetition Period (when activated):					ms
Auto_period bits = 00	t_{AUTO_00}	105	150	195	
Auto_period bits = 01	t_{AUTO_01}	52.5	75	97.5	
Auto_period bits = 10	t_{AUTO_10}	26.2	37.5	47.8	
Auto_period bits = 11	t_{AUTO_11}	13.1	17.7	24.4	

Notes

- 33. Only when the WD_dis bit set to logic [0] (default). Watchdog timeout defined from the rising edge on RST to rising edge HS[0,1]
- 34. In Direct Input mode, the lower frequency limit is 0 Hz with RSTB=5.0 V and 4.0 Hz with RSTB=0.0 V. Duty-cycle applies to instants at which $V_{HS} = 50\% V_{PWR}$. For low duty-cycle values, the effective value will also depend on the value of the selected slew rate.
- 35. The device can be operated outside the specified duty cycle and frequency ranges (basic protective functions OC, SC, UV, OV, OT remain active) but the availability of the diagnostic functions OL_ON, OL_OFF, OS is affected.
- 36. Values guaranteed from 60 Hz to 1.0 kHz (recommended switching frequency range for internal clock operation).

Table 4. Dynamic Electrical Characteristics (continued)

Unless specified otherwise: $8.0\text{ V} \leq V_{PWR} \leq 36\text{ V}$, $3.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$, $-40\text{ }^\circ\text{C} \leq T_A \leq 125\text{ }^\circ\text{C}$, $\text{GND} = 0\text{ V}$. Typical values are average values evaluated under nominal conditions $T_A = 25\text{ }^\circ\text{C}$, $V_{PWR} = 28\text{ V}$ & $V_{DD} = 5.0\text{ V}$, unless specified otherwise.

Parameter	Symbol	Min	Typ	Max	Unit
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GND PIN TEMPERATURE SENSING FUNCTION

Thermal Prewarning Detection Threshold ⁽³⁷⁾	T_{OTWAR}	110	125	140	$^\circ\text{C}$
Temperature Sensing output voltage @ $T_A = 25\text{ }^\circ\text{C}$ ($470\ \Omega < R_{CSNS} < 10\text{ k}\Omega$)	T_{FEED}	918	1078	1238	mV
Gain Temperature Sensing output @ $T_A = 25\text{ }^\circ\text{C}$ ($470\ \Omega < R_{CSNS} < 10\text{ k}\Omega$) ⁽³⁷⁾	DT_{FEED}	10.7	11.1	11.5	$\text{mV}/^\circ\text{C}$
Temperature Sensing Error, range $[-40\text{ }^\circ\text{C}, 150\text{ }^\circ\text{C}]$, default ⁽³⁷⁾	T_{FEED_ERROR}	-15	–	+15	$^\circ\text{C}$
Temperature Sensing Error, $[-40\text{ }^\circ\text{C}, 150\text{ }^\circ\text{C}]$ after 1 point calibration @ $25\text{ }^\circ\text{C}$ ⁽³⁷⁾	$T_{FEED_ERROR_CAL}$	-5.0	–	+5.0	$^\circ\text{C}$

SPI INTERFACE ELECTRICAL CHARACTERISTICS⁽³⁸⁾

Maximum Operating Frequency of the Serial Peripheral Interface (SPI) ⁽⁴⁴⁾	f_{SPI}	–	–	8.0	MHz
Required Low-state Duration for reset RSTB ⁽³⁹⁾	t_{WRSTB}	10	–	–	μs
Required duration from the Rising to the Falling Edge of CSB (Required Setup Time) ⁽⁴⁰⁾	t_{CSB}	1.0	–	–	μs
Rising Edge of RSTB to Falling Edge of CSB (Required Setup Time) ⁽⁴⁰⁾	t_{ENBL}	5.0	–	–	μs
Falling Edge of CSB to Rising Edge of SCLK (Required Setup Time) ⁽⁴⁰⁾	t_{LEAD}	500	–	–	ns
Falling Edge of SCLK to Rising Edge of CSB (Required Setup lag Time) ⁽⁴⁰⁾	t_{LAG}	60	–	–	ns
Required High State Duration of SCLK (Required Setup Time) ⁽⁴⁰⁾	t_{WSCLKh}	50	–	–	ns
Required Low State Duration of SCLK (Required Setup Time) ⁽⁴⁰⁾	t_{WSCLKl}	50	–	–	ns
SI to Falling Edge of SCLK (Required Setup Time) ⁽⁴¹⁾	$t_{SI(SU)}$	15	–	–	ns
Falling Edge of SCLK to SI (Required hold Time of the SI signal) ⁽⁴¹⁾	$t_{SI(H)}$	30	–	–	ns
SO Rise Time $C_L = 80\text{ pF}$	t_{RSO}	–	–	20	ns
SO Fall Time $C_L = 80\text{ pF}$	t_{FSO}	–	–	20	ns
SI, CSB, SCLK, Max. Rise Time allowing operation at $f_{SPI} = 8.0\text{ MHz}$ ⁽⁴¹⁾	t_{RSI}	–	–	11	ns
SI, CSB, SCLK, Max. Fall Time allowing operation at $f_{SPI} = 8.0\text{ MHz}$ ⁽⁴¹⁾	t_{FSI}	–	–	11	ns
Time from Rising Edge of SCLK to reach a valid level at the SO pin ⁽⁴²⁾	t_{VALID}	–	–	44	ns
Time from Falling Edge of CSB to reach low-impedance on SO (access time) ⁽⁴³⁾	t_{SOEN}	–	–	30	ns

Notes:

37. Values were obtained by lab. characterization
38. Parameters guaranteed by design. It is recommended to tie unused SPI-pins to GND by resistors $1.0\text{ k} < R < 10\text{ k}$
39. RSTB low duration is defined as the minimum time required to switch off the channel when previously put ON in SPI mode (direct inputs inactive).
40. Minimum setup time required for the device is the minimum required time that the microcontroller must wait or remain in a given state.
41. Rise and Fall time of incoming SI, CSB, and SCLK signals.
42. Time required for output data to be available for use at SO, measured with a $1.0\text{ k}\Omega$ series resistor connected CSB.
43. Time required for output data to be terminated at SO measured with a $1.0\text{ k}\Omega$ series resistor connected CSB.
44. For clock frequencies $> 4.0\text{ MHz}$, series resistors on the SPI pins should preferably be removed. Otherwise, 470 pF ($V_{MAX} > 40\text{ V}$) ceramic speed-up capacitors in parallel with the $>8.0\text{ k}\Omega$ input resistors are required on pins SCLK, SI, SO, CS

TIMING DIAGRAMS

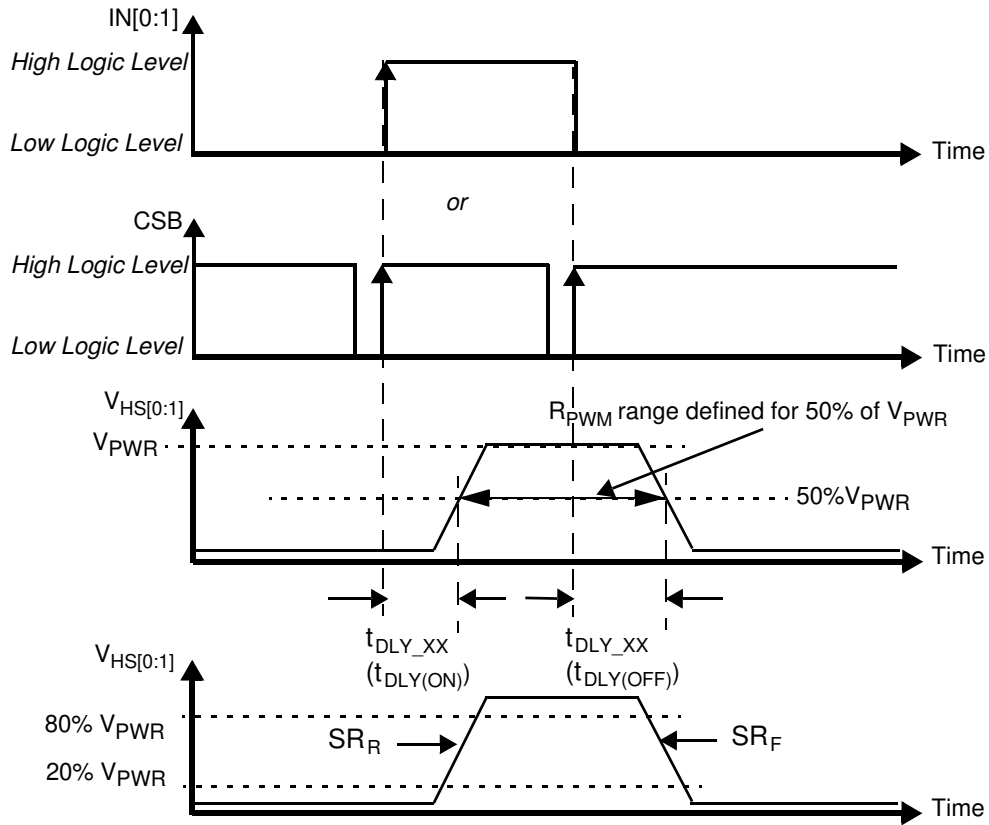


Figure 4. Output Voltage Slew Rate and Delay

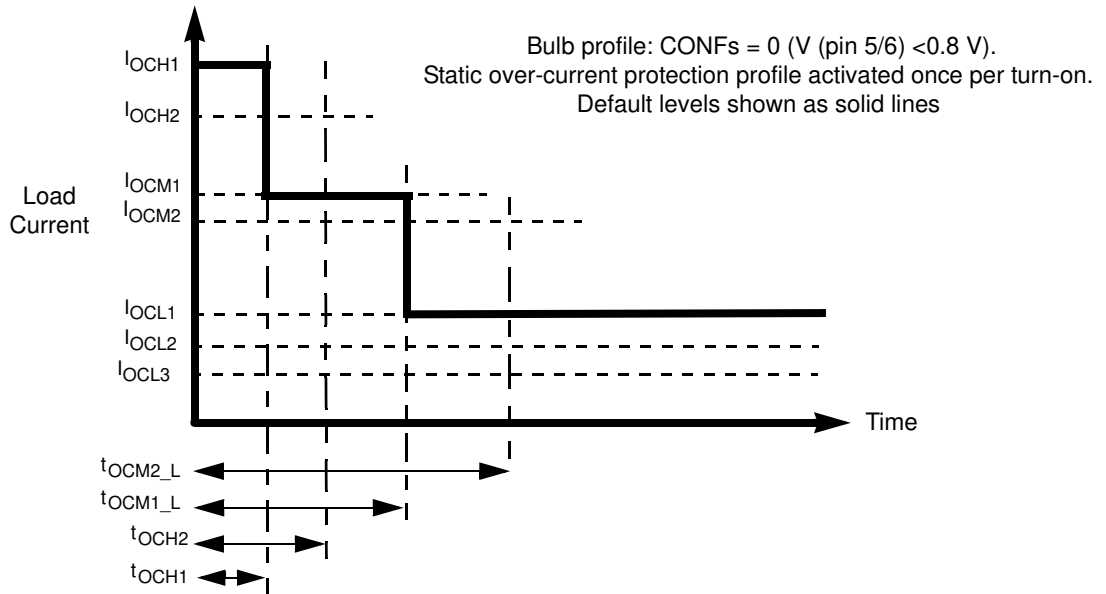


Figure 5. Over-current Protection Profile for Bulb Applications

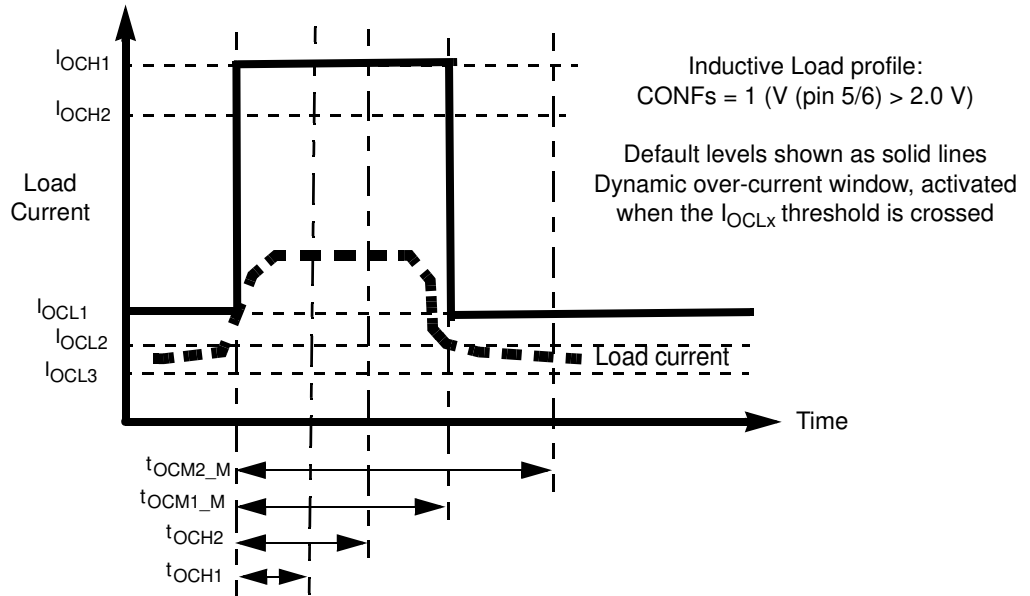


Figure 6. Over-current Protection Profile for Applications with Inductive Loads (DC motors, solenoids)

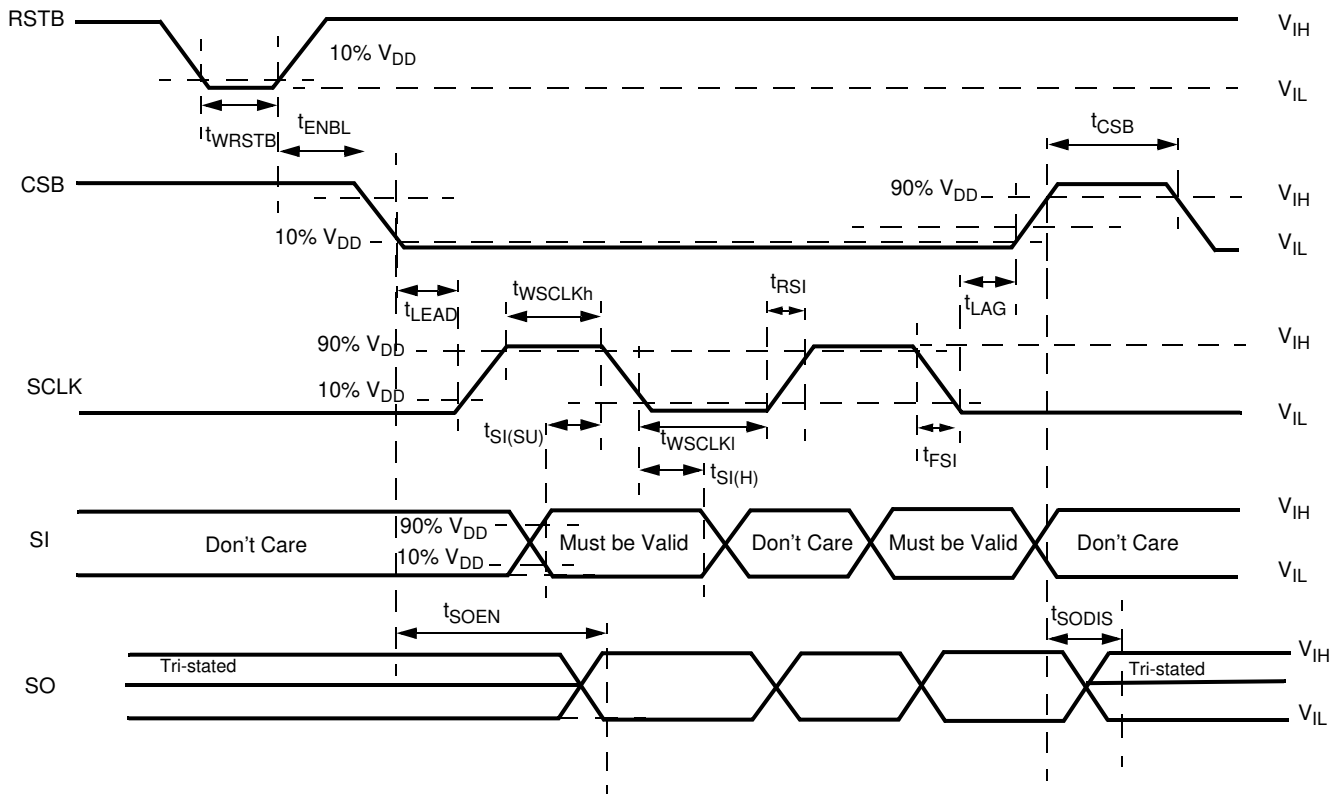


Figure 7. Timing Requirements During SPI Communication

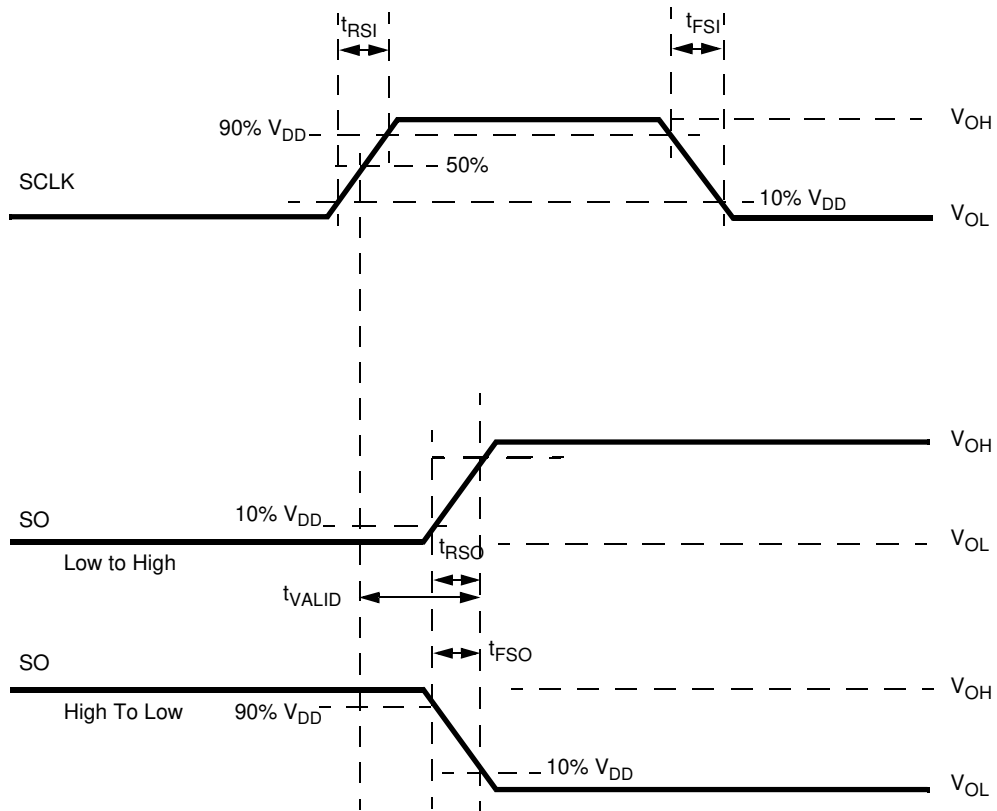


Figure 8. Timing Diagram for Serial Output (SO) Data Communication

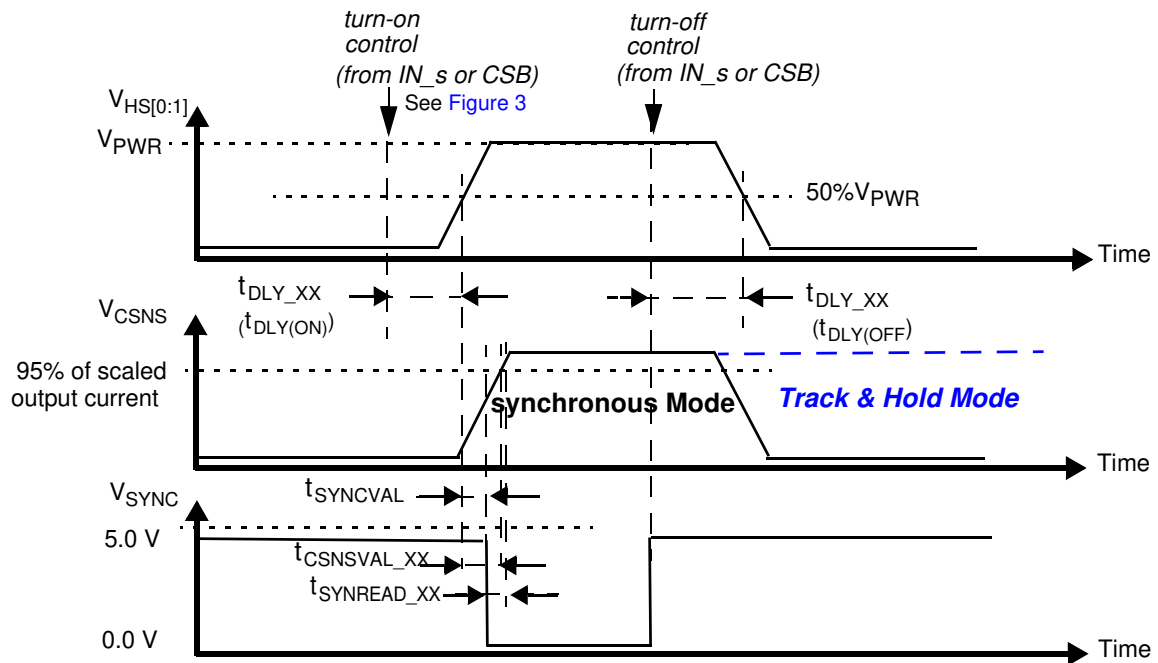


Figure 9. Synchronous & Track-and-Hold Current Sensing Modes: Associated Delay & Settling Times

FUNCTIONAL DESCRIPTION

INTRODUCTION

The 20XS4200 is a two-channel, 24 V high side switch with integrated control and diagnostics designed for truck, bus, and industrial applications. The device provides a high number of protective functions. Both low $R_{DS(ON)}$ channels (<20 m Ω) can independently drive various load types like light bulbs, solenoid actuators, or DC motors. Device control and diagnostics are configured through a 16-bit SPI port with daisy chain capability.

Independently programmable output voltage slew rates allow satisfying electromagnetic compatibility (EMC) requirements.

Both channels can independently be operated in three different switching modes: internal clock, internal PWM mode (fully autonomous operation), external clock, internal PWM mode, and direct control switching mode.

Current sensing with an adjustable ratio is available on both channels, allowing both high current (bulbs) and low current (LED) monitoring. By activating the Track & Hold Mode, current monitoring can be performed during the switch-Off phase. This allows random access to the current sense functionality. A patented offset compensation technique further enhances current sense accuracy.

To avoid turning off upon inrush current, while being able to monitor it, the device features a dynamic over-current threshold profile. For bulbs, this profile is a stair function with stages of which the height and width are programmable through the SPI port. DC motors can be protected from overheating by activating a specific window-shaped over-current profile that allow stall currents of limited duration.

Whenever communication with the external micro-controller is lost, the device enters Fail-safe operation mode, but remains operational, controllable, and protected.

PIN ASSIGNMENT AND FUNCTIONS

Functions and register bits that are implemented independently for both channels have extension “_s”. Max. ratings of the pins are given in [Table 2](#).

OUTPUT CURRENT MONITORING (CSNS)

The CS pin allows independent current monitoring of channel 0 or channel 1 up to the steady-state over-current threshold. It can also be used to sense the device temperature. The different functions are selected by setting bits CSNS1_en and CSNS0_en to the appropriate value ([Table 21](#)). When the CSNS pin is sensed during switch-off in the (optional) track & hold mode (see [Figure 8](#)), it will output the scaled value of the load current as it was just before turn-Off. When several devices share the same pull-down resistor, the CSNS pins of devices the current of which is not monitored must be tri-stated. This is accomplished by setting CSNS0_en = 0 and CSNS1_en = 0 in the GCR register ([Table 9](#)). Settling time ($t_{CSNSVAL_XX}$) is defined as the time between the instant at the middle of the output voltage's rising edge ($HS[0:1] = 50\%$ of V_{PWR}), and the instant at which the voltage on the CSNS-pin has settled to $\pm 5.0\%$ of its final value. Anytime an over-current window is active, the CSNS pin is disabled (see [Over-current Detection on Resistive and Inductive Loads](#)). The current and temperature sensing functions are unavailable in Fail-safe mode and in Normal mode when operating without the V_{DD} supply voltage. In order to generate a voltage output, a pull-down resistor is required ($R(CSNS) = 1.0$ k Ω typ. and $470 < R(CSNS) < 10$ k). When the current sense resistor connected to the CSNS pin is disconnected, the CSNS voltage is clamped to $V_{CL(CSNS)}$. The CSNS pin can source currents up to about 5.6 mA.

CURRENT SENSE SYNCHRONIZATION (SYNC)

To synchronize current sensing with an external process, the SYNC signal can be connected to a digital input of an external MCU. SYNC is asserted logic low when the current sense signal is accurate and ready to be read. The current sense signal on the CSNS pin has the specified accuracy $t_{SYNREAD_XX}$ seconds after the falling edge on the SYNC pin ([Figure 9](#)) and remains valid until a rising edge is generated. The rising edge that is generated by the SYNC pin at the turn-OFF instant (internal or external) may also be used to implement synchronization with the external MCU. Parameter t_{SYNVAL_XX} is defined as the time between the instant at the middle of the output-voltage rising edge ($HS[0:1] = 50\%$ of VPWR), and the instant at which the voltage on the SYNC-pin drops below 0.4 V (V_{SOL}). The SYNC pins of different devices can be connected together to save μ -controller input channels. However, in this configuration, the CSNS function of only one device should be active at a time. Otherwise, the MCU will not be able to determine the origin of the SYNC signal. The SYNC pin is open drain and requires an external pull-up resistor to VDD.

DIRECT CONTROL INPUTS (IN0 AND IN1)

The IN[0:1] pins allow direct control of both channels. A logic [0] level turns off the channel and a logic[1] level turns it on ([Channel Control in Normal Mode](#)). When the device is in Sleep mode, a transition from logic 0 to logic 1 on any of these pins will wake it up ([Sleep Mode](#)). If it is desired to automatically turn on the channels after a transition to Fail-safe mode, inputs IN[0] and IN[1] must be externally connected to the VPWR pin by a pull-up resistor (e.g. 10 k Ω typ.). However, this will prevent the device from going into

Sleep mode. Both IN pins are internally connected to a pull-down resistor.

CONFIGURATION INPUTS (CONF0 AND CONF1)

The CONF[0:1] input pins allow configuring both channels for the appropriate load type. CONF = 0 activates the bulb over-current protection profile, and CONF = 1 the DC motor profile. These inputs are connected to an internal voltage regulator of 3.3 V by an internal pull-up current source I_{UP} . Therefore, CONF = 1 is the default value when these pins are disconnected. Details on how to configure the channels are given in [Table 8](#).

FAULT STATUS (FSB)

This open-drain output is asserted low when any of the following faults occurs (see [Fault Mode](#)): over-current (OC), over-temperature (OT), Output connected to V_{PWR} , Severe short-circuit (SC), Open-load in ON state (OL_ON), Open-load in OFF state (OL_OFF), External Clock-fail (CLOCK_fail), over-voltage (OV), under-voltage (UV). Each fault type has its own assigned bit inside the STATR, FAULTR_s, or DIAGR_s register. Fault type identification and fault bit reset are accomplished by reading out these registers. They are part of the SO register ([Fault Mode](#)) and are accessed through the SPI port.

PWM CLOCK (CLOCK)

This pin is the input for an external clock signal that controls the internal PWM Module. The clock signal is monitored by the device. The PWM module controls ON-time and turn-ON delay of the selected channels. The CLOCK pin should not be confused with the SCLK pin, which is the clock pin of the SPI interface. CLOCK has an internal pull-down current source (I_{DWN}) to GND.

RESET (RSTB)

All SPI register contents are reset when RSTB = 0. When RSTB = 0, the device returns to Sleep mode t_{IN} sec. after the last falling edge of the last active IN[0:1] signal. As long as the Reset input (RSTB pin) is at logic 0 and both direct input states are low, the device remains in Sleep mode ([Channel configuration through the SPI](#)). A 0-to-1 transition on RSTB wakes up the device and starts a watchdog timer to check the continuous presence of the SPI signals. To do this, the device monitors the contents of the first bit (WDIN bit) of all SPI words following that transition (regardless the register it is contained in). When this contents is not alternated within a duration t_{WDTO} , SPI communication is considered lost, and Fail-safe mode is entered ([Entering Fail-safe Mode](#)). RSTB is internally pulled-down to GND by resistor R_{DWN} .

CHIP SELECT (CSB)

Data communication over the SPI port is enabled when the CSB pin is in the logic [0] state. Data from the Input Shift registers are locked in the addressed SI registers on the rising edge of CSB. The device transfers the contents of one of the eight internal registers to the SO register on the falling edge of CSB. The SO output driver is enabled when CSB is logic [0]. CSB should transition from a logic [1] to a logic [0] state only when SCLK is at logic [0] ([Figure 7](#) and [Figure 8](#)). CSB is internally pulled up to V_{DD} through I_{UP} .

SPI SERIAL CLOCK (SCLK)

The SCLK pin clocks the SPI data communication of the device. The serial input pin (SI) transfers data to the SI shift registers on the falling edge of the SCLK signal while data in the SO registers are transferred to the SO pin on the rising edge of the SCLK signal. The SCLK pin must be in low state when CSB makes any transition. For this reason, it is recommended to have the SCLK pin in the logic [0] state when the device is not accessed (CSB is at logic [1]). When CSB is set to logic [1], the signals at the SCLK and SI pins are ignored and the SO output is tri-stated (high-impedance). The SCLK pin is connected to an internal pull-down current source I_{DWN} .

SERIAL INPUT (SI)

Serial input (SI) data bits are shifted in at this pin. SI data is read on the falling edge of SCLK. 16-bit data packages are required on the SI pin (see [Figure 7](#)), starting with bit D15 (MSB) and ending with D0 (LSB). All the internal device registers are addressed and controlled by a 4-bit address (D9-D12) described in [Table 13](#). Register addresses and function attribution are described in [Table 14](#). The SI pin is internally connected to a pull-down current source, I_{DWN} .

SUPPLY OF THE DIGITAL CIRCUITRY (VDD)

This pin supplies the SPI circuit (3.3 V or 5.0 V). When lost, all circuitry becomes supplied by a V_{PWR} derived voltage, except the SPI's SO shift-register that can no longer be read.

GROUND (GND)

This is the GND pin common for both the SPI and the other circuitry.

POSITIVE SUPPLY PIN (VPWR)

This pin is the positive supply and the common input pin of both switches. A 100 nF ceramic capacitor must be connected between VPWR and GND, close to the device. In addition, it is recommended to put a ceramic capacitor of at least 1.0 μ F in parallel with this 100 nF capacitor.

SERIAL OUTPUT (SO)

The SO pin is a tri-stateable output pin that conveys data from one of the 13 internal SO registers or from the previous SI register to the outside world. The SO pin remains in a high-impedance state (tri-state) until the CSB pin becomes logic [0]. It then transfers the SPI data (device state, configuration, fault information). The SO pin changes state at the rising edge of the SCLK signal. For daisy-chaining, it can be read out on the falling edge of SCLK. V_{DD} must be present before the SO registers can be read. The SO register assignment is described in [Table 15](#).

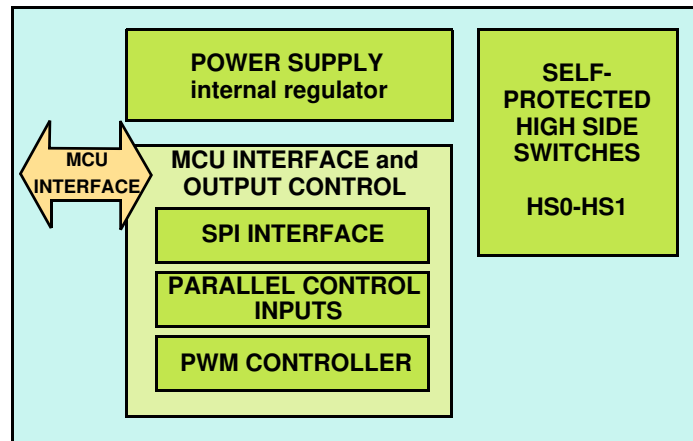
POWER SWITCH OUTPUT PINS (HS0 AND HS1)

HS0 and HS1 are the output pins of the power switches, to be connected to the loads. A ceramic capacitor (≤ 22 nF (+/- 20%)) is recommended between these pins and GND for optimal EMC performances.

FAIL-SAFE OUTPUT (FSOB)

This pin (active low) is used to indicate loss of SPI communication or loss of SPI supply voltage, V_{DD} . This open-drain output requires an external pull-up resistor to VPWR.

FUNCTIONAL INTERNAL BLOCK DESCRIPTION



POWER SUPPLY

The device will operate with supply voltages from 6.0 to 58 V (V_{PWR}), but will be full spec. compliant only between 8.0 and 36 V. The VPWR pin supplies power to the internal regulator, analog, and logic circuit blocks. The VDD pin (5.0 V typ.) supplies the output register of the Serial Peripheral Interface (SPI). Consequently, the SPI registers cannot be read without presence of V_{DD} . The employed IC architecture guarantees a low quiescent current in Sleep mode.

SWITCH OUTPUT PINS HS0 & HS1

HS0 and HS1 are the output pins of the power switches. Both channels are protected against various kinds of short-circuits and have active clamp circuitry that may be activated when switching off inductive loads. Many protective and diagnostic functions are available. For large inductive loads, it is recommended to use a freewheeling diode. The device can be configured to control the output switches in parallel, which guarantees good switching synchronization.

COMMUNICATION INTERFACE AND DEVICE CONTROL

In Normal mode the output channels can either be controlled by the direct inputs or by the internal PWM module, which is configured by the SPI register settings. For bidirectional SPI communication, V_{DD} has to be in the authorized range. Failure diagnostics and configuration are also performed through the SPI port. The reported failure types are: open-load, short-circuit to battery, severe short-circuit to ground, over-current, over-temperature, clock-fail, and under and over-voltage. The SPI port can be supplied either by a 5.0 V or by a 3.3 V voltage supply. For direct input control, V_{DD} is not required.

A Pulse Width Modulation (PWM) circuit allows driving loads at frequencies up to 1.0 kHz from an external or an internal clock. SPI communication is required to set these options.