Contents

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List of tables

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List of figures

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1 Pin description

Figure 1. Pin connection (top view)

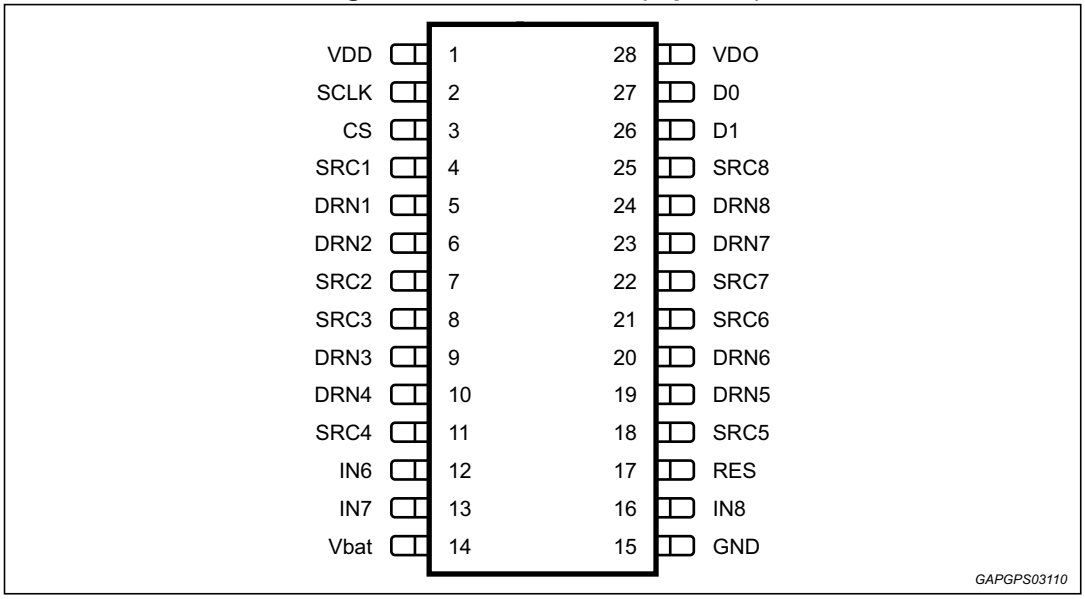

Table 2. Pin description

N°	Pin	Function
1	VDD	5 Volt supply input
2	SCLK	SPI serial clock input
3	CS	SPI chip select (active low)
4	SRC1	Source pin of configurable driver #1 (0.7 Ω Rds_{on} @ +25 °C)
5	DRN1	Drain pin of configurable driver #1(0.7 Ω Rds_{on} @ +25 °C)
6	DRN2	Drain pin of configurable driver #2 (0.7 Ω Rds_{on} @ +25 °C)
7	SRC2	Source pin of configurable driver #2 (0.7 Ω Rds_{on} @ +25 °C)
8	SRC3	Source pin of configurable driver #3 (0.7 Ω Rds_{on} @ +25 °C)
9	DRN3	Drain pin of configurable driver #3 (0.7 Ω Rds_{on} @ +25 °C)
10	DRN4	Drain pin of configurable driver #4 (0.7 Ω Rds_{on} @ +25 °C)
11	SRC4	Source pin of configurable driver #4 (0.7 Ω Rds_{on} @ +25 °C)
12	IN6	Discrete input used to PWM output driver #6
13	IN7	Discrete input used to PWM output driver #7
14	Vbat	Battery supply voltage
15	GND	Analog ground
16	IN8	Discrete input used to PWM output driver #8
17	RES	Reset input (active low)
18	SRC5	Source pin of configurable driver #5 (0.7 Ω Rds_{on} @ +25 °C)

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Table 2. Pin description (continued)

N°	Pin	Function
19	DRN5	Drain pin of configurable driver #5 (0.7 Ω Rds_{on} @ +25 °C)
20	DRN6	Drain pin of configurable driver #6 (0.7 Ω Rds_{on} @ +25 °C)
21	SRC6	Source pin of configurable driver #6 (0.7 Ω Rds_{on} @ +25 °C)
22	SRC7	Source pin of configurable driver #7 (0.7 Ω Rds_{on} @ +25 °C)
23	DRN7	Drain pin of low-side driver #7 (0.7 Ω Rds_{on} @ +25 °C)
24	DRN8	Drain pin of low-side driver #8 (0.7 Ω Rds_{on} @ +25 °C)
25	SRC8	Source pin of configurable driver #8 (0.7 Ω Rds_{on} @ +25 °C)
26	DI	SPI data in
27	DO	SPI data out
28	VDO	Microcontroller logic interface voltage

Note: The exposed slug must be soldered on the PCB and connected to GND.

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2 Operating conditions

2.1 Operating range

This part may not operate if taken outside the operating range. Once the condition is returned within the specified maximum rating or the power is recycled, the part will recover with no damage or degradation.

Table 3. Operating range

Symbol	Parameter	Value	Unit
V_{dd}	Supply voltage	4.5 to 5.5	V
V_{bat} (operative range)	Battery supply voltage	4.5V to 18	V
V_{bat} @ JSC		18 to 27	
V_{bat} @ low battery		3.5 to 4.5	
V_{bat} @ load dump		27 to 40	
T_j	Thermal junction temperature range	-40 to 150	°C
	Snubbing voltage of DRN1-8	min 50	VDC
I_{Ox}	Output current 1-8	max 800	mA
Eso	Maximum clamping energy at switch-off	20	mJ

2.1.1 Functional operative range

$$4.5\ V \le V_{bat} \le 18\ V \quad (-40\ °C \le T_j \le 150\ °C);$$

All the electrical capabilities are guaranteed by characterization as reported in *Section 3: Electrical performance characteristics*.

2.1.2 Jump start conditions

$$18\ V \le V_{bat} \le 27\ V \quad (-40\ °C \le T_j \le 150\ °C);$$

Operation at Jump start condition for a maximum duration of 1 minute.

All ouputs are switched according to the commands on the SPI bus or the PWM inputs. The SPI bus and the inputs are functional during the Jump-Start condition.

The over-temperature shutdown and over current protection of the device are not guaranteed to stay functional for Vbat between 18 V and 27 V.

The reliability and the functionality of the L9733XP are not compromised when the Jump-Start condition is not repeated for more than five times.

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2.1.3 Operation at low battery condition

$$3.5\ V \le V_{bat} \le 4.5\ V \quad (-40\ °C \le T_j \le 150\ °C);$$

All outputs are able to keep the status according to the commands on the SPI bus or the PWM inputs. Switching commands entered via the SPI bus might not be executed by the L9733 at low-battery condition. The SPI bus and the inputs are functional during the Low-Battery condition.

2.1.4 Operation at load dump condition

$$27\ V \le V_{bat} \le 40\ V \quad (-40\ °C \le T_j \le 150\ °C)$$

There is not an internal circuit that switches OFF the drivers during load dump condition.

The over-temperature shutdown and over current protection of the device are not guaranteed to stay functional during load dump condition.

2.1.5 Loss of protection against short to battery

When the battery supply voltage, $V_{bat\ (pin\ 14)}$ is switched off during a short-to-battery condition at an output in high-side configuration, the protection circuits are no longer functional, and the L9733 may fail with EOS.

2.2 Absolute maximum ratings

This part may be irreparably damaged if taken outside the specified absolute maximum ratings. Operation outside the absolute maximum ratings may also cause a decrease in reliability.

Table 4. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{DD}	Supply voltage	-0.3 to 7	V
V_{bat}	Supply voltage	-0.3 to 40	V
-	CS,DI,DO,SCLK,EN,IN6,IN7,IN8,VDO	-0.3 to 7.0	V
-	SRCx pin	min. -24	VDC
-	Max. value of V_{SRCx} = Minimum of {V_{bat} +1V ||| V_{DRNx}+0,3 V ||| +40 V}		-
-	DRN1-8(1)	-0.3 to 60	VDC
I_{OL}	Current limit of output 1-8 (-40 °C)	2.5	A
I_{OP}	Over current protection at output 1-8 (-40 °C)	3	A
	Maximum clamping energy	20	mj
ESD	Human body model - All pins	±2 (2)	kV
	Human body model - Driver outputs	±4 (2)	kV

1. For the DRNx the MAX ASB value is the Max Clamp Voltage (see *Table 6* on page 13 - DRNx Clamp voltage).
2. Device is only protected vs. GND.

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2.3 Thermal data

Table 5. Thermal data

Symbol	Parameter	Min	Typ	Max	Unit
T_{amb}	Operating ambient temperature	-40	-	125	°C
T_{stg}	Storage temperature	-50	-	150	°C
T_j	Maximum operating junction temperature	-	-	150	°C
R_{th}	Thermal shutdown temperature	151	175	200	°C
$R_{th\text{-}hys}$	Thermal shutdown temperature hysteresis	7	10	25	°C
$R_{Th\ j\text{-}amb}$	Thermal resistance junction-to-ambient (1)	-	-	24	°C/W
$R_{Th\ j\text{-}case}$	Thermal resistance junction-to-case	-	-	3	°C/W

1. With 2s2p PCB thermally enhanced.

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3 Electrical performance characteristics

These are the electrical capabilities this part was designed to meet. It is required that every part meets these characteristics.

3.1 DC characteristics

T_{amb} = -40 to 125 °C, V_{dd} = 4.5 to 5.5 Vdc, V_{bat} = 4.5 to 18 Vdc (high-side configuration), unless otherwise specified.

Table 6. DC characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$IN6v_{ih}$	IN6 input voltage	-	-	-	0.7vdo	V
$IN6v_{il}$		-	0.3vdo	-	-	V
I_{IN6il}	IN6 input current	In6 = 0 VDC	-	-	|10|	µA
I_{IN6ih}		In6 = VDO	10	-	100	µA
$IN7v_{ih}$	IN7 input voltage	-	-	-	0.7vdo	V
$IN7v_{il}$		-	0.3vdo	-	-	V
I_{IN7il}	IN7 input current	In7 = 0 VDC	-	-	|10|	µA
I_{IN7ih}		In7 = VDO	10	-	100	µA
$IN8v_{ih}$	IN8 input voltage	-	-	-	0.7vdo	V
$IN8v_{il}$		-	0.3vdo	-	-	V
I_{IN8il}	IN8 input current	In8 = 0 VDC	-	-	|10|	µA
I_{IN8ih}		In8 = VDO	10	-	100	µA
CS_{ih}	CS input voltage	-	-	-	0.7vdo	V
CS_{il}		-	0.3vdo	-	-	V
I_{CSih}	CS input current	CS = VDO	-	-	|10|	µA
I_{CSil}		CS = 0 VDC	10	-	100	µA
$SCLK_{ih}$	SCLK input voltage	-	-	-	0.7vdo	V
$SCLK_{il}$		-	0.3vdo	-	-	V
I_{SCLKih}	SCLK input current	SCLK = VDO	-	-	|10|	µA
I_{SCLKil}		SCLK = 0 VDC	10	-	100	µA
DI_{ih}	DI input voltage	-	-	-	0.7vdo	V
DI_{il}		-	0.3vdo	-	-	V
I_{DIih}	DI input current	DI = VDO	-	-	|10|	µA
I_{DIil}		DI = 0 VDC	10	-	100	µA
DO_{ol}	DO output voltages	I_{DO} = 2.5 mA	-	-	0.4	V
DO_{oh}		I_{DO} = -2.5 mA	vdo-0.6	-	-	V

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Table 6. DC characteristics (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
I_{DOzol}	DO Tri-state currents	DO = 0 VDC	-	-	|10|	µA
I_{DOzoh}		DO = VDO	-	-	|10|	µA
RES_{ih}	RES input voltage	-	-	-	0.7vdo	V
RES_{il}		-	0.3vdo	-	-	V
I_{RESil}	RES input current	RES = 0 VDC	10	-	100	µA
I_{RESih}		RES = VDO	-	-	|10|	µA
POR_{th}	Power on reset threshold	@ -40 °C	2.8	-	4.2	V
		@ 25 °C	2.8	-	3.7	
		@ 125 °C	2	-	3.4	
I_{slp}	Vbat sleep current	VDD = SRC1-8 = 0VDC DRN1-DRN8=18VDC, Vb. Sum currents (T_{amb} > 0 °C) (T_{amb} @ -40 °C)	-	-	 10 3	 µA µA
I_{vbat}	Vbat current	VDD = 5 V All Outputs Commanded On	-	-	15	mA
I_{VDD}	Max. VDD current	All Outputs Commanded On	-	-	8.5	mA
I_{VDD}	Min. VDD current	All Outputs Commanded Off	0.5	-		mA
I_{DRN1lk} - I_{DRN8lk}	DRN1 - DRN8 leakage currents (low-side)	VDD = 0 VDC: SRC1-8 = 0 VDC DRN1- DRN8 = 16 VDC DRN1- DRN8 = 40 VDC	-	-	 5 10	 µA µA
I_{SRC1lk} - $I_{SRC8lk.}$	SRC1 – SRC8 Leakage currents (high-side)	VDD = 0 VDC: SRC1-8 = 0 VDC DRN1- 8 = 16 V DRN1- 8 = 40 VDC	-	-	 -5 -10	 µA µA
$I_{Drn1-8sink}$	DRN1 – DRN8 sink current (low-side)	SRC1-8 = GND DI = AC00h R_{load} ≤ 11 kΩ R_{load} ≤ 200 kΩ	 10 120	-	 100 280	 µA µA
R_{DRN1-8}	Open load detection resistance	VBAT ≥ 9 V	11	-	200	KΩ
$I_{Drn1-8source}$	Source current	DRN1-DRN8 = GND	-10	-	-100	µA
$I_{src1-8sink}$	SRC1 – SRC8 sink/source current (high-side)	DRN1- 8 = Vb, DI = AC00h SCR1- 8 = Vb	 10	-	 100	 µA
$I_{src1-8source}$		SCR1- 8 = GND	-18	-	-100	µA
$V_{Drn1-8open}$	DRN1 – DRN8 open load voltage (low-side)	SRC1- 8 = GND, DI = AC00h DRN1- DRN8 = Open VDD=4.9 to 5.1 VDC	2.7	-	3.1	V
		SRC1- 8 = GND, DI = AC00h DRN1- DRN8 = Open VDD = 4.5 to 5.5 V	2.5	-	3.5	V

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Table 6. DC characteristics (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$V_{src1-8open}$	SRC1 – SRC8 open load voltage (High-side) DRN1 - DRN8	DRN1-8 = Vb, DI = AC00h SCR1-8 = open	2.0	-	2.8	V
$I_{DRN1limit}$ - $I_{DRN8limit}$	DRN1 - DRN8 current limits (low-side)	DI = ACFFh, DI = AAFFh SRC1 – SRC8 = 0 VDC DRN1 - DRN8 = 4.5 - 16 VDC (T_{amb} > 0 °C) (T_{amb} @ -40 °C)	 1 1	-	 2.2 2.5	 A A
$I_{DRN1OVC}$- $I_{DRN8OVC}$	DRN1 - DRN8 overcurrent threshold (low-side)	DI = AC00h, DI = AA00h SRC1 – SRC8 = 0 VDC DRN1 - DRN8 = 4.5 - 16 VDC (T_{amb} > 0 °C) (T_{amb} - 40 °C)	 1 1	-	 2.7 3	 A A
$I_{SRC1limit}$- $I_{SRC8limit}$	SRC1 – SRC8 current limits (high-side)	DI = ACFFh, DI = AAFFh DRN1 - DRN8 = Vb SRC1 – SRC8 = GND (T_{amb} > 0 °C) (T_{amb} - 40 °C)	 1 1	-	 2.2 2.5	 A A
$I_{SRC1OVC}$- $I_{SRC8OVC}$	Overcurrent threshold (high-side)	DRN1 - DRN8 = Vbat SRC1 – SRC8 = GND (T_{amb} > 0 °C) (T_{amb} - 40 °C)	 1 1	-	 2.7 3	 A A
$DRN1_{Cl+}$ - $DRN8_{Cl}$+	DRN1 - DRN8 Clamp voltages (low-side)	DI = AC00h SRC1-8 = GND, I_{DRN1-8} = 350 mA	50	-	60	V
$SRC1_{Cl+}$- $SRC8_{Cl}$+	SRC1 – SRC8 Clamp voltages (High-side)	DI = AC00h DRN1-8 = Vbat, I_{SRC1-8} = -350 mA	-24	-	-14	V
$V_{Drn1-8open}$ - $DRN1-8_{VthGND}$	Short to GND threshold distance from open load voltage (low-side)	SRC1 – SRC8 = GND: Decrease Drn1 - Drn8 until Faults are ”Set”	0.3	-	0.7	V
$DRN1-8_{VthVbat}$- $V_{Drn1-8open}$	DRN1 - DRN8 Short to Vbat threshold distance from open load voltage (low-side)	DI = AC00h SRC1 – SRC8 = GND: Increase Drn1 - Drn8 until Faults are ”Not Set”	0.3	-	0.7	V
$V_{Drn1-8open}$ - $SRC1-8_{VthGND}$	SRC1 - SRC8 Short to GND threshold distance from open load voltage (High-side)	DI = AC00h Drn1 – Drn8 = Vb: Decrease SRC1 - SRC8 until Faults are ”Not Set”	0.2	-	0.6	V
$SRC1-8_{VthVbat}$- $V_{Drn1-8open}$	SRC1 – SRC8 Short to Vbat threshold distance from open load voltage (High-side)	DI = AC00h Drn1 – Drn8 = Vbat: Increase SCR1 - SCR8 until Faults are ” Set”	0.2	-	0.6	V

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Table 6. DC characteristics (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$Rdson_{Drn1-8}$ (1)	On resistance (Drn to SRC1-8)	@ +125 °C @ I_{DRN} = 350 mA	-	-	1.2	Ω
		@ +25 °C @ IDRN = 350 mA	-	-	0.7	Ω
		@ -40 °C @ I_{DRN} = 350 mA	-	-	0.5	Ω
$Drn1\text{-}8_{ther}$ (2)	Thermal shutdown temperature	DI = ACFFh, I_{Drn1-8} = 1 mA, SRC1 – SRC8 = GND, Increase temperature until Drn1 - Drn8 > 2 VDC, Verify DO Bits 0-15 are ”Set”	151	-	200	°C
$Drn1\text{-}8_{hyst}$ (2)	Hysteresis	Drn1 - Drn8 < 2 VDC	5	-	15	°C

1. $R_{dsonDrn1-8} \leq 1.2\ \Omega$; at V_{bat} between 3.5 V and 27 V and T between -40 °C and 150 °C
2. Design Information, not tested.

3.2 AC characteristics

T_{amb} = -40 to 125 °C, V_{dd} = 4.5 to 5.5 Vdc, V_{bat} = 4.5 to 18 Vdc, unless otherwise specified

Table 7. AC characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$T_{filtDRN1-8}$	DRN1 - DRN8 Open load & short to GND filter time (low-side) (Latch mode)	DI = AC00h, DI = A3FFh SRC1 – SRC8 = GND	300	-	900	µs
$T_{filtSRC1-8}$	SRC1 - SRC8 Open load & short to Vbat filter time (high-side) (Latch mode)	DI = AC00h, DI = A3FFh DRN1 – DRN8 = Vb	300	-	900	µs
$T_{delDRN1-8}$	DRN1 - DRN8 Overcurrent switch off delay (low-side)	DI = ACFFh, DI = AA00h SRC1 – SRC8 = GND	10	-	75	µs
$T_{delSRC1-8}$	SRC1 - SRC8 Overcurrent switch off delay (high-side)	DI = ACFFh, DI = AA00h DRN1 – DRN8 = Vb	10	-	75	µs
T_{res}	Restart time after overcurrent switch off time (Int)	DI = ACFFh, DI = AA00h	120	-	450	ms
$Drn1\text{-}8_{htol}$	Slew rate turn on	Outputs loaded as *Figure 4* See *Figure 2*	0.65	-	1.95	V/µs
$Drn1\text{-}8_{ltoh}$	Turn off (low-side)	See *Figure 2*	0.5	-	1.5	V/µs

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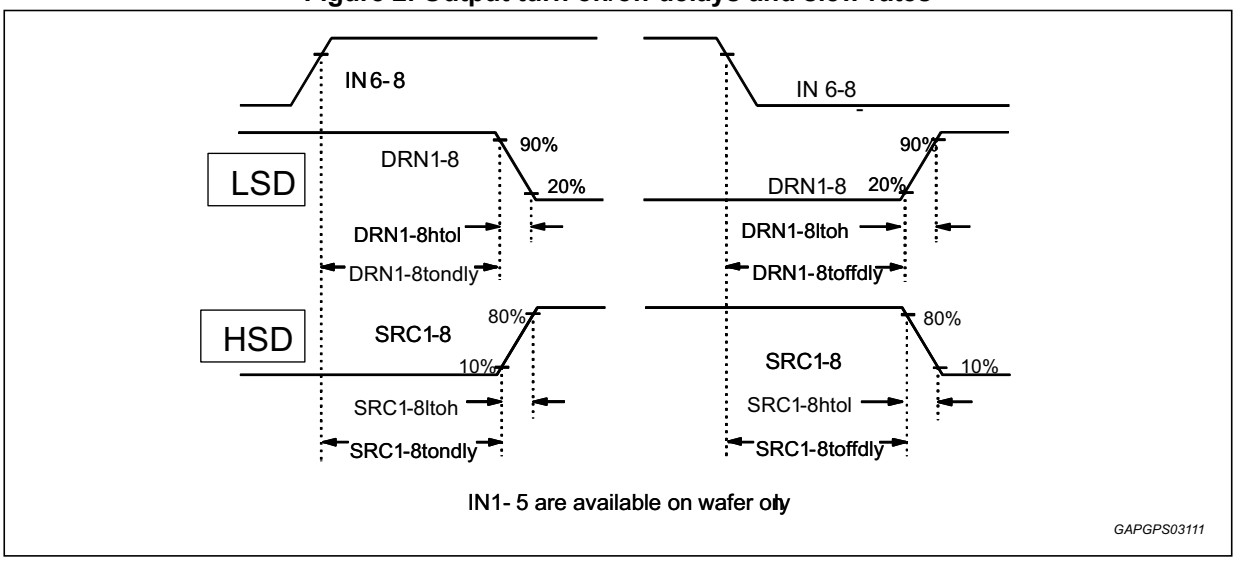
Table 7. AC characteristics (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$SRC1\text{-}8_{htol}$	Slew rate turn on	Outputs loaded as *Figure 4* See *Figure 2*	0.65	-	1.95	V/µs
$SRC1\text{-}8_{ltoh}$	Turn off (High-side)	See *Figure 2*	0.5	-	1.5	V/µs
$Drn1\text{-}8_{tondly}$	Delay time Turn on	Outputs loaded as *Figure 4* See *Figure 2*	2	-	20	µs
$Drn1\text{-}8_{toffdly}$	Turn off (low-side)	See *Figure 2*	10	-	100	µs
$SRC1\text{-}8_{tondly}$	Delay time Turn on	Outputs loaded as *Figure 4* See *Figure 2*	2	-	20	µs
$SRC1\text{-}8_{toffdly}$	Turn off (high-side)	See *Figure 2*	10	-	100	µs
$Drn1\text{-}8_{offon}$	Delay delta	$Drn1\text{-}8_{toffdly}$ - $Drn1\text{-}8_{tondly}$	10	-	60	µs
$SRC1\text{-}8_{offon}$	Delay delta	$SRC1\text{-}8_{toffdly}$ - $SRC1\text{-}8_{tondly}$	10	-	60	µs

Figure 2. Output turn on/off delays and slew rates



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3.3 SPI characteristics and timings

T_{amb}= -40 to 125 °C, V_{dd} = 4.5 to 5.5 Vdc, V_{bat} = 4.5 to 18 Vdc, unless otherwise specified

Table 8. SPI characteristics and timings

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$DINC_{in}$	Input capacitance	-	-	-	20	pF
$SCLK_{Cin}$			-	-	20	pF
DO_{rise}	Output data (do) rise time	50 pF from DO to Ground See *Figure 5*	-	-	70	ns
DO_{fall}	Output data (do) fall time	See *Figure 5*	-	-	70	ns
DO_a	Access time	See *Figure 6*	-	-	350	ns
DO_{sum}	Set up time	See *Figure 6*	20	-	-	ns
DO_{hm}	Hold time	See *Figure 6*	10	-	-	ns
DO_{dis}	Output data (DO) disable time	No Capacitor on DO, See *Figure 5*	-	-	400	ns
tth_{Filt}	Filter time	All Fault bits are “Set”	5	-	20	µs
SCLKwid	SCLK width	See *Figure 5*, @ f_{SCLK} = 5.4MHz(1)	185	-	-	ns
SCLKlm	SCLK low time	See *Figure 5*, @ f_{SCLK} = 5.4MHz(1)	58	-	-	ns
SCLKhm	SCLK high time	See *Figure 5*, @ f_{SCLK} = 5.4MHz(1)	58	-	-	ns
SCLKrise	SCLK rise time	See *Figure 5*, @ f_{SCLK} = 5.4MHz(1)	-	-	21	ns
SCLKfall	SCLK fall time	See *Figure 5*, @ f_{SCLK} = 5.4MHz(1)	-	-	21	ns
CSrise	Channel select (CS) rise time	See *Figure 5* (1)	-	-	100	ns
CSfall	Channel select (CS) fall time	See *Figure 5* (1)	-	-	100	ns
CSlead	Channel select (CS) lead time	See *Figure 6* (1)	455	-	-	ns
CSlag	Channel select (CS) lag time	See *Figure 6* (1)	50	-	-	ns
DIrise	Input data (DI) rise time	See *Figure 5*, @ f_{SCLK} = 5.4MHz(1)	-	-	30	ns
DIfall	Input data (DI) fall time	See *Figure 5* @ f_{SCLK} = 5.4MHz(1)	-	-	30	ns
DIsus	Input data (DI) set-up time	See *Figure 6*, @ f_{SCLK} = 5.4MHz(1)	15	-	-	ns
DIhs	Input data (DI) hold time	See *Figure 6*, @ f_{SCLK} = 5.4MHz(1)	10	-	-	ns
CS2SCLK	CS rise to SCLK rise	See *Figure 6*, @ f_{SCLK} = 5.4MHz(1)	40	-	300	ns

1. Guaranteed by design.

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Figure 3. DO loading for disable time measurement

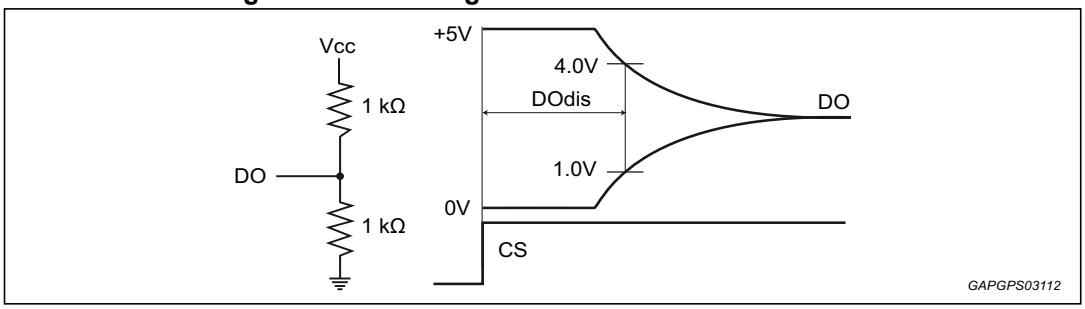


Figure 4. Output loading for slew rate measurements

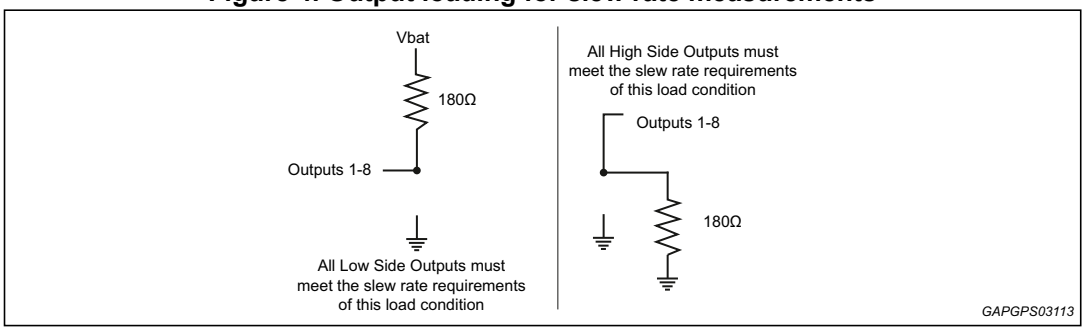


Figure 5. SPI input/output timings

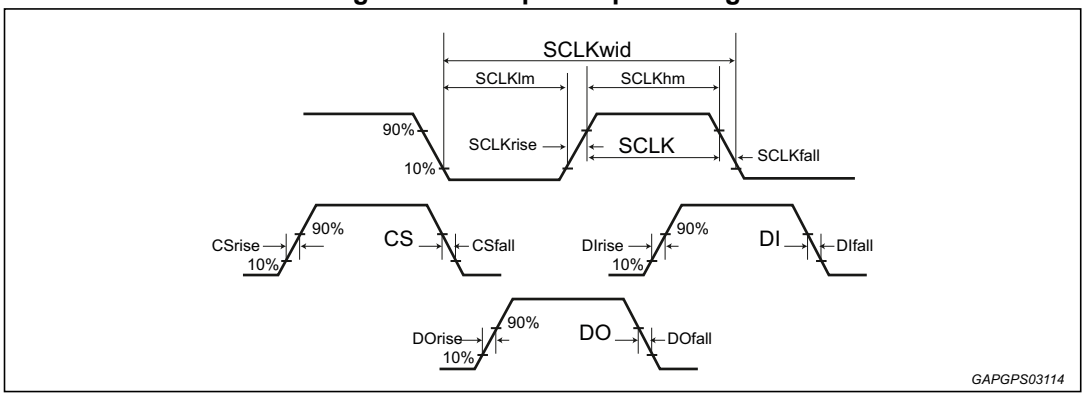
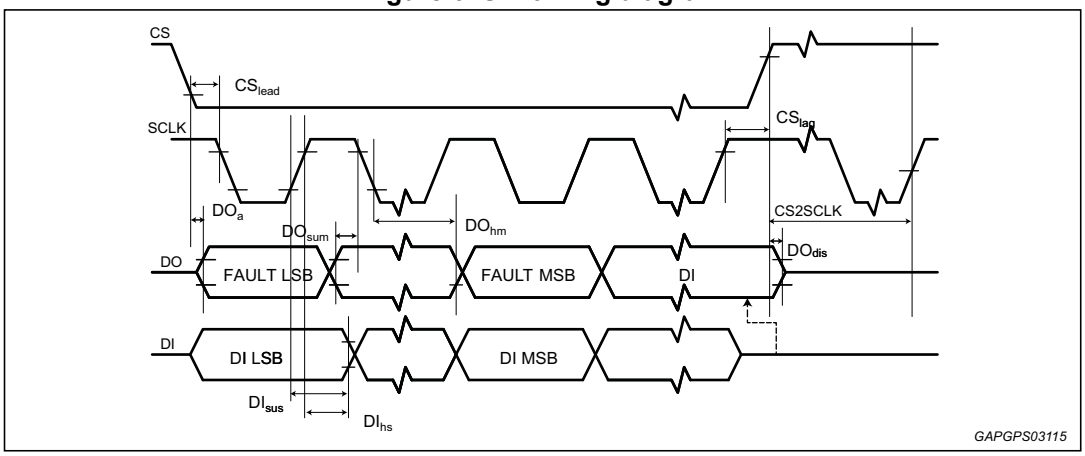


Figure 6. SPI timing diagram



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4 Functional description

L9733 integrates 8 self-configuring outputs (OUT1-8) which are able to drive either incandescent lamps, inductive loads (non-pwm'd, in pwm an external diode to reduce flyback power dissipation is necessary), or resistive loads biased to Vbat (low-side configuration) or to GND (high-side configuration). These outputs can be enabled and disabled via the SPI bus. Each of these outputs has a short circuit protection (with 0.8-2.4 Amps threshold) selectable via SPI bus between a filtered switching OFF overcurrent protection or a linear current limitation (default condition after power ON is switching OFF protection enabled).

An over-temperature protection as described in *Section 2.1* is available for each output. When a high-side configured output is commanded OFF after having been commanded ON, the source voltage will go to (VGND - 15 V). This is due to the design of the circuitry and the transconductance of the MOSFET. When a low-side configured output is commanded OFF after having been commanded ON, the output voltage will rise to the internal zener clamp voltage (50 VDC minimum) due to the flyback of the inductive load.

Outputs 1-8 are able to drive any combination of inductive loads or lamps at one time. Inductive loads for the L9733 can range from 35 mH to a maximum of 325 mH. The recommended worst-case solenoid loads (at -40 °C) are calculated using a minimum resistance of 40 Ω for each output. The maximum single pulse inductive load energy the L9733 output is able to be safely handled is 20 mJ at -40 °C to 125 °C (Worst-case load of 325 mH and 40 Ω).

4.1 Configurations for outputs 1-8

The drain and source pins for each output must be connected in one of the two following configurations (see *Figure 7*).

4.1.1 Low-side drivers

When any combination of outputs 1-8 are connected in a low-side drive configuration the source of the applicable output (Src1-8) shall be connected to ground. The drain of the applicable output (Drn1-8) shall be connected to the low-side of the load.

4.1.2 High-side drivers

When any combination of outputs 1-8 are connected in a high-side drive configuration the drain of the applicable output (Drn1-8) shall be connected to Vbat. The source of the applicable output (Src1-8) shall be connected to the high-side of the load.

4.2 Outputs 1-5

These five outputs can be used as either high or low-side drives. The room temperature Rdson of these outputs is 0.7 Ω A current limited (100 µA max) voltage generator is connected to Src 1-5 for open load and short to GND detection when a low-side configured output is commanded OFF. Another current limited (100 µA max if VDrn 1-5 > 60 %Vbat, 280 µA max if VDrn 1-5 < 60 % Vbat) voltage generator is connected to Drn 1-5 for open load and short to V bat detection when a high-side configured output is commanded OFF.

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Drain pins of outputs 1-5 (Drn1-5) are connected to the drains of the N channel MOSFET transistors. Source pins of outputs 1-5 (Src1-5) are connected to the sources of the N-channel MOSFET transistors.

4.3 Outputs 6-8

These three self-configuring outputs can be used to drive either high or low-side loads. In addition to being controlled by the SPI BUS these outputs can also be enabled and disabled via the IN6 & IN7& IN8 inputs. The IN6, IN7 and IN8 inputs are logically OR'd with the SPI commands to allow either the IN6 & IN7 & IN8 inputs or the SPI commands to activate these outputs. The use of the IN6 & IN7 & IN8 pins for PWM control on these outputs should only be done with non-inductive loads if an external flyback diode is not present. The room temperature Rdson of these four outputs is 0.7 Ω. A current limited (100 µA max) voltage generator is connected to Src 6-8 for open load and short to GND detection when a low-side configured output is commanded OFF. Another current limited (100 µA max if VDrn 6-8 > 60%Vbat, 280 µA max if VDrn 6-8 < 60 %Vbat) voltage generator is connected to Drn 6-8 for open load and short to Vbat detection when a high-side configured output is commanded OFF.
Drain pins of Outputs 6-8 (Drn6-8) are connected to the drains of the N channel MOSFET transistors. Source pins of Outputs 6-8 (Src6-8) are connected to the sources of the N channel MOSFET transistors.

4.4 Drn1-8 susceptibility to negative voltage transients

All outputs connected in the low-side configuration must have a ceramic chip capacitor of 0.01 µF to 0.1 µF connected from drain to ground. This is needed to prevent potential problems with the device operation due to the presence of fast negative transient(s) on the drain(s) of the device. Adequate de-coupling capacitors from the Drain (VBAT) to ground shall be provided for high-side configured outputs.

4.5 Supply pins

4.5.1 Main power input (Vdd)

An external +5.0 ±0.5 VDC supply provided from an external source is the primary power source to the L9733. This supply is used as the power source for all of its internal logic circuitry and other miscellaneous functions.

4.5.2 Battery supply (Vbat)

This input is the supply for the on board charge pump. This input shall be connected directly to battery. If this input is not connected to the same supply, without additional voltage drops, of the drains of any high-side connected outputs, then the Rdson of that given output will be higher than the specified maximum.

4.5.3 Discrete inputs voltage supply (VDO)

This pin is used to supply the discrete input stages of L9733 and must be connected to the same voltage used to supply the peripherals of the processor interfaced to L9733.

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4.6 Discrete inputs

4.6.1 Output 6-8 enable input (In6, In7, In8)

This input allows Output 6 (or Output 7, or Output 8) to be enabled via this external pin without the use of the SPI. The SPI command and the In6-7 input are logically OR'd together. A logic "1" on this input (In6, In7 or In8) is enable the corresponding output no matter what the status of the SPI command register is. A logic "0" on this input will disable this output if the SPI command register is not commanding this output on. This pins (In6, In7 or In8) can be left "open" if the internal output device is being controlled only via the SPI. This input has a nominal 100 kΩ resistor connected from this pin to ground, which will pull this pin to ground if an open circuit condition occurs. This input is ideally suited for non-inductive loads that are pulse width modulated (PWM'd). This allows PWM control without the use of the SPI inputs.

4.6.2 Reset input (RES)

When this input goes low it resets all the internal registers and switches off all the output stages. This input has a nominal 100 kΩ resistor connected from this pin to VDD, which will pull this pin to VDD if an open circuit condition occurs.

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5 Serial peripheral interface (SPI)

The L9733 has a serial peripheral interface consisting of Serial Clock (SCLK), Data Out (DO), Data In (DI), and Chip Select (CS). All outputs will be controlled via the SPI. The input pins CS, SCLK, and DI, thanks to VDO pin, have level input voltages allowing proper operation from microcontrollers that are using 5.0 or 3.3 volts for their Vdd supply. The design of the L9733 allows a "daisy-chaining" of multiple L9733's to further reduce the need for controller pins.

5.1 Serial data output (DO)

This output pin is in a tri-state condition when CS is a logic '1'. When CS is a logic '0', this pin transmits 16 bits of data from the fault register to the digital controller. After the first 16 bits of DO fault data are transmitted (after a CS transition from a logic '1' to a logic '0'), then the DO output sequentially transmits the digital data that was just received (16 SCLK cycles earlier) on the DI pin. The DO output continues to transmit the 16 SCLK delayed bit data from the DI input until CS eventually transitions from a logic '0' to a logic '1'. DO data changes state 10 nsec or later, after the falling edge of SCLK. The LSB is the first bit of the byte transmitted on DO and the MSB is the last bit of the byte transmitted on DO, once CS transitions from a logic '1' to a logic '0'.

5.2 Serial data input (DI)

This input takes data from the digital controller while CS is low. The L9733 accepts a 16 bit byte to command the outputs on or off. The L9733 also serially wraps around the DI input bits to the DO output after the DO output transmits its 16 fault flag bits. The LSB is the first bit of each byte received on DI and the MSB is the last bit of each byte received on DI, once CS transitions from a logic '1' to a logic '0'. The last 4 bits (b15-b12) of the first 16 bit byte are used as key-word. The 4 bits (b11-b8) of the first 16 bits byte are used to select writing mode between OUT8-1 status and diagnosis operating mode . The DI input has a nominal 100 kΩ resistor connected from this pin to the VDO pin, which pulls this pin to VDO if an open circuit condition occurs.

5.3 Chip select (CS)

This is the chip select input pin. On the falling edge of CS, the DO pin is released from tri-state mode. While CS is low, register data are shifted in and shifted out the DI pin and DO pin, respectively, on each subsequent SCLK. On the rising edge of CS, the DO pin is tri-stated and the fault register is "Cleared" if a valid DI byte has been received. A valid DI byte is defined as such:

- a multiple of 16 bits was received;
- a valid key-word was received.

The fault data is not cleared unless all of the 2 previous conditions have been met. The CS input has a nominal 100 kΩ resistor connected from this pin to the VDO pin, which pulls this pin to VDO if an open circuit condition occurs.

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5.4 Serial clock (SCLK)

This is the clock signal input for synchronization of serial data transfer. DI data is shifted into the DI input on the rising edge of SCLK and DO data changes on the falling edge of SCLK. The SCLK input has a nominal 100 kΩ resistor connected from this pin to the VDO pin, which pulls this pin to VDO if an open circuit condition occurs.

5.5 Initial input command register and fault register SPI cycle

After initial application of Vdd to the L9733, the input command register and the fault register are "Cleared" by the POR circuitry and that means that the default condition for the output status is Off, the default diagnostic mode is No Latch and the switching OFF overcurrent protection is enable. During the initial SPI cycle, and all subsequent cycles, valid fault data will be clocked out of DO (fault bits).

5.6 Input command register

An input byte (16 bits) is routed to the Command Register. The content of this Command Register is given in *Table 10*. Additional DI data will continue to be wrapped around the DO pin. If CS should happen to go high before complete reception of the current byte, this just transmitted byte shall be ignored (invalid).

Table 9. Bit command register definition

Key word				**Writing mode: output**				**Output status**							
MSB															**LSB**
1	0	1	0	1	1	0	0	OUT 8	OUT 7	OUT 6	OUT 5	OUT 4	OUT 3	OUT 2	OUT 1
b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Key word				**Writing mode: diag**				**Driver diag mode**							
MSB															**LSB**
1	0	1	0	0	0	1	1	Diag 8	Diag 7	Diag 6	Diag 5	Diag 4	Diag 3	Diag 2	Diag 1
b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
Key word				**Writing mode: protect**				**Driver overcurrent protection**							
MSB															**LSB**
1	0	1	0	1	0	1	0	Ilim 8	Ilim 7	Ilim 6	Ilim 5	Ilim 4	Ilim 3	Ilim 2	Ilim 1
b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0

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Table 10. Command register logic definition

Bit	State	Status	Writing mode
b0-b7	0	OUT1 - OUT8 are commanded off	Output
b0-b7	1	OUT1 - OUT8 are commanded on	Output
b0-b7	0	OUT1 - OUT8 diagnostic is No Latch Mode	Diag
b0-b7	1	OUT1 - OUT8 diagnostic is Latch Mode	Diag
b0-b7	0	OUT1 - OUT8 switching OFF overcurrent protection	Protection
b0-b7	1	OUT1 - OUT8 linear overcurrent protection	Protection

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6 Other L9733 features

6.1 Charge pump usage

In order to provide low Rdson values when connected in a high-side configuration, a charge pump to drive the internal gate voltage(s) above Vbat is implemented. The charge pump used on the L9733 doesn't need external capacitor. The L9733 uses a common charge pump and oscillator for all the 8 configurable output channels. The charge pump uses the Vbat supply connected directly to the Vb pin. The normal range of the Vbat voltage is 10 to 18V18V. However, the L9733 is functional with Vbat voltages as low as 4.5 V DC with eventually a degradation of Rdson.

The frequency range of this charge pump is from 3.6 to 7.6 MHz. The frequency is above 1.8 MHz in order to be above the AM radio band and below 8.0 MHz so that harmonics do not get within the FM radio band.

6.2 Waveshaping

Both the turn on and the turn off slew rates on all outputs (OUT1-8) are limited to between 10 µs and 100 µs for both rise and fall times (10 to 90 %, and vice versa), to reduce conducted EMC energy in the vehicle's wiring harness. The characteristics of the turn-on and turn-off voltage is linear, with no discontinuities, during the output driver state transition.

6.3 POR register initialization

When the L9733 wakes up, the Vdd supply to the L9733 is allowed from 0 to 5 VDC in 0.3 to 3ms. The L9733 has a POR circuit, which monitors the Vdd voltage. When the Vdd voltage reaches an internal threshold, and remains above this trip level for at least 5 to 20 µs, the Command and Fault registers are "cleared". Before Vdd reaches this trip level, none of the eight outputs are allowed to momentarily glitch on.

6.4 Thermal shutdown

Each of the eight outputs has independent thermal protection circuitry that disables each output driver once the local N-Channel MOSFET's device temperature reaches between +151 and +200 °C. A filter is present to validate the thermal fault (5 µs to 20 µs). There is a 5 to 15 °C hysteresis between the enable and disable temperature levels. The faulted channel will periodically turn off and on until the fault condition is cleared, the ambient temperature is decreased sufficiently or the output is commanded off. If a thermal shutdown, of one or more output drivers, is active during the falling edge of the chip select (CS) signal all the bits of the Fault Register are "set" to "1" (thermal shutdown is not latched and could be read only in the moment it is present). The thermal fault is cleared on the rising edge of Chip Select if a valid DI byte is received.

Note: Due to the design of the L9733 each output's thermal limit "may not" be truly independent to the extent that if one output is shorted, it may impact the operation of other outputs (due to lateral heating in the die).

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7 Fault operation

The fault diagnostic capability consists of one internal 16 bits shift register and 2 bits are used for each output. The diagnostic information is: no fault present, overcurrent, open load and short circuit.

For L9733XP all of the faults will be cleared on the rising edge of chip select if a valid DI byte is received.

For L9733CN the OVC register are cleared when the end of the diagnosis restart time T_{res} is reached or by the input signal (IN) in low state. The other faults are cleared on the rising edge of chip select if a valid DI byte is received.

Table 11. Fault register definition

OUT 8		OUT 7		OUT6		OUT5		OUT4		OUT3		OUT2		OUT1	
MSB															LSB
D1	D0	D1	D0	D1	D0	D1	D0	D1	D0	D1	D0	D1	D0	D1	D0
b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0

Table 12. Fault logic definition

D1	D0	Fault status
0	0	No fault is present
0	1	Open load
1	0	Short circuit to GND (low-side) or short circuit to Vbat (high-side)
1	1	Overcurrent

If all the bits b0-b15 of the fault register have value '1' it means that a thermal fault, at least on one of the eight independent Outputs, occurred.

7.1 Low-side configured output fault operation

The diagnostic circuitry verifies for the low-side configured output the following condition: Normal operation, open load, short circuit to GND and overcurrent (only if the switching OFF protection, selectable for each channel via SPI bus, is active).

The diagnostic circuitry operates in two different modes, selected for each channel by SPI: no latch mode and latch mode. The fault priority is overcurrent and then open load or short circuit to GND, this means that if an overcurrent occurs the fault register is always overwritten and following open load or short to GND faults that happen before that the register is cleared will be ignored.

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7.1.1 No latch mode

This diagnostic operating mode doesn't latch open load and short to GND faults.

1. **Open load**
   The diagnostic of open load is detected only in OFF condition sensing the Drn1-8 output voltage. This fault is detected on the falling edge of the CS input if the power drain voltage is inside the voltage range limited by the two thresholds **Vth_Vbat** and **Vth_GND**. An internal current limited voltage regulator fixes the drain voltage inside the described range when no load is connected.
2. **Short circuit to GND**
   The diagnostic of short circuit to GND is detected only in OFF condition sensing the Drn1-8 output voltage. This fault is detected on the falling edge of the CS input if the power drain voltage is lower than the **Vth_GND** threshold.
3. **Overcurrent**
   The diagnostic of overcurrent is detected only in ON condition, if the switching OFF protection of the channel is enabled (default), sensing the current level of the output power transistor. If the output current has been above the short threshold **Iovc** for the filtering time **Tdel** the output power is switched off and at the same time an overcurrent fault is written in the fault register.
   There are three possibilities to restart one output after the fault has occurred:
   - Automatically after a time **Tres**
   - On the rising edge of CS if two valid DI bytes have been received and first the Output Status in the command register is written with logic '0' and then with a logic “1” in the following SPI cycle
   - On the rising edge (low to high transition) at the corresponding parallel input pin (only for Outputs 6-8).
   - If the switching OFF protection is not active the On phase overcurrent protection is a linear current limitation and no diagnosis is available.

The use of the IN6-8 pins for PWM control on the outputs 6-8 could generate bad diagnostic behavior when the falling edge of CS happens a short time after the falling edge of IN6-8 during the power MOS transient. Software filtering may be needed to ignore fault signals during Drn6-8 transient after falling edge of IN6-8.

7.1.2 Latch mode

This diagnostic operating mode latches all faults when they happen.

1. **Open load**
   The diagnostic of open load is detected only in OFF condition sensing the Drn1-8 output voltage. This fault is detected if the power drain voltage is inside the voltage range limited by the two thresholds Vth_Vbat and Vth_GND for the filtering time **Tfilt**. An internal current limited voltage regulator fixes the drain voltage inside the described range when no load is connected.
2. **Short circuit to GND**
   The diagnostic of short circuit to GND is detected only in OFF condition sensing the Drn1-8 output voltage. This fault is detected if the power drain voltage is lower than the Vth_GND threshold for the filtering time Tfilt.
3. **Overcurrent**
   The diagnostic of overcurrent is detected only in ON condition, if the switching OFF protection of the channel is enabled (default), sensing the current level of the output power transistor. If the output current has been above the short threshold Iovc for the

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filtering time Tdel the output power is switched off and at the same time an overcurrent fault is written in the fault register. If the switching OFF protection is not active the On phase overcurrent protection is a linear current limitation and no diagnosis is available. There are three possibilities to restart one output after the fault has occurred:

– Automatically after a time **Tres**
– On the rising edge of CS if two valid DI bytes have been received and first the Output Status in the command register is written with logic '0' and then with a logic “1” in the following SPI cycle
– On the rising edge (low to high transition) at the corresponding parallel input pin (only for Outputs 6-8).
If the power MOS transient, after a switching-off command, is longer than Tdel filtering time, a bad diagnostic behavior happens and software filtering may be needed.

7.2 High-side configured output fault operation

The diagnostic circuitry verifies for the high-side configured output the following condition: Normal operation, open load, short circuit to Vbat and overcurrent (only if the switching OFF protection, selectable for each channel via SPI bus, is active).

The diagnostic circuitry operates in two different modes, selected for each channel by SPI: no latch mode and latch mode. The fault priority is overcurrent and then open load or short circuit to Vb, this means that if an overcurrent occurs the fault register is always overwritten and following open load or short to Vbat faults that happen before that the register is cleared will be ignored.

7.2.1 No latch mode

This diagnostic operating mode doesn't latch open load and short to Vbat faults.

1. **Open load**
The diagnostic of open load is detected only in OFF condition sensing the Src1-8 output voltage. This fault is detected on the falling edge of the CS input if the power drain voltage is inside the voltage range limited by the two thresholds Vth_Vbat and Vth_GND. An internal current limited voltage regulator fixes the drain voltage inside the described range when no load is connected.
2. **Short Circuit to Vb**
The diagnostic of short circuit to Vbat is detected only in OFF condition sensing the Src1-8 output voltage. This fault is detected on the falling edge of the CS input if the power drain voltage is higher than the **Vth_Vbat** threshold.
3. **Overcurrent**
The diagnostic of overcurrent is detected only in ON condition, if the switching OFF protection of the channel is enabled (default), sensing the current level of the output power transistor. If the output current has been above the short threshold Iovc for the filtering time Tdel the output power is switched off and at the same time an overcurrent fault is written in the fault register.
There are three possibilities to restart one output after the fault has occurred:
   – Automatically after a time **Tres**
   – On the rising edge of CS if two valid DI bytes have been received and first the Output Status in the command register is written with logic '0' and then with a logic “1” in the following SPI cycle

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- On the rising edge (low to high transition) at the corresponding parallel input pin (only for Outputs 6-8).
- If the switching OFF protection is not active the On phase overcurrent protection is a linear current limitation and no diagnosis is available.
  The use of the IN6-8 pins for PWM control on the outputs 6-8 could generates bad diagnostic behavior when the falling edge of CS happens a short time after the falling edge of IN6-8 during the power MOS transient. Software filtering may be needed to ignore fault signals during Drn6-8 transient after falling edge of IN6-8.

7.2.2 Latch mode

This diagnostic operating mode latches all faults when they happen.

1. **Open load**
   The diagnostic of open load is detected only in OFF condition sensing the Src1-8 output voltage. This fault is detected if the power drain voltage is inside the voltage range limited by the two thresholds **Vth_Vbat** and **Vth_GND** for the filtering time **Tfilt**. An internal current limited voltage regulator fixes the drain voltage inside the described range when no load is connected.
2. **Short Circuit to Vb**
   The diagnostic of short circuit to Vbat is detected only in OFF condition sensing the Src1-8 output voltage. This fault is detected if the power drain voltage is higher than the **Vth_Vbat** threshold for the filtering time **Tfilt**.
3. **Overcurrent**
   The diagnostic of overcurrent is detected only in ON condition, if the switching OFF protection of the channel is enabled (default), sensing the current level of the output power transistor. If the output current has been above the short threshold **Iovc** for the filtering time **Tdel** the output power is switched off and at the same time an overcurrent fault is written in the fault register.

There are three possibilities to restart one output after the fault has occurred:

- Automatically after a time **Tres**
- On the rising edge of CS if two valid DI bytes have been received and first the Output Status in the command register is written with logic '0' and then with a logic “1” in the following SPI cycle
- On the rising edge (low to high transition) at the corresponding parallel input pin (only for Outputs 6-8).
  If the switching OFF protection is not active the On phase overcurrent protection is a linear current limitation and no diagnosis is available.

If the power MOS transient, after a switching-off command, is longer than **Tdel** filtering time, a bad diagnostic behavior happens and software filtering may be needed.

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Figure 7. Application schematic

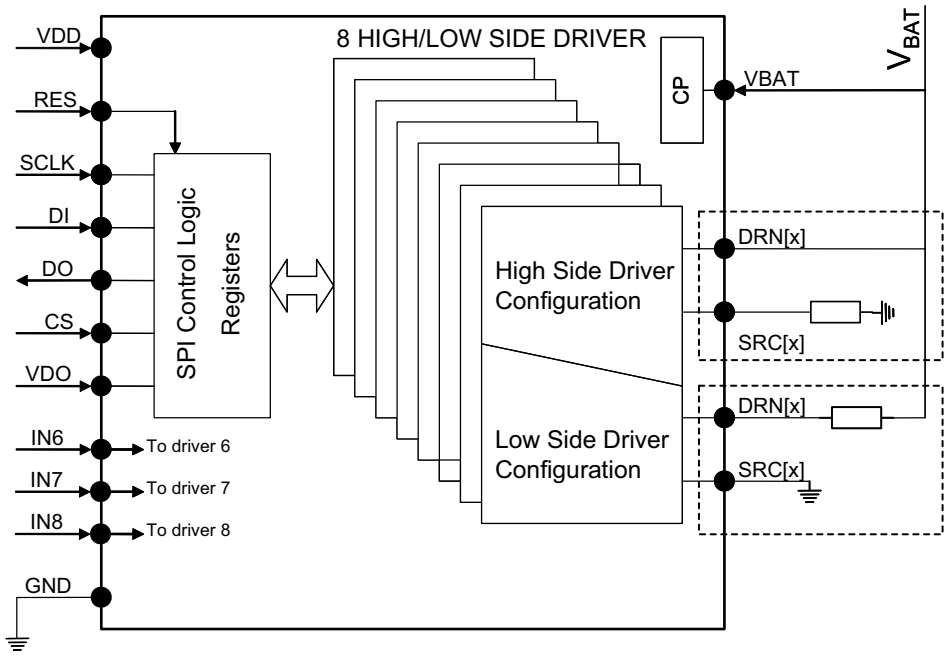
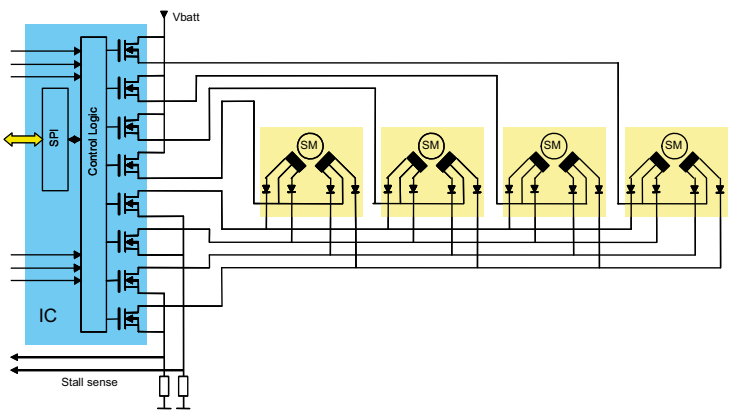
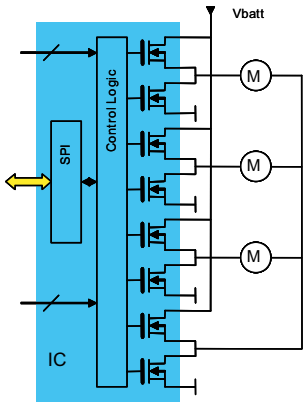


Figure 8. HVAC applicative examples



Four flap motors become sequentially driven. Unipolar stepper motor are selected by 4 high-side configured switches. If the decoupling diodes is inside the motor housing, only 8 wires are needed to drive this arrangement.



4 channels configured to low- and 4 channels configured to high side build a quad half bridge. This can drive 3 DC-motors sequantially.

GAPGPS03117

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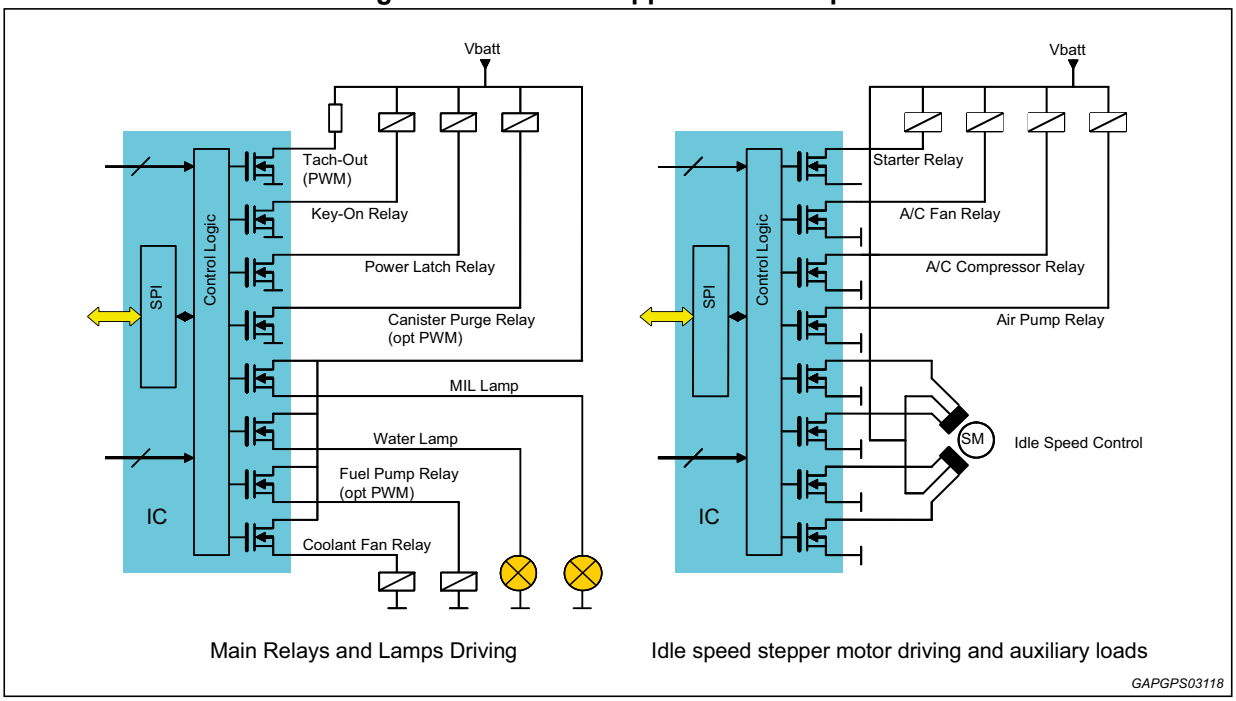
Figure 9. Powertrain applicative examples



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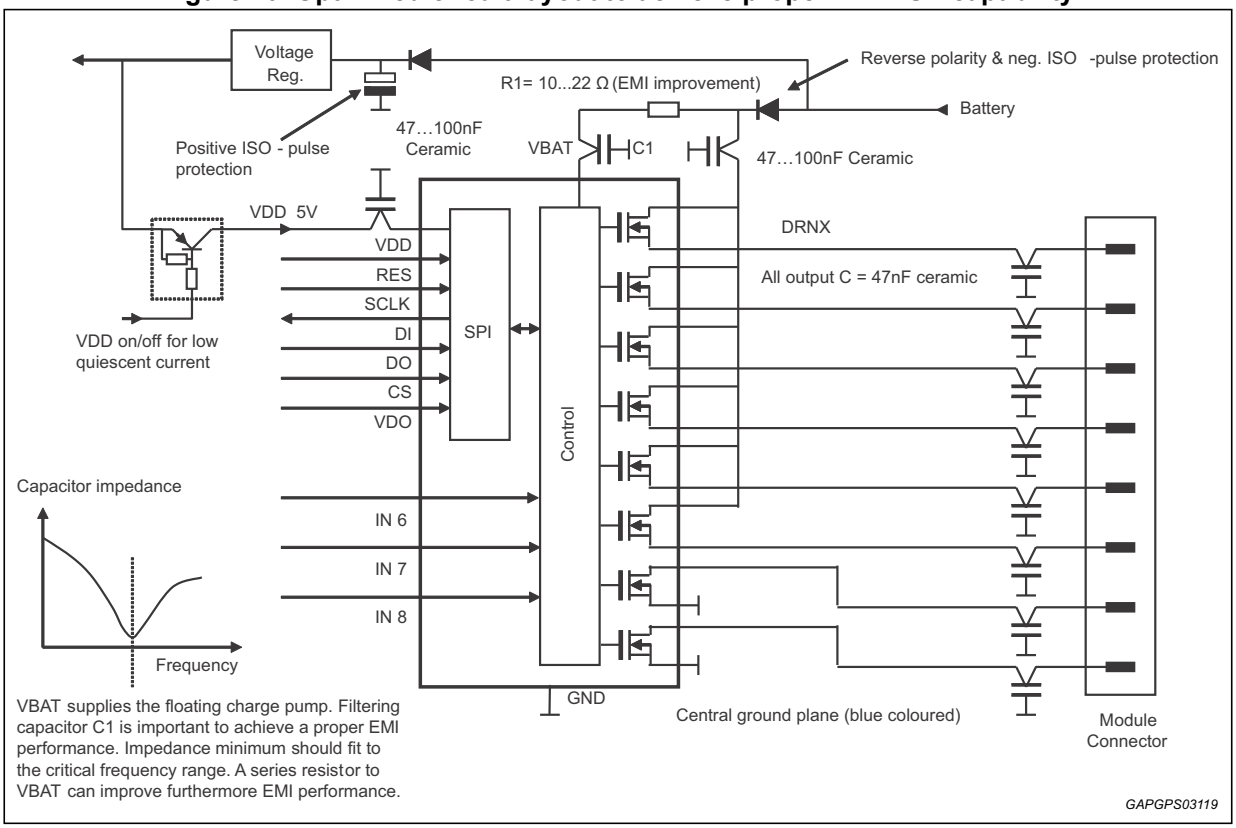
8 Application circuit

Figure 10. Optimized circuit layout to achieve proper EMI/ESD capability



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9 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: *www.st.com*.

ECOPACK® is an ST trademark.

9.1 PowerSSO-28 (exposed pad) package information

Figure 11. PowerSSO-28 (exposed pad) package outline

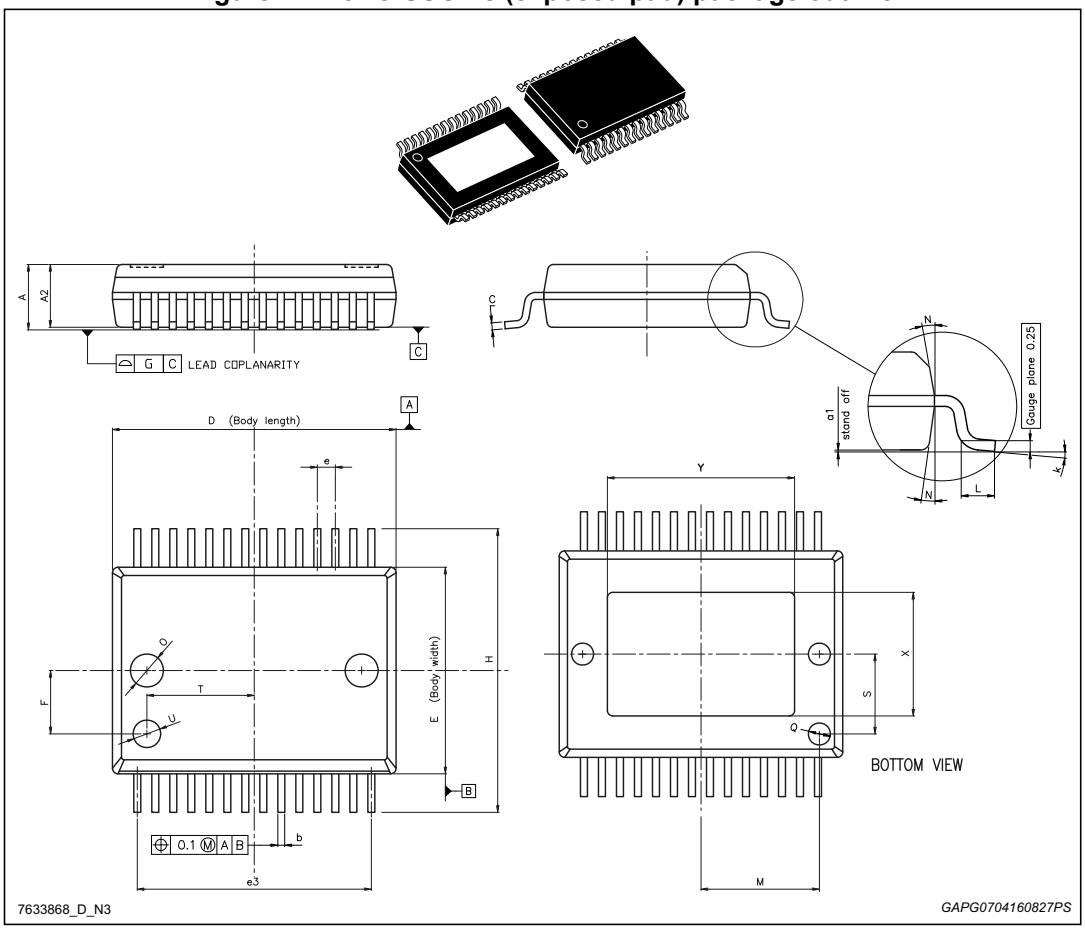

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Table 13. PowerSSO-28 (exposed pad) package mechanical data

Ref	Dimensions					
	Millimeters			Inches[1]		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	2.15	-	2.45	0.0846	-	0.0965
A2	2.15	-	2.35	0.0846	-	0.0925
a1	-	-	0.1	-	-	0.0039
b	0.18	-	0.36	0.0071	-	0.0142
c	0.23	-	0.32	0.0091	-	0.0126
D [2]	10.1	-	10.50	0.3976	-	0.4134
E [2]	7.4	-	7.6	0.2913	-	0.2992
e	-	0.65	-	-	0.0256	-
e3	-	8.45	-	-	0.3327	-
F	-	2.3	-	-	0.0906	-
G	-	-	0.1	-	-	0.0039
G1	-	-	0.06	-	-	0.0024
H	10.1	-	10.5	0.3976	-	0.4134
h	-	-	0.4	-	-	0.0157
k	5° (Typ.)					
L	0.6	-	1	0.0236	-	0.0394
M	-	4.3	-	-	0.1693	-
N	10° (Max.)					
O	-	1.2	-	-	0.0472	-
Q	-	0.8	-	-	0.0315	-
S	-	2.9	-	-	0.1142	-
T	-	3.65	-	-	0.1437	-
U	-	1	-	-	0.0394	-
X	4.2	-	4.8	0.1654	-	0.1890
Y	6.6	-	7.2	0.2598	-	0.2835

1. Values in inches are converted from mm and rounded to 4 decimal digits.
2. "D" and "E" do not include mold flash or protrusions Mold flash or protrusions shall not exceed 0.15 mm per side (0.006").

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10 Revision history

Table 14. Document revision history

Date	Revision	Changes
13-Apr-2005	1	Initial release.
15-Jun-2006	2	Changed only look and feel.
08-Aug-2006	3	Modified *Table 9: Bit command register definition on page 22*.
28-May-2007	4	Changed the min. value of the CSlead parameter on the *Table 8*.
17-Jul-2007	5	Updated *Table 6* and *Table 7*. Added new *Figure 4*. Changed the status from Preliminary data to Datasheet.
03-Aug-2007	6	Updated in *Table 4* the ESD parameter.
12-Jun-2008	7	Added order codes in *Table 1: Device summary on page 1*. Added “CS2SCLK” parameter in *Table 8: SPI characteristics and timings*. Updated *Figure 6: SPI timing diagram*.
02-Dec-2008	8	Updated *Table 1: Device summary on page 1*. Removed all references to the SO-28 package. Updated *Section 2.1: Operating range* and *Section 2.2: Absolute maximum ratings*. Added *Section 2.1.1: Functional operative range*, *Section 2.1.2: Jump start conditions*, *Section 2.1.3: Operation at low battery condition* and *Section 2.1.4: Operation at load dump condition*. Added *Section 8: Application circuit*. Added “POR_{th}” parameter in *Table 6: DC characteristics*.
13-May-2009	9	Updated *Table 1: Device summary on page 1*. Updated *Figure 11: PowerSSO28 mechanical data and package dimensions*.
27-Jul-2010	10	Updated *Table 1: Device summary on page 1*. Updated *Section 7: Fault operation on page 25*.
19-Sep-2013	11	Updated Disclaimer.
02-May-2016	12	Modified in cover page the title and added “AEC-Q100 (Rev. F) qualified” in Features bullet. Updated *Section 9: Package information*.

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