

IO-Link communication master transceiver IC

Datasheet – production data

Features

- Supply voltage from 18 to 32.5 V
- Programmable output stages: high-side, low-side or push-pull ($< 2 \Omega$)
- Up to 500 mA L+ protected high-side driver
- Supports COM1, COM2 and COM3 mode
- Additional IEC61131-2 type-1 input
- Short-circuit and overcurrent output protection through current limitation and programmable cutoff current
- 3.3 V / 5 V, 50 mA linear regulator
- 5 mA IO-Link digital input
- Fast mode I²C for IC control, configuration and diagnostic
- Diagnostic dual LED sequence generator and driver
- 5 V and 3.3 V compatible I/Os
- Overvoltage protection ($> 36 \text{ V}$)
- Overtemperature protection
- ESD protection
- Miniaturized: VFQFPN-26L 3.5 x 5 x 1 mm package

Applications

- Industrial sensors
- Factory automation
- Process control

Description

The L6360 is a monolithic IO-Link master port compliant with PHY2 (3 wires) supporting COM1 (4.8 kbaud), COM2 (38.4 kbaud) and COM3 (230.4 kbaud) modes.

The C/Q_O output stage is programmable: high-side, low-side or push-pull; also cutoff current,



cutoff current delay time, and restart delay are programmable.

Cutoff current and cutoff current delay time, combined with thermal shutdown and automatic restart protect the device against overload and short-circuit.

C/Q_O and L+ output stages are able to drive resistive, inductive and capacitive loads. Inductive loads up to 10 mJ can be driven.

Supply voltage is monitored and low voltage conditions are detected.

The L6360 transfers, through the PHY2(C/Q_O pin), data received from a host microcontroller through the USART (IN C/Q_O pin), or to the USART (OUT C/Q_I pin) data received from PHY2 (C/Q_I pin).

To enable full IC control, configuration and monitoring (i.e. fault conditions stored in the status register), the communication between the system microcontroller and the L6360 is based on a Fast mode 2-wire I²C.

The L6360 has nine registers to manage the programmable parameters and the status of the IC.

Monitored fault conditions are: L+ line, overtemperature, C/Q overload, linear regulator undervoltage, and parity check.

Internal LED driver circuitries, in open drain configuration, provide two programmable sequences to drive two LEDs.

Contents

1	Block diagram	7
2	Pin connections	8
3	Absolute maximum ratings	10
4	Recommended operating conditions	11
5	Electrical characteristics	12
6	Device configuration	18
6.1	I ² C single master bus interface	18
6.1.1	Introduction	18
6.1.2	Main features	18
6.1.3	General description	18
6.1.4	SDA/SCL line control	18
6.1.5	Mode selection	19
6.1.6	Functional description	20
6.1.7	Communication flow	21
6.1.8	I ² C address	21
6.1.9	Internal registers	22
6.1.10	Startup default configuration	34
6.2	Interrupt	36
6.3	Demagnetization	37
6.3.1	Fast demagnetization	38
6.3.2	Slow demagnetization	39
6.4	I ² C protocol	40
6.4.1	Protocol configuration	40
6.4.2	Operating modes	41
7	Physical layer communication	53
7.1	Transceiver	54
7.2	IEC 61131-2 type 1 digital inputs	55

8	Diagnostic LED sequence generator and driver	55
9	Linear regulator	56
10	Application example	57
11	EMC protection considerations	58
	11.1 Supply voltage protection	58
	11.2 I/O lines protection	61
12	Package mechanical data	63
13	Revision history	64

List of tables

Table 1.	Device summary	7
Table 2.	Pin description	8
Table 3.	Absolute maximum ratings	10
Table 4.	Recommended operating conditions	11
Table 5.	Thermal data	11
Table 6.	Electrical characteristics - power section	12
Table 7.	Electrical characteristics - linear regulator	15
Table 8.	Electrical characteristics - logic inputs and outputs	15
Table 9.	Electrical characteristics - LED driving	15
Table 10.	Electrical characteristics - I ² C (Fast mode)	15
Table 11.	Main parameter typical variation vs. +/- 1% variation of R _{bias} value	17
Table 12.	Register addresses	22
Table 13.	EN _{CGQ} : C/Q pull-down enable	26
Table 14.	I _{COQ} : C/Q _O HS and LS cutoff current	27
Table 15.	t _{dcoq} : C/Q _O HS and LS cutoff current delay time	27
Table 16.	t _{rcoq} : C/Q _O restart delay time	27
Table 17.	t _{dbg} : C/Q _I de-bounce time	28
Table 18.	EN _{CGI} : I/Q pull-down enable	28
Table 19.	CQ _{PDG} : C/Q pull-down generator switching	28
Table 20.	L _{+COD} : L+ cutoff disable	29
Table 21.	t _{dcol} : L+ HS cutoff current delay time	29
Table 22.	t _{rcoj} : L+ restart delay	29
Table 23.	t _{dbi} : I/Q de-bounce time	29
Table 24.	C/Q output stage configuration	30
Table 25.	Parameter default configuration	34
Table 26.	Register default configuration	34
Table 27.	Current Write mode direction bit	43
Table 28.	Sequential Write mode direction bit	46
Table 29.	Read mode: register address	47
Table 30.	Address register	52
Table 31.	Linear regulator selection pin	56
Table 32.	Supply voltage protection component description	58
Table 33.	Refined supply voltage protection component description	59
Table 34.	V _H protection component description	60
Table 35.	Typical protection in IO-Link application component description	61
Table 36.	IO-Link and SIO applications extended protection component description	62
Table 37.	Mechanical data for VFQFPN - 26-lead 3.5 x 5 x 1 mm - 0.50 pitch	63
Table 38.	Document revision history	64

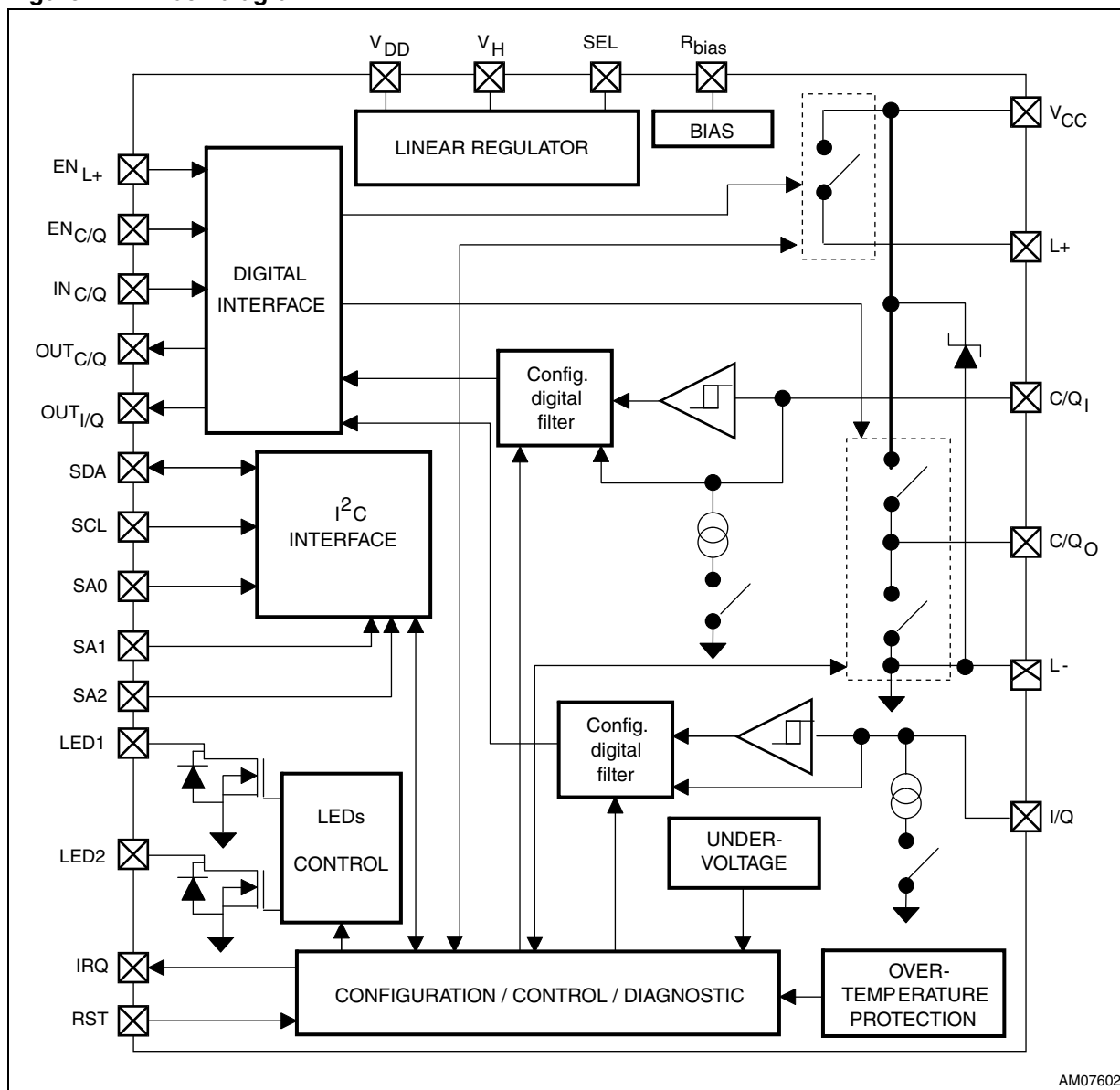
List of figures

Figure 1.	Block diagram	7
Figure 2.	Pin connections (top view)	8
Figure 3.	Rise/fall time test setup	16
Figure 4.	Normalized rise and fall time vs. output capacitor value (typ. values in push-pull configuration)	16
Figure 5.	A master transmitter addressing a slave receiver with a 7-bit address (the transfer is not changed)	19
Figure 6.	A master reads data from the slave immediately after the first byte	19
Figure 7.	Transfer sequencing	20
Figure 8.	I ² C communication	21
Figure 9.	Status register	23
Figure 10.	Power-on bit behavior	24
Figure 11.	Overtemperature (OVT) bit behavior	24
Figure 12.	Cutoff behavior	25
Figure 13.	Control register 1	26
Figure 14.	Control register 2	28
Figure 15.	Configuration register	30
Figure 16.	LED1 registers	32
Figure 17.	LED2 registers	33
Figure 18.	Parity register	33
Figure 19.	Power stage. Q2 is not present on L+ output	37
Figure 20.	Fast demagnetization principle schematic. Load connected to L-	38
Figure 21.	Fast demagnetization waveform. Load connected to L-	38
Figure 22.	Slow demagnetization schematic block. Load connected to L-	39
Figure 23.	Slow demagnetization waveform. Load connected to GND	39
Figure 24.	Device initialization	40
Figure 25.	Current Write mode flow chart procedure	41
Figure 26.	Current Write mode frames	42
Figure 27.	Sequential Write mode flow chart procedure	44
Figure 28.	Sequential Write mode frames	45
Figure 29.	Microcontroller parity check calculus	46
Figure 30.	Register sequence in sequential Write mode	47
Figure 31.	Current Read mode flow chart procedure	48
Figure 32.	Current Read mode frames	49
Figure 33.	Current read communication flow	49
Figure 34.	Sequential/random Read mode	50
Figure 35.	Sequential/random read communication flow	51
Figure 36.	Block diagram communication mode	53
Figure 37.	System communication mode	53
Figure 38.	C/Q or L+ channel cutoff protection	54
Figure 39.	C/Q or L+ channel current limitation and cutoff protection with latched restart	54
Figure 40.	LED drivers	55
Figure 41.	Linear regulator	56
Figure 42.	Linear regulator principle schematic	56
Figure 43.	Application example	57
Figure 44.	Supply voltage protection with uni-directional Transil	58
Figure 45.	Refined supply voltage protection	59
Figure 46.	V _H protection vs. V _{CC}	60

Figure 47. Typical protection in IO-Link applications	61
Figure 48. IO-Link and SIO applications extended protection	62
Figure 49. Package outline for VFQFPN - 26-lead 3.5 x 5 x 1 mm - 0.50 pitch	63

1 Block diagram

Figure 1. Block diagram



AM07602

Table 1. Device summary

Order code	Package	Packaging
L6360	VFQFPN 3.5 x 5 x 1 - 26 leads	Tray
L6360TR	VFQFPN 3.5 x 5 x 1 - 26 leads	Tape and reel

2 Pin connections

Figure 2. Pin connections (top view)

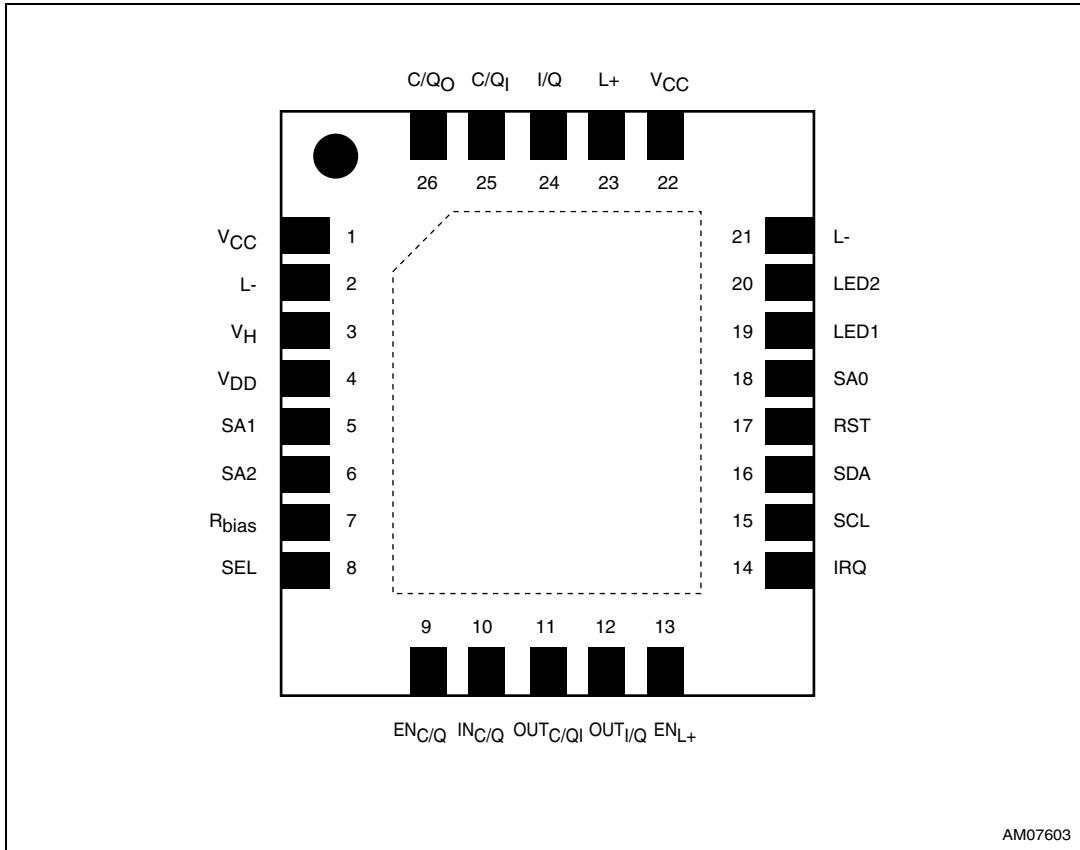


Table 2. Pin description

Pin	Name	Description	Type
1	V _{CC}	IC power supply	Supply
2	L-	L- line (IC ground)	Supply
3	V _H	Linear regulator supply voltage	Supply
4	V _{DD}	Linear regulator output voltage	Output
5	SA1	Serial address 1	Input
6	SA2	Serial address 2	Input
7	R _{bias}	External resistor for internal reference generation	Input
8	SEL	Linear regulator 3.3 V/5 V voltage selection. Output is 5 V when SEL pin is pulled to GND.	Input
9	EN _{C/Q}	C/Q output enable	Input
10	IN _{C/Q}	C/Q channel logic input	Input
11	OUT _{C/Q}	C/Q channel logic output	Output
12	OUT _{I/Q}	I/Q channel logic output	Output

Table 2. Pin description (continued)

Pin	Name	Description	Type
13	EN _{L+}	L+ switch enable. When EN _{L+} is high the switch is closed	Input
14	IRQ	Interrupt request signal (open drain)	Output
15	SCL	Serial clock line	Input
16	SDA	Serial data line	Input/output
17	RST	Reset - active low	Input
18	SA0	Serial address 0	Input
19	LED1	Status/diagnostic LED (open drain)	Output
20	LED2	Status/diagnostic LED (open drain)	Output
21	L-	L- line (IC ground)	Supply
22	V _{CC}	IC power supply	Supply
23	L+	L+ line	Supply
24	I/Q	I/Q channel line	Input
25	C/Q _I	Transceiver (C/Q channel) line	Input
26	C/Q _O	Transceiver (C/Q channel) line	Output

3 Absolute maximum ratings

Table 3. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	V_{CLAMP}	V
V_{SEL}	Linear regulator selection pin voltage	-0.3 to 4	V
V_{DD}	Linear regulator output voltage	5.5	V
V_H	Linear regulator input voltage	V_{CC}	V
$V_{INC/Q}, ENC/Q, ENL+$	$IN_{C/Q}, EN_{C/Q}, EN_{L+}$ voltage	-0.3 to $V_{DD} + 0.3$	V
$V_{SDA}, SCL, SA0, 1, 2$	I ² C voltage	-0.3 to $V_{DD} + 0.3$	V
$V_{LED1, 2}$	LED1, 2 voltage	-0.3 to $V_{DD} + 0.3$	V
$V_{C/Q}, V_{I/Q}$	C/Q _I , I/Q voltage	-0.3 to $V_{CC} + 0.3$	V
V_{RST}	Reset voltage	-0.3 to $V_{DD} + 0.3$	V
V_{IRQ}	IRQ voltage	-0.3 to $V_{DD} + 0.3$	V
V_{Rbias}	External precision resistance voltage	-0.3 to 4	V
V_{ESD}	Electrostatic discharge (human body model)	2000	V
I_{CLAMP}	Current through V_{CLAMP} in surge test (1 kV, 500 Ω) condition	2	A
$I_{C/Q}, I_{L+}$	C/Q _O , L+ current (continuous)	Internally limited	A
$I_{OUTC/Q}, I_{OUTI/Q}$	OUT _{C/Q} , OUT _{I/Q} output current	± 5	mA
I_{SDA}	I ² C transmission data current (open drain pin)	10	mA
I_{IRQ}	Interrupt request signal current	10	mA
$I_{LED1, 2}$	LED1, 2 current	10	mA
E_{load}	L+ demagnetization energy	10	mJ
P_{TOT}	Power dissipation at $T_C = 25\text{ °C}$	Internally limited	W
P_{LR}	Linear regulator power dissipation	200	mW
T_J	Junction operating temperature	Internally limited	°C
T_{STG}	Storage temperature	-55 to 150	°C

4 Recommended operating conditions

Table 4. Recommended operating conditions

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
V_{CC}	Supply voltage	-	18		32.5	V
V_H	Linear regulator input voltage		7		V_{CC}	V
f_{SCL}	SCL clock frequency				400	kHz
R_{bias}	Precision resistance		-0.1%	124	0.1%	k Ω
T_J	Junction temperature		-40		125	$^{\circ}C$

Table 5. Thermal data

Symbol	Parameter	Typ.	Unit
$R_{th\ j-case}$	Thermal resistance, junction-to-case	6	$^{\circ}C/W$
$R_{th\ j-amb}$	Thermal resistance, junction-to-ambient ⁽¹⁾	50	$^{\circ}C/W$

1. Mounted on FR4 PCB with 2 signal Cu layers and 2 power Cu layers interconnected through vias.

5 Electrical characteristics

(18 V < V_{CC} < 30 V; -25 °C < T_J < 125 °C; V_{DD} = 5 V; unless otherwise specified.)

Table 6. Electrical characteristics - power section

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
V _{CLAMP}	Voltage clamp	I = 5 mA	36			V
V _{UV}	Undervoltage ON-threshold		16	17	18	V
V _{UVH}	Undervoltage hysteresis		0.3	1		V
V _{REGLN5H}	Linear regulator undervoltage high threshold	SEL = L	4.3		4.7	V
V _{REGLN5L}	Linear regulator undervoltage low threshold	SEL = L	3.6		4.2	V
V _{REG5HYS}	Linear regulator undervoltage hysteresis	SEL = L	0.1			V
V _{REGLN33H}	Linear regulator undervoltage high threshold	SEL = H	2.8		3.1	V
V _{REGLN33L}	Linear regulator undervoltage low threshold	SEL = H	2.5		2.7	V
V _{REG33HYS}	Linear regulator undervoltage hysteresis	SEL = H	0.1			V
V _{QTHH}	C/Q ₁ and I/Q upper voltage threshold		10.5		12.9	V
V _{QTHL}	C/Q ₁ and I/Q lower voltage threshold		8		11.4	V
V _{QHY}	C/Q and I/Q hysteresis voltage		1			V
V _{demag}	L+ demagnetization voltage	I = 5 mA	-8.5	-6.5	-4.8	V
V _{fHS}	C/Q high-side freewheeling diode forward voltage	I = 10 mA		0.5		V
V _{fLS}	C/Q low-side freewheeling diode forward voltage	I = 10 mA		0.5		V
V _{LTHOFF}	L+ line diagnostic lower threshold		9	10	11	V
V _{LTHY}	L+ line diagnostic hysteresis		0.1	1		V
V _{LTHON}	L+ line diagnostic upper threshold		10	11	12	V
I _S	Supply current	OFF-state		100		μA
		ON-state V _{CC} at 32.5 V		4		mA
I _{OFFCQ}	OFF-state C/Q _O current	EN _{C/Q} = 0, V _{C/Q} = 0 V			1	μA
I _{COQ}	C/Q _O low- and high-side cutoff current	Programmable (see Control register 1)	70	115	190	mA
			150	220	300	mA
			290	350	440	mA
			430	580	720	mA

Table 6. Electrical characteristics - power section (continued)

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
I_{LIMQ}	C/Q _O low- and high-side limitation current		500		1600	mA
I_{OFFL}	L+ OFF-state current	$EN_{L+} = 0,$ $V_{L+} = 0\text{ V}$	0		200	μA
I_{COL}	L+ cutoff current		480	580	730	mA
I_{LIML}	L+ limitation current		500		1600	mA
$I_{INC/Qi}$	C/Q _I pull-down current	Programmable (see section Control register 2)	5		6.5	mA
			2		3.3	mA
$I_{INI/Q}$	I/Q pull-down current	(see Control register 2)	2		3	mA
R_{ONL}	L+ high-side ON-state resistance	$I_{OUT} = 0.2\text{ A}$ at $T_J = 25\text{ }^\circ\text{C}$		1		Ω
		$I_{OUT} = 0.2\text{ A}$ at $T_J = 125\text{ }^\circ\text{C}$			2	Ω
R_{ONCQH}	C/Q _O high-side ON-state resistance	$I_{OUT} = 0.2\text{ A}$ at $T_J = 25\text{ }^\circ\text{C}$		1		Ω
		$I_{OUT} = 0.2\text{ A}$ at $T_J = 125\text{ }^\circ\text{C}$			2	Ω
R_{ONCQL}	C/Q _O low-side ON-state resistance	$I_{OUT} = 0.2\text{ A}$ at $T_J = 25\text{ }^\circ\text{C}$		0.6		Ω
		$I_{OUT} = 0.2\text{ A}$ at $T_J = 125\text{ }^\circ\text{C}$			1.2	Ω
$t_{dINC/Q}$	IN _{C/Q} to C/Q _O propagation delay time	Push-pull (CQ _O rising edge)		140		ns
		Push-pull (CQ _O falling edge)		160		ns
$t_{ENC/Q}$	EN _{C/Q} to C/Q _O propagation delay time	Push-pull (CQ _O rising edge)		110		ns
		Push-pull (CQ _O falling edge)		225		ns
t_{rPP}	C/Q rise time in push-pull configuration	10% to 90%. See Figure 3	250		860	ns
t_{fPP}	C/Q fall time in push-pull configuration	10% to 90%. See Figure 3	290		860	ns
t_{rHS}	C/Q rise time in high-side configuration			410		ns
t_{fHS}	C/Q fall time in high-side configuration			700		ns
t_{rLS}	C/Q rise time in low-side configuration			750		ns
t_{fLS}	C/Q fall time in low-side configuration			530		ns
t_{ENL}	EN _L to L+ propagation delay time			1		μs
t_{rL+}	L+ rise time			3		μs
t_{fL+}	L+ fall time			25		μs
$t_{dC/Qi}$	C/Q _I to OUT _{C/Q} (falling) propagation delay time			40		ns
	C/Q _I to OUT _{C/Q} (rising) propagation delay time			100		ns
$t_{dI/Q}$	I/Q to OUT _{I/Q} (falling) propagation delay time			40		ns
	I/Q to OUT _{I/Q} (rising) propagation delay time			100		ns

Table 6. Electrical characteristics - power section (continued)

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
t_{dcoq}	C/Q _O low- and high-side cutoff current delay time	Programmable (see Control register 1)		100		μs
				150		μs
				200		μs
				250		μs
t_{rcoq}	C/Q _O restart delay time	Programmable (see Control register 1)		$255 \times t_{dcoq}$		
				Latched ⁽¹⁾		
t_{dbq}	C/Q _I de-bounce time	Programmable (see Control register 1)		0		μs
				5		μs
				20		μs
				100		μs
t_{dbl}	I/Q de-bounce time	Programmable (see Control register 2)		0		μs
				5		μs
				20		μs
				100		μs
t_{dcol}	L+ cutoff current delay time	Programmable (see Control register 2)		500		μs
				0		μs
t_{rcol}	L+ restart delay time	Programmable (see Control register 2)		64		ms
				Latched ⁽¹⁾		
T_{JSD}	Junction temperature shutdown			150		°C
T_{JHYST}	Junction temperature thermal hysteresis			20		°C
T_{JRST}	Junction temperature restart threshold			130		°C

1. Unlatch through I²C communication.

Table 7. Electrical characteristics - linear regulator

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
V_{DD}	Linear regulator output voltage	SEL = L	4.84	5	5.13	V
		SEL = H	3.22	3.3	3.37	V
I_{LIMLR}	Linear regulator output current limitation		65			mA

Table 8. Electrical characteristics - logic inputs and outputs

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
V_{IL}	Input low-level voltage				0.8	V
V_{IH}	Input high-level voltage		2.2			V
V_{IHIS}	Input hysteresis voltage			0.2		V
I_{IN}	Input current	$V_{IN} = 5\text{ V}$			1	μA
V_{OL}	Output low-level voltage	$I_{OUT} = -2\text{ mA}$			0.5	V
V_{OH}	Output high-level voltage	$I_{OUT} = 2\text{ mA}$	$V_{DD} - 0.5\text{ V}$			V
V_{LIRQ}	Open drain output low-level voltage	$I_{OUT} = 2\text{ mA}$			0.5	V

Table 9. Electrical characteristics - LED driving

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
$V_{LED1, 2}$	Open drain output low-level voltage	$I_{LED} = 2\text{ mA}$	-		0.5	V
I_{LED}	LED1, 2 leakage current	$V_{LED1} = V_{LED2} = 5\text{ V}$		3		nA

Table 10. Electrical characteristics - I²C (Fast mode)⁽¹⁾

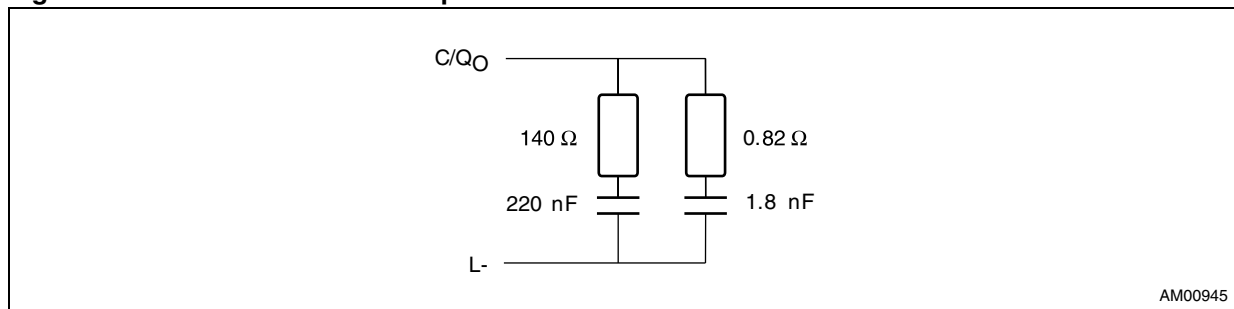
Symbol	Parameter	Test condition	Min.	Max.	Unit
$V_{IL(SDA)}$	SDA low-level input voltage			0.3	V
$V_{IH(SDA)}$	SDA high-level input voltage			$0.7 \times V_{DD}$	V
$V_{IL(SCL)}$	SCL low-level input voltage			0.3	V
$V_{IH(SCL)}$	SCL high-level input voltage			$0.7 \times V_{DD}$	V
I_{IN}	I ² C SDA, SCL input current	$(0.1 \times V_{DD}) < V_{IN} < (0.9 \times V_{DD})$	-10	10	μA
$t_{r(SDA)}$	I ² C SDA rise time		$20 + 0.1 C_b$	300	ns
$t_{r(SCL)}$	I ² C SCL rise time		$20 + 0.1 C_b$	300	ns
$t_{f(SDA)}$	I ² C SDA fall time		$20 + 0.1 C_b$	300	ns
$t_{f(SCL)}$	I ² C SCL fall time		$20 + 0.1 C_b$	300	ns
$t_{su(SDA)}$	SDA setup time		100		ns
$t_h(SDA)$	SDA hold time			0.9	μs

Table 10. Electrical characteristics - I²C (Fast mode)⁽¹⁾ (continued)

Symbol	Parameter	Test condition	Min.	Max.	Unit
t _{su(STA)}	Repeated START condition setup		0.6		μs
t _{su(STO)}	STOP condition setup time		0.6		μs
t _{w(START/STOP)}	STOP to START condition time (bus free)		1.3		μs
t _{w(SCLL)}	SCL clock low time		1.3		μs
t _{w(SCLH)}	SCL clock high time		0.6		μs
C _b	Capacitance for each bus line			400	pF
C _I	Capacitance for each I/O pin			10	pF

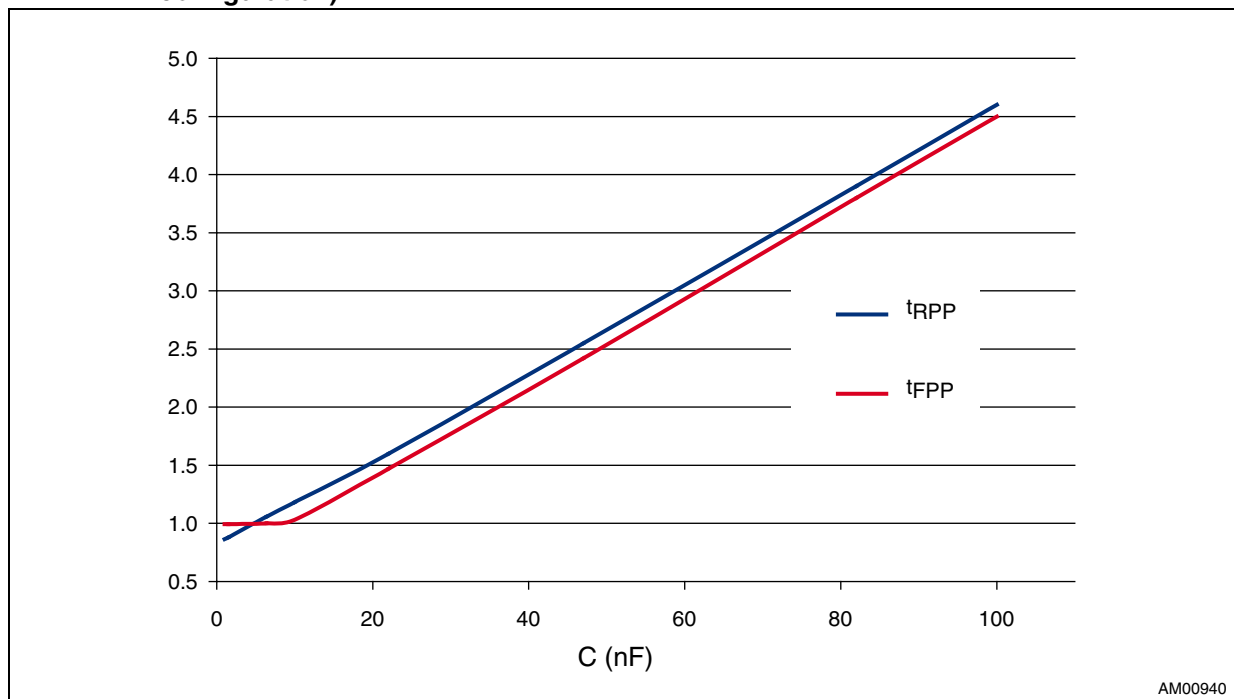
1. Values based on standard I²C protocol requirement.

Figure 3. Rise/fall time test setup



AM00945

Figure 4. Normalized rise and fall time vs. output capacitor value (typ. values in push-pull configuration)



AM00940

Table 11. Main parameter typical variation vs. +/- 1% variation of R_{bias} value

Symbol	Parameter	Typ. variation vs. R_{bias}		
		R_{bias} [k Ω]		
		122.74	124	125.24
I_s	Supply current	0.76%	0	-0.50%
$I_{INC/Qi}$	Input current C/Q _i pin (5.5 mA)	0.93%	0	-0.93%
$I_{INC/Qi}$	Input current C/Q _i pin (2.5 mA)	0.75%	0	-1.13%
$I_{INI/Q}$	Input current I/Q pin (2.5 mA)	0.85%	0	-0.85%
t_{dcoq}	C/Q _O low- and high-side cutoff current delay time	-2.44%	0	2.00%
I_{COQ}	C/Q _O low- and high-side cutoff current (115 mA)	1.19%	0	-1.28%
t_{dcol}	L+ cutoff current delay time (500 μ s)	-0.95%	0	0.47%
I_{COL}	L+ cutoff current	1.36%	0	-0.91%
t_{rcol}	L+ restart delay time	-0.93%	0	0.97%
V_{UV}	Undervoltage ON-threshold	0.00%	0	0.00%
V_{DD}	Linear regulator output voltage (3.3 V)	-0.03%	0	0.03%
V_{DD}	Linear regulator output voltage (5 V)	-0.02%	0	0.02%
I_{LIMQ}	C/Q _O high-side limitation current	0.64%	0	-0.71%
I_{LIMQ}	C/Q _O low-side limitation current	0.28%	0	-1.47%
I_{LIML}	L+ limitation current	0.47%	0	-2.09%
V_{QTHH}	C/Q _i and I/Q upper voltage threshold	0.00%	0	0.00%
V_{QTHL}	C/Q _i and I/Q lower voltage threshold	0.00%	0	0.00%
V_{QHY}	C/Q and I/Q hysteresis voltage	0.00%	0	0.00%
t_{rPP}	C/Q rise time in push-pull configuration	-1.59%	0	1.18%
t_{fPP}	C/Q fall time in push-pull configuration	-2.14%	0	0.94%
$t_{dINC/Q}$	$I_{NC/Q}$ to C/Q _O propagation delay time	-1.44%	0	0.75%
$t_{dINC/Q}$	$I_{NC/Q}$ to C/Q _O propagation delay time	-2.36%	0	0.18%
$t_{dC/Qi}$	C/Q _i to OUT _{C/Q} propagation delay time	0.49%	0	1.13%
$t_{dC/Qi}$	C/Q _i to OUT _{C/Q} propagation delay time	1.82%	0	0.03%
t_{dbq}	C/Q _i de-bounce time (100 μ s)	-1.76%	0	1.50%
t_{dcoq}	C/Q _O low- and high-side cutoff current delay time (200 μ s)	-1.27%	0	2.00%
I_{COQ}	C/Q _O low-side cutoff current (220 mA)	0.39%	0	-1.56%
I_{COQ}	C/Q _O low-side cutoff current (350 mA)	0.36%	0	-1.43%
I_{COQ}	C/Q _O low-side cutoff current (580 mA)	0.65%	0	-1.72%
t_{rcoq}	C/Q _O restart delay time	-0.90%	0	0.97%
I_{COQ}	C/Q _O high-side cutoff current (220 mA)	0.84%	0	-0.84%
I_{COQ}	C/Q _O high-side cutoff current (350 mA)	1.38%	0	-0.69%
I_{COQ}	C/Q _O high-side cutoff current (580 mA)	1.08%	0	-1.08%

6 Device configuration

SDA and SCL configure the L6360 device through I²C.

6.1 I²C single master bus interface

6.1.1 Introduction

The I²C bus interface serves as an interface between the microcontroller and the serial I²C bus.

It provides single master functions, and controls all I²C bus-specific sequencing, protocol and timing.

It supports fast I²C mode (400 kHz).

6.1.2 Main features

- Parallel bus / I²C protocol converter
- Interrupt generation
- Fast I²C mode
- 7-bit addressing.

6.1.3 General description

In addition to receiving and transmitting data, this interface converts it from serial to parallel format and vice versa.

The interface is connected to the I²C bus by a data pin (SDA) and a clock pin (SCL).

6.1.4 SDA/SCL line control

SDA is a bi-directional line, SCL is the clock input. SDA should be connected to a positive supply voltage via a current-source or pull-up resistor. When the bus is free, both lines are HIGH.

The output stages of devices connected to the bus must have an open drain or open collector output to perform the wired AND function. Data on the I²C bus can be transferred at rates up to 400 Kbit/s in fast mode.

The number of interfaces connected to the bus is limited by the bus capacitance.

For a single master application, the master's SCL output can be a push-pull driver provided that there are no devices on the bus which would stretch the clock.

Transmitter mode: the microcontroller interface holds the clock line low before transmission.

Receiver mode: the microcontroller interface holds the clock line low after reception.

When the I²C microcontroller cell is enabled, the SDA and SCL ports must be configured as floating inputs.

In this case, the value of the external pull-up resistors used depends on the application.

When the I²C microcontroller cell is disabled, the SDA and SCL ports revert to being standard I/O port pins.

On the L6360, the SDA output is an open drain pin.

6.1.5 Mode selection

Possible data transfer formats are:

- The master transmitter transmits to the slave receiver. The transfer direction is not changed (see [Figure 5](#)).
- The slave receiver acknowledges each byte.
- The master reads data from the slave immediately after the first byte (see [Figure 6](#)). At the moment of the first acknowledge, the master transmitter becomes a master receiver and the slave receiver becomes a slave transmitter.

This first acknowledge is still generated by the slave.

Subsequent acknowledges are generated by the master. The STOP condition is generated by the master which sends a not-acknowledge (\bar{A}) just prior to the STOP condition.

Figure 5. A master transmitter addressing a slave receiver with a 7-bit address (the transfer is not changed)

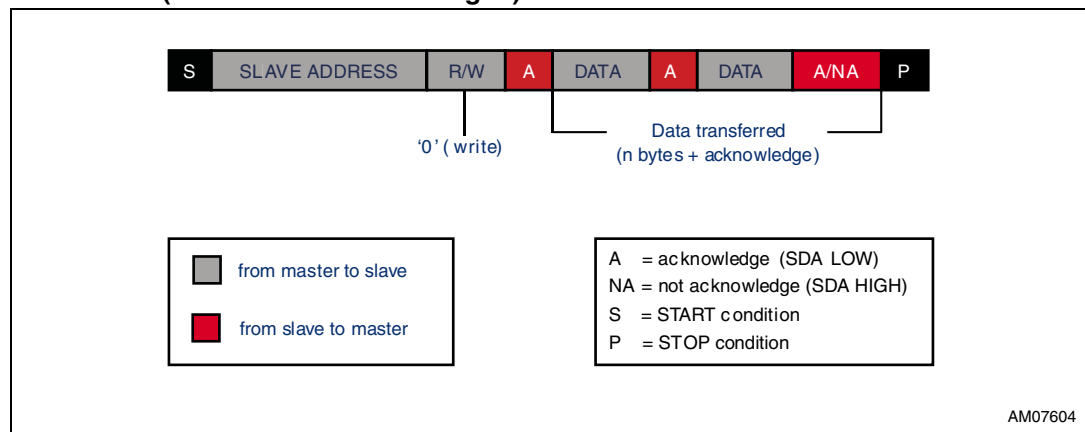
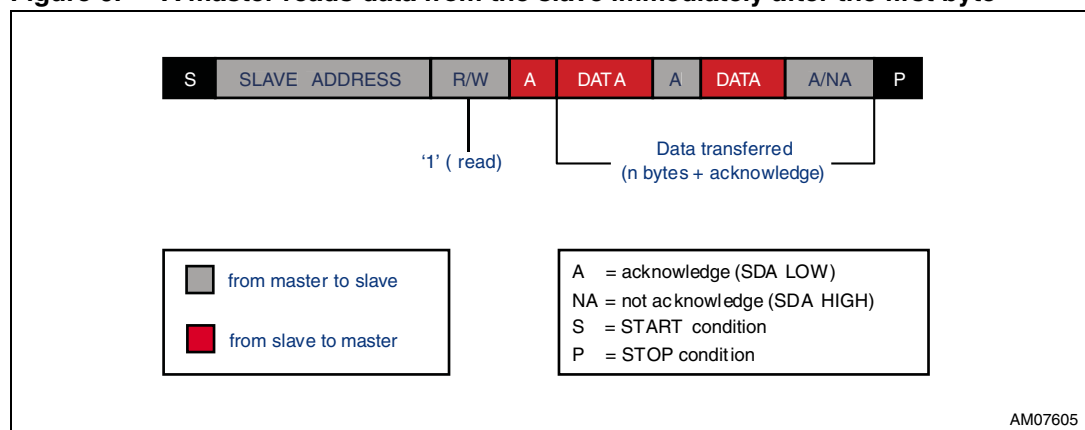


Figure 6. A master reads data from the slave immediately after the first byte



On the microcontroller, the interface can operate in the two following modes:

- Master transmitter/receiver
- Idle mode (default state)

The microcontroller interface automatically switches from idle to master receiver after it detects a START condition and from master receiver to idle after it detects a STOP condition.

On the L6360 the interface can operate in the two following modes:

- Slave transmitter/receiver
- Idle mode (default state)

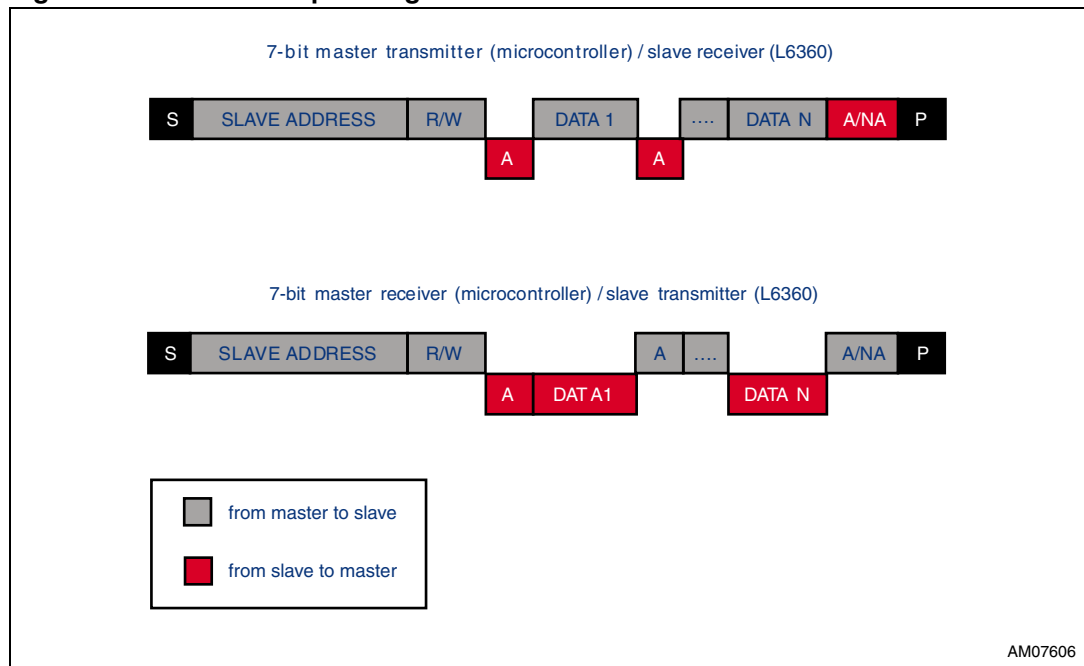
The interface automatically switches from idle to slave transmitter after it detects a START condition and from slave transmitter to idle after it detects a STOP condition.

6.1.6 Functional description

By default, the I²C microcontroller interface operates in idle; to switch from default Idle mode to Master mode a START condition generation is needed.

The transfer sequencing is shown in *Figure 7*.

Figure 7. Transfer sequencing



6.1.7 Communication flow

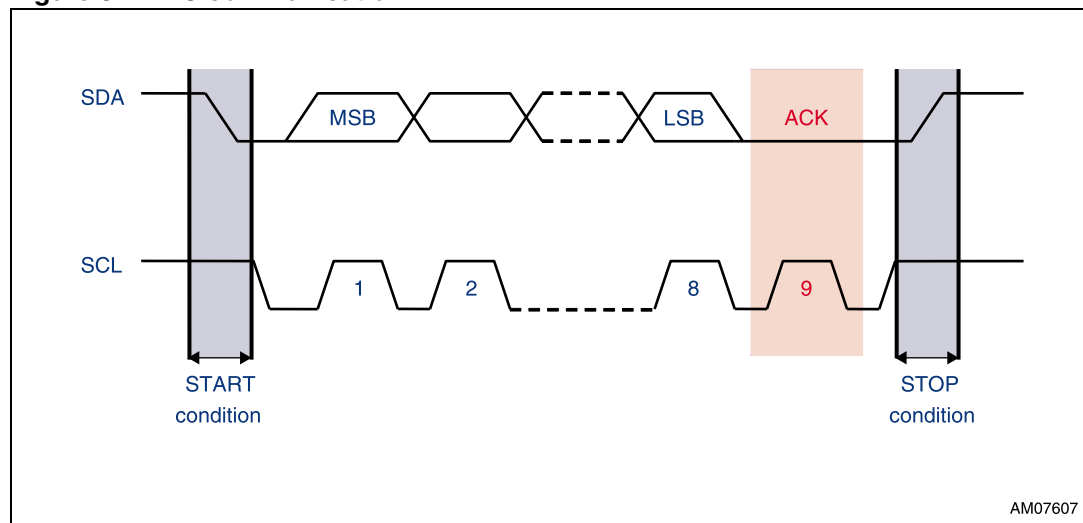
The communication is managed by the microcontroller that generates the clock signal.

A serial data transfer always begins with a START condition and ends with a STOP condition.

Data is transferred as 8-bit bytes, MSB first.

The first byte following the START condition contains the address (7 bits). A 9th clock pulse follows the 8th clock cycle of a byte transfer, during which the receiver must send an acknowledge bit to the transmitter.

Figure 8. I²C communication



Each byte is followed by an acknowledgment bit as indicated by the A or A blocks in the sequence. A START condition immediately followed by a STOP condition (void message) is a prohibited format.

6.1.8 I²C address

Each I²C connected to the bus is addressable by a unique address.

The I²C address is 7 bits long, and there is a simple master/slave relationship.

The LSB of the L6360 address can be programmed by means of dedicated IC pins (SA0, SA1 and SA2, which can be hard wired to V_{DD} or GND, or handled by μ C outputs): the microcontroller can interface up to 8 L6360 ICs.

The I²C inside the device has 5 pins:

- SDA: data
- SCL: clock
- SA0: LSB of L6360 address
- SA1: bit 1 of L6360 address
- SA2: bit 2 of L6360 address

The I²C L6360 IC address is:

- Fixed part (4 MSBits): set to "1100"
- Programmable part (3 LSBits) by hardware: from "000 to 111" connecting SAx pins to GND or V_{DD}.

In L6360 the SDA is an open drain pin.

6.1.9 Internal registers

The L6360 has some internal registers to perform control, configuration, and diagnostic operations.

These registers are listed below:

- Status register
- Configuration register
- Control register 1
- Control register 2
- LED1 register MSB
- LED1 register LSB
- LED2 register MSB
- LED2 register LSB
- Parity register.

Each register is addressable:

Table 12. Register addresses

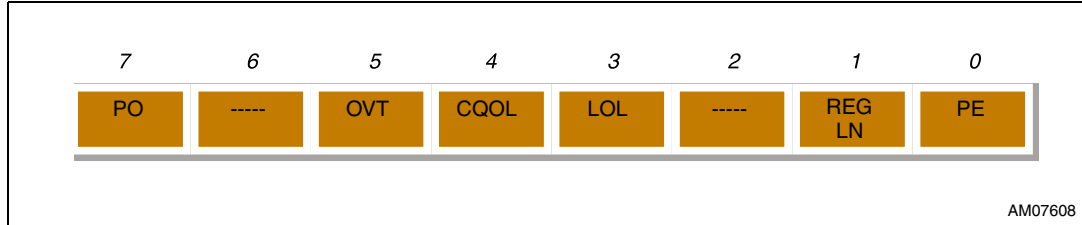
Address	Register name
0000	Status register
0001	Configuration register
0010	Control register 1
0011	Control register 2
0100	LED1 MSB
0101	LED1 LSB
0110	LED2 MSB
0111	LED2 LSB
1000	Parity register

Status register

Read only

Reset Value: [00000000]

Figure 9. Status register



The status register stores diagnostic information. It can be read to check the status of the run-time of the device (faults, warning, transmission corrupted, etc.).

When a fault condition occurs, a bit (corresponding to the fault condition) in the status register is set and an interrupt (via the IRQ pin) is generated.

If there is no persistent fault condition, the status register is cleared after a successful *current read*.

Bit 7 = **PO**: *Power-on (L+ line)*.

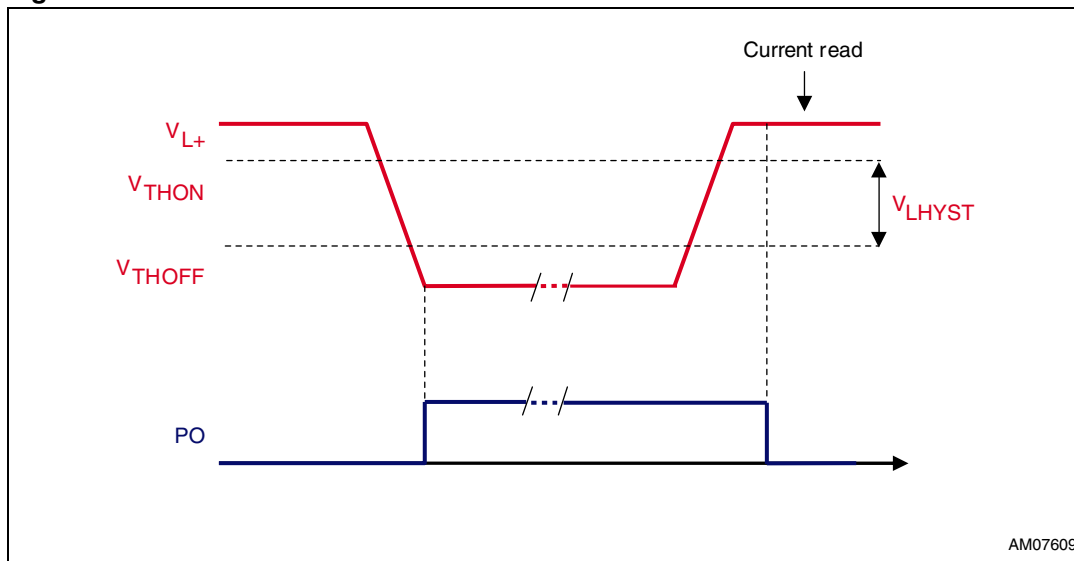
This bit indicates the status of L+ line voltage.

If the voltage goes under the lower threshold (V_{LTHOFF}) and EN_{L+} is high, the PO bit is set. It is reset after a successful *current read* if the L+ voltage has returned above the upper threshold V_{LTHON} and the read operation has begun after the bit has been set.

When the PO bit is high, IRQ is generated.

During EN_{L+} transition (from low-level to high-level) and during L+ line voltage transition, a fault condition is reported setting the PO bit and activating the IRQ pin. To reset the fault a successful *current read* is necessary.

Figure 10. Power-on bit behavior



Bit 6 = **not used: always at zero**

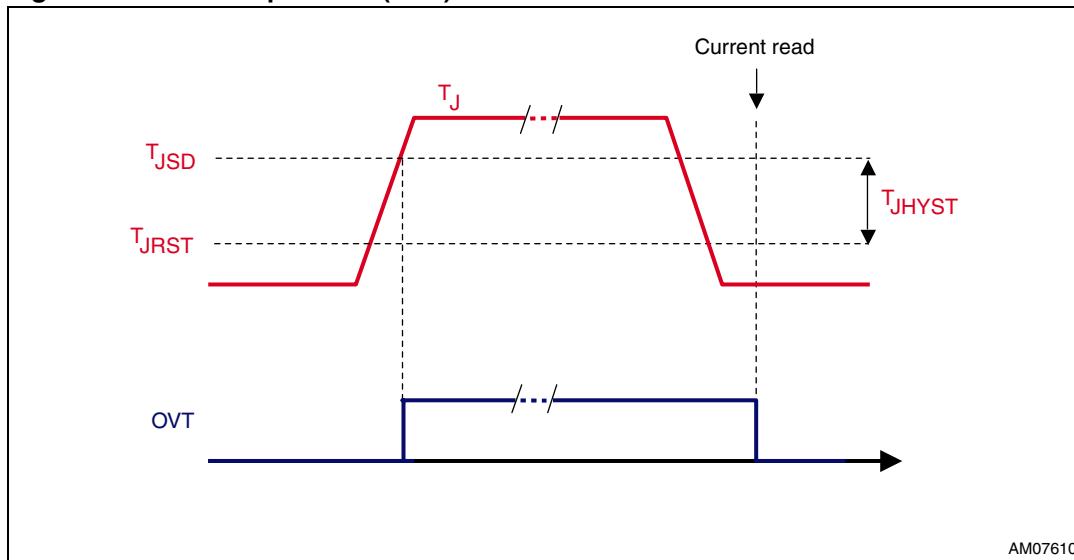
Bit 5 = **OVT**: *Overtemperature fault*

This bit indicates the status of the IC internal temperature.

If the temperature goes above the thermal shutdown threshold ($T > T_{JSD}$) the OVT bit is set. It is reset after a successful *current read* if the temperature has returned below the thermal restart threshold ($T_{JDS} - T_{JHIST}$) and the read operation has begun after the bit has been set.

When OVT bit is high, the power outputs are disabled and IRQ is generated.

Figure 11. Overtemperature (OVT) bit behavior



Bit 4 = **CQOL**: C/Q overload

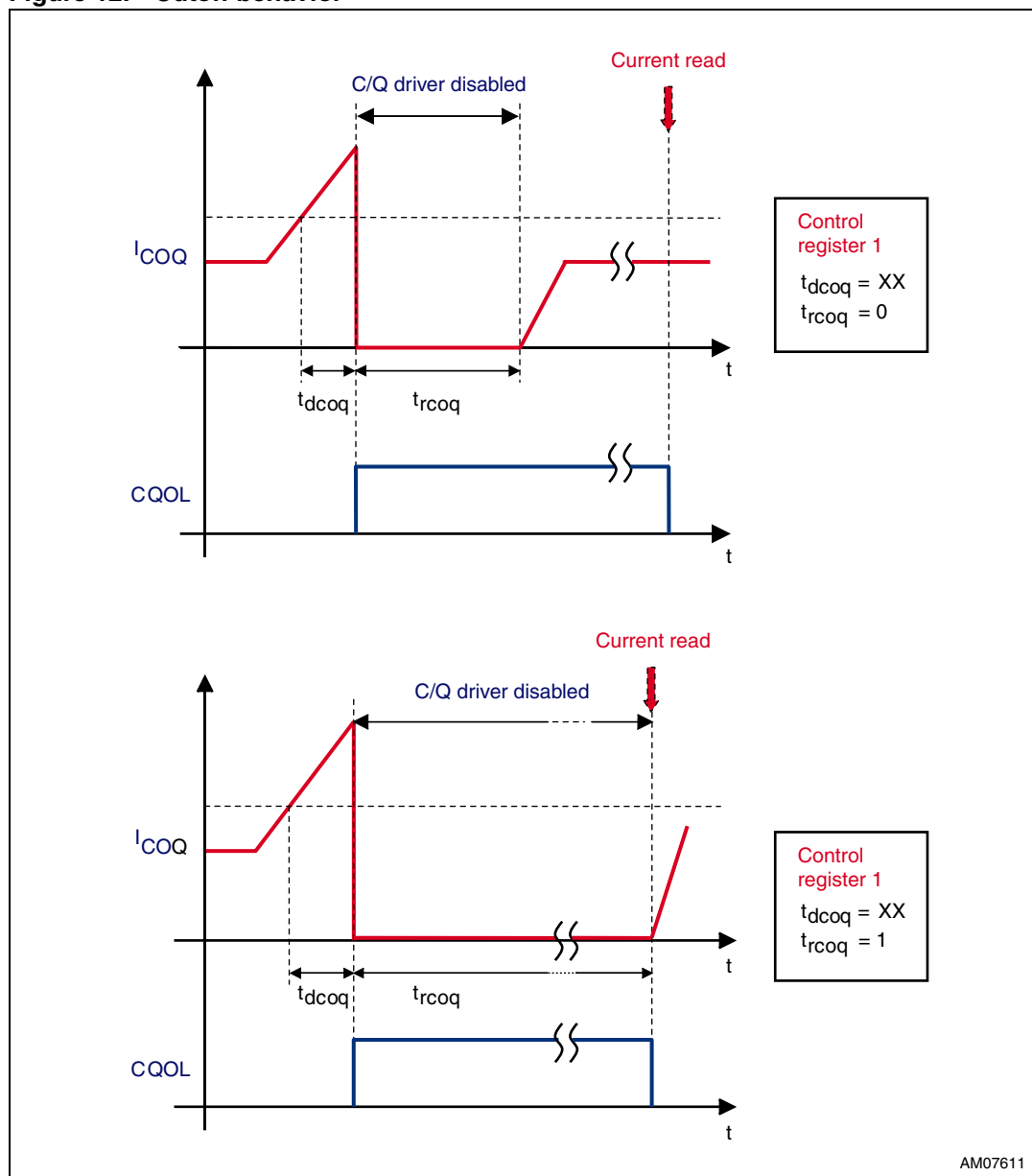
This bit is set if a cutoff occurs on the C/Q channel.

It is reset after a successful *current read* if the restart delay time (t_{rcoq}) has elapsed or the protection is latched (bit $t_{rcoq} = 1$ in *Control register 1*). The read operation should begin after the CQOL bit has been set. See also the *Control register 1* and *Transceiver* sections.

When **CQOL** bit is high, IRQ is generated.

When **CQOL** bit is high and the protection is latched (bit $t_{rcoq} = 1$ in *Control register 1*), the C/Q power output is disabled. See *Figure 12*.

Figure 12. Cutoff behavior



Bit 3 = **LOL**: *L+ overload*

This bit is set if a cutoff occurs on the L+ driver.

It is reset after a successful *current read* if the restart delay time (t_{rcol}) has elapsed or the protection is latched (bit $t_{rcol} = 1$ in [Control register 2](#)). The read operation should begin after the LOL bit has been set. See also the [Control register 2](#) and [Transceiver](#) sections.

When **LOL** bit is high, IRQ is generated.

When **LOL** bit is high and the protection is latched (bit $t_{rcol} = 1$ in [Control register 2](#)), the L+ power output is disabled.

The behavior is the same as the C/Q driver (see [Figure 12](#)).

Bit 2 = **not used: always at zero**

Bit 1 = **REG LN**: *Linear regulator undervoltage fault*

This bit is set in case of undervoltage of the linear regulator output (V_{REGLNL}). It is reset after a successful *current read* if the linear regulator output has returned to normal operation and the read operation has begun after the bit has been set.

When REG LN bit is high, IRQ is generated.

Bit 0 = **PE**: *Parity check error*

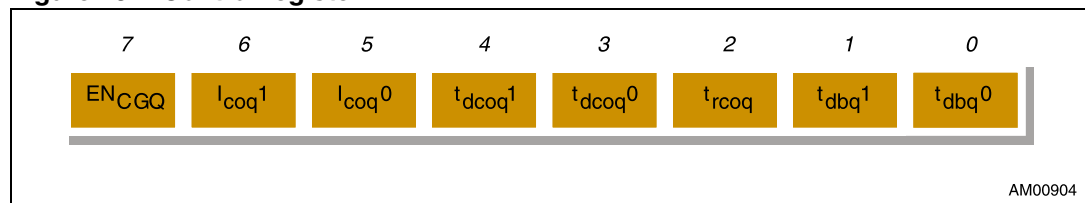
This flag is set if parity error occurs.

Control register 1

Read/write

Reset value: [00100001]

Figure 13. Control register 1



The control register holds the parameters to control the L6360. See also the [Transceiver](#) section.

Bit 7 = **ENCGQ**: C/Q_I pull-down enable

Table 13. ENCGQ: C/Q pull-down enable

ENCGQ	Pull-down generator status	
0	Always OFF	
1	If EN _{C/Q} = 0	ON
	If EN _{C/Q} = 1	OFF

Bit 6:5 = I_{COQ} [1:0]: C/Q_O HS and LS cutoff current

This bit is used to configure the cutoff current value on the C/Q channel, as shown in [Table 14](#).

Table 14. I_{COQ} : C/Q_O HS and LS cutoff current

I_{COQ} [1]	I_{COQ} [0]	Typ.
0	0	115 mA
0	1	220 mA
1	0	350 mA
1	1	580 mA

Bit 4:3 = t_{dCOQ} [1:0]: C/Q_O HS and LS cutoff current delay time

The channel output driver is turned off after a delay (t_{dCOQ}) programmable by means of these two bits:

Table 15. t_{dCOQ} : C/Q_O HS and LS cutoff current delay time

t_{dCOQ} [1]	t_{dCOQ} [0]	Typ.
0	0	100 μ s
0	1	150 μ s
1	0	200 μ s
1	1	250 μ s ⁽¹⁾

1. According to power dissipation at 2 kHz switching, $C < 1 \mu$ F, power dissipation 0.7 W.

Bit 2 = t_{rCOQ} : C/Q_O restart delay time

After a cutoff event, the channel driver automatically restarts after a delay (t_{rCOQ}) programmable by means of this bit:

Table 16. t_{rCOQ} : C/Q_O restart delay time

t_{rCOQ}	Typ.
0	255 x t_{dCOQ}
1	Latched ⁽¹⁾

1. Unlatch through I²C communication (reading or writing any internal registers).

Bit 1:0 = t_{dbq} [1:0]: C/Q_I de-bounce time

De-bounce time is the minimum time that data must be in a given state after a transition.

It is a programmable time, and can be configured as shown in [Table 17](#).

Table 17. t_{dbq} : C/Q_I de-bounce time

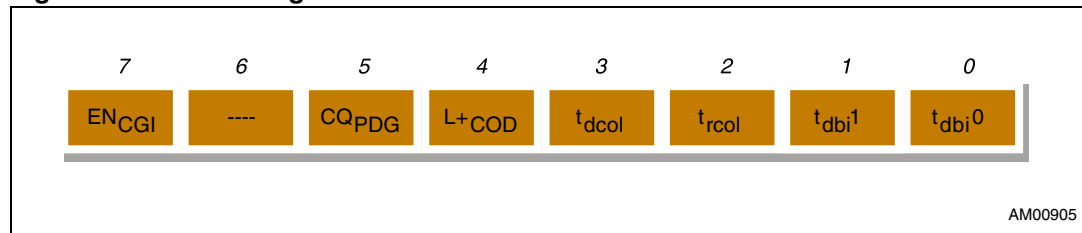
t_{dbq} [1]	t_{dbq} [0]	Typ.
0	0	0 μ s
0	1	5 μ s
1	0	20 μ s
1	1	100 μ s

Control register 2

Read/write

Reset value: [0x100001]

Figure 14. Control register 2



The control register holds the parameters to control the L6360. See also the [Transceiver](#) section.

Bit 7 = EN_{CGI}: I/Q pull-down enable

Table 18. EN_{CGI}: I/Q pull-down enable

EN _{CGI}	Pull-down generator status
0	Always OFF
1	Always ON

Bit 5 = CQ_{PDG}: C/Q, channel pull-down generators

In order to reduce consumption, it is possible to switch from default to low-power configuration by resetting the CQ_{PDG} bit.

Table 19. CQ_{PDG}: C/Q pull-down generator switching

CQ _{PDG}	Pull-down generator status
0	I _{INI/Qi} (input current C/Q _I pin) = 2.5 mA
1	I _{INC/Qi} (input current C/Q _I pin) = 5.5 mA

Bit 4 = **L+COD**: *L+ cutoff disable*

The cutoff function on the L+ switch can be enabled or disabled according to the L+COD bit.

Table 20. L+COD: L+ cutoff disable

L+COD	L+ cutoff current status
0	Enabled
1	Disabled

As the cutoff function is intended to protect the integrated switches against overload and short-circuit, disabling the cutoff is not recommended.

Bit 3 = **t_{dcol}**: *L+ cutoff current delay time*

The channel output driver is turned off after a delay (t_{dcol}) programmable by means of this bit:

Table 21. t_{dcol}: L+ HS cutoff current delay time

t _{dcol}	Typ.
0	500 μ s
1	0 μ s

Bit 2 = **t_{rcol}**: *L+ restart delay time*

After a cutoff event, the channel driver automatically restarts again after a delay (t_{rcol}) programmable by means of this bit:

Table 22. t_{rcol}: L+ restart delay

t _{rcol}	Typ.
0	64 ms
1	Latched ⁽¹⁾

1. Unlatch through I²C communication (reading or writing any internal registers).

Bit 1:0 = **t_{dbi} [1:0]**: *I/Q de-bounce time*

De-bounce time is the minimum time that data must be in a given state after a transition. It is a programmable time, and it can be configured as shown in [Table 23](#).

Table 23. t_{dbi}: I/Q de-bounce time

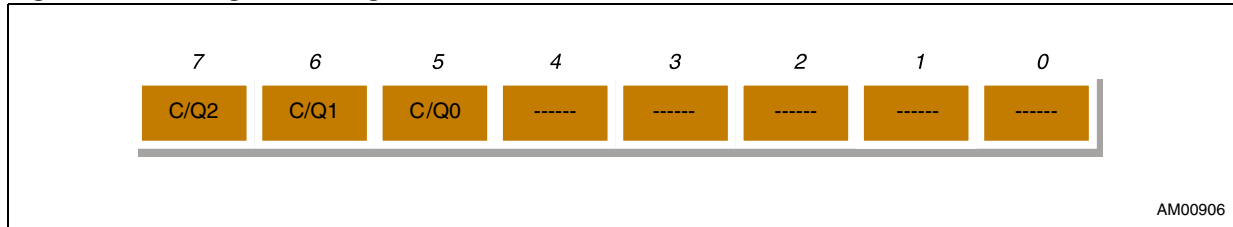
t _{dbi} [1]	t _{dbi} [0]	Typ.
0	0	0 μ s
0	1	5 μ s
1	0	20 μ s
1	1	100 μ s

Configuration register

Read/write

Reset value: [100xxxxx]

Figure 15. Configuration register



AM00906

The configuration register holds data to configure the L6360 IC.

Bit 7:5 = **C/Q[2:0]**: *C/Q output stage configuration*

Table 24. C/Q output stage configuration

C/Q[2]	C/Q[1]	C/Q[0]	Configuration	Notes
0	0	0	OFF	HS and LS are OFF regardless of the state of EN _{C/Q} and IN _{C/Q} . The receiver is OFF regardless of the state of EN _{C/Q} .
0	0	1	Low-side	HS is always disabled. LS is ON when IN _{C/Q} is high and EN _{C/Q} is high, OFF in all other cases. Slow asynchronous decay when the LS is turned off by EN _{C/Q} or in case of cutoff. The receiver is OFF when EN _{C/Q} is high: OUT _{C/Q} is high. The receiver is ON when EN _{C/Q} is low: if C/Q ₁ is high, OUT _{C/Q} is low. if C/Q ₁ is low, OUT _{C/Q} is high.
0	1	0	High-side	LS is always disabled. HS is ON when IN _{C/Q} is low and EN _{C/Q} is high, OFF in all other cases. Slow asynchronous decay if the HS is turned off by EN _{C/Q} or in case of cutoff. The internal pull-down current generator on C/Q ₁ should be disabled through Control register 1 , unless C/Q ₁ is connected to C/Q ₀ through a 100 Ω (or more) resistor. The receiver is OFF when EN _{C/Q} is high: OUT _{C/Q} is high. The receiver is ON when EN _{C/Q} is low: if C/Q ₁ is high, OUT _{C/Q} is low. if C/Q ₁ is low, OUT _{C/Q} is high.

In order to reduce the risk of damage to the output stage (e.g. switching from push-pull inductive load to any transceiver configuration while an inductive load has some residual energy), the user must not switch between any two “active” (low-side, high-side, push-pull, low-side ON, high-side ON, push-pull inductive load) configurations of the bridge.

For example, if the microcontroller needs to switch from push-pull to high-side configuration, it needs to modify the configuration register twice:

First-step: switch from push-pull to OFF (or TRISTATE)

Second-step: switch from OFF (or TRISTATE) to high-side

If the microcontroller asks for a forbidden jump between configurations, the IC remains in the previous configuration and reports a parity error to the microcontroller.

In case of sequential write, no parity error is generated if the microcontroller rewrites the configuration register with the previous value; if the operation, instead, requires a forbidden jump, all data are rejected also for other registers (and a parity error is raised).

The L+ switch is a high-side switch. HS is ON when EN_{L+} is high, otherwise it is OFF. Fast decay with active clamp (-V_{demag}) is operated when the HS is turned off or in the case of cutoff.

Receiver I/Q is always ON.

Bit 4:2 = **not used**

Bit 1:0 = **not used**

LED registers

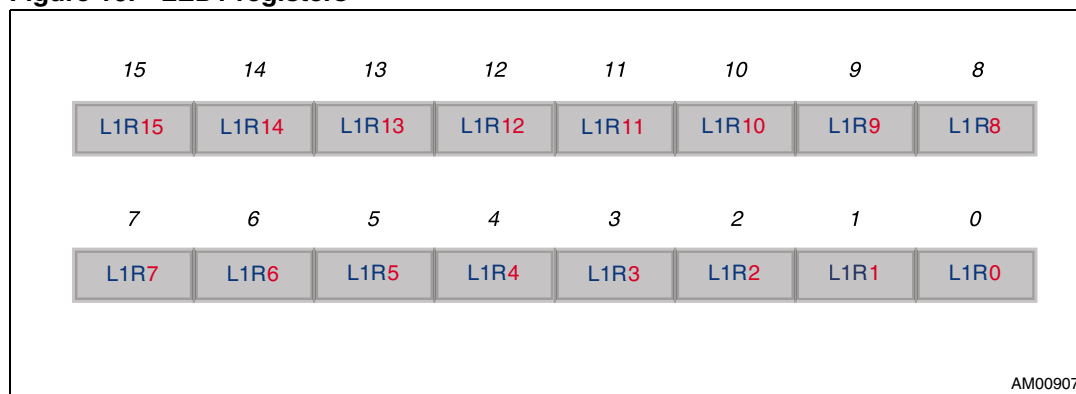
See also the [Diagnostic LED sequence generator and driver](#) section.

These registers are used to configure the two LED drivers integrated in the IC. Each LED driver has two associated registers and turns on or off the external LED according to the information stored in the registers, which are scanned with a rate of 63 ms per bit. LED drivers can be used for status or diagnostic information, or for other purposes, and should be configured by the host microcontroller.

LED1 registers

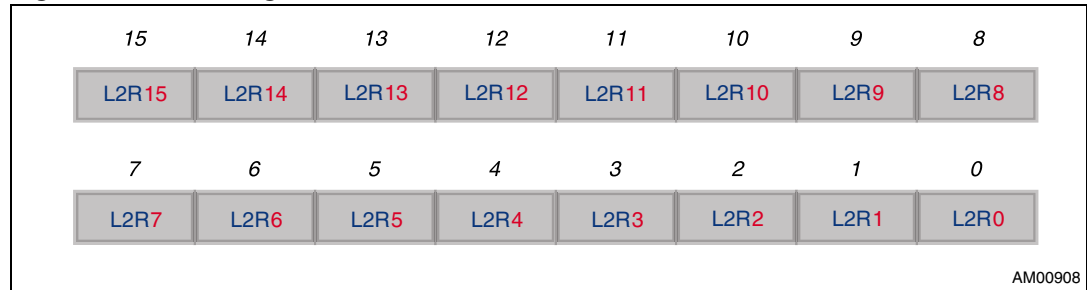
Reset value: [00000000]

Figure 16. LED1 registers



LED2 registers

Reset value: [00000000]

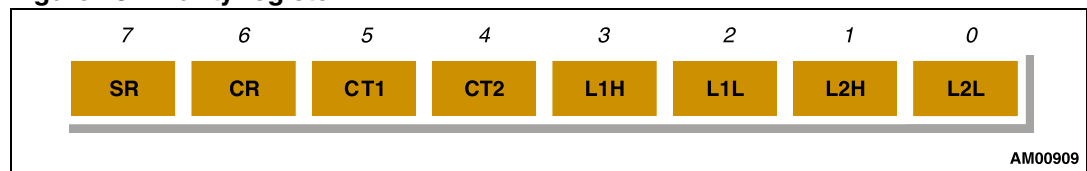
Figure 17. LED2 registers

AM00908

Parity register

Read only

Reset value: [00000000]

Figure 18. Parity register

AM00909

This register stores the parity of each register, calculated after the L6360 receives data registers.

- Bit 7 = **SR**: *Status register parity*
This bit is the parity of the status register.
- Bit 6 = **CR**: *Configuration register parity*
This bit is the parity of the configuration register.
- Bit 5 = **CT1**: *Control register 1 parity*
This bit is the parity of control register 1.
- Bit 4 = **CT2**: *Control register 2 parity*
This bit is the parity of control register 2.
- Bit 3 = **L1H**: *LED1 high register parity*
This bit is the parity of the LED1 MSB register (15 down to 8).
- Bit 2 = **L1L**: *LED1 low register parity*
This bit is the parity of the LED1 LSB register (7 down to 0).
- Bit 1 = **L2H**: *LED2 high register parity*
This bit is the parity of the LED2 MSB register (15 down to 8).
- Bit 0 = **L2L**: *LED2 low register parity*
This bit is the parity of the LED2 LSB register (7 down to 0).

6.1.10 Startup default configuration

[Table 25](#) and [Table 26](#) show the device registers default configuration.

Table 25. Parameter default configuration

Parameter	Default value
I_{COQ}	220 mA
t_{dCOQ}	100 μ s
t_{rCOQ}	25 ms
t_{dbq}	5 μ s
t_{dcol}	0 μ s
t_{rcol}	64 ms
t_{bdq}	5 μ s
Output stage	TRISTATE

Table 26. Register default configuration

Registers	Bit position	Bit name	Reset value
Status register	Bit 7	PO	0
	Bit 6	Not used	x
	Bit 5	OVT	0
	Bit 4	CQOL	0
	Bit 3	IQOL	0
	Bit 2	Not used	x
	Bit 1	REG LN	0
	Bit 0	PE	0
Configuration register	Bit 7	C/Q2	1
	Bit 6	C/Q1	0
	Bit 5	C/Q0	0
	Bit 4	Not used	x
	Bit 3	Not used	x
	Bit 2	Not used	x
	Bit 1	Not used	x
	Bit 0	Not used	x

Table 26. Register default configuration (continued)

Registers	Bit position	Bit name	Reset value
Control register 1	Bit 7	EN _{CGQ}	0
	Bit 6	I _{coq1}	0
	Bit 5	I _{coq0}	1
	Bit 4	t _{dcoq1}	0
	Bit 3	t _{dcoq0}	0
	Bit 2	t _{rcoq}	0
	Bit 1	t _{dbq1}	0
	Bit 0	t _{dbq0}	1
Control register 2	Bit 7	EN _{CGI}	0
	Bit 6	Not used	x
	Bit 5	CQ _{PDG}	1
	Bit 4	L+ _{COD}	0
	Bit 3	t _{dcoi0}	0
	Bit 2	t _{rcoi}	0
	Bit 1	t _{dbi1}	0
	Bit 0	t _{dbi0}	1
LED1 register MSB	Bit 7	L1R15	0
	Bit 6	L1R14	0
	Bit 5	L1R13	0
	Bit 4	L1R12	0
	Bit 3	L1R11	0
	Bit 2	L1R10	0
	Bit 1	L1R9	0
	Bit 0	L1R8	0
LED1 register LSB	Bit 7	L1R7	0
	Bit 6	L1R6	0
	Bit 5	L1R5	0
	Bit 4	L1R4	0
	Bit 3	L1R3	0
	Bit 2	L1R2	0
	Bit 1	L1R1	0
	Bit 0	L1R0	0

Table 26. Register default configuration (continued)

Registers	Bit position	Bit name	Reset value
LED2 register MSB	Bit 7	L2R15	0
	Bit 6	L2R14	0
	Bit 5	L2R13	0
	Bit 4	L2R12	0
	Bit 3	L2R11	0
	Bit 2	L2R10	0
	Bit 1	L2R9	0
	Bit 0	L2R8	0
LED2 register LSB	Bit 7	L2R7	0
	Bit 6	L2R6	0
	Bit 5	L2R5	0
	Bit 4	L2R4	0
	Bit 3	L2R3	0
	Bit 2	L2R2	0
	Bit 1	L2R1	0
	Bit 0	L2R0	0
Parity register	Bit 7	SR	0
	Bit 6	CR	0
	Bit 5	CT1	0
	Bit 4	CT2	0
	Bit 3	L1H	0
	Bit 2	L1L	0
	Bit 1	L2H	0
	Bit 0	L2L	0

6.2 Interrupt

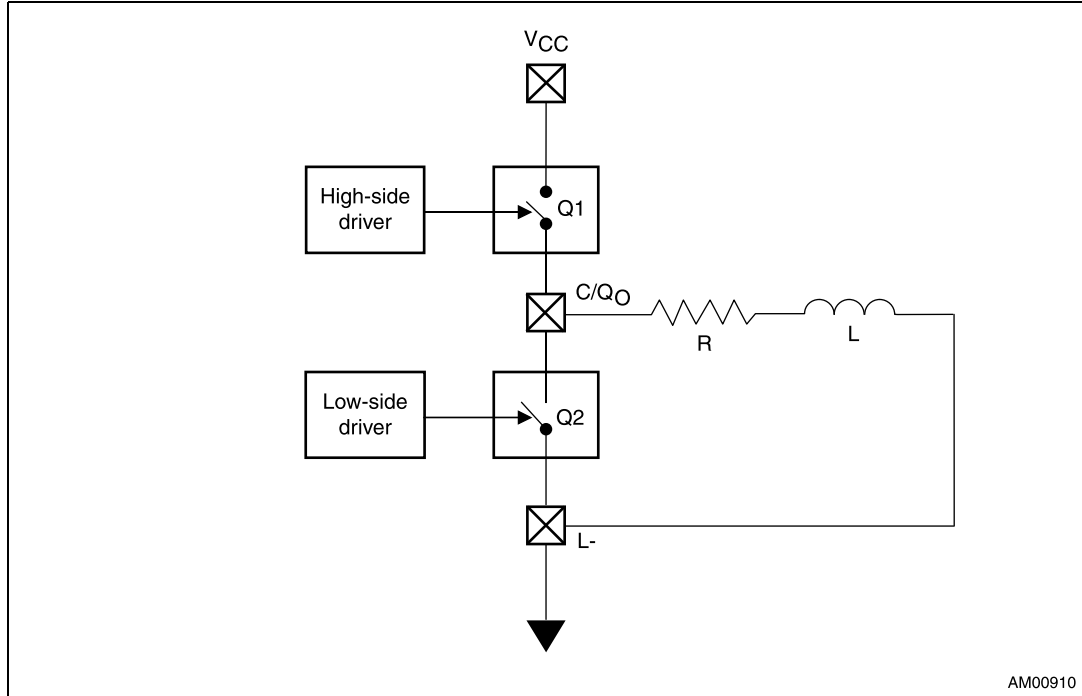
The IRQ pin (interrupt pin) should normally be held to a high logic level by an external pull-up resistor or microcontroller pin configuration. The internal structure is an open drain transistor.

It should be connected directly to the microcontroller so, in the case of a fault event (C/Q overload, power-on L+ line, overtemperature condition, etc.), it is pulled down to a low logic level, reporting the fault condition to the microcontroller. See also the [Status register](#) section.

6.3 Demagnetization

The power stage can be represented as in [Figure 19](#).

Figure 19. Power stage. Q2 is not present on L+ output



When a power stage output (C/Q or L+) is connected to an inductance, the energy stored in the load is:

Equation 1

$$E = \frac{1}{2}LI^2$$

This energy must be properly dissipated at the switch-off. Without an appropriate circuitry the output voltage would be pulled to very negative values, therefore recovering the stored energy through the power transistor's breakdown.

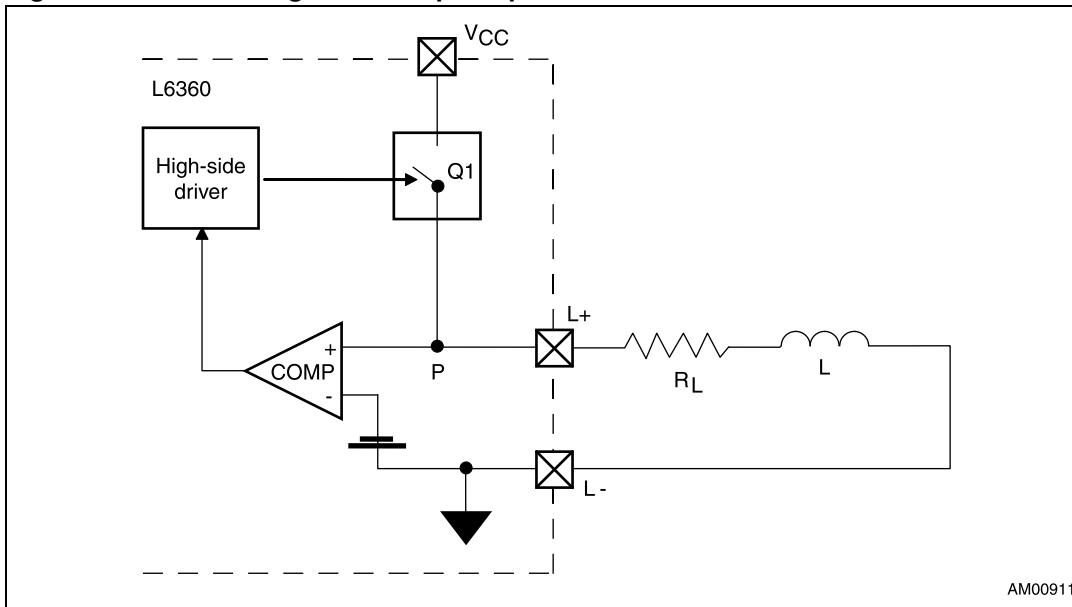
To avoid this, the output voltage must be clamped so that the voltage across the power switch does not exceed its breakdown voltage.

In the case of load connected between the C/Q_O pin and V_{CC}, at switch-off (of the low-side switch) the output is pushed to a voltage higher than V_{CC}.

6.3.1 Fast demagnetization

Applies to L+ channel only.

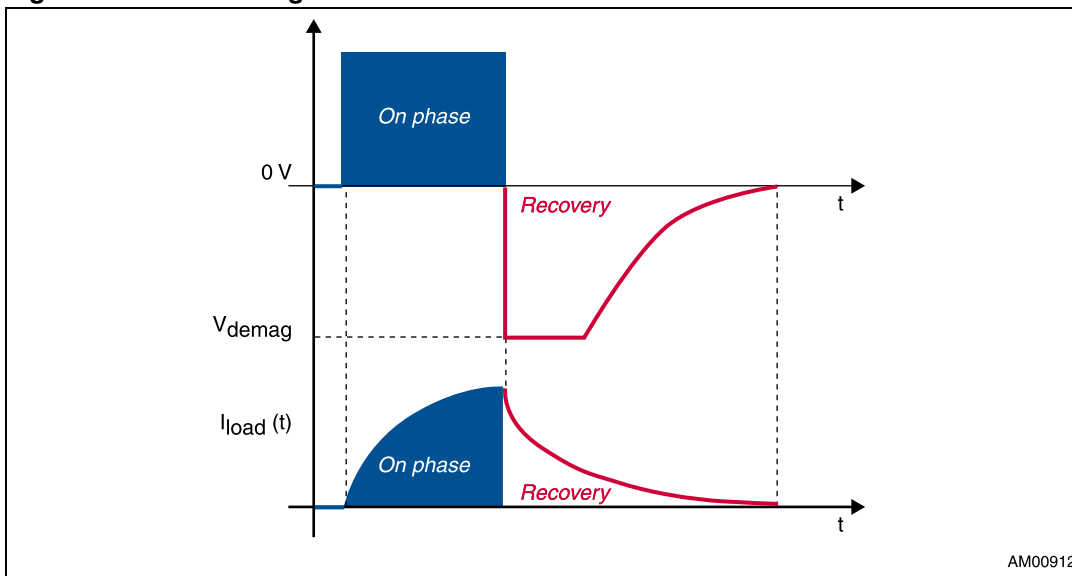
Figure 20. Fast demagnetization principle schematic. Load connected to L-



When a high-side driver turns off an inductance, a reversed polarity voltage appears across the load.

The output pin (L+) of the power switch becomes more negative than the ground until it reaches the demagnetization voltage, V_{demag} . The conduction state of the power switch Q1 is linearly modulated by an internal circuitry in order to keep the voltage at C/Q or the I/Q pin at about V_{demag} until the energy in the load has been dissipated. The energy is dissipated in both IC internal switch and load resistance.

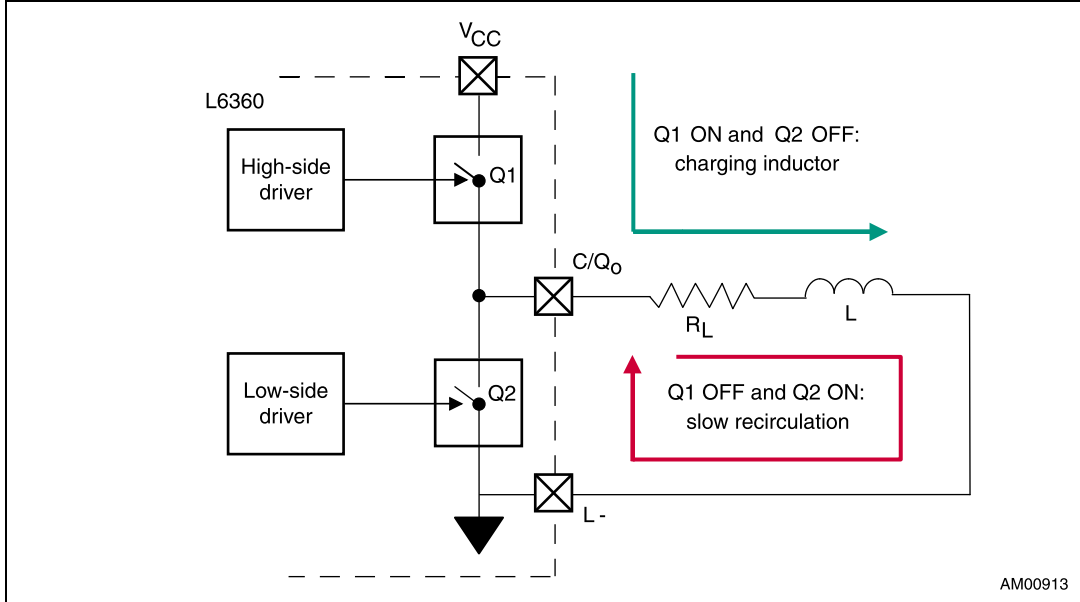
Figure 21. Fast demagnetization waveform. Load connected to L-



6.3.2 Slow demagnetization

Applies to C/Q channel.

Figure 22. Slow demagnetization schematic block. Load connected to L-

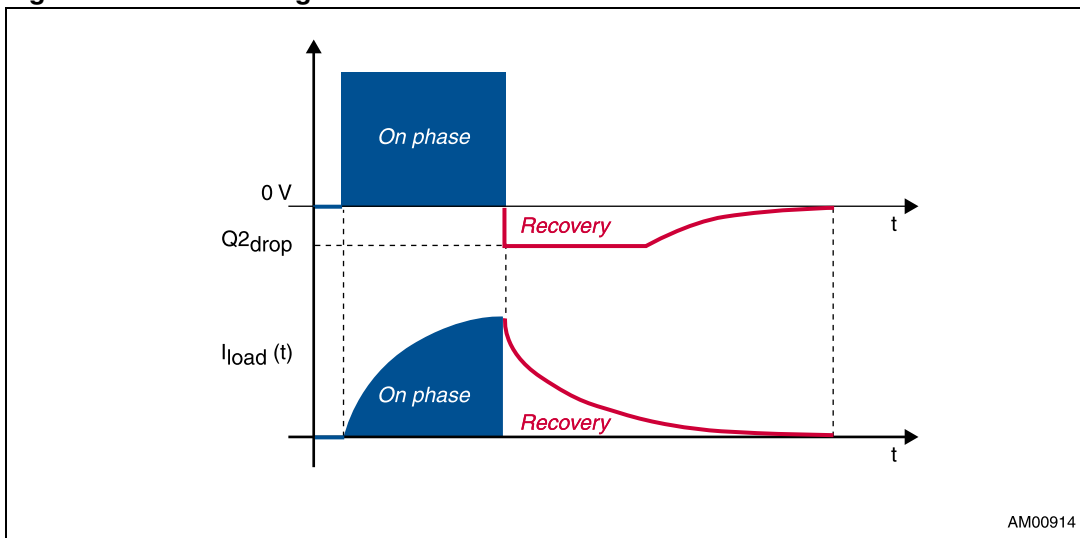


When a high-side driver turns off an inductance a reversed polarity voltage appears across the load.

In slow demagnetization configuration the low-side switch Q2 is ON and the C/Q pin is pulled at a voltage slightly (depending on Q2 drop) below the ground (L-). The energy is dissipated in both the IC internal switch and the load resistance.

In the case of load connected between the C/Q pin and V_{CC} , at switch-off (of the low-side switch Q2), the switch Q1 is ON and the output is pushed to a voltage slightly higher than V_{CC} .

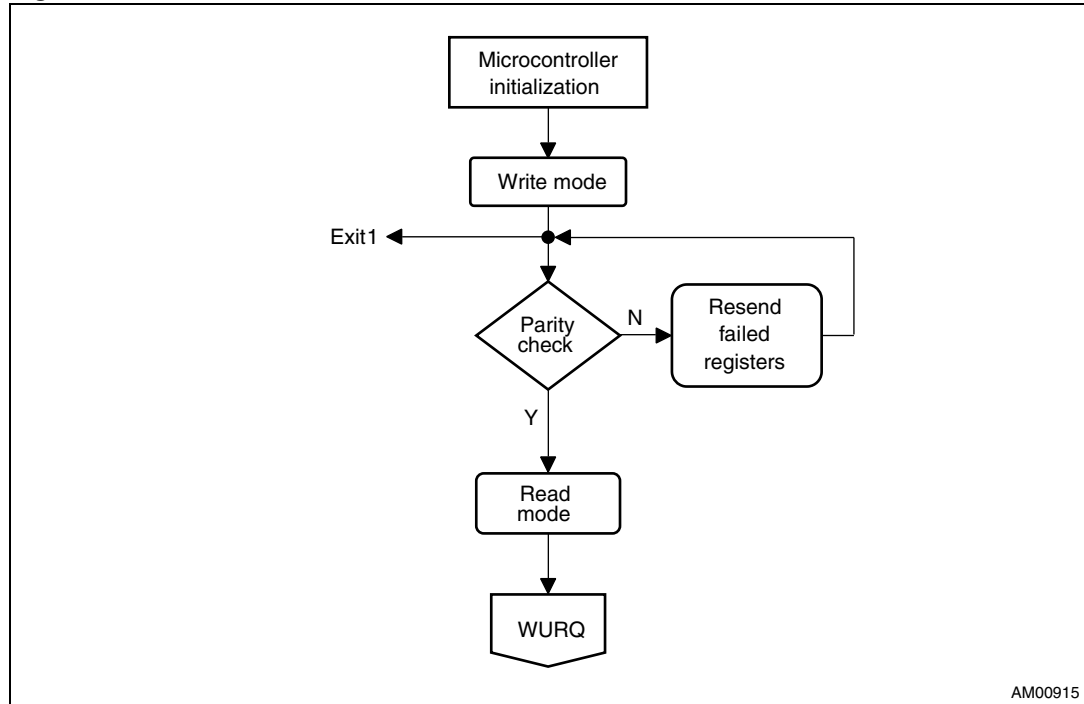
Figure 23. Slow demagnetization waveform. Load connected to GND



6.4 I²C protocol

6.4.1 Protocol configuration

Figure 24. Device initialization



AM00915

Microcontroller initialization: Microcontroller initialization phase.

Write mode: The L6360 is configured by the microcontroller through I²C.

To configure the device, it is necessary to write its internal registers (see [Write modes](#) section).

Parity check: L6360 calculates the parity of each received register and stores it in the parity register. After which, it compares it with the parity transmitted together with the data.

If the parity check of one or more registers failed, the “parity error bit” in the status register is set and an interrupt is generated by the L6360.

The microcontroller can now read the status register and the parity register (*current read*). So the microcontroller can understand the interrupt cause and which register failed the transmission. If the parity check is ok, the flow goes on ([Read modes](#)).

Write register failed: The microcontroller can again write the register(s) that failed the check.

Read mode: Read status register to monitor if the configuration was good ([Read modes](#)).

6.4.2 Operating modes

Write modes

The L6360 is configured by the microcontroller through I²C. To configure the device, it is necessary to write its internal registers.

There are two writing modes:

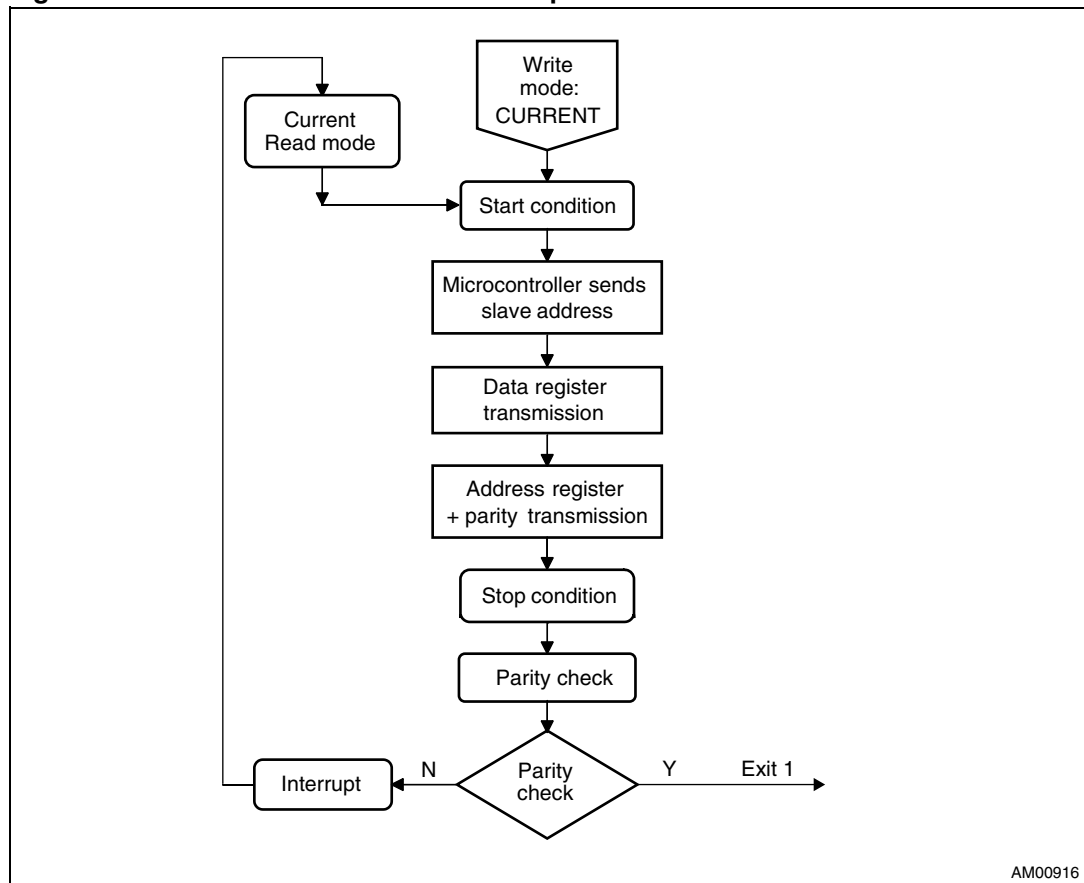
- **Current:** single register
- **Sequential:** all registers in sequence

Current Write mode

The microcontroller I²C is configured as master transmitter.

The L6360 I²C is configured as the slave receiver.

Figure 25. Current Write mode flow chart procedure



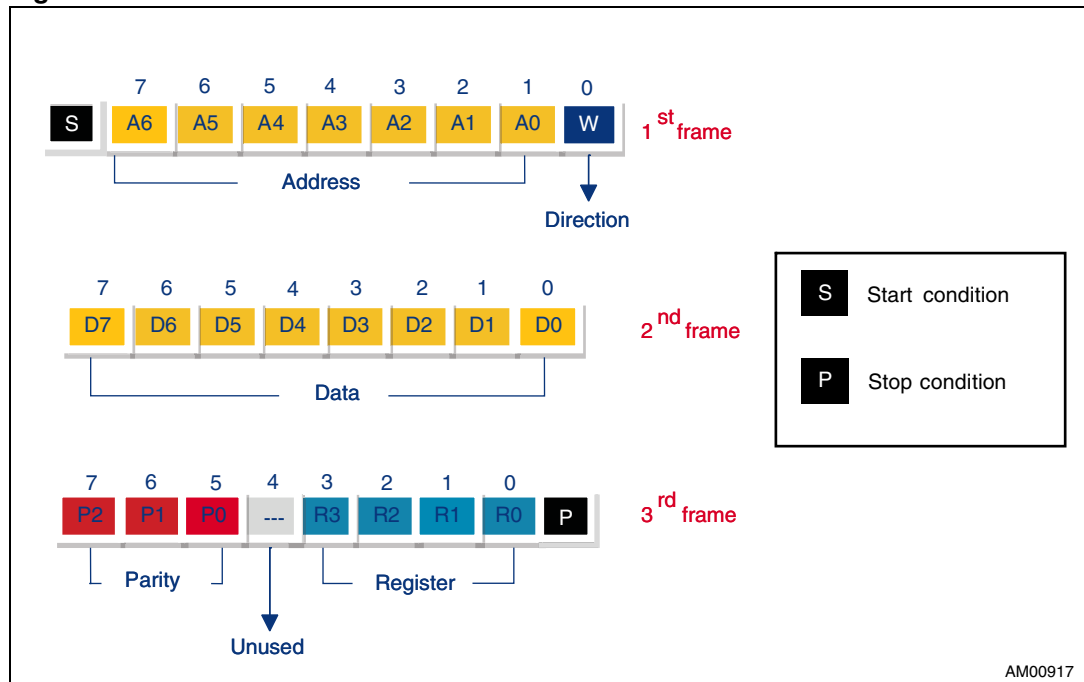
1. Microcontroller I²C establishes the communication: START condition
2. Microcontroller I²C sends the slave address on the I²C bus to check if the slave is online (1st frame)
3. After the address is matched, the microcontroller starts the data transmission: the 2nd frame is the data to be written into the selected register (see 3rd frame)
4. The 3rd frame is composed of the address of the register to be written and of the parity of the 2nd frame.
5. Microcontroller I²C finishes the communication: STOP condition
6. The L6360 calculates the parity of the data received
7. The L6360 compares its parity calculation with the parity bits in the 3rd frame (sent by the microcontroller)
8. If the parities match, the protocol flow goes on (exit), otherwise the PE bit inside the L6360 status register is set and the flow goes to the next state.
9. The L6360 generates an interrupt to report the parity check error.
10. The microcontroller sends a read request to the device. The L6360 then sends the status and parity registers. The microcontroller can resend the corrupted data register.
11. Back to step 1.

The I²C frame (configuration, control, diagnostic phases) must provide:

- Slave address (7 bits)
- Transmission direction (read/write)
- Data (8 bits: data register)
- Parity bits (P2, P1, P0)
- Registers address (4 bits: 16 registers addressable)

The three frames are shown in *Figure 26* and below:

Figure 26. Current Write mode frames



1st frame

Bit 7÷1: L6360 address

Bit 0: Direction

Table 27. Current Write mode direction bit

W bit	Master	Slave
0	Write mode	Read mode
1	Read mode	Write mode

2nd frame

Bit 7÷0: Data register

3rd frame

Bit 7÷5: Parity bits

Bit 4: Unused

Bit 3÷0: Register address

The parity check bits are calculated as shown in [Equation 2](#):**Equation 2**

$$P0 = D7 \oplus D6 \oplus D5 \oplus D4 \oplus D3 \oplus D2 \oplus D1 \oplus D0$$

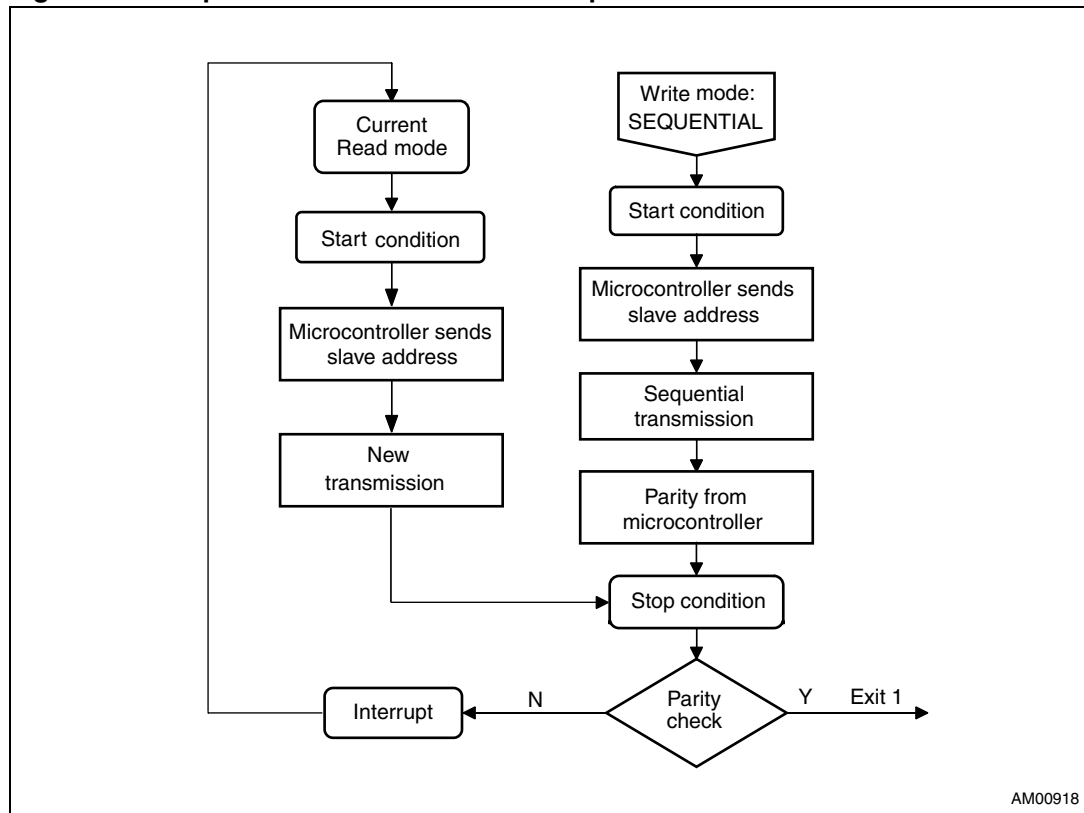
$$P1 = D7 \oplus D5 \oplus D3 \oplus D1 \text{ (odd parity)}$$

$$P2 = D6 \oplus D4 \oplus D2 \oplus D0 \text{ (even parity)}$$

If parity error occurs, the register are not overwritten.

Sequential Write mode

Figure 27. Sequential Write mode flow chart procedure



AM00918

1. The microcontroller I²C establishes the communication: START condition.
2. The microcontroller I²C sends the slave address on the I²C bus to check if the slave is online (1st frame).
3. After the address is matched, the microcontroller starts the sequential transmission (2nd ÷ 8th frame).
4. The microcontroller sends its parity register (last frame: 9th frame).
5. Microcontroller I²C finishes the communication: STOP condition.
6. The L6360 calculates the parity of the registers received, and stores the results in the parity register.
7. The L6360 compares its parity register with the parity register sent by the microcontroller (9th frame).
8. If the parities match, the protocol flow goes on (EXIT), otherwise the PE bit inside the L6360 status register is set, and the flow goes to the next state.
9. The L6360 generates an interrupt to report the parity check error.
10. The microcontroller sends a read request to the device. In this phase the L6360 sends the status register and the parity register allowing the microcontroller to verify which register failed the configuration.

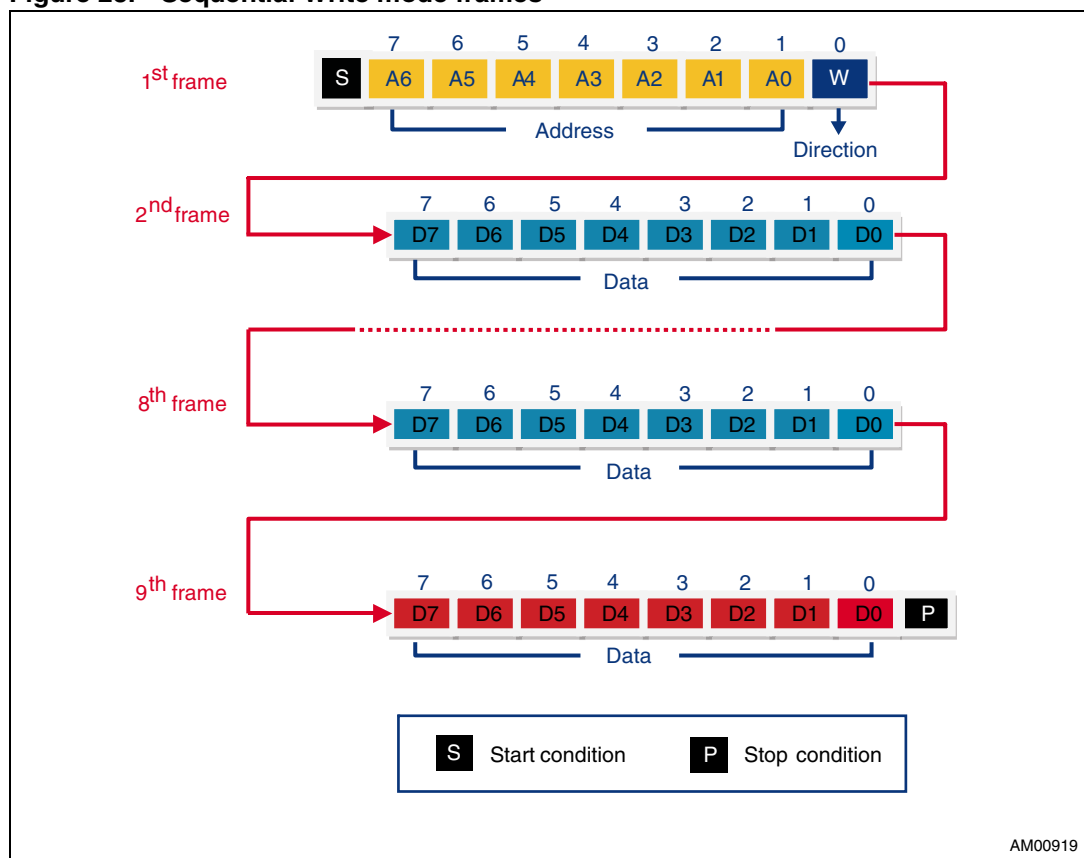
11. Now the microcontroller can perform a new write sequential procedure.
12. Microcontroller I²C establishes the communication: START condition.
13. Microcontroller I²C sends the slave address on the I²C bus to check if the slave is online.
14. The microcontroller resends the data registers.
15. Back to step 5.

The I²C frame (configuration, control, diagnostic phases) must provide:

- Slave address (7 bits)
- Transmission direction (read/write)
- Data (8 bits: data registers)

The 9 frames are shown below:

Figure 28. Sequential Write mode frames



1st frame

Bit 7÷1: L6360 address

Bit 0: Direction (write/read)

Table 28. Sequential Write mode direction bit

W	Master	Slave
0	Write mode	Read mode
1	Read mode	Write mode

2nd ÷ 8th frame

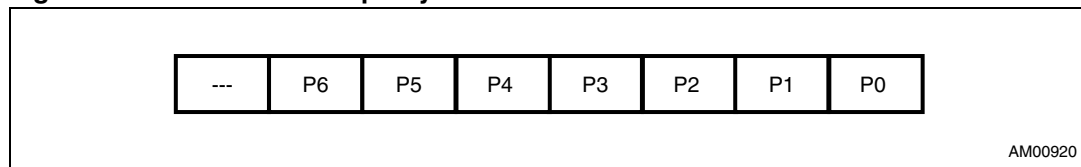
Bit 7÷0: Data register

9th frame

Bit 7÷0: Microcontroller parity register

The microcontroller parity check (for each register) calculus performed is shown below:

Figure 29. Microcontroller parity check calculus



Bit 6 = **P6**: *Microcontroller configuration register parity*

This bit is the parity of the configuration register.

Bit 5 = **P5**: *Microcontroller control register 1 parity*

This bit is the parity of control register 1.

Bit 4 = **P4**: *Microcontroller control register 2 parity*

This bit is the parity of control register 2.

Bit 3 = **P3**: *Microcontroller LED1 register high parity*

This bit is the parity of the LED1 MSB register (15 down to 8).

Bit 2 = **P2**: *Microcontroller LED1 register low parity*

This bit is the parity of the LED1 LSB register (7 down to 0).

Bit 1 = **P1**: *Microcontroller LED2 register high parity*

This bit is the parity of the LED2 MSB register high (15 down to 8).

Bit 0 = **P0**: *Microcontroller LED2 register low parity*

This bit is the parity of the LED2 LSB register high (7 down to 0).

For each register, a parity check is calculated as shown in [Equation 3](#), in general formulas:

Equation 3

$$PX = D7 \oplus D6 \oplus D5 \oplus D4 \oplus D3 \oplus D2 \oplus D1 \oplus D0 \text{ (X = 0 to 6)}$$

D7 ÷ D0 indicates bits inside each register.

If parity error occurs, the registers are not overwritten.

In this writing mode, all writable registers and the microcontroller parity register are sent.

Figure 30. Register sequence in sequential Write mode

<i>2nd frame</i>	0001	<i>Configuration register</i>
<i>3rd frame</i>	0010	<i>Control register 1</i>
<i>4th frame</i>	0011	<i>Control register 2</i>
<i>5th frame</i>	0100	<i>LED1 register H</i>
<i>6th frame</i>	0101	<i>LED1 register L</i>
<i>7th frame</i>	0110	<i>LED2 register H</i>
<i>8th frame</i>	0111	<i>LED2 register L</i>
<i>9th frame</i>		<i>Microcontroller parity</i>

AM00921

Read modes

The status register and parity check register are read only.

The other registers are readable/writable (by microcontroller).

There are three reading modes:

- **Current:** status register only
- **Sequential:** all registers in sequence
- **Random:** to read registers in sequence starting from a register address fixed by the microcontroller.

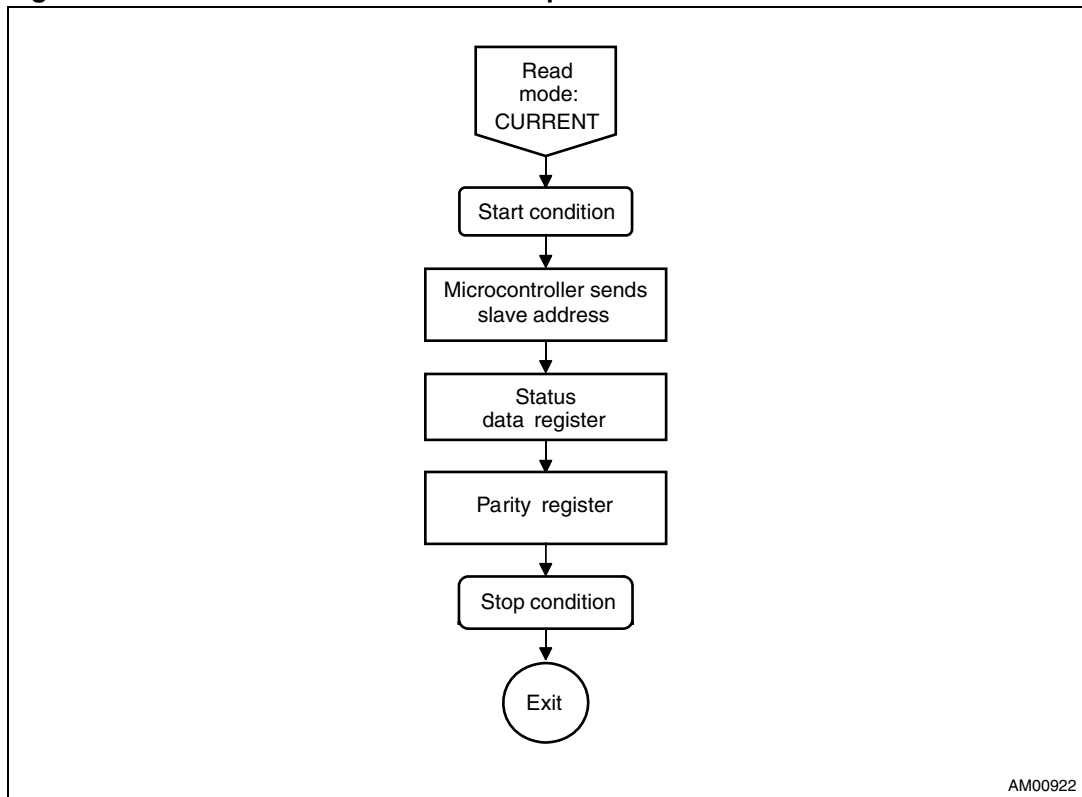
All registers are addressed as shown in [Table 30](#):

Table 29. Read mode: register address

Address	Register name
0000	Status register
0001	Configuration register
0010	Control register 1
0011	Control register 2
0100	LED1 register MSB
0101	LED1 register LSB
0110	LED2 register MSB
0111	LED2 register LSB
1000	Parity register

Current Read mode

Figure 31. Current Read mode flow chart procedure



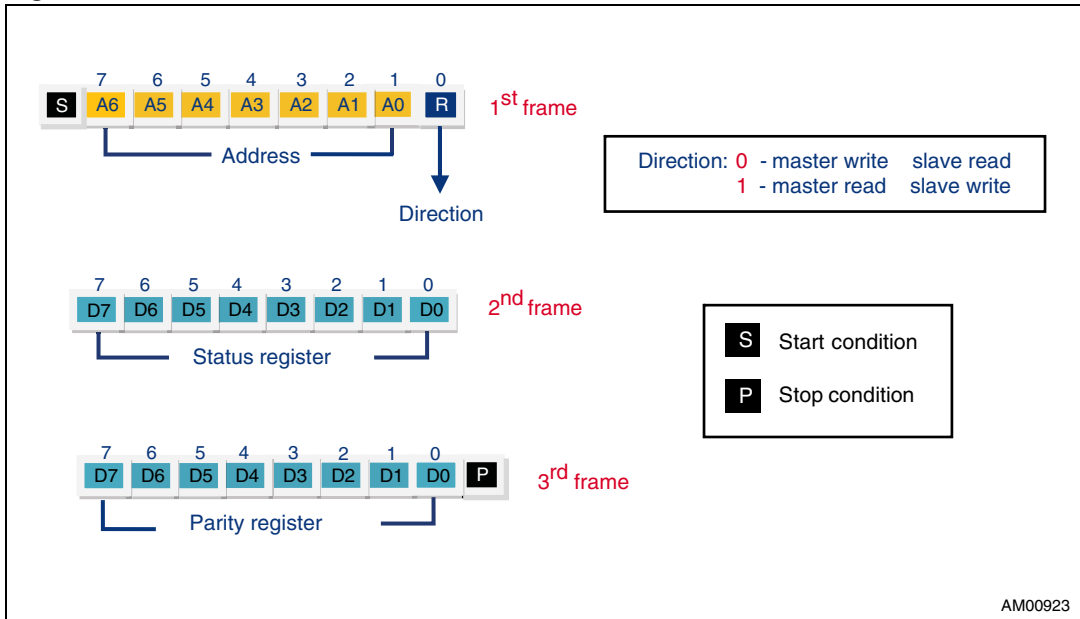
1. Microcontroller I²C establishes the communication: START condition
2. Microcontroller I²C sends slave address on the I²C bus to check if the slave is online (1st frame)
3. After the address is matched, the L6360 sends its status register (2nd frame)
4. The L6360 sends its parity register (3rd frame)
5. Microcontroller I²C finishes the communication: STOP condition.

The I²C frame (configuration, control, diagnostic phases) must provide:

- *Slave address (7 bits)*
- *Transmission direction (read/write)*
- *Data (8-bit data registers): status and parity registers.*

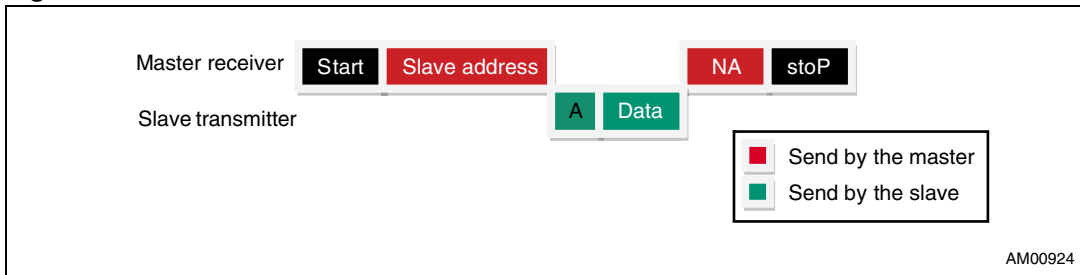
The three frames are shown in *Figure 32*.

Figure 32. Current Read mode frames



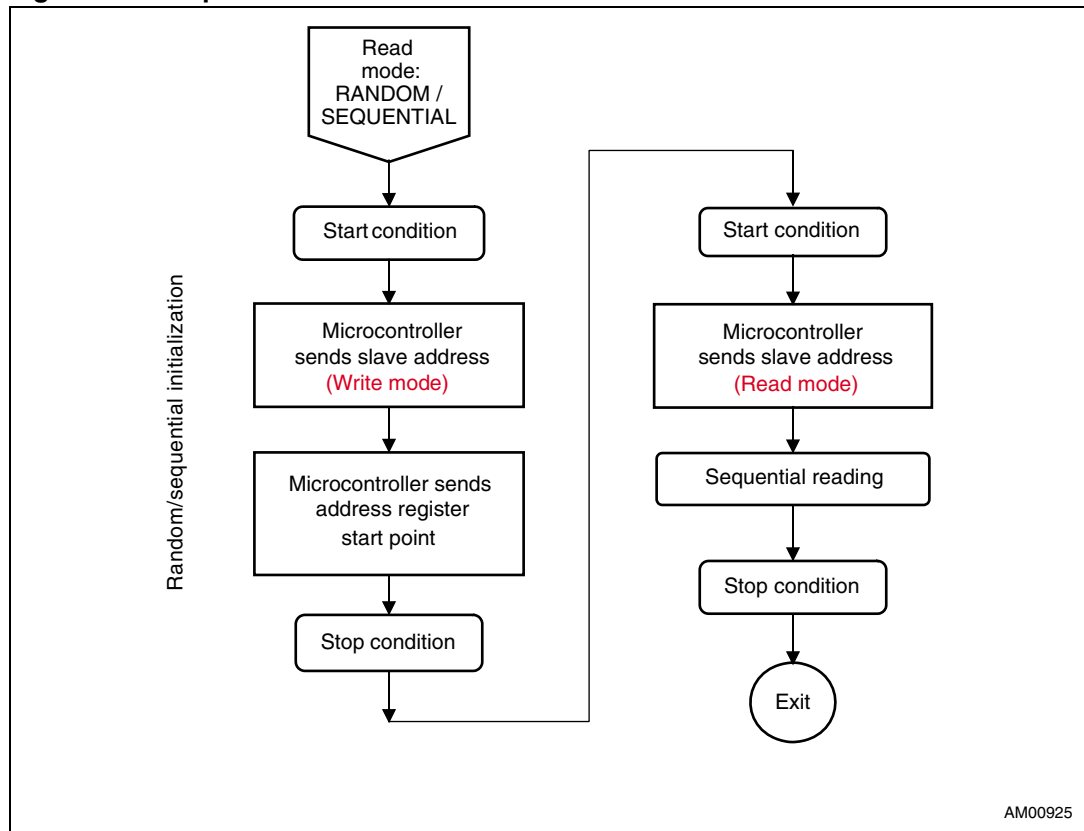
When a “read request” comes from the microcontroller (it is configured as master receiver), the IC (slave transmitter) sends the contents of the status and parity registers.

Figure 33. Current Read communication flow



Sequential/random Read modes

Figure 34. Sequential/random Read mode



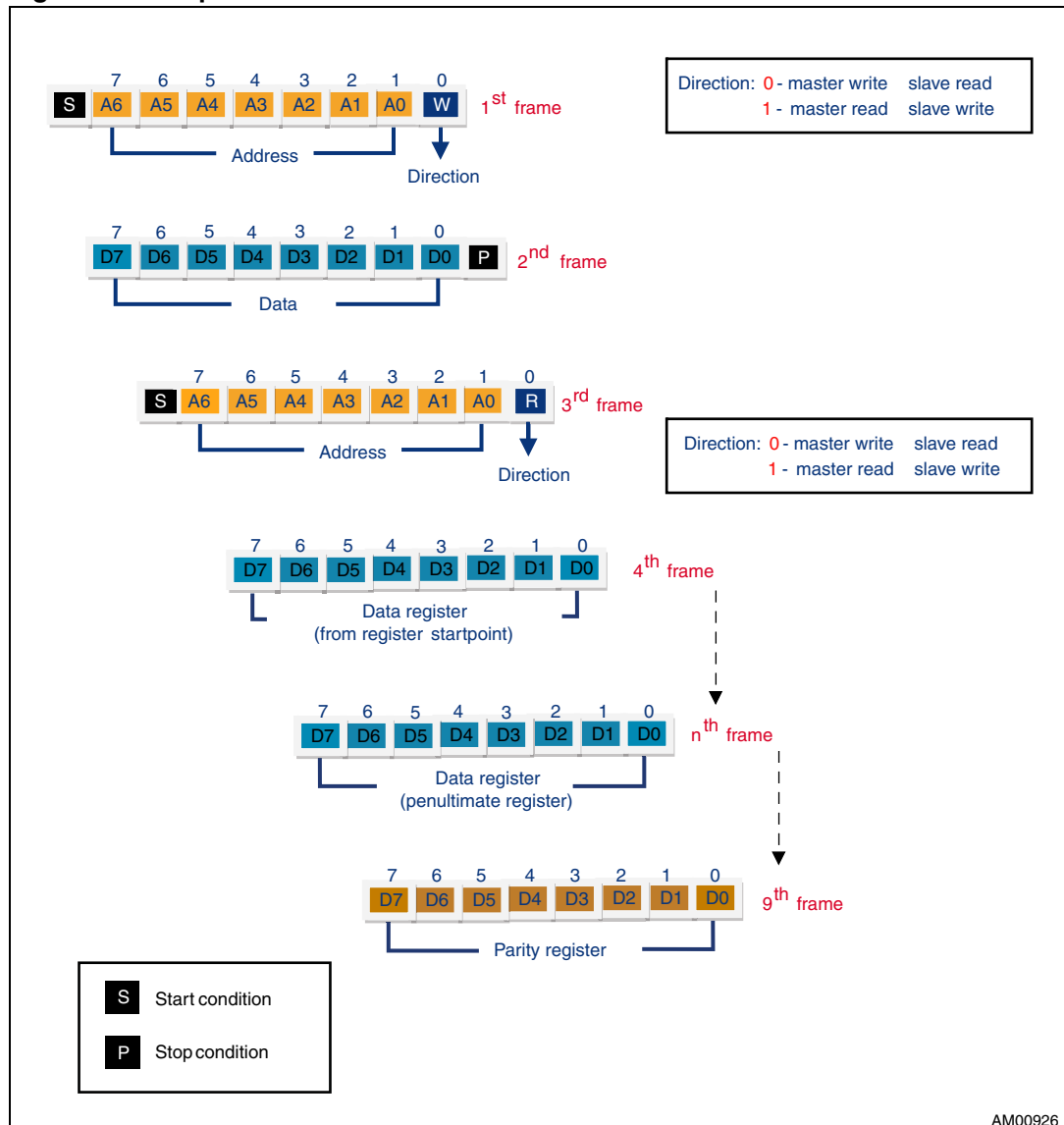
1. Random/sequential Read mode initialization: Microcontroller I²C establishes the communication: START condition.
2. Microcontroller I²C sends the slave address, in Write mode, on the I²C bus to check if the slave is online (1st frame).
3. Microcontroller I²C sends the register address start point, which sets the first register to read in sequence (2nd frame).
4. Microcontroller I²C finishes the communication: STOP condition.
5. Microcontroller I²C sends the slave address, in Read mode, on the I²C bus to check if the slave is online (3rd frame).
6. After the address is matched, the L6360 sends its registers in sequential mode, starting from the register set in the 2nd frame.
7. Microcontroller I²C finishes the communication: STOP condition.

The I²C frame (configuration, control, diagnostic phases) must provide:

- Slave address (7 bits)
- Transmission direction (read/write)
- Data (8-bit data register)

The frames structure is shown in *Figure 35*:

Figure 35. Sequential/random read communication flow



AM00926

1st frame

Bit 7 ÷ 1: L6360 address

Bit 0: Direction (write)

2nd frame

Bit 7 ÷ 0: Address register starting point

Table 30. Address register

Address	Register name
0000	Status register
0001	Configuration register
0010	Control register 1
0011	Control register 2
0100	LED1 register MSB
0101	LED1 register LSB
0110	LED2 register MSB
0111	LED2 register LSB
1000	Parity register

3rd frame

Bit 7 ÷ 1: L6360 address

Bit 0: Direction (read)

4th ÷ nth frame

Bit 7÷0: Data register (from address register starting point to penultimate address register)

9th frame

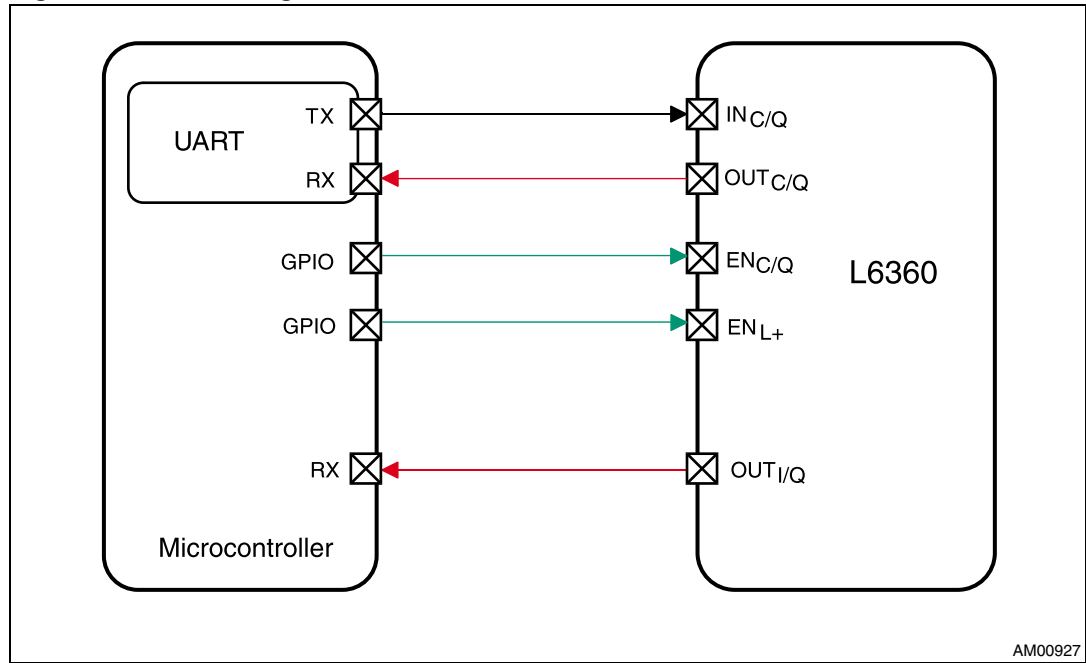
Bit 7÷0: Parity register (the last register)

7 Physical layer communication

The IC transfers the data received (on the $IN_{C/Q}$ digital input pin) at the C/Q_O output. The $EN_{C/Q}$ pin allows the C/Q_O line to be put into TRISTATE.

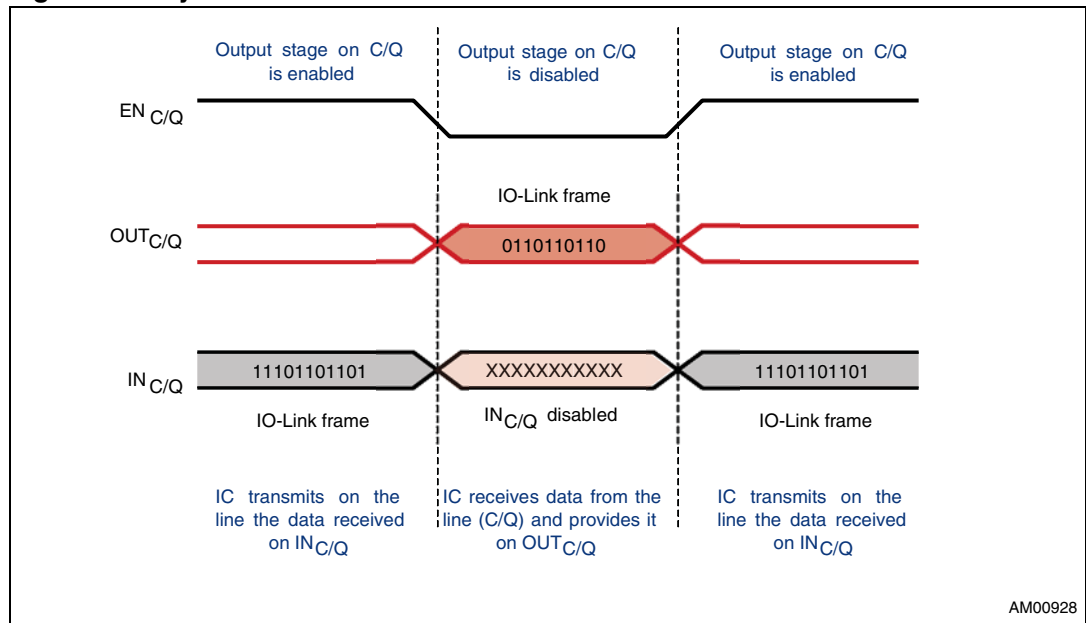
Data received from the line (C/Q_I and I/Q pins) is transferred to the digital output pins $OUT_{C/Q}$ and $OUT_{I/Q}$.

Figure 36. Block diagram communication mode



AM00927

Figure 37. System communication mode



AM00928

7.1 Transceiver

Output drivers (C/Q₀ and L+) are protected against short-circuit or overcurrent by means of two different functions.

One is the current limiting function: output current is linearly limited to I_{LIMQ/L}.

The cutoff protection, on the other side, is intended to turn off the drivers when the output current exceeds a (programmable for the C/Q₀ driver) threshold (I_{COQ/L}). When the current reaches the (programmed) cutoff value the channel output driver is turned off after a programmable delay (t_{dcoq/l}). The channel output driver automatically restarts again after a programmable delay time (t_{rcoq/l}). See [Figure 38](#).

Figure 38. C/Q or L+ channel cutoff protection

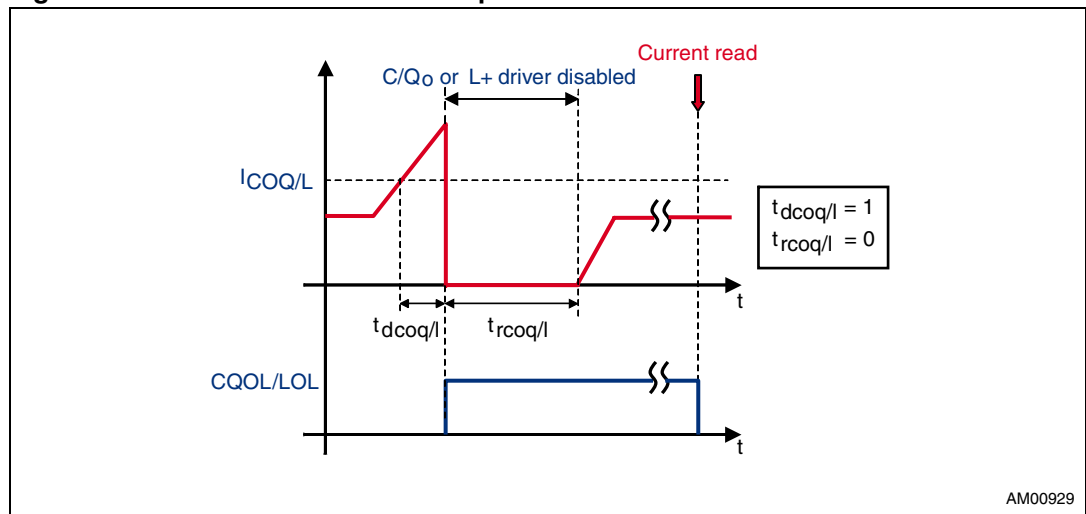
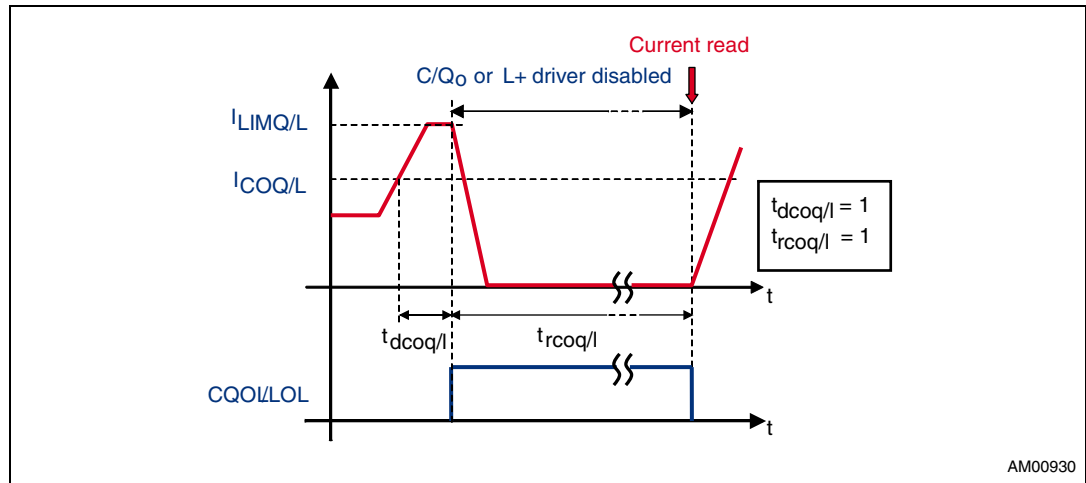


Figure 39. C/Q or L+ channel current limitation and cutoff protection with latched restart



For CQOL/LOL bit reset see the related [Status register](#) section.

7.2 IEC 61131-2 type 1 digital inputs

Two IEC61131-2 type 1 inputs are provided: one is available on C/Q₁ (as per IO-Link specification to support SIO mode) and one on the I/Q pin.

Both are provided with a programmable de-bounce filter (t_{dbq} and t_{dbi} , see [Table 17](#) and [Table 23](#)) to prevent false triggering.

8 Diagnostic LED sequence generator and driver

Each LED indication block can drive, through open drain output, one external LED.

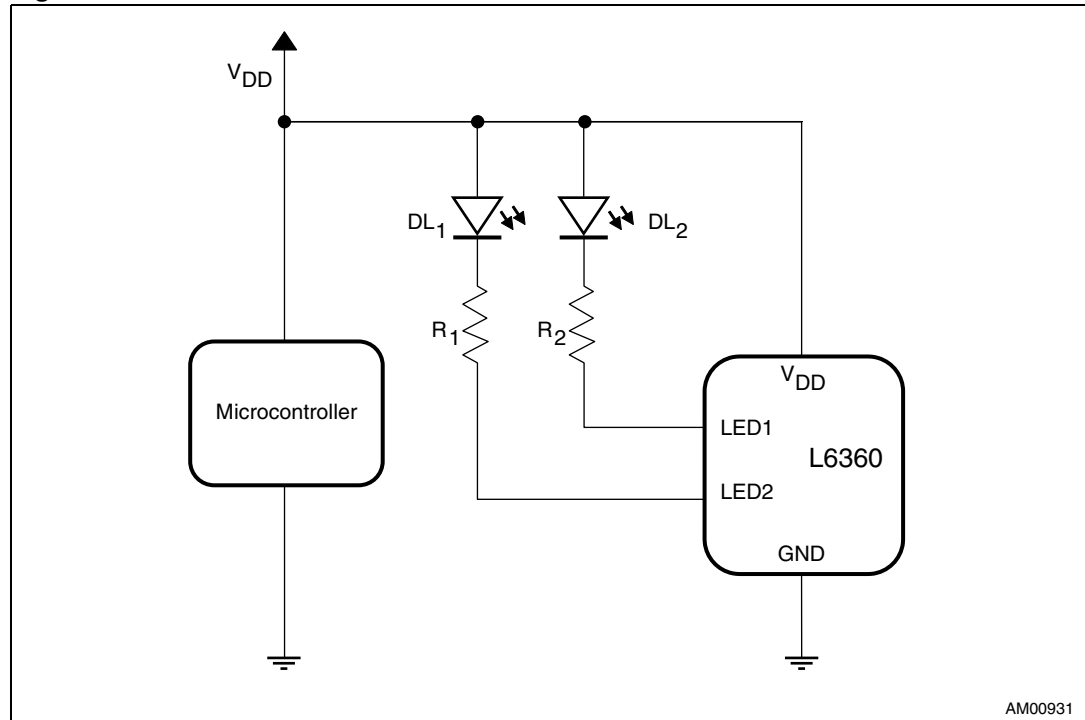
LED drivers can be used for status or diagnostic information, or for other purposes, and should be configured by the host microcontroller.

Two sequences of 16 bits can be programmed (through I²C) to generate user specific sequences; each LED driver has two associated registers and turns the external LED on or off according to the information stored in the registers, which are scanned at a rate of 63 ms per bit; total sequence time of each LED is approximately 1 s.

See also the [LED registers](#) section.

[Figure 40](#) shows how to wire up the two LEDs:

Figure 40. LED drivers



9 Linear regulator

The L6360 embeds a linear regulator with output voltage selectable (by the SEL pin) at 3.3 V or 5 V.

The input voltage is V_H (see [Table 3](#)) and the maximum power dissipation is 200 mW.

The linear regulator minimum limitation current value is I_{LIMLR} (see [Table 7](#)).

Figure 41. Linear regulator

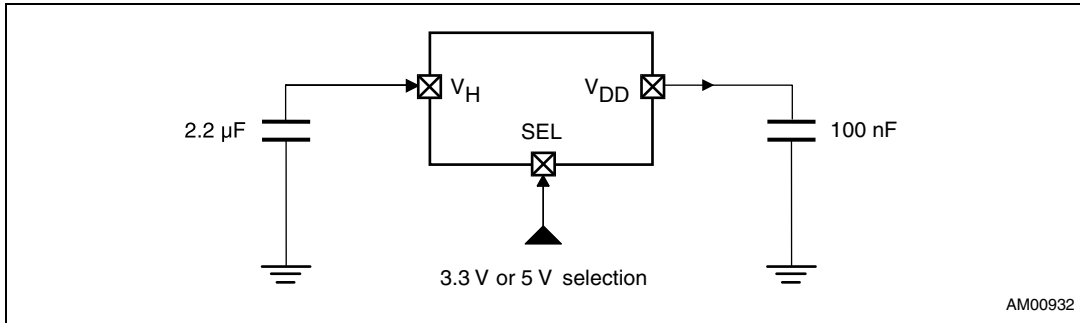


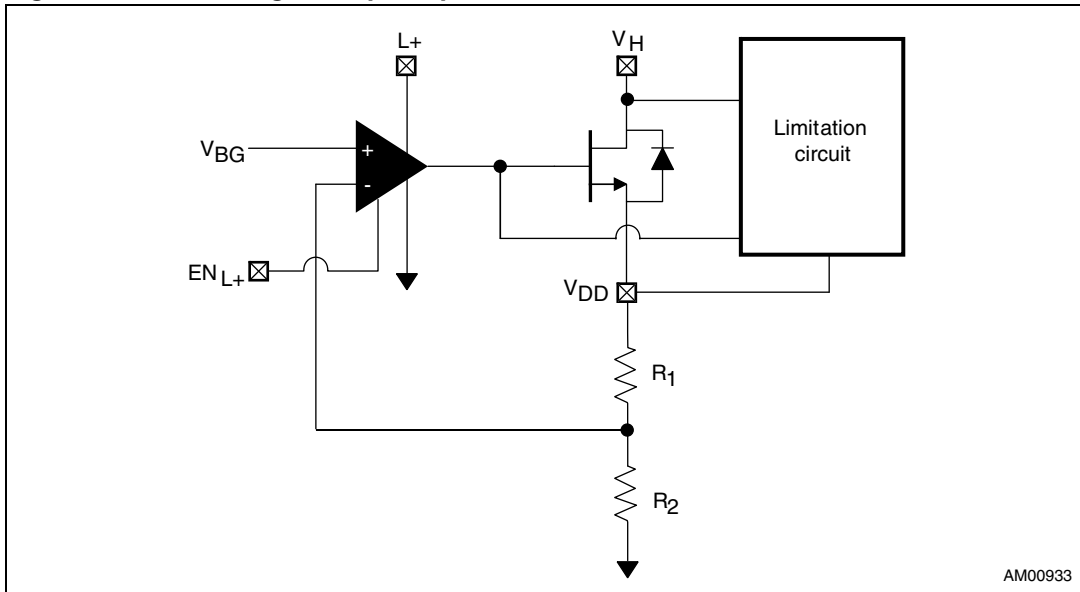
Table 31. Linear regulator selection pin

SEL	V_{DD}
0	5 V \pm 2.5%
1	3.3 V \pm 2%

The linear regulator cannot be turned off as it is necessary to supply (through V_{DD} pin) internal circuitries.

It can also be used to supply external circuitry (e.g. the microcontroller).

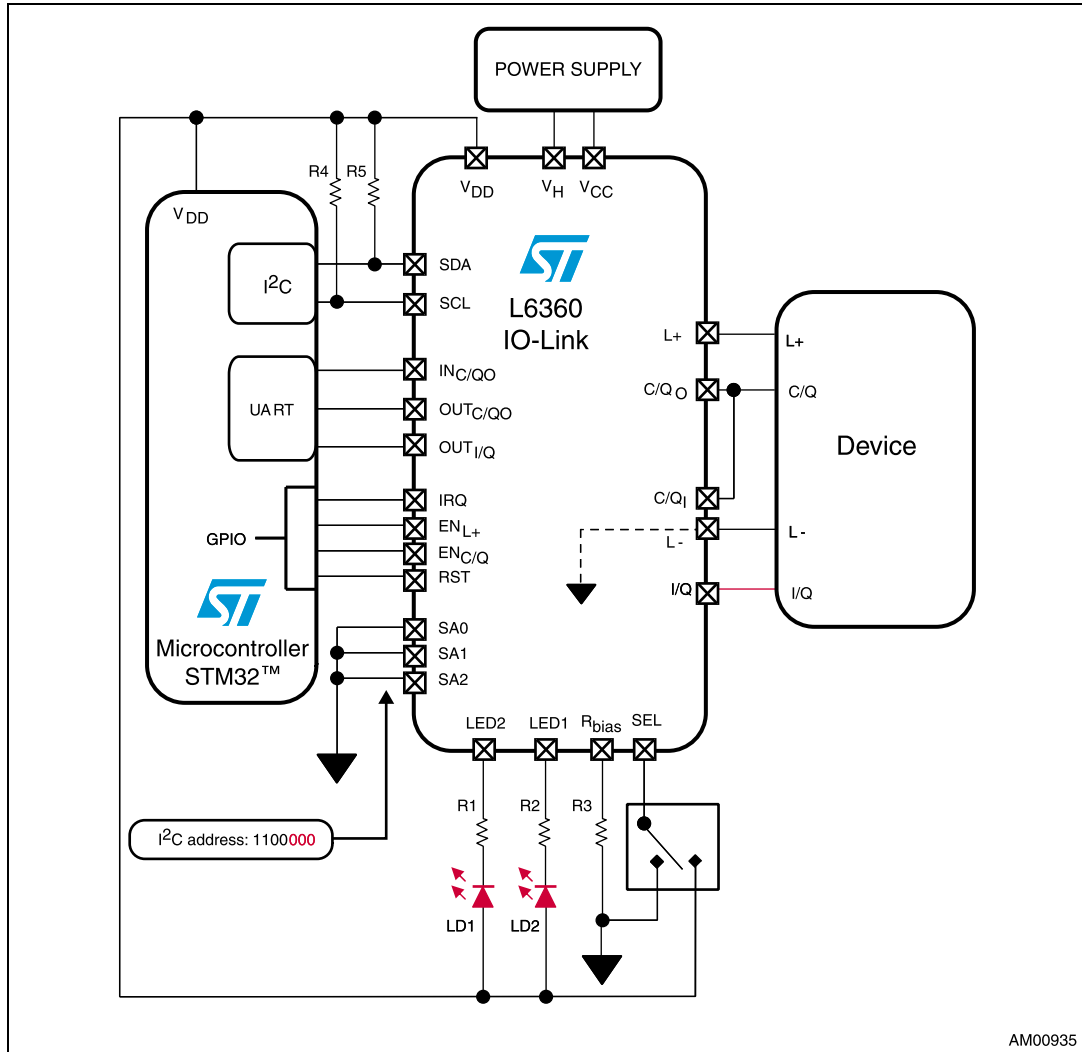
Figure 42. Linear regulator principle schematic



10 Application example

The IO-Link master system typically consists of a microcontroller and physical layer and it communicates with an IO-Link device. The principle connection can be seen in [Figure 43](#).

Figure 43. Application example



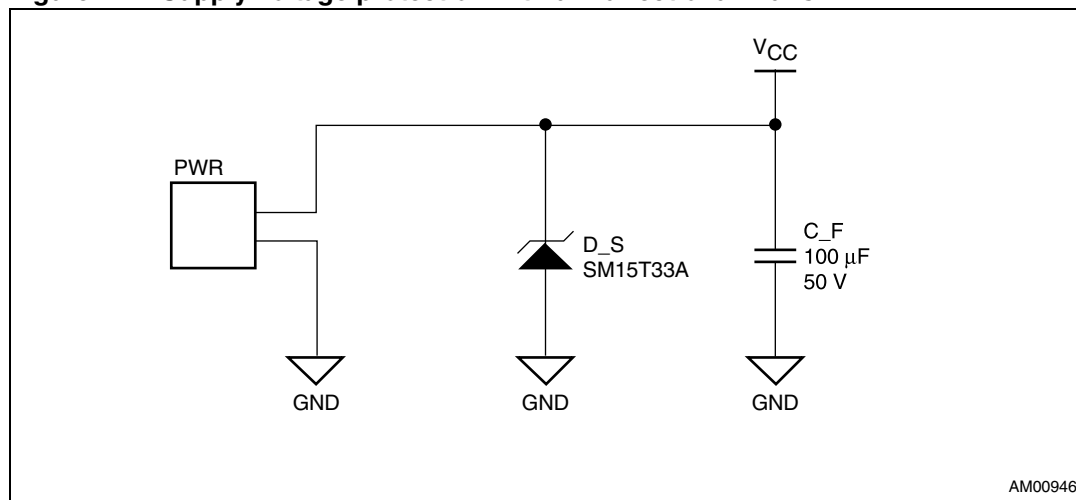
11 EMC protection considerations

Depending on final product use and environmental conditions, the master application may require additional protection.

11.1 Supply voltage protection

In order to avoid overvoltages on a system supply, a voltage suppressor such as Transil™ can be added. A simple protection diagram example is shown in [Figure 44](#).

Figure 44. Supply voltage protection with uni-directional Transil



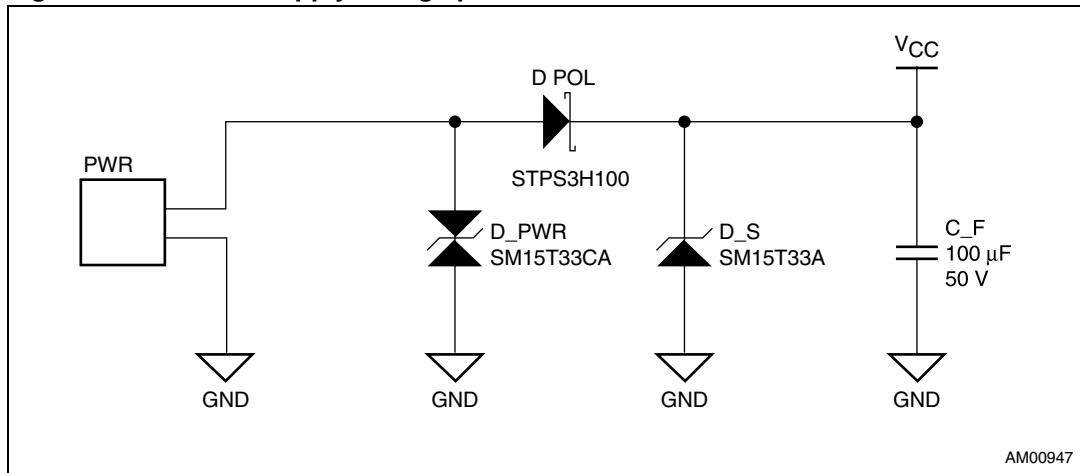
Performance of the above mentioned example is limited and does not include reverse polarity protection. It is just a cost-effective solution.

Table 32. Supply voltage protection component description

Part	Function	Description
D_S	Supply overvoltage protection	Works as a primary overvoltage clamp to limit supply line distortions - like surge pulses, oscillations caused by line parasitic parameters (inductance) during plug-in phase, etc. 1500 W is recommended to provide reliable protection, uni-directional type helps to avoid negative stress of the L6360.
C_F	Filtering bulk capacitor	An energy buffer for application supply, filters the application supply to avoid high ripple during power driver switching, etc.

A more sophisticated solution can be seen in [Figure 45](#).

Figure 45. Refined supply voltage protection



The above reference diagram provides an extended level of protection in both polarities as well as the reverse polarity protection.

Table 33. Refined supply voltage protection component description

Part	Function	Description
D_PWR	Primary overvoltage protection	Works as a primary overvoltage clamp to limit supply line distortions - like surge pulses, oscillations caused by line parasitic parameters (inductance) during plug-in phase, etc. 1500 W is recommended to provide reliable protection, uni-directional type is chosen to cover reverse polarity protection.
D_POL	Reverse polarity protection	Avoids reverse direction current flow and negative voltage stress of the L6360. Its current rating (3 A) is chosen in accordance with the maximum driving capabilities of the L6360 power stages. Schottky type is recommended to limit power dissipation (low VF). Voltage rating (100 V) comes from negative surge to the supply condition.
D_S	D_PWR support and IO overvoltage protection	a) Shares a positive surge current with the primary protection and limits the overvoltage amplitude. b) clamps surges applied to the L6360 C/Q and L+ lines.
C_F	Filtering bulk capacitor	An energy buffer for application supply, filters the application supply to avoid high ripple during power driver switching, etc.

If the V_H pin of the L6360 is supplied from a separate power supply or if it is decoupled from the main power supply and blocked by bulk capacitors, an additional circuit may be required to ensure the V_H voltage is always lower than (or equal to) the main supply voltage (V_{CC}). A possible solution with diode is shown in [Figure 46](#).

Figure 46. V_H protection vs. V_{CC}

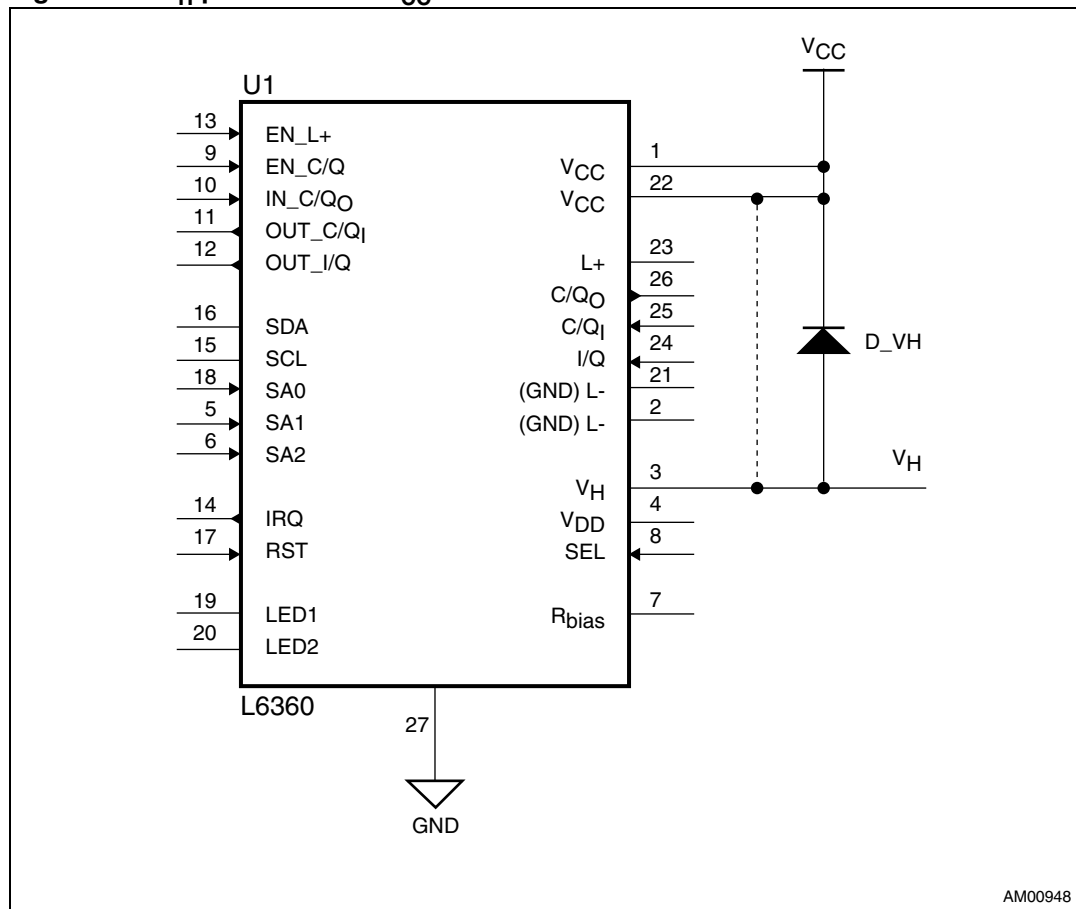


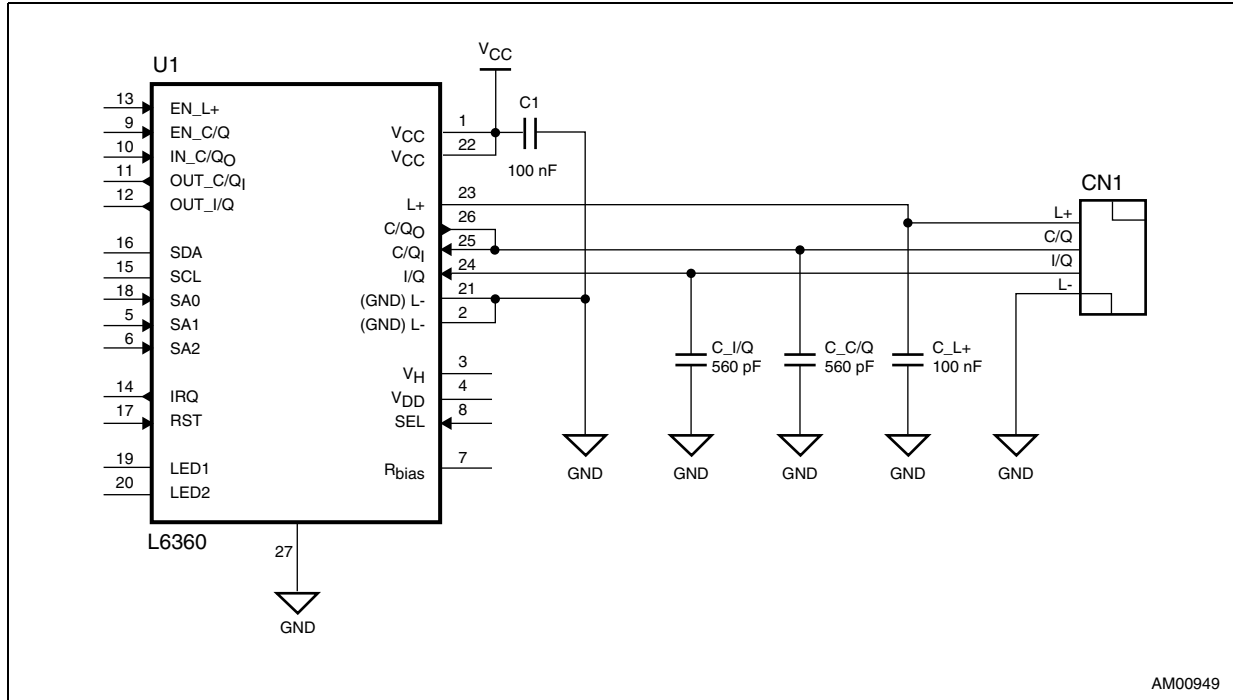
Table 34. V_H protection component description

Part	Function	Description
D_VH	VH overvoltage protection	V_H voltage must be always lower than (or equal to) V_{CC} . Even during the powering-up and down of an application. This fact must be taken into consideration if V_H is supplied from another source (V_{CC} and V_H not connected together), charged capacitors, etc. In some cases a diode placed between V_{CC} and V_H may help to avoid this violation.

11.2 I/O lines protection

Figure 47 shows external components (capacitors) suitable for IO-Link communication - protection level in accordance with specification.

Figure 47. Typical protection in IO-Link applications



AM00949

Table 35. Typical protection in IO-Link application component description

Part	Function	Description
C_1	Power supply blocking	Energy buffer for the L6360 supply, makes chip supply voltage stable, limits EMI noise.
C_I/Q, C_C/Q, C_L+	Filtration capacitors	Work as a basic protection against fast transient signals like burst or radio-frequency domain applied to the lines. Limit voltage spikes frequency spectrum and amplitude.

If an extended protection level is required, the solution seen in *Figure 48* is recommended. It provides robust protection according to IEC61131-2. It is suitable for IO-Link communication and is backward compatible with SIO (standard I/O). It protects the L6360 application against high energy surge pulses according to the IEC61000-4-5 standard. All the lines are protected against ± 2.5 kV surge pulse amplitude in common mode and ± 1 kV in differential mode considering $42 \Omega/0.5 \mu\text{F}$ generator coupling.

Figure 48. IO-Link and SIO application extended protection

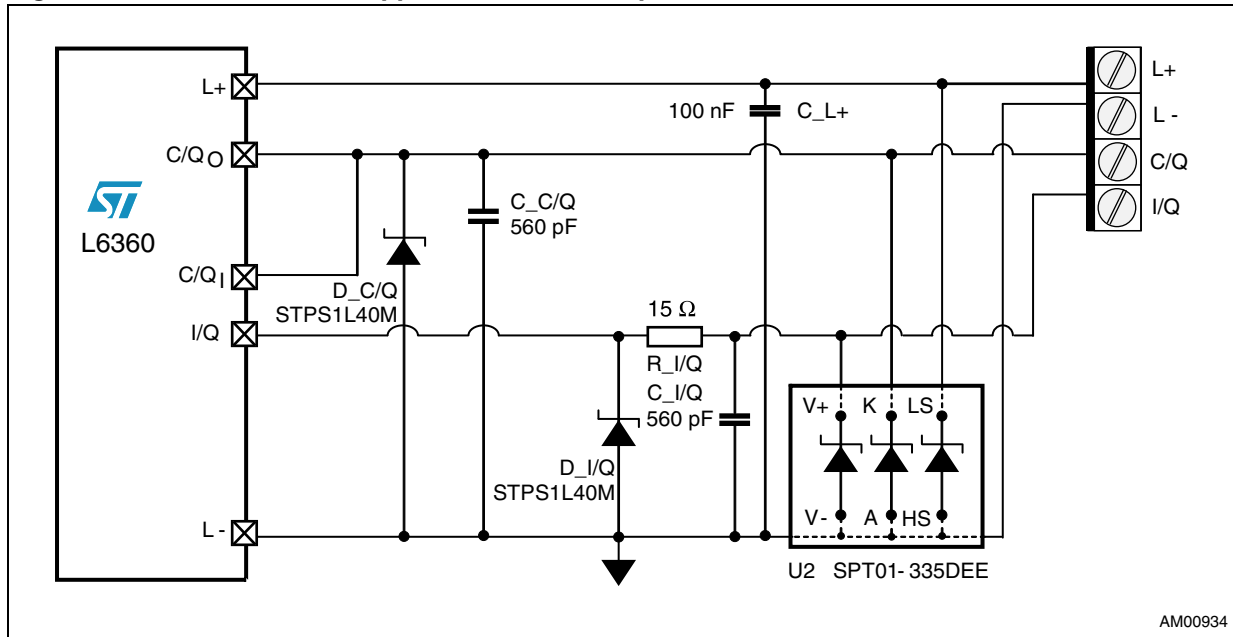


Table 36. IO-Link and SIO applications extended protection component description

Part	Function	Description
C_I/Q, C_C/Q, C_L+	Filtration capacitors	Work as a basic protection against fast transient signals like burst or radio-frequency domain applied to the lines. Limit voltage spike frequency spectrum and amplitude.
D_I/Q, D_C/Q	Negative voltage spike suppression	Schottky diodes with low VF clamp the disturbance applied to the lines in a reverse polarity direction. Capable of conducting high surge current pulses to avoid high peak current flow through L6360 pins.
R_I/Q	Surge current limitation	Reduces the current flow in the L6360 - the I/Q pin in both polarities when e.g. surge noise is applied to the line. If this resistor is omitted, the I/Q line surge immunity is lower.
U2 (SPT01-335DEE)	Overvoltage protection	Primary surge protection to avoid overvoltage on the L6360 interface. Protects L+ switch against negative voltage pulses. Shares current flow of negative surge pulses with the additional Schottky diodes on C/Q and I/Q lines. Clamps positive surge pulse amplitude applied to I/Q line.

12 Package mechanical data

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK[®]2 packages, depending on their level of environmental compliance. ECOPACK2 specifications, grade definitions and product status are available at: www.st.com. ECOPACK2 is an ST trademark.

Figure 49. Package outline for VFQFPN - 26-lead 3.5 x 5 x 1 mm - 0.50 pitch

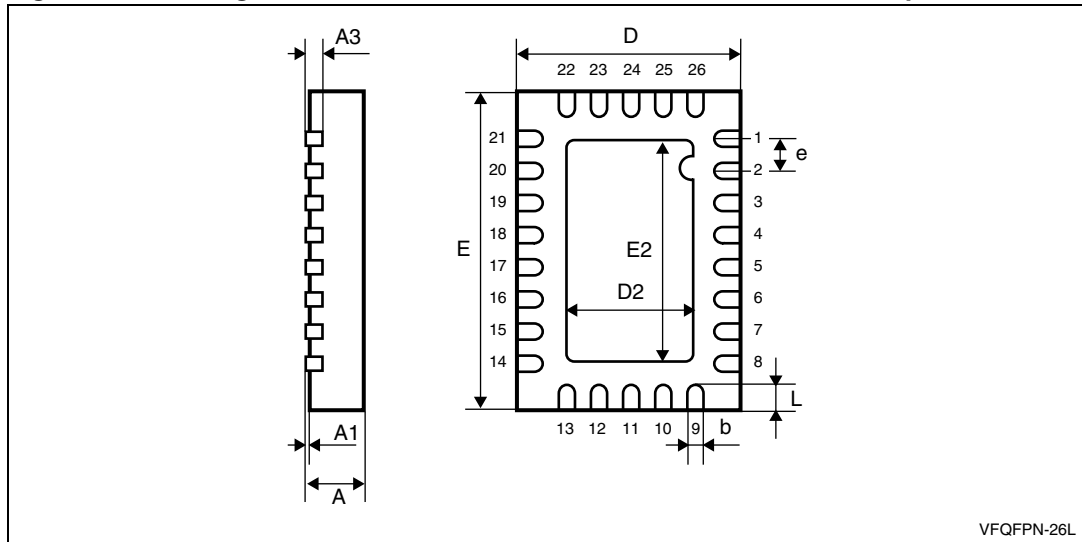


Table 37. Mechanical data for VFQFPN - 26-lead 3.5 x 5 x 1 mm - 0.50 pitch^{(1) (2) (3)}

Symbol	Dimensions		
	Min.	Typ.	Max.
A	0.80	0.90	1.00
A1	0	0.02	0.05
A2		0.20	
b	0.18	0.25	0.30
D	3.50		
D2	1.90	2.00	2.10
E	5.00		
E2	3.40	3.50	3.60
e		0.50	
L	0.30	0.40	0.50

1. VFQFPN stands for thermally enhanced "very thin fine pitch quad flat package no lead".

2. Very thin profile: $0.80 < A \leq 1.00$ mm.

3. All dimensions are in millimeters.

13 Revision history

Table 38. Document revision history

Date	Revision	Changes
12-Mar-2012	1	Initial release.
15-Mar-2012	2	Updated E_{load} definition in Table 3: Absolute maximum ratings . Updated Figure 36: Block diagram communication mode .
25-Jan-2013	3	Updated Table 4: Recommended operating conditions .

Please Read Carefully:

Information in this document is provided solely in connection with ST products. STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All ST products are sold pursuant to ST's terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the ST products and services described herein, and ST assumes no liability whatsoever relating to the choice, selection or use of the ST products and services described herein.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted under this document. If any part of this document refers to any third party products or services it shall not be deemed a license grant by ST for the use of such third party products or services, or any intellectual property contained therein or considered as a warranty covering the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

UNLESS OTHERWISE SET FORTH IN ST'S TERMS AND CONDITIONS OF SALE ST DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF ST PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

UNLESS EXPRESSLY APPROVED IN WRITING BY TWO AUTHORIZED ST REPRESENTATIVES, ST PRODUCTS ARE NOT RECOMMENDED, AUTHORIZED OR WARRANTED FOR USE IN MILITARY, AIR CRAFT, SPACE, LIFE SAVING, OR LIFE SUSTAINING APPLICATIONS, NOR IN PRODUCTS OR SYSTEMS WHERE FAILURE OR MALFUNCTION MAY RESULT IN PERSONAL INJURY, DEATH, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE. ST PRODUCTS WHICH ARE NOT SPECIFIED AS "AUTOMOTIVE GRADE" MAY ONLY BE USED IN AUTOMOTIVE APPLICATIONS AT USER'S OWN RISK.

Resale of ST products with provisions different from the statements and/or technical features set forth in this document shall immediately void any warranty granted by ST for the ST product or service described herein and shall not create or extend in any manner whatsoever, any liability of ST.

ST and the ST logo are trademarks or registered trademarks of ST in various countries.

Information in this document supersedes and replaces all information previously supplied.

The ST logo is a registered trademark of STMicroelectronics. All other names are the property of their respective owners.

© 2013 STMicroelectronics - All rights reserved

STMicroelectronics group of companies

Australia - Belgium - Brazil - Canada - China - Czech Republic - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan - Malaysia - Malta - Morocco - Philippines - Singapore - Spain - Sweden - Switzerland - United Kingdom - United States of America

www.st.com

