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STP16DPS05

Low voltage 16-bit constant current LED sink driver with outputs error detection

Features

- Low voltage power supply down to 3 V
- 16 constant current output channels
- Adjustable output current through external resistor
- Short and open output error detection
- Serial data IN/Parallel data OUT
- 3.3 V micro driver-able
- Output current: 20-85 mA
- 30 MHz clock frequency
- Available in high thermal efficiency TSSOP exposed pad
- ESD protection 2.0 kV HBM, 200 V MM

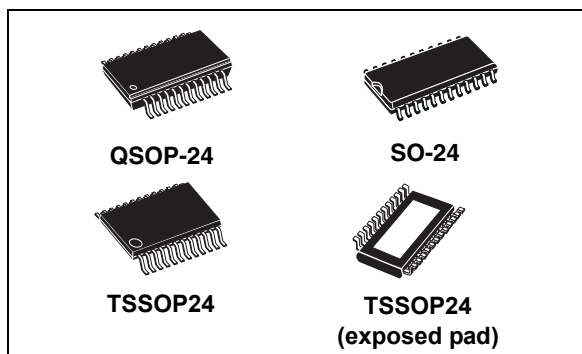
Description

The STP16DPS05 is a monolithic, low voltage, low current power 16-bit shift register designed for LED panel displays. The device contains a 16-bit serial-in, parallel-out shift register that feeds a 16-bit D-type storage register. In the output stage, sixteen regulated current sources were designed to provide 5-100 mA constant current to drive the LEDs.

The STP16DP05 features open and short LED detections on the outputs. The STP16DP05 is backward compatible with STP16C/L596. The detection circuit checks 3 different conditions that can occur on the output line: short to GND, short to V_O or open line.

Table 1. Device summary

Order codes	Package	Packaging
STP16DPS05MTR	SO-24 (tape and reel)	1000 parts per reel
STP16DPS05TTR	TSSOP24 (tape and reel)	2500 parts per reel
STP16DPS05XTTR	TSSOP24 exposed pad (tape and reel)	2500 parts per reel
STP16DP05PTR	QSOP-24	2500 parts per reel



The data detection results are loaded in the shift register and shifted out via the serial line output.

The detection functionality is implemented without increasing the pin count number, through a secondary function of the LATCH and output enable pin (DM1 and DM2 respectively), a dedicated logic sequence allows the device to enter or leave from detection mode. Through an external resistor, users can adjust the STP16DPS05 output current, controlling in this way the light intensity of LEDs, in addition, user can adjust LED's brightness intensity from 0% to 100% via $\overline{OE}/DM2$ pin.

The STP16DPS05 guarantees a 20 V output driving capability, allowing users to connect more LEDs in series. The high clock frequency, 30 MHz, makes the device suitable for high data rate transmission. The 3.3 V voltage supply is well useful for applications that interface any 3.3V micro. Compared with a standard TSSOP package, the TSSOP exposed pad increases heat dissipation capability by a 2.5 factor.

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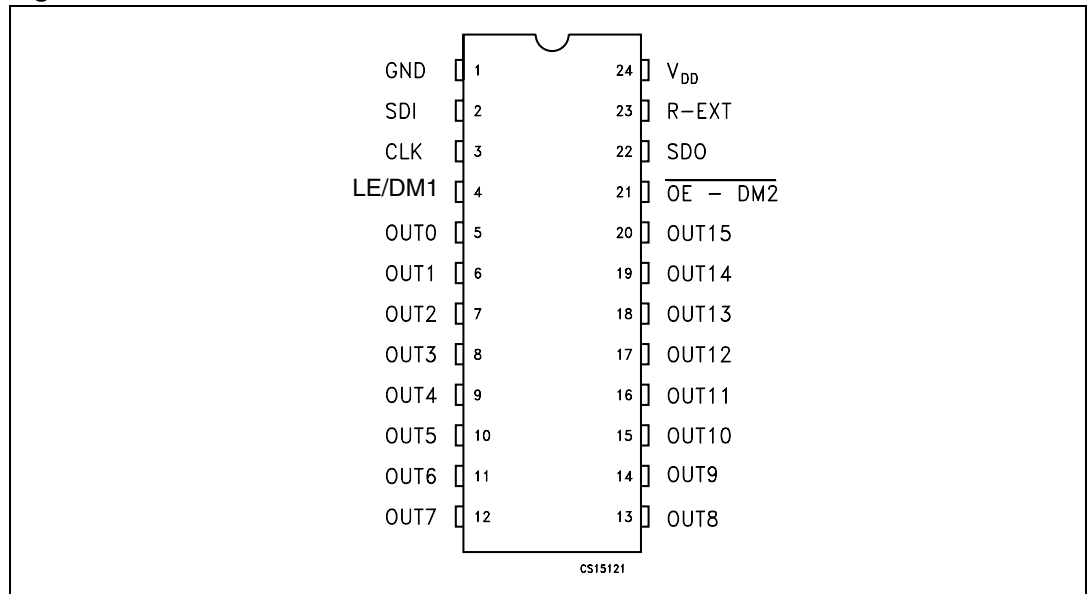
1 Summary description

Table 2. Typical current accuracy

Output voltage	Current accuracy		Output current	V _{DD}	Temperature
	Between bits	Between ICs			
≥ 1.3 V	±1.5%	±5%	20 to 100 mA	3.3 V to 5 V	25 °C

1.1 Pin connection and description

Figure 1. Pin connection



Note: The exposed pad should be electrically connected to a metal land electrically isolated or connected to ground.

Table 3. Pin description

Pin n°	Symbol	Name and function
1	GND	Ground terminal
2	SDI	Serial data input terminal
3	CLK	Clock input terminal
4	LE/DM1	Latch input terminal - detect mode 1 (see operation principle)
5-20	OUT 0-15	Output terminal
21	OE/DM2	Input terminal of output enable (active low) - detect mode 1 (see operation principle)
22	SDO	Serial data out terminal
23	R-EXT	Input terminal of an external resistor for constant current programming
24	V _{DD}	Supply voltage terminal

2 Electrical ratings

2.1 Absolute maximum ratings

Stressing the device above the rating listed in the [Table 4](#) may cause permanent damage to the device. These are stress ratings only and operation of the device at these or any other conditions above those indicated in the operating sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 4. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{DD}	Supply voltage	0 to 7	V
V_O	Output voltage	-0.5 to 20	V
I_O	Output current	100	mA
V_I	Input voltage	-0.4 to V_{DD}	V
I_{GND}	GND terminal current	1600	mA
f_{CLK}	Clock frequency	50	MHz
T_J	Junction temperature range ⁽¹⁾	-40 to +170	°C

1. Such absolute value is achieved according the thermal shutdown

2.2 Thermal data

Table 5. Thermal data

Symbol	Parameter	Value	Unit	
T_{OPR}	Operating temperature range	-40 to +125	°C	
T_{STG}	Storage temperature range	-55 to +150	°C	
R_{thJA}	Thermal resistance junction-ambient ⁽¹⁾	SO-24	42.7	°C/W
		TSSOP24	55	°C/W
		TSSOP24 ⁽²⁾ exposed pad	37.5	°C/W
		QSOP-24	55	°C/W

1. According with JEDEC JESD51-7

2. The exposed pad should be soldered directly to the PCB to realize the thermal benefits.

2.3 Recommended operating conditions

Table 6. Recommended operating conditions

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{DD}	Supply voltage		3.0	-	5.5	V
V_O	Output voltage			-	20	V
I_O	Output current	OUTn	5	-	100	mA
I_{OH}	Output current	SERIAL-OUT		-	+1	mA
I_{OL}	Output current	SERIAL-OUT		-	-1	mA
V_{IH}	Input voltage		$0.7V_{DD}$	-	$V_{DD}+0.3$	V
V_{IL}	Input voltage		-0.3	-	$0.3 V_{DD}$	V
t_{wLAT}	LE/DM1 pulse width	$V_{DD} = 3.0\text{ V to }5.0\text{ V}$	6	-		ns
t_{wCLK}	CLK pulse width		8	-		ns
t_{wEN}	$\overline{OE/DM2}$ pulse width		100	-		ns
$t_{SETUP(D)}$	Setup time for DATA		10	-		ns
$t_{HOLD(D)}$	Hold time for DATA		5	-		ns
$t_{SETUP(L)}$	Setup time for LATCH		10	-		ns
f_{CLK}	Clock frequency	Cascade operation ⁽¹⁾		-	30	MHz

1. If the device is connected in cascade, it may not be possible to achieve the maximum data transfer. Please consider the timings carefully.

3 Electrical characteristics

$V_{DD} = 5\text{ V}$, $T = 25\text{ °C}$, unless otherwise specified

Table 7. Electrical characteristics

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{IH}	Input voltage high level		$0.7V_{DD}$		V_{DD}	V
V_{IL}	Input voltage low level		GND		$0.3V_{DD}$	V
I_{OH}	Output leakage current	$V_{OH} = 20\text{ V}$			1	μA
V_{OL}	Output voltage (Serial-OUT)	$I_{OL} = 1\text{ mA}$			0.4	V
V_{OH}	Output voltage (Serial-OUT)	$I_{OH} = -1\text{ mA}$	$V_{OH} - V_{DD} = -0.4\text{ V}$			V
I_{OL1}	Output current	$V_O = 0.3\text{ V}$, $R_{ext} = 3.9\text{ k}\Omega$	4.25	5	5.75	mA
I_{OL2}		$V_O = 0.3\text{ V}$, $R_{ext} = 970\ \Omega$	19	20	21	
I_{OL3}		$V_O = 1.3\text{ V}$, $R_{ext} = 190\ \Omega$	96	100	104	
ΔI_{OL1}	Output current error between bit (all output ON)	$V_O = 0.3\text{ V}$, $R_{EXT} = 3.9\text{ k}\Omega$		± 5	± 8	%
ΔI_{OL2}		$V_O = 0.3\text{ V}$, $R_{EXT} = 970\ \Omega$		± 1.5	± 3	
ΔI_{OL3}		$V_O = 1.3\text{ V}$, $R_{EXT} = 190\ \Omega$		± 1.2	± 3	
$R_{SIN(up)}$	Pull-up resistor		150	300	600	$\text{K}\Omega$
$R_{SIN(down)}$	Pull-down resistor		100	200	400	$\text{K}\Omega$
$I_{DD(OFF1)}$	Supply current (OFF)	$R_{EXT} = 970$ OUT 0 to 15 = OFF		5	6	mA
$I_{DD(OFF2)}$		$R_{EXT} = 240$ OUT 0 to 15 = OFF		13	14	
$I_{DD(ON1)}$	Supply current (ON)	$R_{EXT} = 970$ OUT 0 to 15 = ON		6	7	
$I_{DD(ON2)}$		$R_{EXT} = 240$ OUT 0 to 15 = ON		13.5	14.5	
Thermal	Thermal protection ⁽¹⁾			170		$^{\circ}\text{C}$

1. Guaranteed by design (not tested)
The thermal protection switches OFF only the outputs current

V_{DD} = 5 V, T = 25 °C, unless otherwise specified

Table 8. Switching characteristics

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit		
t _{PLH1}	Propagation delay time, CLK-OUT _n , LE/DM1 = H, OE/DM2 = L		V _{DD} = 3.3 V	-	40 to 44	44	ns	
			V _{DD} = 5 V	-	20 to 44	44		
t _{PLH2}	Propagation delay time, LE/DM1 -OUT _n , OE/DM2 = L		V _{DD} = 3.3 V	-	51	77	ns	
			V _{DD} = 5 V	-	32	47		
t _{PLH3}	Propagation delay time, OE/DM2-OUT _n , LE/DM1 = H		V _{DD} = 3.3 V	-	49 to 57	57 to 77	ns	
			V _{DD} = 5 V	-	27 to 32	32 to 41		
t _{PLH}	Propagation delay time, CLK-SDO		V _{DD} = 3.3 V	-	21.5 to 22	32	ns	
			V _{DD} = 5 V	-	14.5 to 15	21.5		
t _{PHL1}	Propagation delay time, CLK-OUT _n , LE/DM1 = H, OE/DM2 = L	V _{IH} = V _{DD} V _{IL} = GND I _O = 20 mA R _{EXT} = 1 KΩ	C _L = 10 pF V _L = 3.0 V R _L = 60 Ω	V _{DD} = 3.3 V	-	15 to 18	25	ns
				V _{DD} = 5 V	-	11 to 13	14.5 to 16	
t _{PHL2}	Propagation delay time, LE/DM1 -OUT _n , OE/DM2 = L			V _{DD} = 3.3 V	-	13 to 18	18 to 25	ns
				V _{DD} = 5 V	-	9 to 12	12.5 to 15	
t _{PHL3}	Propagation delay time, OE/DM2-OUT _n , LE/DM1 = H			V _{DD} = 3.3 V	-	11.5 to 12	12 to 18	ns
				V _{DD} = 5 V	-	8.5 to 10	9.7 to 12	
t _{PHL}	Propagation delay time, CLK-SDO			V _{DD} = 3.3 V	-	25.5	38	ns
				V _{DD} = 5 V	-	17.5 to 20.5	25	
t _{ON}	Output rise time 10~90% of voltage waveform			V _{DD} = 3.3 V	-	34 to 20	24 to 53.5	ns
				V _{DD} = 5 V	-	12.5 to 9	9 to 18.5	
t _{OFF}	Output fall time 90~10% of voltage waveform			V _{DD} = 3.3 V	-	5.5 to 3.3	3.3 to 8.5	ns
				V _{DD} = 5 V	-	4.5 to 2.8	2.8 to 6.5	
t _r	CLK rise time ⁽¹⁾			-		5000	ns	
t _f	CLK fall time ⁽¹⁾			-		5000	ns	

1. In order to achieve high cascade data transfer, please consider tr/tf timings carefully.

4 Equivalent circuit and outputs

Figure 2. $\overline{\text{OE}}/\text{DM2}$ terminal

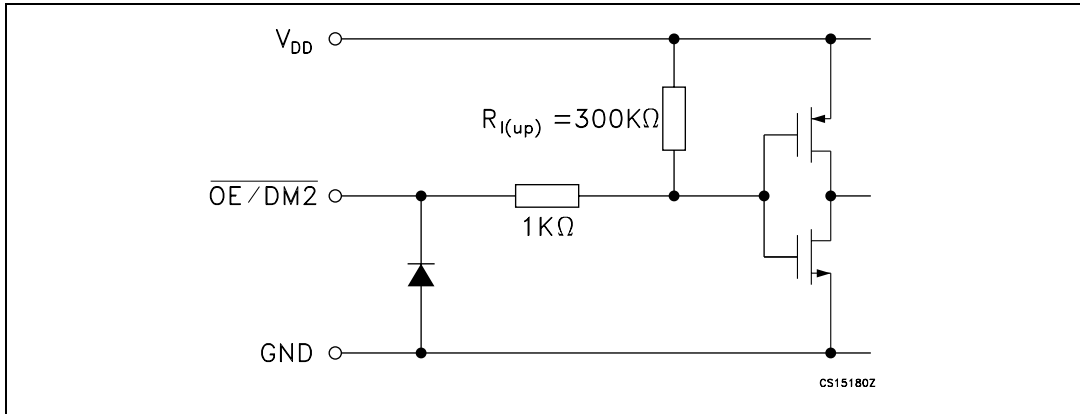


Figure 3. LE/DM1 terminal

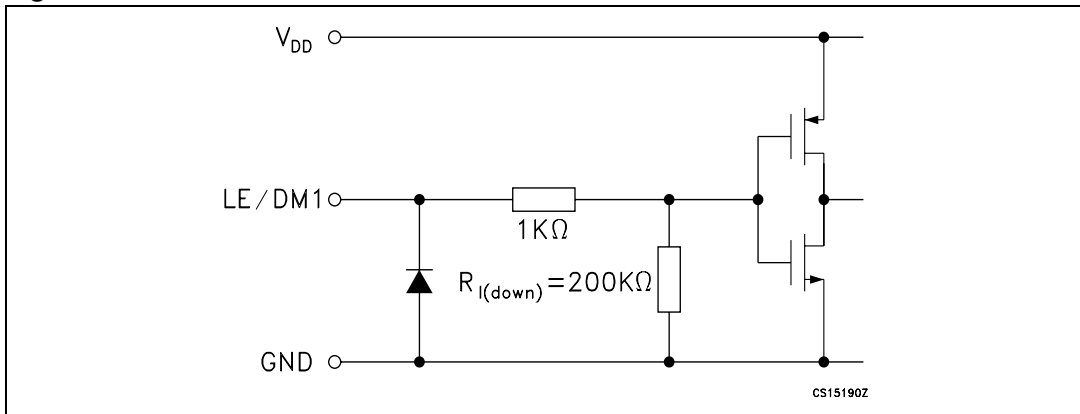


Figure 4. CLK, SDI terminal

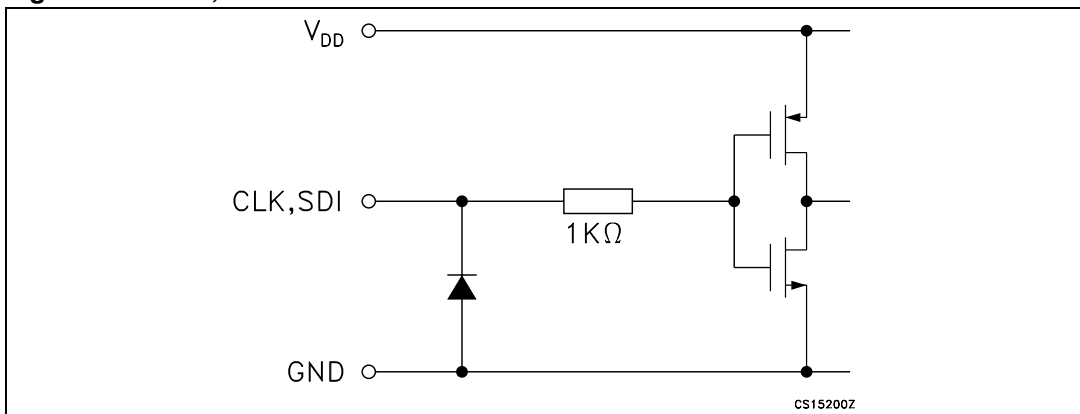


Figure 5. SDO terminal

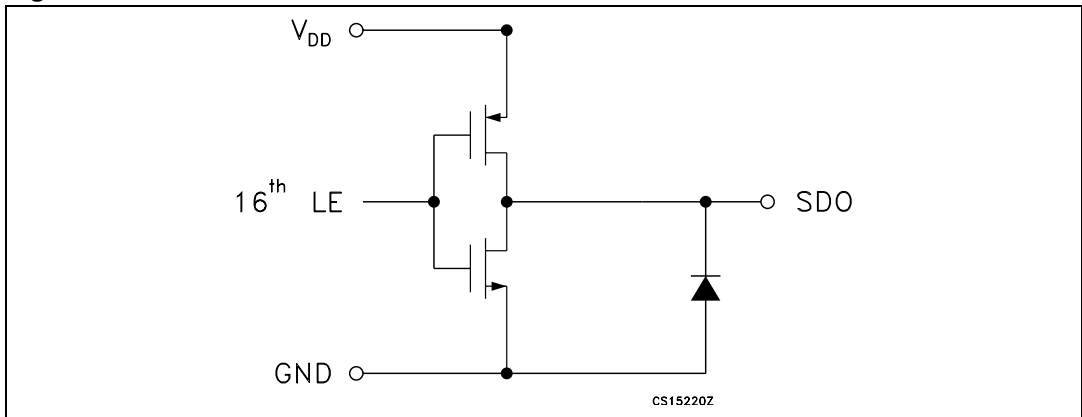
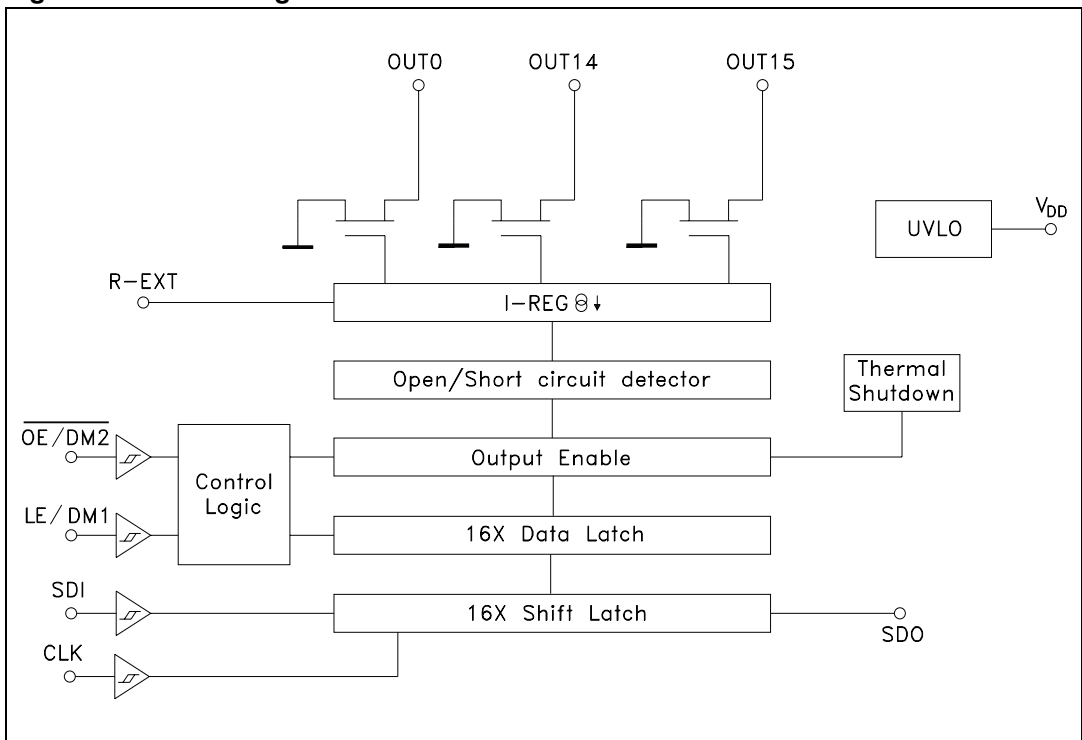


Figure 6. Block diagram



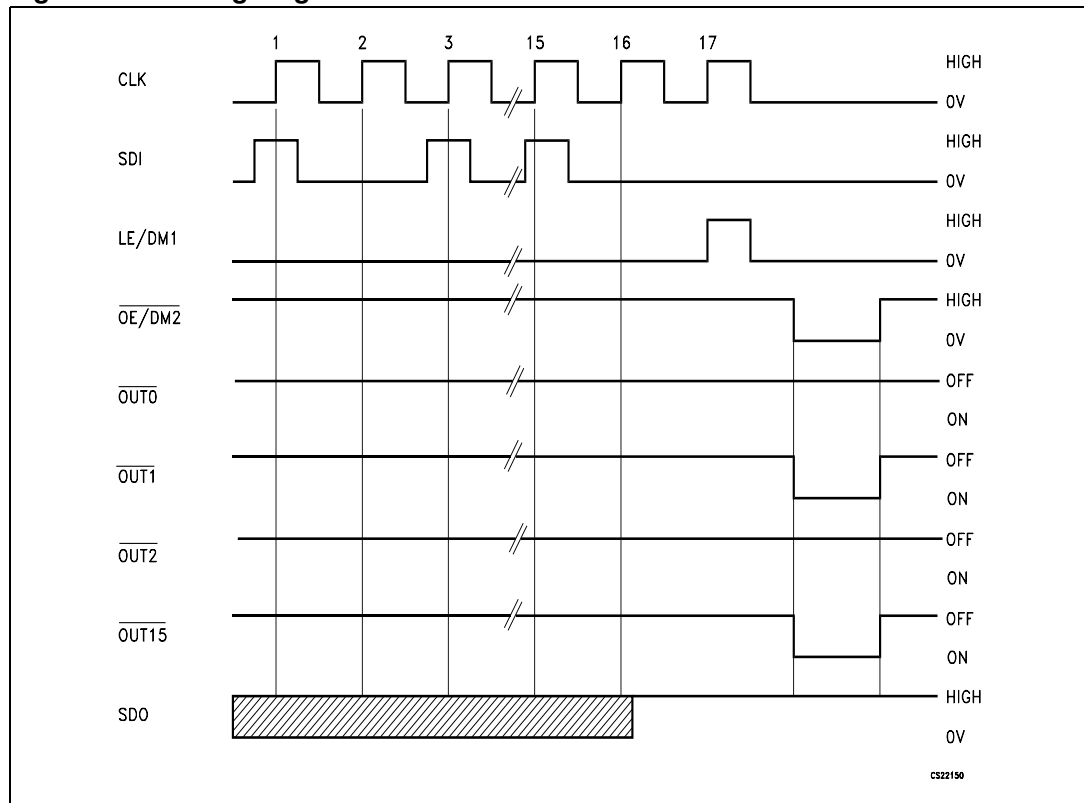
5 Timing diagrams

Table 9. Truth table

CLOCK	LE/DM1	OE/DM2	SERIAL-IN	OUT0 OUT7 OUT15	SDO
	H	L	Dn	Dn Dn - 7 Dn -15	Dn - 15
	L	L	Dn + 1	No change	Dn - 14
	H	L	Dn + 2	Dn + 2 Dn - 5 Dn -13	Dn - 13
	X	L	Dn + 3	Dn + 2 Dn - 5 Dn -13	Dn - 13
	X	H	Dn + 3	OFF	Dn - 13

Note: $OUTn = ON$ when $Dn = H$ $OUTn = OFF$ when $Dn = L$

Figure 7. Timing diagram



- Note:
- 1 Latch and output enable are level sensitive and ARE NOT synchronized with rising-or-falling edge of CLK signal.
 - 2 When LE/DM1 terminal is low level, the latch circuits hold previous set of data
 - 3 When LE/DM1 terminal is high level, the latch circuits refresh new set of data from SDI chain.
 - 4 When OE/DM2 terminal is at low level, the output terminals - Out0 to Out15 respond to data in the latch circuits, either '1' for ON or '0' for OFF
 - 5 When OE/DM2 terminal is at high level, all output terminals will be switched OFF.

Figure 8. Clock, serial-in, serial-out

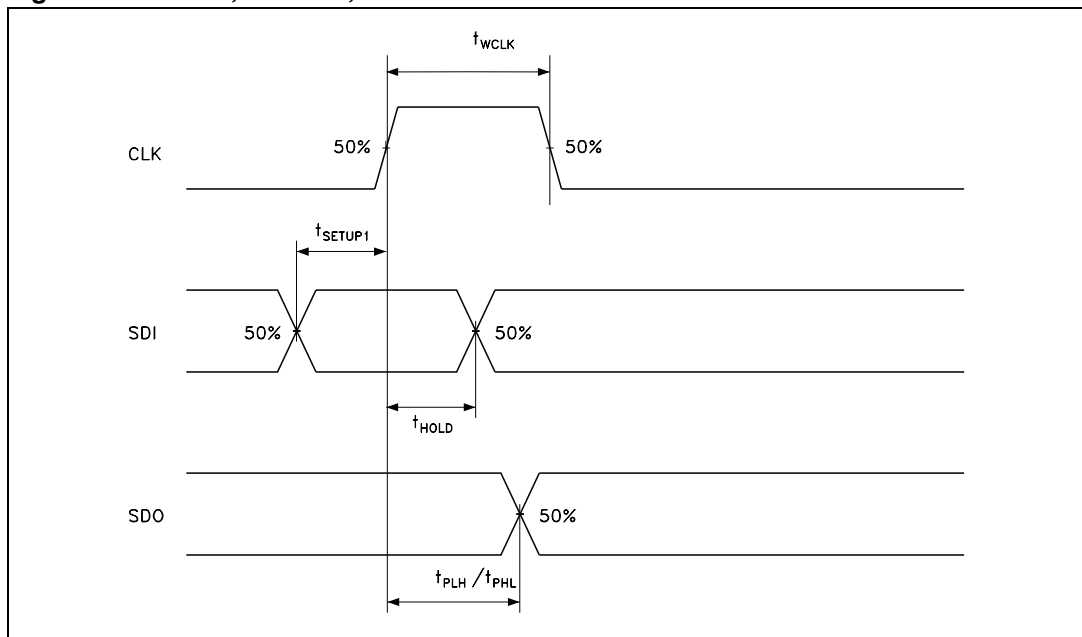


Figure 9. Clock, serial-in, latch, enable, outputs

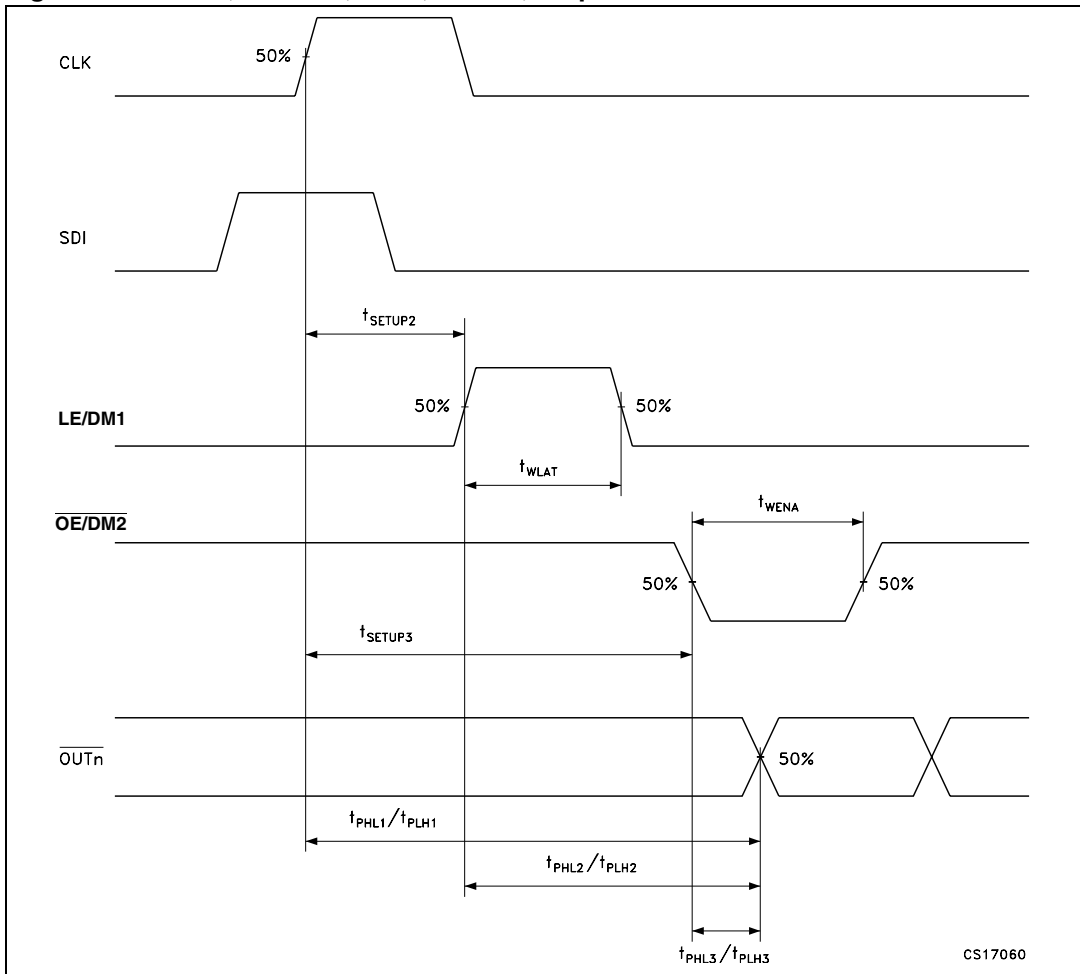
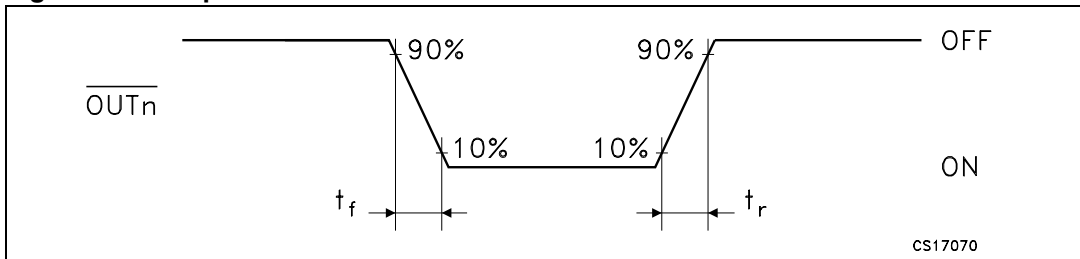


Figure 10. Outputs



6 Typical characteristics

Figure 11. Output current- R_{EXT} resistor

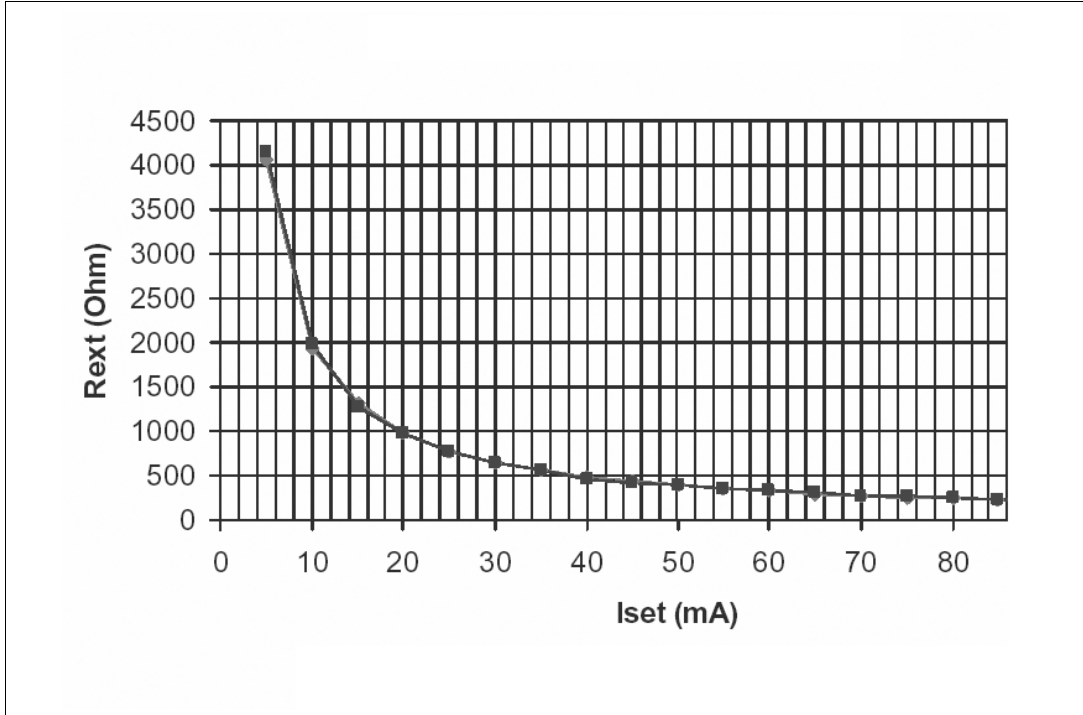


Table 10. Output current- R_{EXT} resistor

R_{ext} (Ω)	Output current (mA)
976	20
780	25
652	30
560	35
488	40
433	45
389	50
354	55
325	60
300	65
278	70
259	75
241	80
229	85

Conditions:

Temperature = 25 °C, V_{DD} = 3.3 V; 5.0 V, I_{SET} = 3 mA; 5 mA; 10 mA; 20 mA; 50 mA; 80 mA.

Figure 12. I_{SET} vs drop out voltage (V_{drop})

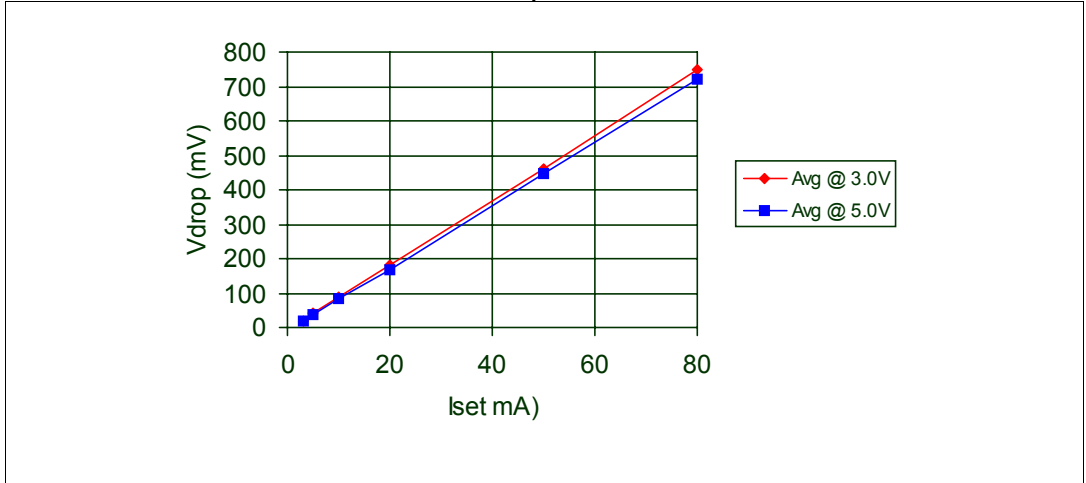
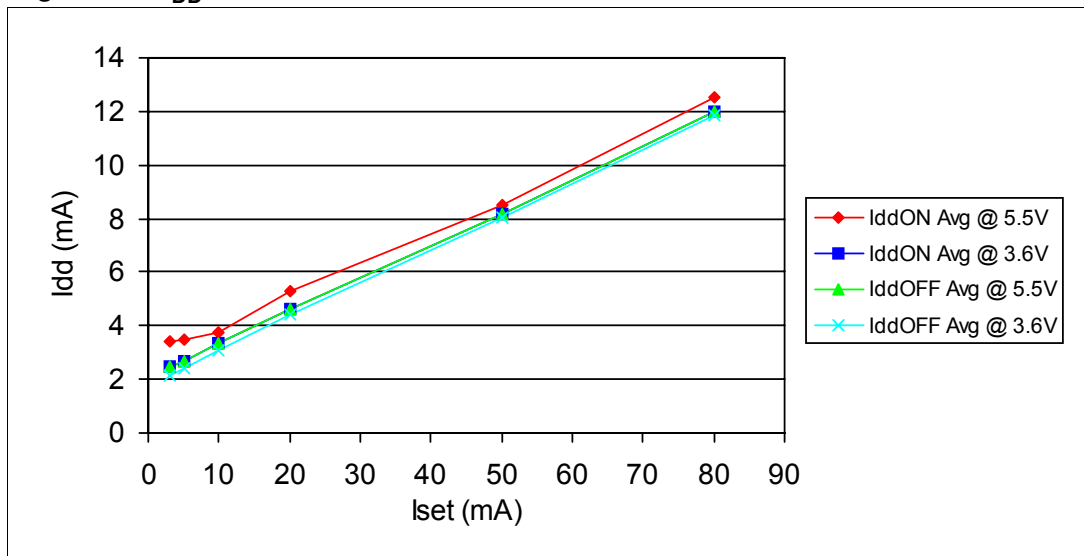


Table 11. I_{SET} vs drop out voltage (V_{drop})

Iout (mA)	Avg @ 3.0 V	Avg @ 5.0 V
3	19.33	22.66
5	36.67	40.33
10	77.33	80
20	158.67	157.33
50	406	406
80	692	668

Figure 13. I_{DD} ON/OFF

7 Detection mode functionality

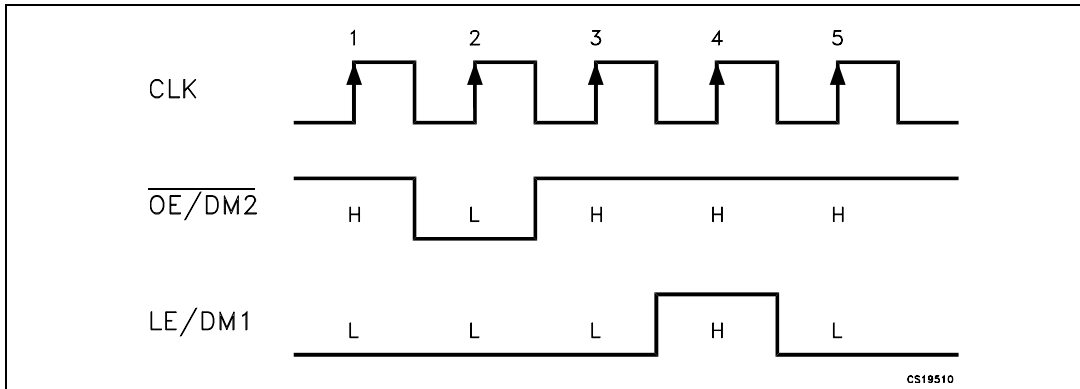
7.1 Phase one: “entering in detection mode“

From the “normal mode” condition the device can switch to the “error mode” by a logic sequence on the $\overline{OE/DM2}$ and LE/DM1 pins as showed in the following table and diagram:

Table 12. Entering in detection truth table

CLK	1°	2°	3°	4°	5°
$\overline{OE/DM2}$	H	L	H	H	H
LE/DM1	L	L	L	H	L

Figure 14. Entering in detection timing diagram

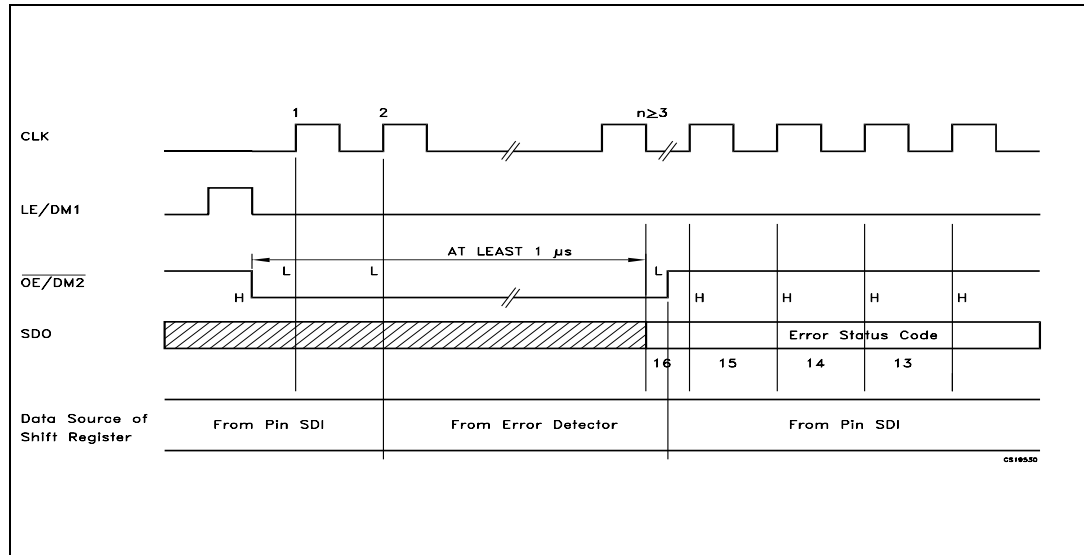


After these five CLK cycles the device goes into the “error detection mode” and at the 6th rise front of CLK the SDI data are ready for the sampling.

7.2 Phase two: “error detection”

The 16 data bits must be set “1” in order to set ON all the outputs during the detection. The data are latched by LE/DM1 and after that the outputs are ready for the detection process. When the microcontroller switches the $\overline{OE}/DM2$ to LOW, the device drives the LEDs in order to analyze if an OPEN or SHORT condition has occurred.

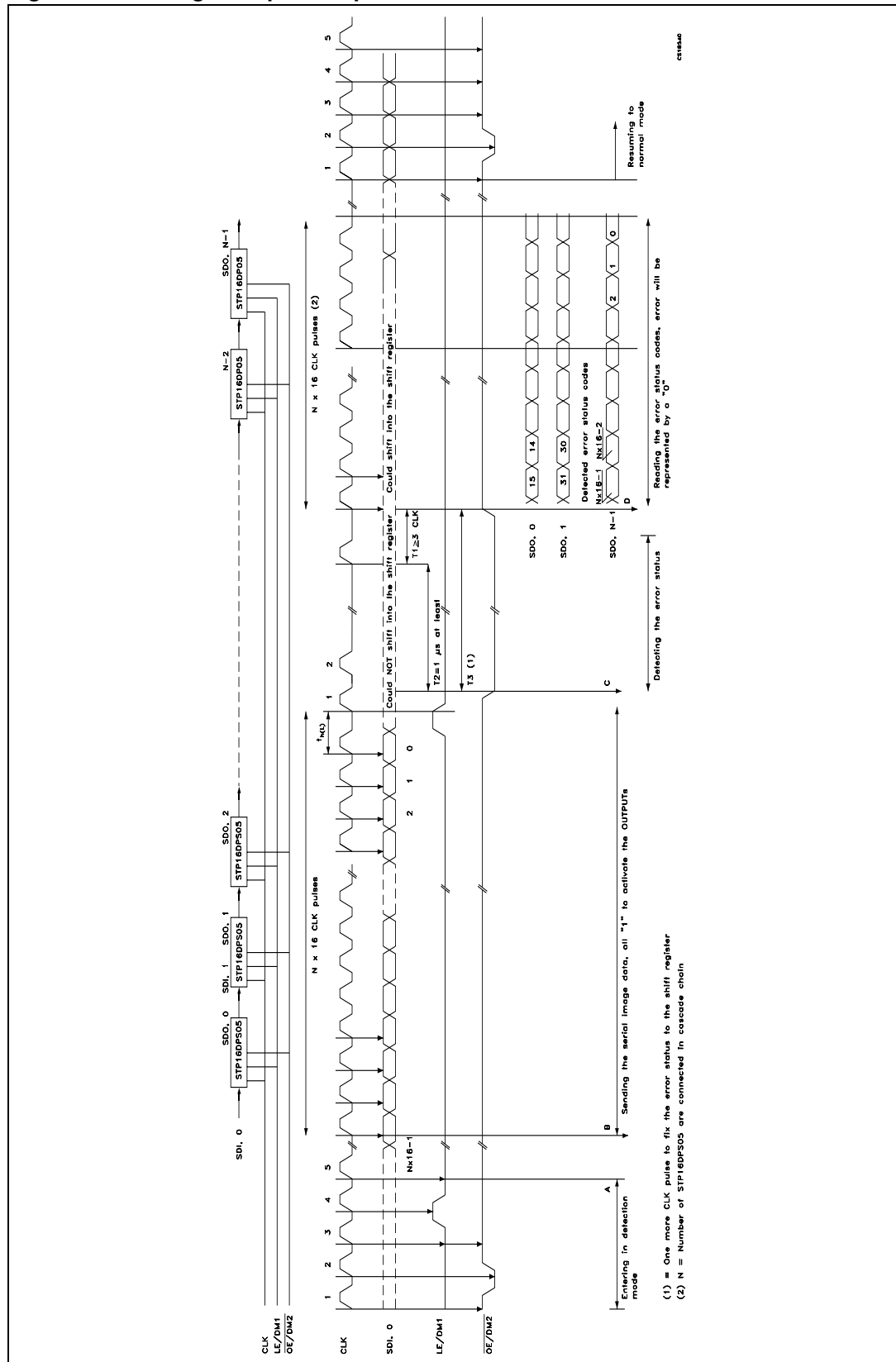
Figure 15. Detection diagram



The LEDs status will be detected at least in 1 microsecond and after this time the microcontroller sets $\overline{OE}/DM2$ in HIGH state and the output data detection result will go to the microprocessor via SDO.

Detection mode and normal mode use both the same format data. As soon as all the detection data bits are available on the serial line, the device may go back to normal mode of operation. To re-detect the status the device must go back in normal mode and re-entering in error detection mode.

Figure 16. Timing example for open and/or short detection



7.3 Phase three: “resuming to normal mode”

The sequence for re-entering in normal mode is showed in the following table and diagram:

Figure 17. Resuming to normal mode timing diagram

CLK	1°	2°	3°	4°	5°
$\overline{OE/DM2}$	H	L	H	H	H
LE/DM1	L	L	L	L	L

Note: For proper device operation the “Entering in detection” sequence must be follow by a “resume mode” sequence, it is not possible to insert consecutive equal sequence.

7.4 Error detection conditions

$V_{DD} = 3.3$ to 5 V temperature range -40 to 125 °C

Table 13. Detection conditions

SW-1 or SW-3b	Open line or output short to GND detected	$\implies I_{ODEC} \leq 0.5 \times I_O$	No error detected	$\implies I_{ODEC} \geq 0.5 \times I_O$
SW-2 or SW-3a	Short on LED or short to V-LED detected	$\implies V_O \geq 2.4$ V	No error detected	$\implies V_O \leq 2.2$ V

Note: Where: I_O = the output current programmed by the R_{EXT} , I_{ODEC} = the detected output current in detection mode

Figure 18. Detection circuit

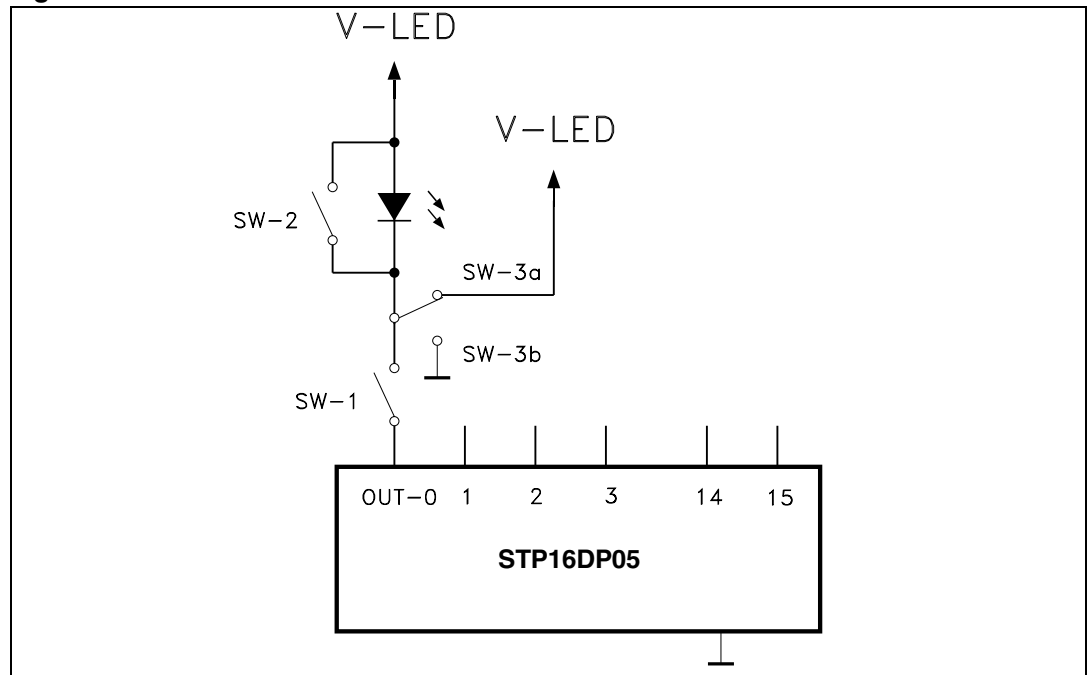
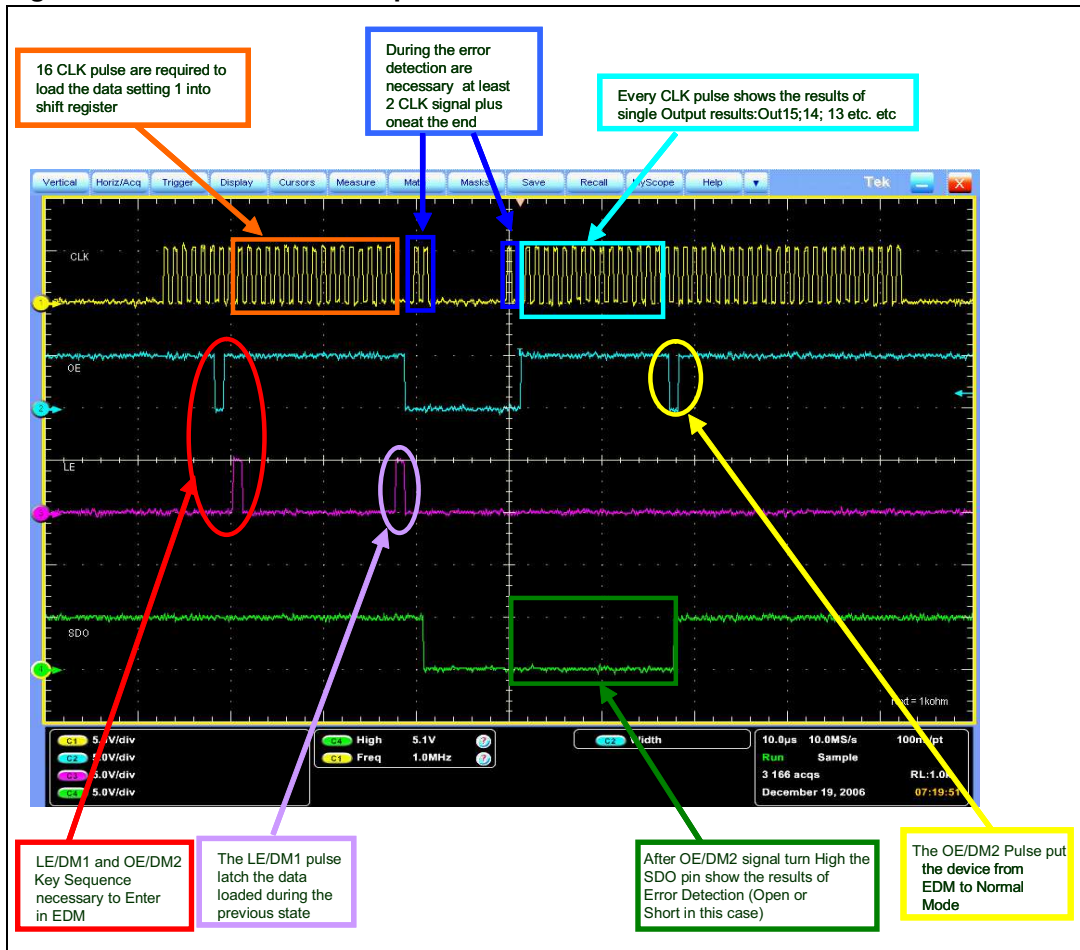
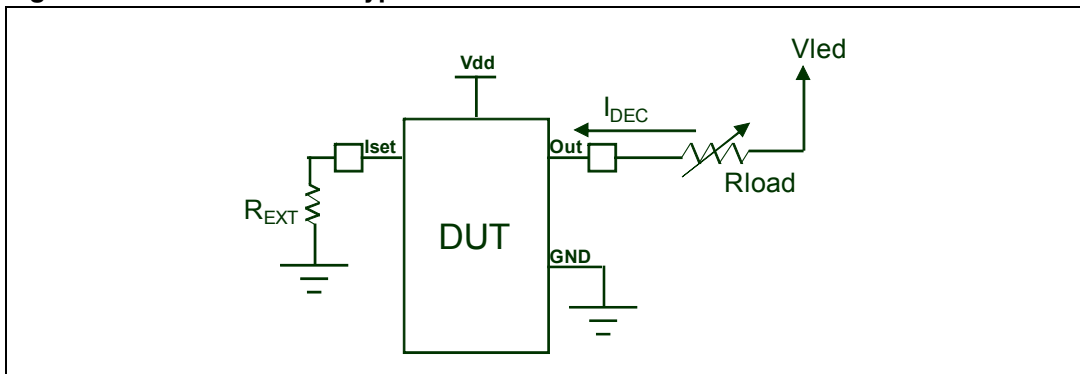


Figure 19. Error detection sequence



Typical schematic used to perform the error detection:

Figure 20. Error detection typical schematic



Using the follow formula is possible measure the Iodec

$$I_{ODEC} = (V_{led} - V_{load}) / R_{load}$$

The tables below shows the I_{ODEC} average value at 3.3 V and 5.0 V of power supply voltage.

The I_{ODEC} is the current value recognized by the devices output open error detection

Table 14. I_{ODEC} average value at 3.3 V

Vdd (V)	Iset (mA)	Rext (Ω)	Iout AVG (mA)
3.3	5	4270	2.097
	10	2056	6.79
	20	1006	10.46
	50	382	26.92
	80	251	35.03

Table 15. I_{ODEC} average value at 5 V

Vdd (V)	Iset (mA)	Rext (Ω)	Iout AVG (mA)
5	5	4270	1.98
	10	2056	6.09
	20	1006	9.67
	50	382	25.54
	80	251	38.9

7.5 Auto power-saving

The auto power-saving feature minimizes the quiescent current if no active data is detected on the latches and auto powers-up the device as the first active data is latched.

Figure 21. Auto power-saving feature



Conditions:

Temp. = 25 °C, Vdd = 3.3 V, Vin = Vdd, VLed = 3.0 V, Iset = 20 mA

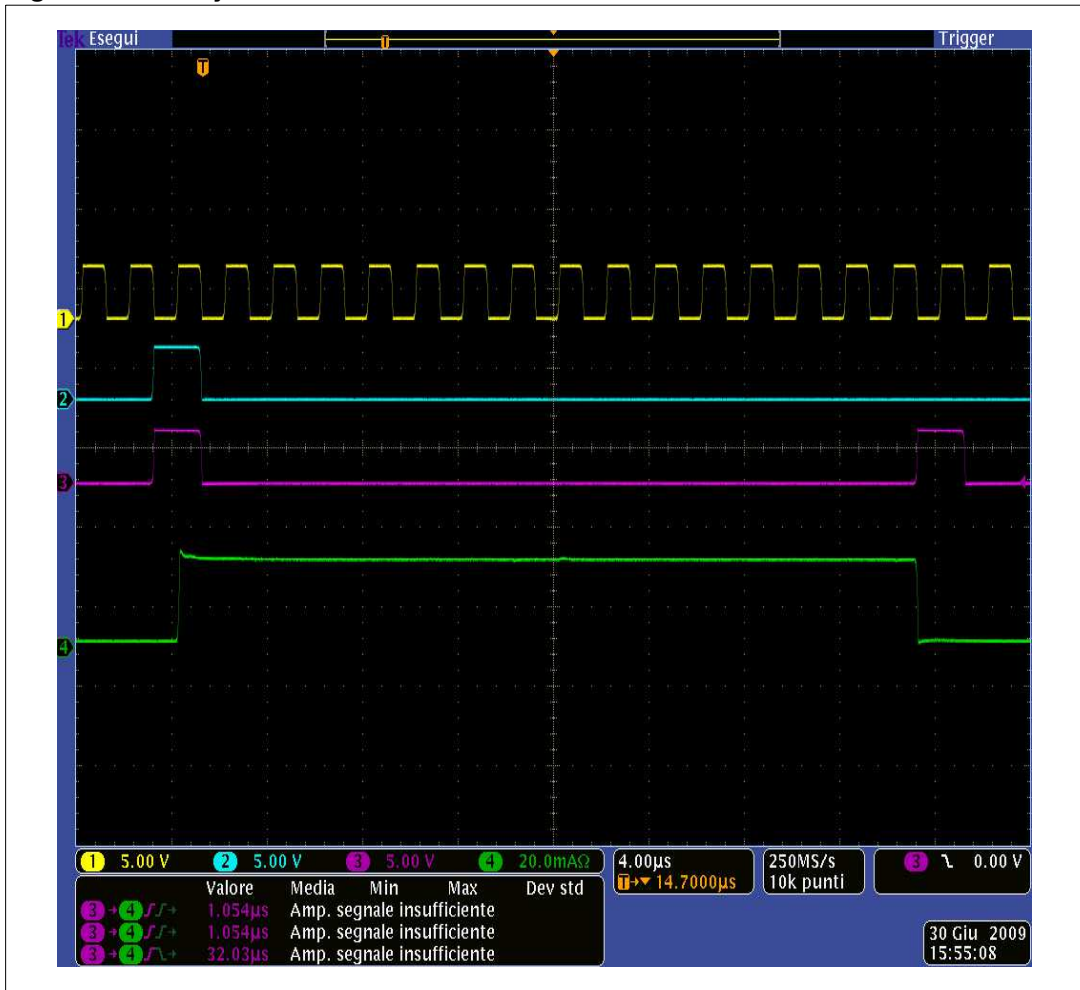
Ch1 (Yellow) = IDD, Ch2 (Blue) = SDI, Ch3 (Purple) = LE/DM1, Ch4 (Green) = CLK

I_{dd} consumption:

I_{dd} (normal operation) = 5.15 mA

I_{dd} (shutdown condition) = 163 µA

Figure 22. Delay LE-OUT



After 16 clock cycles without data change, device will enter in Auto power save mode as expected. Delay TLE-OUT = 1.053 µs

Conditions:

Temp. = 25 °C, Vdd = 3.3 V, Vin = Vdd, VLed = 3.0 V, Iset = 20 mA

Ch1 (Yellow) = CLK, Ch2 (Blue) = SDI, Ch3 (Purple) = LE/DM1, Ch4 (Green) = IOOUT

Figure 23. Behaviour auto power saving



Note: When the device goes from auto power-saving to normal operating condition, the first output that switches ON shows the T_{ON} condition as seen in the plot above.

Temp. = 25°C, Vdd = 3.3 V, Vin = Vdd, VLed = 3.0 V, Iset = 20 mA

Ch1 (Yellow) = IDD, Ch2 (Blue) = SDI, Ch3 (Purple) = LE/DM1, Ch4 (Green) = CLK

8 Package mechanical data

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

Table 16. QSOP-24 mechanical data

Dim.	mm.			inch		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	1.54	1.62	1.73	0.061	0.064	0.068
A1	0.1	0.15	0.25	0.004	0.006	0.010
A2		1.47			0.058	
b	0.31	0.2		0.012	0.008	
c	0.254	0.17		0.010	0.007	
D	8.56	8.66	8.76	0.337	0.341	0.345
E	5.8	6	6.2	0.228	0.236	0.244
E1	3.8	3.91	4.01	0.150	0.154	0.158
e		0.635			0.025	
L	0.4	0.635	0.89	0.016	0.025	0.035
h	0.25	0.33	0.41	0.010	0.013	0.016
<	8°	0°				