



# NEX1316X-Q100

## 16-channel automotive linear LED driver

Rev. 1.2 — 23 October 2025

Product data sheet

## 1. General description

NEX1316X-Q100 is an AEC-Q100 Grade 1 qualified 16-channel, 40 V high-side LED driver with up to 100 mA output current per channel, PWM and analog dimming support, and MTP for configurable depending on application requirements in automotive lighting systems.

NEX1316X-Q100 supports 8-bit output current with high accuracy from channel to channel and device to device. Channels can be used in parallel to support higher current output than 100 mA. The low dropout of the device helps mitigate the heat generation of the device itself. The device integrates UART over CAN as the digital interface to enable long distance off-board communication, which is a typical scenario for automotive exterior lighting where different lamp functions are typically located in different PCBs. NEX1316X-Q100 also supports LED open-circuit, short to ground, and single-LED short-circuit diagnostics. Additionally, a configurable watchdog automatically sets the part into Fail-Safe state when the CAN bus connection is lost.

NEX1316X-Q100 can operate at a junction temperature ranging from -40 °C to 150 °C in a thermally enhanced 38-pin HTSSOP38 package.

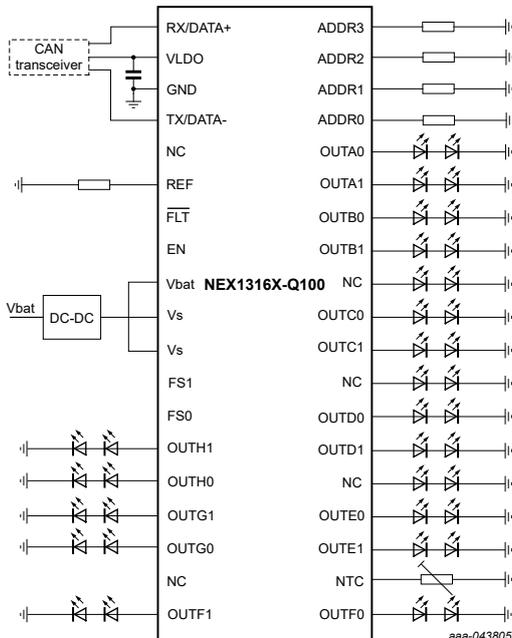


Fig. 1. Typical application

## 2. Features and benefits

- Automotive product qualification in accordance with AEC-Q100 (Grade 1)
  - Specified from -40 °C to 125 °C
- Function safety capable
  - Provide documents to support function safety design
- 16-channel precision high-side current output:
  - $V_{Vbat}$ : 4.5 V to 36 V;  $V_{VS}$ : 3.8 V to 20 V
  - Up to 100 mA channel current per channel
  - 2-bit global, 6-bit independent current setting
  - Current accuracy within  $\pm 5\%$  from 5 mA to 100 mA
  - Low voltage drops: 600 mV at 100 mA
  - 12-bit independent PWM dimming
  - Programmable PWM frequency: 200 Hz to 23.4 kHz
- EN pin supports ultra-low quiescent current in sleep mode
  - Linear and exponential dimming method
- Integrated CAN compatible interface:
  - Data rate up to 2 Mbit/s
  - Supports UART data format
  - Supports 27 slave addresses set by resistors
- Diagnostics and protections:
  - Programmable Fail-Safe state
  - LED open-circuit detection
  - LED short-circuit detection
  - Single-LED short-circuit diagnostic
  - Programmable low-supply detection
  - Open-drain FLT pin for fault indication
  - Communication Watchdog
  - 8-bit ADC for pin voltage measurement
  - Overtemperature protection
  - NTC temperature monitoring
  - HBM: ANSI/ESDA/JEDEC JS-001 class 3A exceeds 4000 V
  - CDM: ANSI/ESDA/JEDEC JS-002 class C2b exceeds 750 V

## 3. Applications

- Automotive exterior rear lights
- Automotive exterior headlights

## 4. Ordering information

Table 1. Ordering information

Type number	Temperature range	Name	Description	Version
<a href="#">NEX13160PE-Q100</a>	T <sub>amb</sub> = -40 °C to 125 °C	HTSSOP38	plastic, thermal enhanced thin shrink small outline package; 38 leads; 0.5 mm pitch; 9.7 mm x 4.4 mm x 1.2 mm body	<a href="#">SOT8106-1</a>
<a href="#">NEX13161PE-Q100</a>				

## 5. Marking

Table 2. Marking

Type number	Marking code
NEX13160PE-Q100	N13160
NEX13161PE-Q100	N13161

## 6. Device comparison

Table 3. Device Comparison

Type number	Key features
NEX13160PE-Q100	16-channel + UART + FS capable
NEX13161PE-Q100	16-channel + CAN + FS capable
NEX13240PE-Q100	24-channel + UART + FS capable
NEX13241PE-Q100	24-channel + CAN + FS capable

### 7. Application block diagram

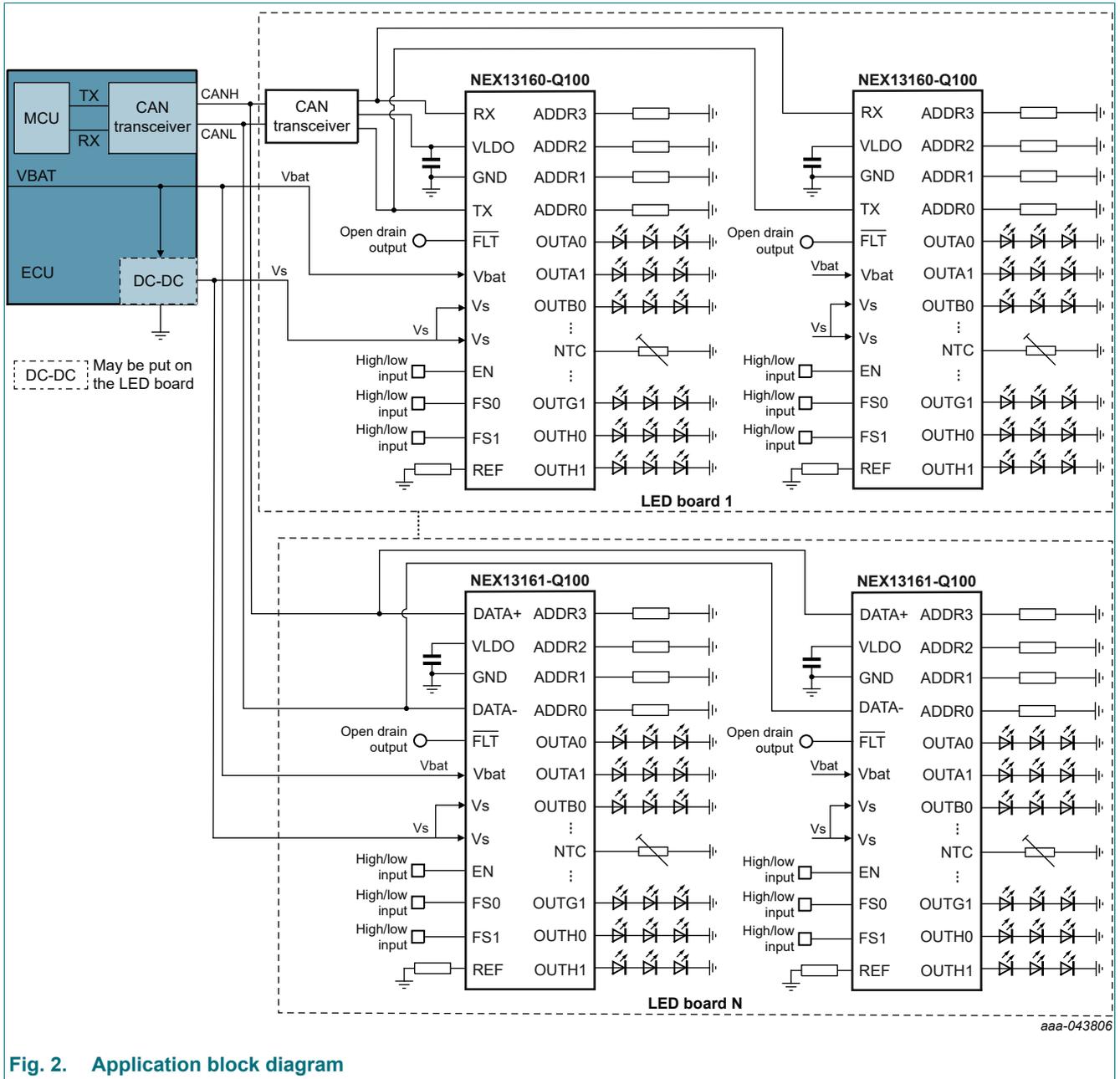


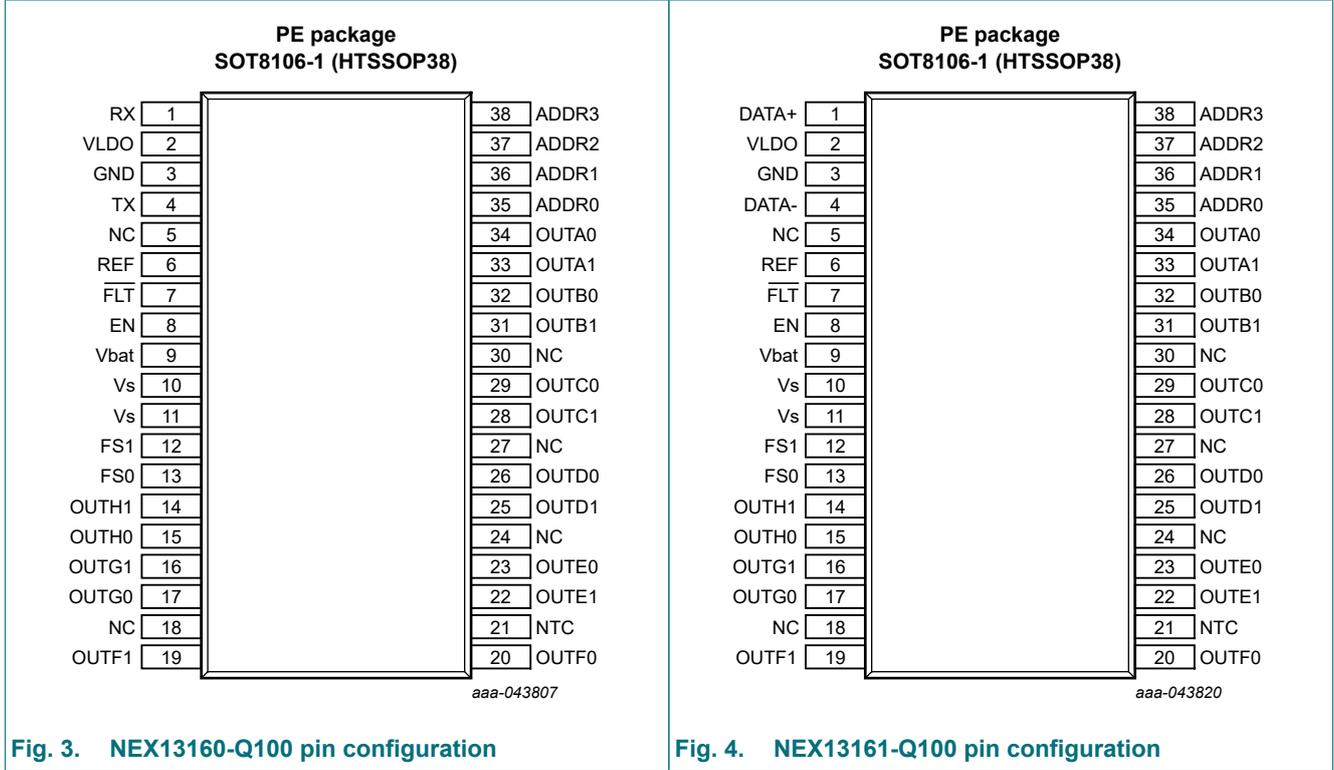
Fig. 2. Application block diagram

aaa-043806

## 8. Pinning information

### 8.1. Pin configuration

Table 4. Pin configuration SOT8106-1 (HTSSOP38)



### 8.2. Pin description

Table 5. Pin description

Symbol	Pin	I/O	Description
RX[1]	1	I	UART RX over CAN physical layer[1]
DATA+[2]			differential interface positive[2]
VLDO	2	Power	output of internal 5 V LDO
GND	3	GND	device ground
TX[1]	4	O	UART TX over CAN physical layer[1]
DATA-[2]			differential interface negative[2]
NC	5	-	not connected
REF	6	I/O	device reference current setting, MTP programming chip-selection input
FLT	7	I/O	open-drain error output
EN	8	I	device enable pin
Vbat	9	Power	power supply for internal circuit
Vs	10	Power	power supply for current output channels
Vs	11	Power	power supply for current output channels
FS1	12	I	Fail-Safe input 1
FS0	13	I	Fail-Safe input 0

Symbol	Pin	I/O	Description
OUTH1 to OUTH0	14 to 15	O	current output channel H1 to H0
OUTG1 to OUTG0	16 to 17	O	current output channel G1 to G0
NC	18	-	not connection
OUTF1 to OUTF0	19 to 20	O	current output channel F1 to F0
NTC	21	-	external NTC thermistor input
OUTE1 to OUTE0	22 to 23	O	current output channel E1 to E0
NC	24	-	not connection
OUTD1 to OUTD0	25 to 26	O	current output channel D1 to D0
NC	27	-	not connection
OUTC1 to OUTC0	28 to 29	O	current output channel C1 to C0
NC	30	-	not connection
OUTB1 to OUTB0	31 to 32	O	current output channel B1 to B0
OUTA1 to OUTA0	33 to 34	O	current output channel A1 to A0
ADDR0	35	I	device address 0
ADDR1	36	I	device address 1
ADDR2	37	I	device address 2
ADDR3	38	I	device address 3

[1] NEX13160-Q100

[2] NEX13161-Q100

## 9. Limiting values

**Table 6. Limiting values**

In accordance with the Absolute Maximum Rating System (IEC 60134). Voltages are referenced to GND (ground = 0 V).

Symbol	Parameter	Conditions	Min	Max	Unit
$V_I$	input voltage	pin Vbat	-0.3	45	V
		pin Vs	-0.3	22	V
		pins DATA+, DATA-	-0.3	20	V
		pins REF, ADDRn, NTC	-0.3	5.5	V
$V_O$	output voltage	pins OUTXn	-0.3	$V_{Vs} + 0.3$	V
		pin VLDO	-0.3	5.5	V
$V_{I/O}$	I/O voltage	pins FS0, FS1, EN	-0.3	$V_{Vbat} + 0.3$	V
		pin $\overline{FLT}$	-0.3	20	V
		pins RX, TX	-0.3	5.5	V
$T_j$	junction temperature		-40	150	°C
$T_{amb}$	ambient temperature		-40	125	°C
$T_{stg}$	storage temperature		-65	150	°C

## 10. ESD Ratings

Table 7. ESD ratings

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{ESD}$	electrostatic discharge voltage	HBM: ANSI/ESDA/JEDEC JS-001 class 3B [1][2]	-14000	-	14000	V
		HBM: ANSI/ESDA/JEDEC JS-001 class 3A [2][3]	-4000	-	4000	V
		CDM: ANSI/ESDA/JEDEC JS-002 class C2b [4]	-750	-	750	V

[1] Pin DATA+, DATA-.

[2] HBM stress testing was performed in accordance with AEC-Q100-002.

[3] Rest pins.

[4] CDM stress testing was performed in accordance with AEC-Q100-011.

## 11. Recommended operating conditions

Table 8. Recommended operating conditions

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{Vbat}$	input voltage	pin Vbat; device supply voltage	4.5	-	36	V
$V_{Vs}$	input voltage	pin Vs; power supply for output current channel	3.8	-	20	V
$I_{OUTXn}$	output current	pins OUTXn; channel output current	-	-	100	mA
$V_{FS0}, V_{FS1}$	input voltage	pin FS0, FS1; external Fail-Safe selection input	0	-	$V_{Vbat}$	V
$V_{EN}$	input voltage	pin EN; device enable input	0	-	$V_{Vbat}$	V
$V_{RX}$	UART input	pin RX	0	-	5	V
$V_{TX}$	UART output	pin TX	0	-	5	V
$V_{DATA+}$	differential interface positive	pin DATA+	0	-	5	V
$V_{DATA-}$	differential interface negative	pin DATA-	0	-	5	V
$V_{VLDO}$	VLDO voltage	pin VLDO; internal 5 V VLDO output	0	-	5	V
$I_{VLDO}$	VLDO current	pin VLDO; current capability	0	-	80	mA
$V_{ADDRn}$	input voltage	pins ADDRn; device address selection	0	-	5	V
$V_{REF}$	pin REF	current reference setting	0	-	5	V
$V_{NTC}$	NTC voltage	pin NTC	0	-	5	V
$V_{FLT}$	pin FLT	error feedback open-drain output	0	-	20	V
$f_{bd(UART)}$	UART baud rate		0.1	-	2	Mbps
$T_{amb}$	ambient temperature		-40	-	125	°C
$T_j$	junction temperature		-40	-	150	°C

## 12. Thermal characteristics

Table 9. Thermal characteristics

Symbol	Parameter	SOT8106-1 (HTSSOP38)	Unit
$R_{\theta JA}$	junction-to-ambient thermal resistance	28.6	°C/W
$R_{\theta JC(TOP)}$	junction-to-case (top) thermal resistance	18.3	°C/W
$R_{\theta JB}$	junction-to-board thermal resistance	11.3	°C/W
$\Theta_{JT}$	junction-to-top char parameter	0.5	°C/W

## 13. Electrical characteristics

Table 10. Static characteristics

At recommended operating conditions. Voltages are referenced to GND (ground = 0 V).

Symbol	Parameter	Conditions	$T_{amb} = -40\text{ °C to }125\text{ °C}$			Unit
			Min	Typ	Max	
<b>Bias</b>						
$V_{Vbat}$	operating input voltage range		4.5	12	40[1]	V
$I_{q(Vbat)}$	quiescent current, all-channels ON	$V_{Vbat} = 12\text{ V}$ ; $R_{REF} = 8.45\text{ k}\Omega$ ; all outputs ON; REFRANGE = 11b; PWM duty = 0	-	7.5	10	mA
	quiescent current, all-channels OFF	$V_{Vbat} = 12\text{ V}$ ; $R_{REF} = 8.45\text{ k}\Omega$ ; REFRANGE = 11b; all outputs OFF	-	7.5	10	mA
$I_{SD(Vbat)}$	shutdown current, Vbat pin	$V_{Vbat} = 12\text{ V}$ ; EN = L	-	2.8	10	$\mu\text{A}$
$I_{q(Vs)}$	quiescent current, all-channels ON	$V_{Vbat} = 12\text{ V}$ ; $V_{Vs} = 12\text{ V}$ ; $R_{REF} = 8.45\text{ k}\Omega$ ; REFRANGE = 11b; PWM Duty = 0; all outputs ON	-	8.5	10	mA
	quiescent current, all-channels-off	$V_{Vbat} = 12\text{ V}$ ; $V_{Vs} = 12\text{ V}$ ; $R_{REF} = 8.45\text{ k}\Omega$ ; REFRANGE = 11b; all outputs OFF	-	22	50	$\mu\text{A}$
$I_{fault(Vbat)}$	quiescent current, Fail-Safe state fault mode	$V_{Vbat} = 12\text{ V}$ ; Fail-Safe state; all outputs OFF; FLT = LOW	-	7.5	10	mA
$I_{fault(Vs)}$	quiescent current, Fail-Safe state fault mode	$V_{Vbat} = 12\text{ V}$ ; $V_{Vs} = 12\text{ V}$ ; Fail-Safe state; all outputs OFF; FLT = LOW	-	22	50	$\mu\text{A}$
$I_{LKG(Vs)}$	Vs leakage current	$V_{Vs} = 20\text{ V}$ ; $V_{Vbat} = 0\text{ V}$	-	-	5	$\mu\text{A}$
		$V_{Vs} = 20\text{ V}$ ; EN = L	-	-	5	$\mu\text{A}$
$V_{Vbat\_POR\_rise}$	Vbat power-on-reset rising threshold		3.95	4.2	4.48	V
$V_{Vbat\_POR\_fall}$	Vbat power-on-reset falling threshold		3.65	3.85	4.1	V
$V_{O(VLDO)}$	VLDO output voltage	$V_{Vbat} > 5.6\text{ V}$ ; $I_{VLDO} = 40\text{ mA}$	4.75	5	5.25	V
$I_{O(VLDO)}$	VLDO output current capability		-	-	80	mA
$I_{VLDO\_limit}$	VLDO output current limit		110	-	-	mA
$V_{LDO\_drop}$	LDO maximum dropout voltage	$V_{Vbat} = 4.9\text{ V}$ ; $I_{VLDO} = 80\text{ mA}$	-	0.55	0.9	V
		$V_{Vbat} = 4.9\text{ V}$ ; $I_{VLDO} = 50\text{ mA}$	-	0.35	0.6	V

Symbol	Parameter	Conditions	T <sub>amb</sub> = -40 °C to 125 °C			Unit
			Min	Typ	Max	
V <sub>VLDO_POR_rise</sub>	VLDO power-on-reset rising threshold		3	3.2	3.5	V
V <sub>VLDO_POR_fall</sub>	VLDO power-on-reset falling threshold		2.75	3	3.25	V
V <sub>VLDO_OV_rise</sub>	VLDO overvoltage rising threshold		5.7	6	6.5	V
V <sub>VLDO_OV_fall</sub>	VLDO overvoltage falling threshold		5.5	5.75	6.2	V
C <sub>VLDO</sub>	supported VLDO loading capacitance		1	-	10	μF
R <sub>PU_NTC</sub>	NTC internal pull-up resistor		-	5.1	-	kΩ
f <sub>osc</sub>	internal oscillator frequency		-2.5%	12	2.5%	MHz
<b>FLT</b>						
V <sub>IL(FLT)</sub>	logic low voltage, FLT		-	-	1	V
V <sub>IH(FLT)</sub>	logic high voltage, $\overline{\text{FLT}}$		1.3	-	-	V
I <sub>pd(FLT)</sub>	FLT pull-down current capability	V <sub>FLT</sub> = 0.4 V	3	6	9	mA
I <sub>LKG(FLT)</sub>	FLT leakage current	V <sub>FLT</sub> = 5 V	-	-	1	μA
<b>Differential data interface</b>						
V <sub>O(DOM)</sub>	DATA+ output voltage (dominant)	V <sub>Vbat</sub> = 12 V	2.75	-	4.5	V
	DATA- output voltage (dominant)	V <sub>Vbat</sub> = 12 V	0.5	-	2.25	V
V <sub>O(DOM)_diff</sub>	Differential output voltage (dominant)	VLDO = 5 V; DATA+ - DATA-	1.5	-	3	V
V <sub>O(REC)_diff</sub>	DATA+, DATA- output voltage (recessive)	VLDO = 5 V; DATA+; DATA-	2	0.5 x VLDO	3	V
	differential output voltage (recessive)	VLDO = 5 V; DATA+ - DATA-	-0.5	-	0.05	V
<b>UART interface</b>						
V <sub>IL(RX)</sub>	input logic low voltage, RX		-	-	0.7	V
V <sub>IH(RX)</sub>	input logic high voltage, RX		2	-	-	V
V <sub>OL(TX)</sub>	low-level output voltage TX,	I <sub>sink</sub> = 5 mA	0	-	0.3	V
V <sub>OH(TX)</sub>	high-level output voltage TX,	I <sub>source</sub> = 5 mA; V <sub>pull-up</sub> = VLDO	4.5	-	5.1	V
I <sub>LKG(TX,RX)</sub>	TX, RX leakage current	V <sub>RX</sub> = 5 V; V <sub>TX</sub> = 5 V	-1	-	1	μA
<b>EN, ADDRn, FSn</b>						
V <sub>IL(FS)</sub>	input logic low voltage, FS		-	-	0.95	V
V <sub>IH(FS)</sub>	input logic high voltage, FS		1.3	-	-	V
V <sub>IL(EN)</sub>	input logic low voltage, EN		-	-	0.7	V
V <sub>IH(EN)</sub>	input logic high voltage, EN		2	-	-	V
R <sub>PD(FS)</sub>	internal pull-down resistance, FS	VLDO = 5 V	-	100	-	kΩ
V <sub>IL(ADDRn)</sub>	logic low voltage ADDR2, ADDR1, ADDR0	VLDO = 5 V	-	-	0.65	V
V <sub>IM(ADDRn)</sub>	logic middle voltage ADDR2, ADDR1, ADDR0	VLDO = 5 V	0.9	-	1.5	V

Symbol	Parameter	Conditions	T <sub>amb</sub> = -40 °C to 125 °C			Unit
			Min	Typ	Max	
V <sub>IH(ADDRn)</sub>	logic high voltage ADDR2, ADDR1, ADDR0	VLDO = 5 V	2	-	-	V
R <sub>ADDRn</sub>	pull-up resistor		-	90	-	kΩ
<b>ADC</b>						
DNL	differential non-linearity		-1	-	1	LSB
INL	differential non-linearity		-2	-	2	LSB
<b>Output drivers</b>						
f <sub>PWM</sub>	PWM dimming frequency range	PWMFREQ=0	-	0.2	-	kHz
		PWMFREQ=15	-	23.4	-	kHz
ΔI <sub>OUT_d2d</sub>	device-to-device accuracy ΔI <sub>(OUT_d2d)</sub> = 1 - I <sub>avg(OUT)</sub> / I <sub>nom(OUT)</sub>	V <sub>Vs</sub> = 8 V; R <sub>REF</sub> = 6.34 kΩ; REFRANGE = 11b; DC = 63; I <sub>OUT</sub> = 100 mA	-5	0	5	%
		V <sub>Vs</sub> = 8 V; R <sub>REF</sub> = 8.45 kΩ; REFRANGE = 11b; DC = 63; I <sub>OUT</sub> = 75 mA	-5	0	5	%
		V <sub>Vs</sub> = 8 V; R <sub>REF</sub> = 8.45 kΩ; REFRANGE = 10b; DC = 63; I <sub>OUT</sub> = 37.5 mA	-5	0	5	%
		V <sub>Vs</sub> = 8 V; R <sub>REF</sub> = 8.45 kΩ; REFRANGE = 01b; DC = 63; I <sub>OUT</sub> = 18.75 mA	-5	0	5	%
ΔI <sub>OUT_c2c</sub>	channel-to-channel accuracy ΔI <sub>(OUT_c2c)</sub> = 1 - I <sub>(OUTn)</sub> / I <sub>avg(OUT)</sub>	V <sub>Vs</sub> = 8 V; R <sub>REF</sub> = 6.34 kΩ; REFRANGE = 11b; DC = 63; I <sub>OUT</sub> = 100 mA	-4	0	4	%
		V <sub>Vs</sub> = 8 V; R <sub>REF</sub> = 8.45 kΩ; REFRANGE = 11b; DC = 63; I <sub>OUT</sub> = 75 mA	-4	0	4	%
		V <sub>Vs</sub> = 8 V; R <sub>REF</sub> = 8.45 kΩ; REFRANGE = 10b; DC = 63; I <sub>OUT</sub> = 37.5 mA	-4	0	4	%
		V <sub>Vs</sub> = 8 V; R <sub>REF</sub> = 8.45 kΩ; REFRANGE = 01b; DC = 63; I <sub>OUT</sub> = 18.75 mA	-5	0	5	%
V <sub>OUT_drop</sub>	output dropout voltage	V <sub>Vs</sub> = 8 V; R <sub>REF</sub> = 8.45 kΩ; REFRANGE = 11b; DC = 38; I <sub>OUT</sub> = 45 mA	-	350	550	mV
		V <sub>Vs</sub> = 8 V; R <sub>REF</sub> = 8.45 kΩ; REFRANGE = 11b; DC = 63; I <sub>OUT</sub> = 75 mA	-	450	700	mV
		V <sub>Vs</sub> = 8 V; R <sub>REF</sub> = 6.34 kΩ; REFRANGE = 11b; DC = 63; I <sub>OUT</sub> = 100 mA	-	600	850	mV
R <sub>REF</sub>			5	-	50	kΩ
C <sub>REF</sub>			0	-	4.7	nF
V <sub>REF</sub>			-	1.235	-	V
K <sub>REF_11</sub>		REFRANGE = 11b	-	512	-	-
K <sub>REF_10</sub>		REFRANGE = 10b	-	256	-	-
K <sub>REF_01</sub>		REFRANGE = 01b	-	128	-	-
K <sub>REF_00</sub>		REFRANGE = 00b	-	64	-	-

Symbol	Parameter	Conditions	T <sub>amb</sub> = -40 °C to 125 °C			Unit
			Min	Typ	Max	
I <sub>REF_OPEN_th</sub>			-	10	-	μA
V <sub>REF_SHORT_th</sub>			-	0.6	-	V
<b>Diagnostics</b>						
V <sub>Vs_UV_th</sub>	Vs undervoltage threshold		2.45	2.85	3	V
V <sub>Vs_LOW_th</sub>	Vs low threshold, LOWVSTH=0		3.8	4	4.4	V
V <sub>OPEN_th_rise</sub>	LED open rising threshold, OPENTH=0, AUTOSS=0	V <sub>Vs</sub> - V <sub>OUTn</sub>	100	200	300	mV
	LED open rising threshold, OPENTH=1, AUTOSS=0	V <sub>Vs</sub> - V <sub>OUTn</sub>	200	300	400	mV
V <sub>OPEN_th_fall</sub>	LED open falling threshold, OPENTH=0, AUTOSS=0	V <sub>Vs</sub> - V <sub>OUTn</sub>	200	300	400	mV
	LED open falling threshold, OPENTH=1, AUTOSS=0	V <sub>Vs</sub> - V <sub>OUTn</sub>	300	400	550	mV
V <sub>OPEN_th_hyst</sub>	LED open hysteresis		-	100	-	mV
V <sub>SG_th_rise</sub>	short to GND rising threshold		0.8	0.9	1	V
V <sub>SG_th_fall</sub>	short to GND falling threshold		1.1	1.2	1.3	V
V <sub>SG_th_hyst</sub>	short to GND hysteresis		-	0.3	-	V
V <sub>SLS_th_rising</sub>	single-LED short rising threshold, SLSTHx = 0		2.3	2.5	2.75	V
V <sub>SLS_th_falling</sub>	single-LED short falling threshold, SLSTHx = 0		2.5	2.8	2.95	V
V <sub>SLS_th_hyst</sub>	single-LED short hysteresis, SLSTHx = 0		-	300	-	mV
<b>MTP</b>						
N <sub>MTP</sub>	number of programming cycles		1000	-	-	-
<b>Temperature</b>						
T <sub>PRETSD</sub>	pre-thermal warning threshold		-	135	-	°C
T <sub>PRETSD_HYS</sub>	pre-thermal warning hysteresis		-	5	-	°C
T <sub>TSD1</sub>	over-temperature protection threshold		-	175	-	°C
T <sub>TSD2</sub>	over-temperature shutdown threshold		-	185	-	°C
T <sub>TSD1_HYS</sub>	over-temperature protection hysteresis		-	15	-	°C
T <sub>TSD2_HYS</sub>	over-temperature shutdown hysteresis		-	15	-	°C

[1] 40 V is only for short-time operating; long-term operating voltage should be lower than 36 V.

Table 11. Timing requirement

Symbol	Parameter	Conditions	T <sub>amb</sub> = -40 °C to 125 °C			Unit
			Min	Typ	Max	
t <sub>BLANK</sub>	diagnostics pulse-width, BLANK = 0h		-	100	-	µs
t <sub>CONV</sub>	time needed to complete one AD conversion		-	55	-	µs
t <sub>retry</sub>	fault retry timer		-	10	-	ms

## 14. Typical characteristics

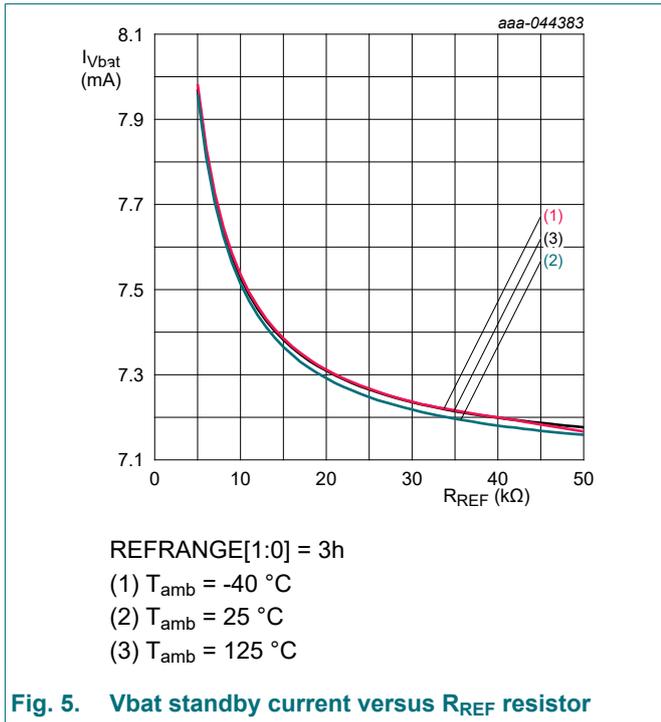


Fig. 5. Vbat standby current versus R<sub>REF</sub> resistor

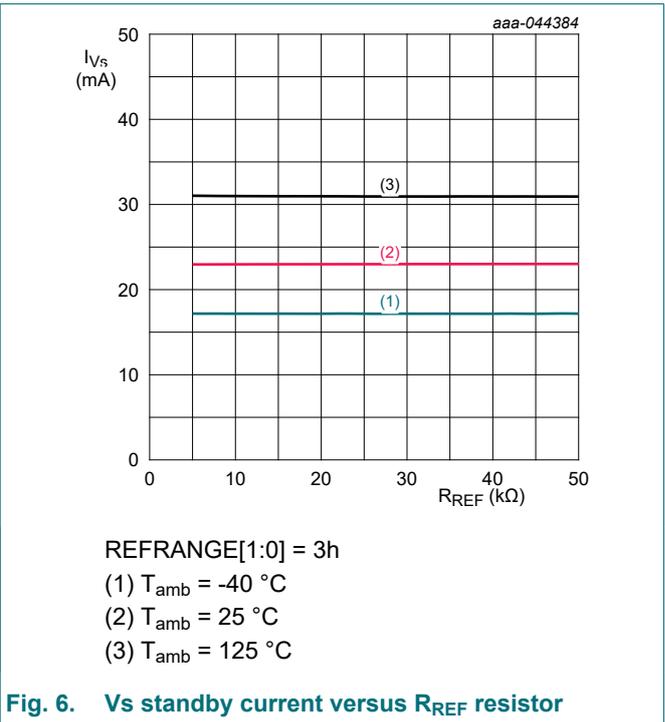
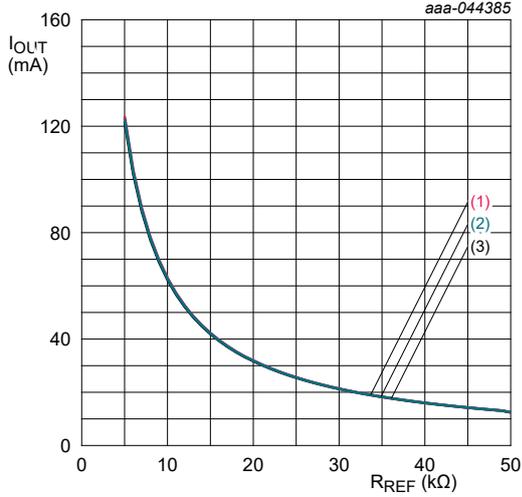
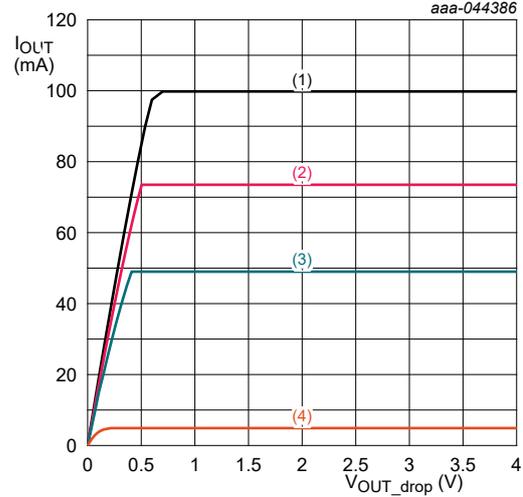


Fig. 6. Vs standby current versus R<sub>REF</sub> resistor



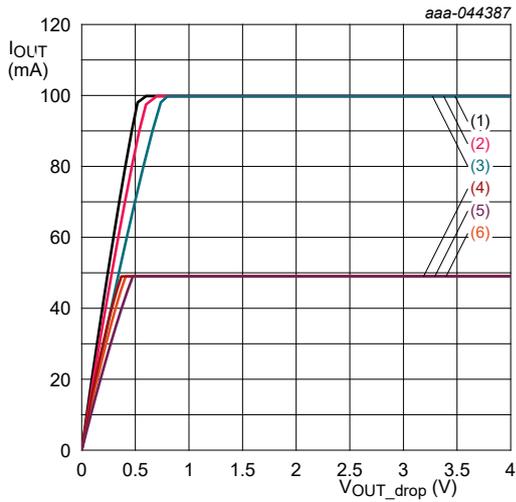
IOUX[5:0] = 3Fh  
 REFRANGE[1:0] = 3h  
 (1)  $T_{amb} = -40\text{ °C}$   
 (2)  $T_{amb} = 25\text{ °C}$   
 (3)  $T_{amb} = 125\text{ °C}$

Fig. 7. Output full-range current versus  $R_{REF}$  Resistor



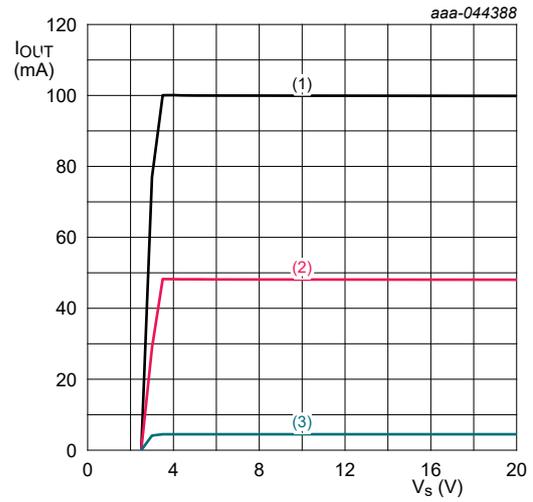
REFRANGE[1:0] = 3h  
 (1)  $I_{OUT} = 100\text{ mA}$   
 (2)  $I_{OUT} = 75\text{ mA}$   
 (3)  $I_{OUT} = 50\text{ mA}$   
 (4)  $I_{OUT} = 5\text{ mA}$

Fig. 8. Output current versus dropout voltage



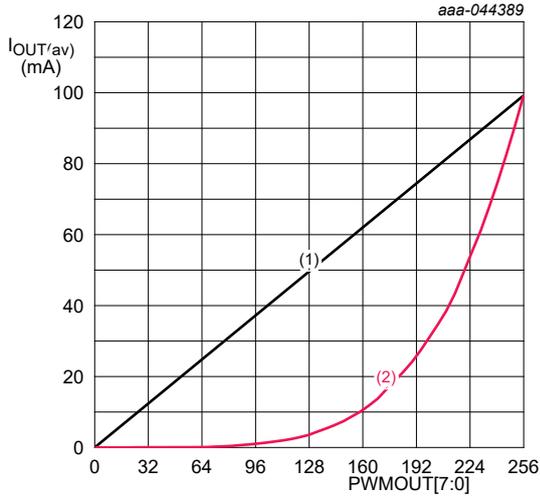
$R_{REF} = 6.34\text{ k}\Omega$  &  $12.6\text{ k}\Omega$   
 REFRANGE[1:0] = 3h  
 (1)  $I_{OUT} = 100\text{ mA}$ ;  $T_{amb} = -40\text{ °C}$   
 (2)  $I_{OUT} = 100\text{ mA}$ ;  $T_{amb} = 25\text{ °C}$   
 (3)  $I_{OUT} = 100\text{ mA}$ ;  $T_{amb} = 125\text{ °C}$   
 (4)  $I_{OUT} = 50\text{ mA}$ ;  $T_{amb} = -40\text{ °C}$   
 (5)  $I_{OUT} = 50\text{ mA}$ ;  $T_{amb} = 25\text{ °C}$   
 (6)  $I_{OUT} = 50\text{ mA}$ ;  $T_{amb} = 125\text{ °C}$

Fig. 9. Output current versus dropout voltage



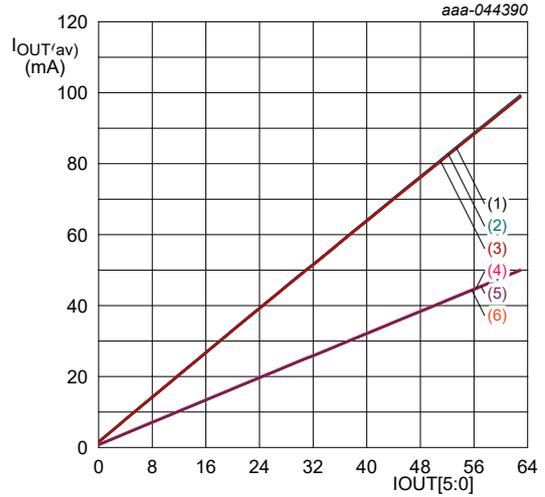
REFRANGE[1:0] = 3h  
 (1)  $I_{OUT} = 100\text{ mA}$   
 (2)  $I_{OUT} = 50\text{ mA}$   
 (3)  $I_{OUT} = 5\text{ mA}$

Fig. 10. Output current versus  $V_S$  voltage



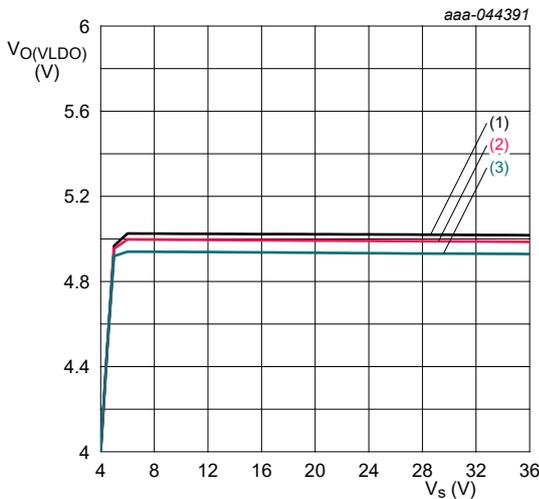
EXPEN = 0 & 1  
 IOUX[5:0] = 3Fh  
 (1) CONF\_EXPEN = 0  
 (2) CONF\_EXPEN = 1

Fig. 11. Average current versus PWMOUT[7:0]



$R_{REF} = 6.34\text{ k}\Omega$  &  $12.6\text{ k}\Omega$   
 REFRANGE[1:0] = 3h  
 (1)  $I_{OUT} = 100\text{ mA}$ ;  $T_{amb} = -40\text{ }^\circ\text{C}$   
 (2)  $I_{OUT} = 100\text{ mA}$ ;  $T_{amb} = 25\text{ }^\circ\text{C}$   
 (3)  $I_{OUT} = 100\text{ mA}$ ;  $T_{amb} = 125\text{ }^\circ\text{C}$   
 (4)  $I_{OUT} = 50\text{ mA}$ ;  $T_{amb} = -40\text{ }^\circ\text{C}$   
 (5)  $I_{OUT} = 50\text{ mA}$ ;  $T_{amb} = 25\text{ }^\circ\text{C}$   
 (6)  $I_{OUT} = 50\text{ mA}$ ;  $T_{amb} = 125\text{ }^\circ\text{C}$

Fig. 12. Output DC current versus IOUX[5:0]



(1)  $T_{amb} = -40\text{ }^\circ\text{C}$   
 (2)  $T_{amb} = 25\text{ }^\circ\text{C}$   
 (3)  $T_{amb} = 125\text{ }^\circ\text{C}$

Fig. 13. LDO output line regulation

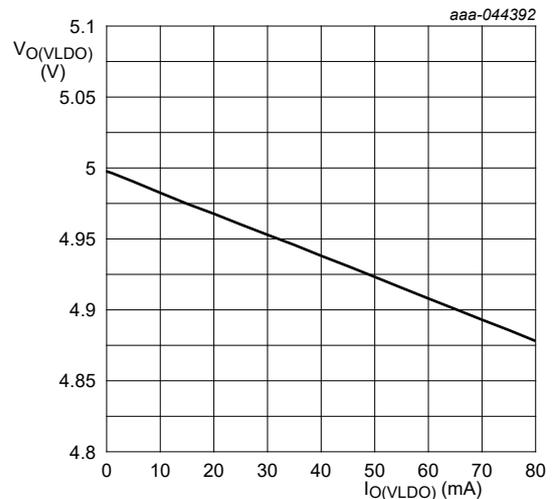


Fig. 14. LDO output load regulation

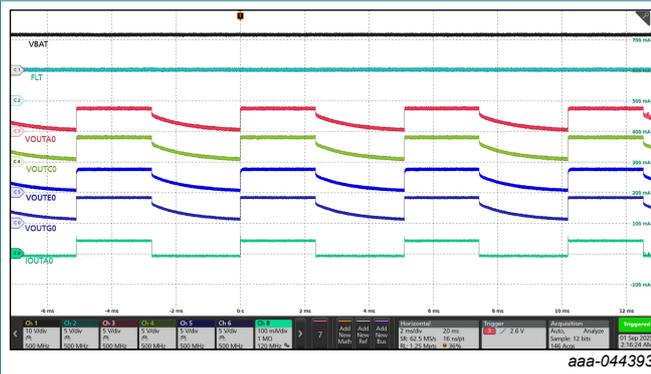


Fig. 15. PWM dimming at 200 Hz

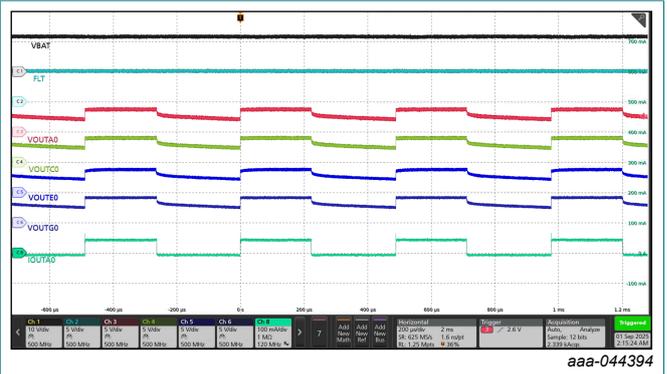


Fig. 16. PWM dimming at 2000 Hz

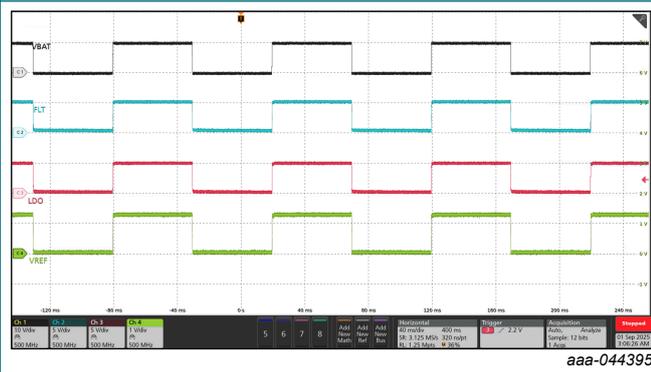


Fig. 17. Vbat start-up and shutdown

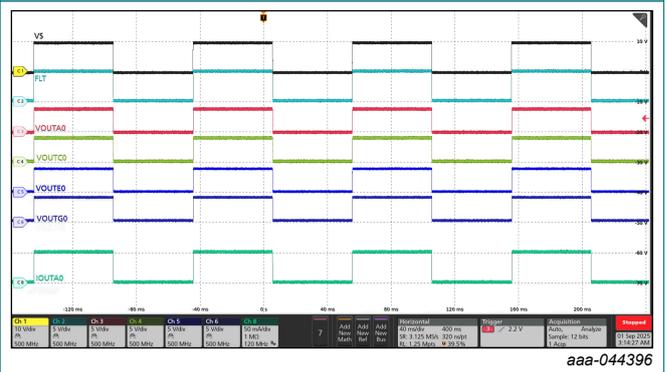


Fig. 18. Vs start-up and shutdown

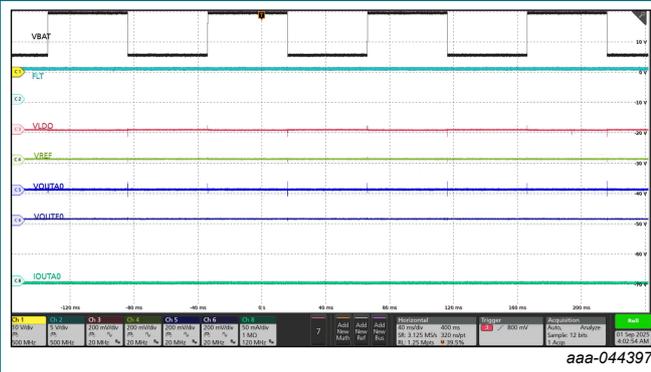


Fig. 19. Vbat transient

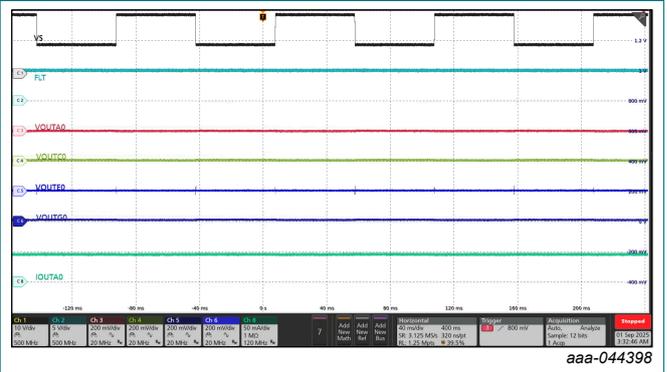


Fig. 20. Vs transient

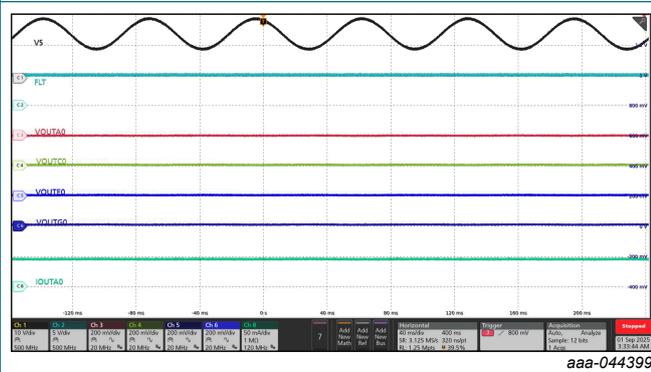


Fig. 21. Super-imposed alternating voltage 15 Hz

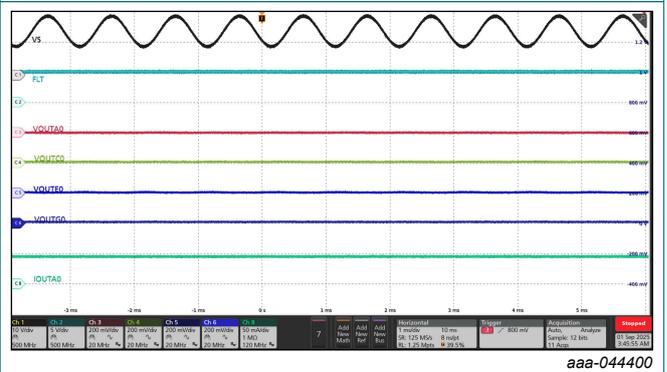


Fig. 22. Super-imposed alternating voltage 1 kHz

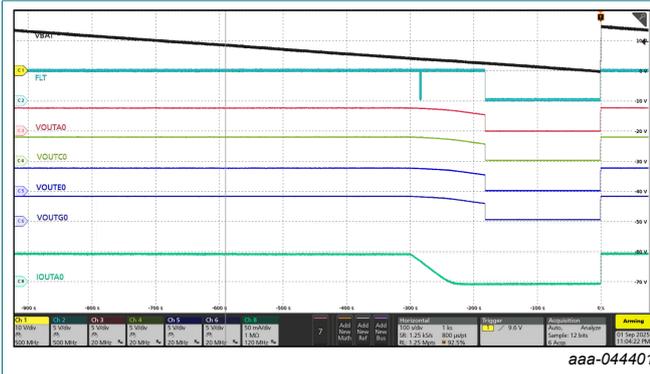


Fig. 23. Slow decrease and quick increase of supply voltage

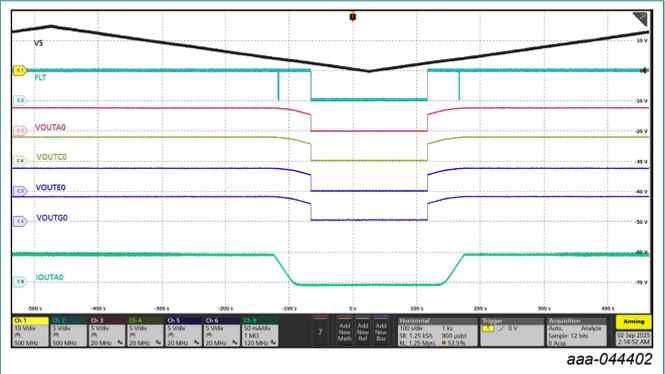


Fig. 24. Slow decrease and slow increase of supply voltage

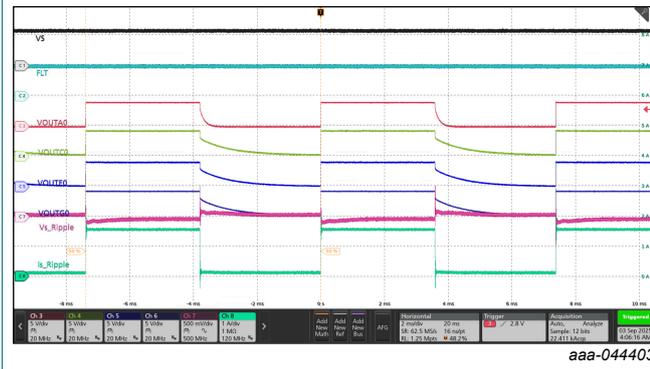


Fig. 25. Phase shift disable

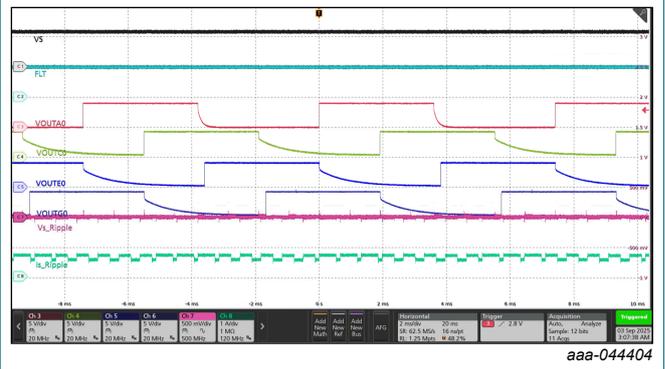


Fig. 26. Phase shift enable

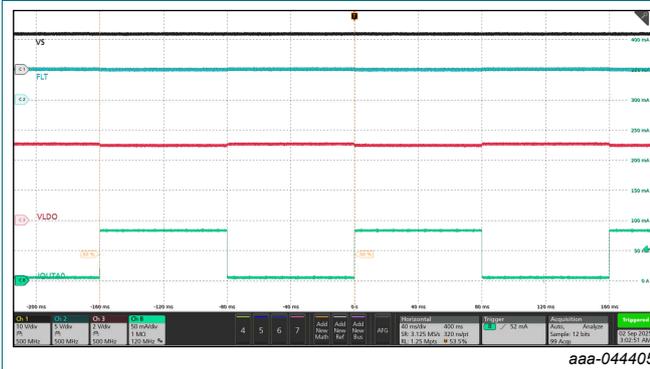


Fig. 27. LDO output load transient

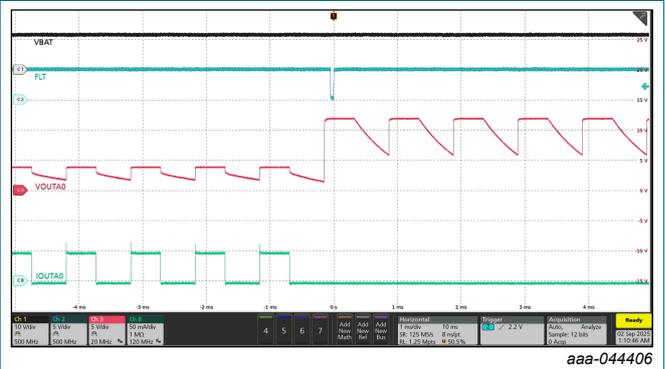


Fig. 28. LED open-circuit detection in NORMAL state

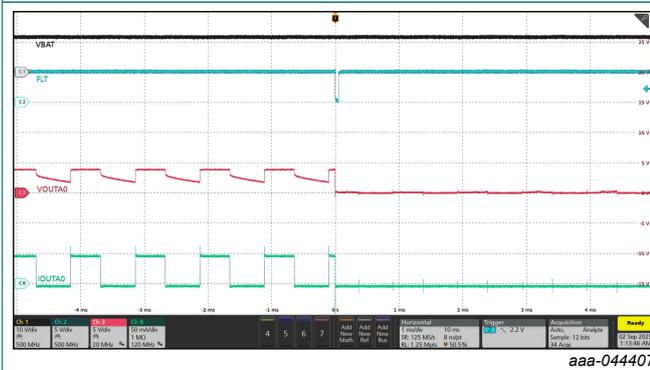


Fig. 29. LED short-circuit detection in NORMAL state

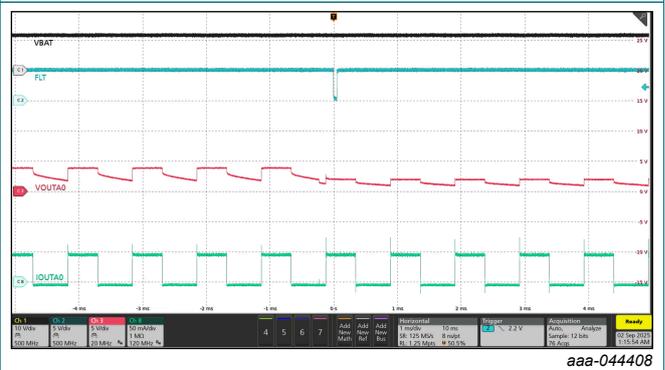


Fig. 30. Single-LED short circuit detection in NORMAL state

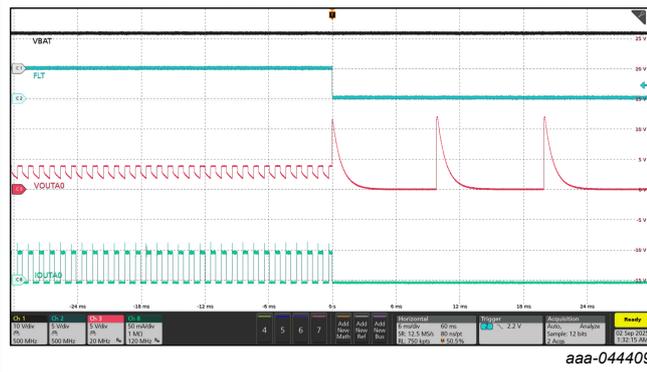


Fig. 31. LED open-circuit detection in Fail-Safe state

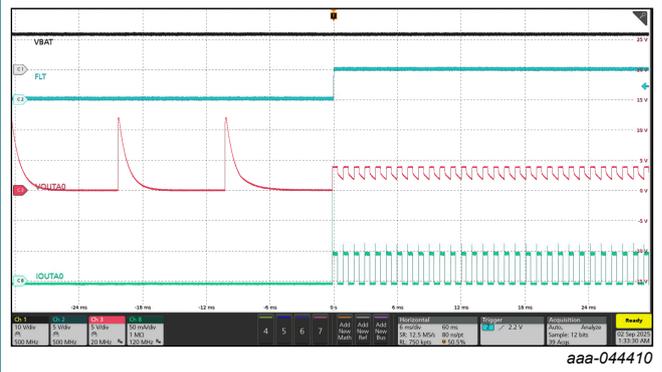


Fig. 32. LED open-circuit recovery in Fail-Safe state

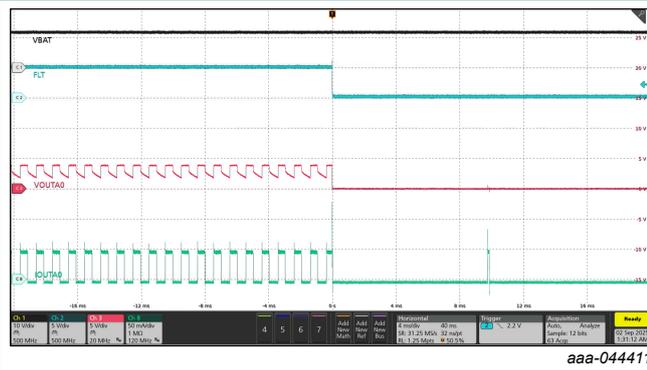


Fig. 33. LED short-circuit detection in Fail-Safe state

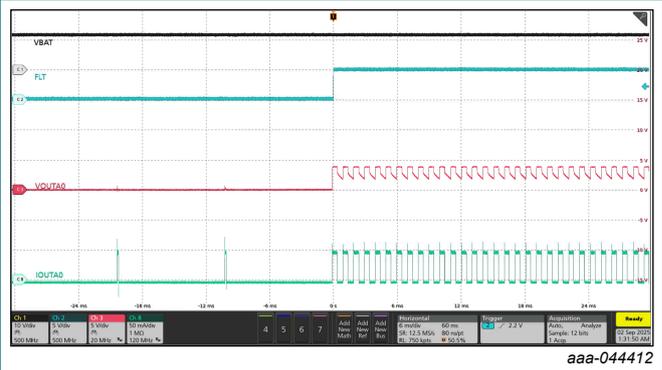


Fig. 34. LED short-circuit recovery in Fail-Safe state

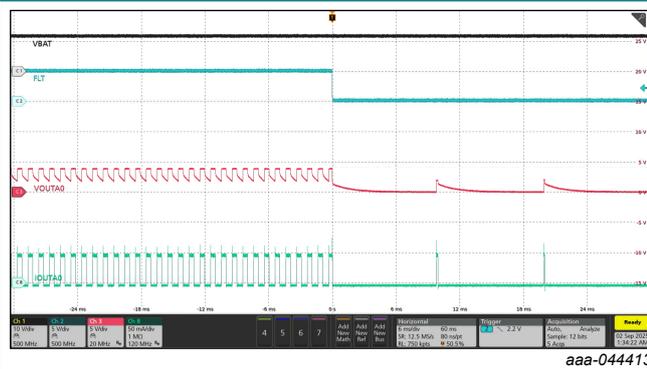


Fig. 35. Single-LED short-circuit detection in Fail-Safe state



Fig. 36. Single-LED short-circuit recovery in Fail-Safe state

## 15. Detailed description

### 15.1. Overview

The NEX1316X-Q100 is an automotive 16-channel LED driver equipped with a UART interface to meet the growing demand for individual control of each LED string. Each channel supports both analog dimming and pulse-width modulation (PWM) dimming, configurable via the UART. The internal MTP (Multi-time Programming memory) enables users to set configurations in the event of communication loss, ensuring compliance with system-level function safety requirements.

The integrated UART interface is compliant with physical layer transceiver such as CAN or LIN transceivers. It can support off board communication with the transition of CAN or LIN transceivers.

To optimize the total system cost, two interface versions are provided. NEX13160-Q100 is the UART version, and NEX13161-Q100 integrates a CAN transceiver to save the external CAN transceiver. For more details, refer to [Fig. 37](#) and [Fig. 38](#).

Each output channel serves as a constant current source, allowing for individually programmable current outputs and PWM duty cycles. The device includes various diagnostic features, such as LED open-circuit, short-circuit, and single-LED short-circuit detection. Additionally, the on-chip analog-to-digital converter (ADC) enables real-time monitoring of output conditions.

To enhance robustness, NEX1316X-Q100 integrates Fail-Safe state machine that automatically switches to Fail-Safe states in case of communication loss, such as MCU failure. Users can program Fail-Safe settings using the MTP, allowing for different configurations in the event of output failure, such as one-fails-all-fail or one-fails-others-on. Each channel can be independently programmed to either remain on or off during Fail-Safe states.

The Fail-Safe state machine also permits the system to operate with pre-programmed MTP settings without the presence of a controller, enabling stand-alone operation. The microcontroller can access each device through the UART interface, allowing full control over the device and LEDs by setting and reading back registers. All MTPs are pre-programmed with default values, and Nexperia recommends that users program the MTP at the end of the production line for application-specific settings and Fail-Safe configurations.

### 15.2. Function block diagram

The NEX1316X-Q100 function block diagrams are shown below:

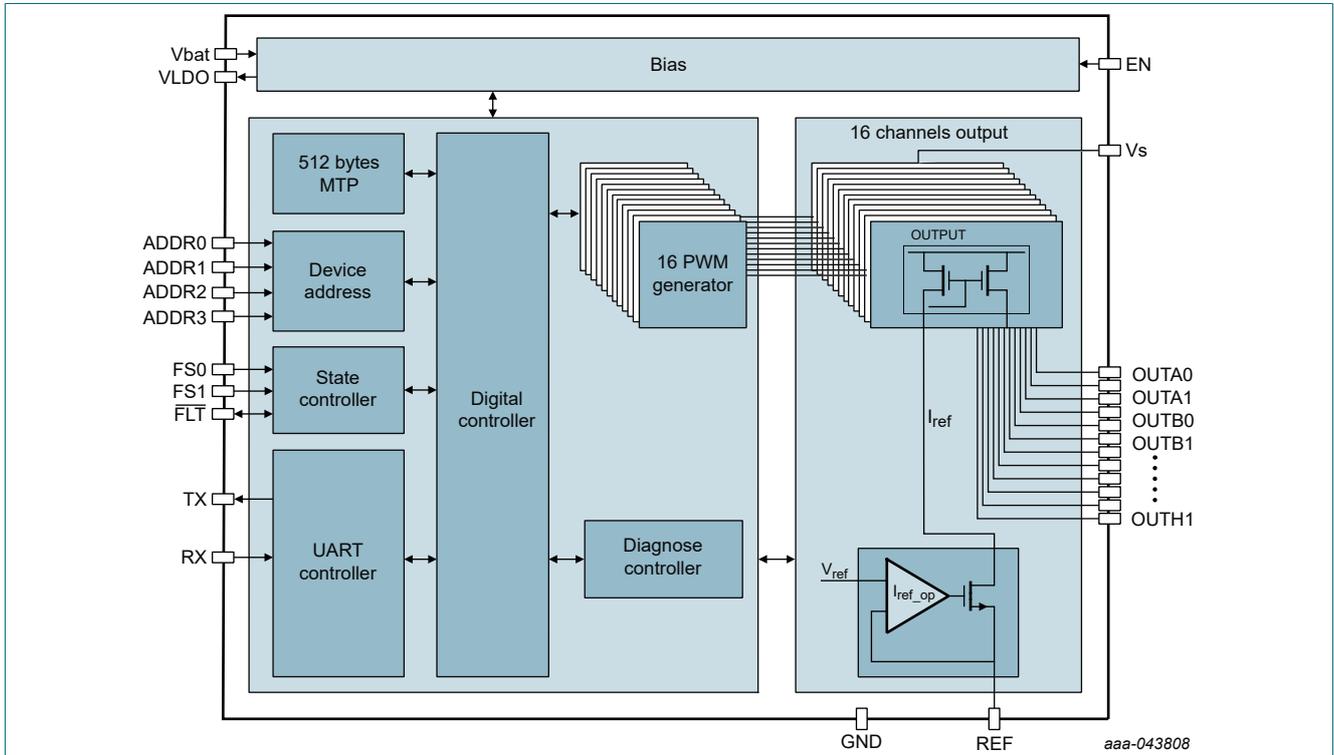


Fig. 37. NEX13160-Q100 function block diagram

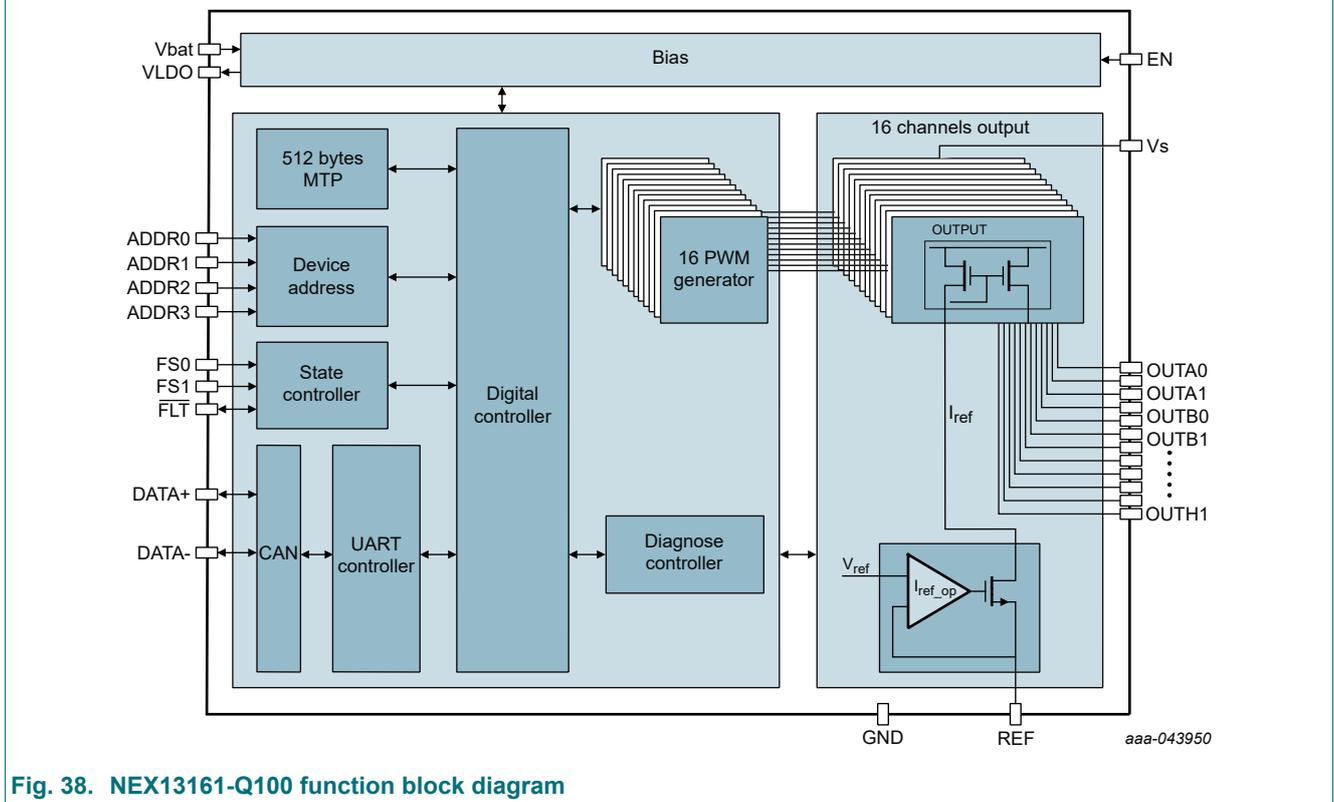


Fig. 38. NEX13161-Q100 function block diagram

## 15.3. Feature description

### 15.3.1. Device bias and power

#### Power supply (Vbat)

NEX1316X-Q100 is AECQ-100 qualified for automotive applications. The power input to the device through Vbat pin can be low to 4.5 V and up to 40 V for automotive battery directly powered systems. All the internal analog and digital circuits except for the current output channels are powered by Vbat.

#### Enable and shutdown (EN)

NEX1316X-Q100 features an enable input that governs operational states. When EN voltage is below  $V_{IL(EN)}$ , the device enters sleep mode with ultra-low quiescent current  $I_{SD(Vbat)}$ , significantly reducing system current consumption in direct battery-connected applications without high-side switches. Upon detecting  $EN > V_{IH(EN)}$  while  $V_{Vbat}$  exceeds  $V_{Vbat\_POR\_rise}$ , the device immediately activates its internal voltage regulator to generate a stable 5 V VLDO for internal analog and digital circuits. When the EN voltage falls below  $V_{IL(EN)}$  with  $V_{Vbat} > V_{Vbat\_POR\_rise}$ , all current outputs will be disabled instantaneously.

#### 5 V Low-Drop-Out linear regulator (VLDO)

NEX1316X-Q100 has an integrated low-drop-out linear regulator to provide power supply to external CAN transceivers. The internal LDO powered by input voltage  $V_{Vbat}$  provides a stable 5 V output with up to 80 mA constant current capability. Nexperia recommends a ceramic capacitor from 1  $\mu$ F to 10  $\mu$ F on the VLDO pin. The LDO has an internal current limit  $I_{VLDO\_limit}$  for protection and soft start. The capacitor charging time must be considered to total start-up time because the device is held in POR state if the capacitor voltage is not charged to above UVLO threshold.

#### Undervoltage Lockout (UVLO) and Power-On-Reset (POR)

NEX1316X-Q100 uses UVLO and POR circuitry to clear its internal registers upon power up and to reset registers with its default values. NEX1316X-Q100 has internal UVLO circuits so that when either input voltage  $V_{Vbat}$  or LDO output voltage  $V_{VLDO}$  is lower than its UVLO threshold, POR is triggered. In POR state, the device resets digital core and all registers to default value. FLAG\_POR and FLAG\_ERR register are set to 1 for each POR cycle to indicate the POR history. Before both powers are above UVLO thresholds, NEX1316X-Q100 stays in POR state with all outputs off and FLT pin pulled down. Once both power supplies are above UVLO threshold, the device enters INIT mode for initialization releasing FLT pin pull-down.

A programmable timer starts counting in INIT state, the timer length can be set by MTP register INITTIMER. When the timer is completed, the device switches to NORMAL state. In INIT state, setting CLR\_POR to 1 clears FLAG\_POR, disables the timer, and sets the device to NORMAL state.

Upon powering up, NEX1316X-Q100 automatically loads all settings stored in MTP to correlated registers and sets the other registers to default value which do not have correlated MTP. All channels are powered up off-state by default to avoid unwanted blinking. Writing 1 to REGDEFAULT manually loads MTP setting to the correlated registers and set the other registers to default value. After REGDEFAULT is set, the FLAG\_POR is cleared to 0.

Writing 1 to CLR\_POR also resets the FLAG\_POR register to 0. Nexperia recommends setting CLR\_REG to 1 to clear the internal registers every time after POR. The REGDEFAULT automatically resets to 0.

#### Power supply (Vs)

NEX1316X-Q100 has an additional Vs input pin for powering all 16 high-side current output channels. The  $V_{Vs}$  can be low to 3.8 V and up to 20 V for either automotive battery directly powered systems or an external DC-DC converter output. An external DC-DC converter can provide a regulated voltage for required LED output forward voltage from wide automotive battery voltage range.

NEX1316X-Q100 has an internal undervoltage detection circuit for Vs input. When the Vs input voltage is lower than undervoltage threshold,  $V_{Vs\_th\_fall}$ , all 16 current output channels are disabled with FLT pin constantly pulled low and register flags set to 1 including FLAG\_ERR bit and FLAG\_VSUV bit. [Table 20](#) shows the detailed fault behavior in NORMAL state.

### Programmable low-supply warning

NEX1316X-Q100 uses its internal ADC to monitor supply voltage  $V_{VS}$ . If the  $V_{VS}$  is below allowable working threshold, the output voltage can be insufficient to keep the LED operating with the desired brightness output as expected. The  $V_{VS}$  is automatically compared with the threshold set by register LOWVSTH.

When the  $V_{VS}$  is below the threshold, the device sets the warning flag register FLAG\_LOWVS and FLAG\_ERR to 1 in the status register. CLRFAULT can clear the FLAG\_LOWVS as well as other fault registers. Low-supply warning will clear LED open and single-LED short faults, the FLAG\_OPENOUTXn and FLAG\_SLSOUTXn can be cleared by CLR\_ERR.

In addition, the LED open circuit and single-LED short-circuit detection is disabled if the  $V_{VS}$  is below threshold to avoid the LED open circuit and to prevent the single-LED short-circuit fault from being mis-triggered. The 5-bit register LOWVSTH has a total of 32 options covering from 4 V to 35 V as shown in [Table 12](#).

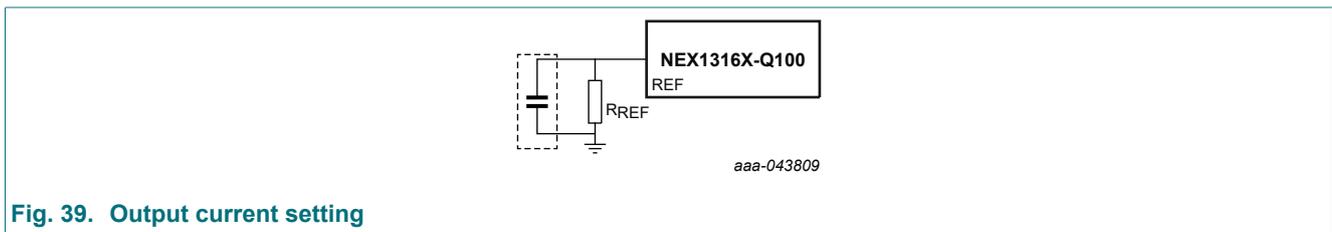
**Table 12. Low supply warning threshold setting**

	Calculation formula
LOWVSTH Voltage (V)	LOWVSTH [4:0] + 4 V

### 15.3.2. Constant current output

#### Constant current output reference current with external resistor ( $R_{REF}$ )

NEX1316X-Q100 must have an external resistor  $R_{REF}$  to set the internal current reference  $I_{REF}$  as shown in below [Fig. 39](#).



**Fig. 39. Output current setting**

The internal current reference,  $I_{full\_range}$ , is generated based on the  $I_{REF}$  multiplied by factor  $K_{REF}$  to provide the full range current reference for each OUTx channel. The  $K_{REF}$  is programmable by 2-bit register REFRANGE with four different options. Use equation (1) to calculate the  $I_{full\_range}$ :

$$I_{full\_range} = \frac{V_{REF}}{R_{REF}} \cdot K_{REF} \quad (1)$$

Where  $V_{REF} = 1.235$  V,  $K_{REF} = 64, 128, 256$  or  $512$  (default).

**Table 13. Reference current range setting**

Reference	$K_{REF}$	Full range current (mA)			
		$R_{REF} = 6.34$ k $\Omega$	$R_{REF} = 8.45$ k $\Omega$	$R_{REF} = 12.7$ k $\Omega$	$R_{REF} = 31.6$ k $\Omega$
11b	512	100	75	50	20
10b	256	50	37.5	25	10
01b	128	25	18.75	12.5	5
00b	64	12.5	9.375	6.25	2.5

Nexperia recommends placing the  $R_{REF}$  resistor as close as possible to the REF pin with an up to 2.2 nF ceramic capacitor in parallel to improve noise immunity. Nexperia recommends a 1 nF ceramic capacitor in parallel with  $R_{REF}$ .

### 64-step programmable high-side constant-current output

NEX1316X-Q100 has 16-channels of high-side current sources. Each channel has its own enable configuration register ENOUTXn. Setting ENOUTXn to 1 enables the channel output, clearing the register to 0 disables the channel output. To

completely turn off the channel current, user can clear channel enable bit ENOUTXn to 0. Upon powering up, ENOUTXn is automatically reset to 0 to prevent unwanted blinking.

Each OUTXn channel supports individual 64-step programmable current setting, also known as Dot Correction (DC). The DC feature can be used to set binning values for output LEDs or to calibrate the LEDs to achieve high brightness homogeneity based on external visual system to further save binning cost. The 6-bit register IOUXn sets the current independently, where n is the channel number from 0 to 15. The OUTXn current can be calculated with equation (2):

$$I_{OUTXn} = \frac{IOUXn+1}{64} \times I_{full\_range} \quad (2)$$

Where:

- IOUXn is programmable from 0 to 63.
- X is from A to H.
- n is from 0 to 1 for different output channel.
- I<sub>full\_range</sub> can be calculated with equation (1).

### 15.3.3. PWM dimming

NEX1316X-Q100 integrates independent 12-bit PWM generators for each OUTXn channel. The integrated PWM generator turns the current output for each OUTXn channel on and off. The average current of each OUTXn can be adjusted by PWM duty cycle independently, therefore, to control the brightness for LEDs in each channel.

#### PWM dimming frequency

The frequency for PWM dimming is programmable by 4-bit register PWMFREQ and register PWMSLOW with 16 options covering from 200 Hz to 23.4 kHz. Select the frequency for PWM dimming based on the minimum brightness requirement in application. NEX1316X-Q100 supports down to 1 μs minimum pulse current for all 16-channel outputs.

Table 14. PWM frequency setting

PWM frequency setting PWMFREQ	PWM cycle frequency
0	200
1	250
2	300
3	350
4	400
5	500
6	600
7	750
8	1000
9	1200
10	2000
11	4000
12	5800
13	7800
14	11700
15	23400

## Blanking time

Since NEX1316X-Q100 supports PWM control for adjusting LED brightness, the voltage on OUTXn is like a pulse waveform. The output voltage and current ramp up to the target value in a certain period after the channel is turned on depending on the value of capacitor on the OUTXn pin. The ramping up period is proportional to the capacitance value of the capacitor.

To prevent the output voltage of each OUTXn being measured in the ramping up transient period, NEX1316X-Q100 integrates a  $t_{\text{BLANK}}$  timer which is programmable by a 4-bit register BLANK to set up the blanking time for all OUTXn. The device does not start the OUTXn diagnostics and ADC measurement until the  $t_{\text{BLANK}}$  timer is overflowed. The  $t_{\text{BLANK}}$  timer is programmable from 20  $\mu\text{s}$  to 4 ms as described in [Table 15](#). Nexperia recommends setting the  $t_{\text{BLANK}}$  less than the PWM dimming period, which is programmable by PWMFREQ register, otherwise the OUTXn diagnostics and ADC measurement only operates properly when PWM duty cycle is set to 100%.

**Table 15. BLANK time setting**

Binary code	BLANK time															
	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
$t_{\text{BLANK}}$ ( $\mu\text{s}$ )	100	20	30	50	80	150	200	300	500	800	1000	1200	1500	2000	3000	4000

## Phase shift PWM dimming

The phase shift PWM dimming mode is enabled by setting PSEN to 1. In phase shift PWM dimming mode, every three current output channels are formed as one group, so a total of eight current output groups are turned on and off at PWM dimming frequency set by PWMFREQ register with a delay configured by PS0. The detailed group information and shift delay are listed in [Table 16](#).

**Table 16. Groups and shift delay**

Group	Outputs	CONF_PS0	Description
Group A	OUTA0, OUTA1	0	delay time is 1/8 of $1/F_{\text{PWM}}$
Group B	OUTB0, OUTB1	1	delay time is 1/12 of $1/F_{\text{PWM}}$
Group C	OUTC0, OUTC1	2	delay time is 1/16 of $1/F_{\text{PWM}}$
Group D	OUTD0, OUTD1	3	delay time is 1/24 of $1/F_{\text{PWM}}$
Group E	OUTE0, OUTE1	-	-
Group F	OUTF0, OUTF1	-	-
Group G	OUTG0, OUTG1	-	-
Group H	OUTH0, OUTH1	-	-

## Linear brightness control

When register EXPEN is set to 0, the MSB 8 bits of 12-bit binary input to PWM generator are directly copied from 8-bit register PWMOUTXn, and the LSB 4 bits are directly copied from 4-bit register PWMLOWOUTXn. The PWM output duty cycle can be calculated with equation (3). The PWM output duty cycle is linearly controlled by the register PWMOUTXn and PWMLOWOUTXn, which provides linear brightness control to each channel output. When PWMOUTXn is 00h, and PWMLOWOUTXn is 0h, the duty cycle is 0% exceptionally.

$$D_{\text{OUTXn}} = \frac{16 \times \text{PWMOUTXn} + \text{PWMLOWOUTXn} + 1}{4096} \times 100\% \quad (3)$$

Where:

PWMOUTXn is decimal number from 0 to 255.

PWMLOWOUTXn is decimal number from 0 to 15.

X is from A to H.

n is from 0 to 1.

Since 12-bit PWM duty cycles require 2 bytes of write operation to update the completed data, the output PWM duty cycle is not changed in between of the two bytes data transmission. NEX1316X-Q100 only updates the PWM duty cycle of any output when its high 8-bit PWMOUTn is written. When very fast brightness change is needed, such as fade-in and fade-out effects, it is essential to change the PWM duty cycles of all channels simultaneously.

To reduce the data transmission for large quantity of the LED pixel control, 8-bit PWM duty cycle resolution can be adopted by writing 0 to 12-bit in DIM register. The master only needs to update high 8-bit PWMOUTXn register to change the brightness of target output channel. The low 4-bit registers PWMLOWOUTXn are ignored. The PWM duty-cycle calculation is shown as equation (4). When PWMOUTXn is 00h, the duty cycle is 0% exceptionally.

$$D_{OUTXn} = \frac{PWMOUTXn+1}{256} \times 100\% \quad (4)$$

Setting SHAREPWM to 1 enables all channels using the PWM duty cycle setting of channels 0 to reduce communication latency.

### Exponential brightness control

NEX1316X-Q100 can generate PWM duty-cycle outputs that follow an exponential curve. When the EXPEN register is set to 1, the integrated conversion circuit provides a one-to-one conversion from the 8-bit register PWMOUTXn to a 12-bit binary code that follows an exponential increment, as illustrated in Fig. 40. When exponential control path is selected, the PWMLOWOUTXn data is neglected. By using the exponential brightness control, LED brightness changes by one LSB is invisible to human eyes especially at low brightness range.

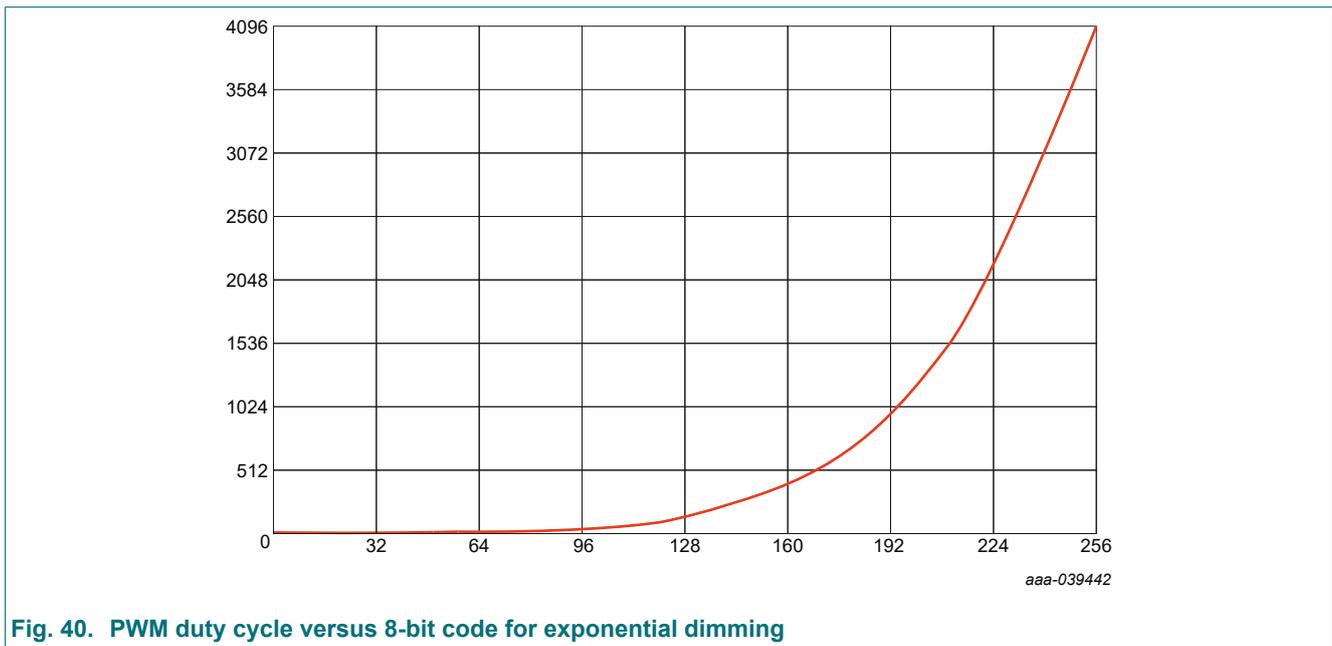


Fig. 40. PWM duty cycle versus 8-bit code for exponential dimming

During power-up or in Fail-Safe state, the registers EXPEN, and PWMFREQ are automatically reset to their default values stored in their corresponding MTP. Both PWMOUTXn and PWMLOWOUTXn are reset to 00h during power up but load their MTP content in Fail-Safe state.

#### 15.3.4. Fail-Safe state operation

In Fail-Safe state, the FS pin can be used as control signal to turn on or turn off the corresponding channel. Each current output channel has its own register, FSOUTXn to set the mapping to FS0 or FS1. When FSOUTXn is set to 0, the corresponding current output channel is controlled by FS0 input, otherwise it is controlled by FS1 input.

NEX1316X-Q100 supports independent channel brightness control through the UART interface. The brightness of each channel is adjustable according to its DC current register I<sub>OUTXn</sub>, PWM duty cycle register PWMOUTXn, PWMLOWOUTXn and channel enable register ENOUTXn setting. The brightness of each channel reflects its register setting value immediately after register is successfully updated through the differential data interface by the master unit.

However, the master unit will lose control for all current channels if the UART communication fails between master unit and NEX1316X-Q100. For example, the interface cable broke by accident. Therefore, the brightness for all output channels of NEX1316X-Q100 is stuck and the ON and OFF control for all output channels are missing too. To keep the basic ON and OFF control for each output channel, NEX1316X-Q100 provides a Fail-Safe state when the communication to master is lost. For detailed description for Fail-Safe state entering and quitting criteria, refer to [Section 15.4](#).

When NEX1316X-Q100 is entering Fail-Safe state, all the registers are set to default value or reloaded from MTP, including IOUTXn, PWMOUTXn and ENOUTXn. The pre-programmed settings in the MTP are loaded and the corresponding registers are reset to the default values.

During the MTP loading process, all the PWM output channels are disabled, and the channels' faults detected in the NORMAL state are cleared. NEX1316X-Q100 provides two hardware input pins, FS0 and FS1 to turn on or off corresponding current output channels in Fail-Safe state. Each current output channel has its own register, FSOUTXn to set the mapping to FS0 or FS1. When FSOUTXn is set to 0, the corresponding current output channel is controlled by FS0 input, otherwise it is controlled by FS1 input.

- If the voltage of FSx input is higher than its high threshold,  $V_{IH(IO)}$ , all current output channels mapped to FSx input are turned on.
- When the voltage of FSx input drops below low threshold,  $V_{IL(IO)}$ , all current out channels mapped to FSx input are turned off.

The flag register FLAG\_EXTFSx shows the FSx input level at real-time. If FSx pin input voltage is logic high, the FLAG\_EXTFSx is set to 1. All FSOUTXn registers load their corresponding MTP data when NEX1316X-Q100 enters Fail-Safe state.

The Fail-Safe state also allows NEX1316X-Q100 to operate as a standalone device without master controlling in the system. The ERR pin is used as a fault indicator to achieve one-fails-all-fail or one-fails-others-on diagnostics requirement. When low quiescent current in fault mode is required, the device must be set as one-fails-all-fail. In this case, if a fault is triggered, the device goes into low current fault mode.

### 15.3.5. 8-bit ADC

NEX1316X-Q100 has integrated a successive-approximation-register (SAR) ADC for diagnostics. It routinely monitors supply voltage if the ADC is idle and uses this voltage to detect  $V_{Vs}$  undervoltage and low  $V_{Vs}$  warning fault.

To manually read the voltage of an ADC channel as listed in [Table 17](#), users must write the 5-bit register ADCCH to select channels. Once ADCCH register is written, the one-time ADC conversion starts and clears FLAG\_ADCDONE register. If the ADC conversion is completed, the ADC result is available in 8-bit register ADC\_OUT and sets FLAG\_ADCDONE to 1. Reading the ADC\_OUT register also clears FLAG\_ADCDONE, and the FLAG\_ADCDONE is set to 0 after reading completion.

Since NEX1316X-Q100 supports PWM control for adjusting LED brightness, the voltage on OUTXn is like a pulse waveform.

- When the current output is enabled by setting ENCHXn to 1, the ADC measures the voltage on assigned OUTXn after the channel is turned on with  $t_{diag\_pulse}$  delay time, which is programmable by 4-bit register BLANK.
- When the channel is disabled by setting ENCHXn to 0, the ADC samples the voltage on assigned OUTXn at off state. The analog value can be calculated based on the read back binary code with equation (5) and [Table 17](#).

$$AnalogValue = a + K \times ADC\_OUT \quad (5)$$

Where ADC\_OUT is the decimal number from 0 to 255.

In ADC auto-scan mode, If MAXOUT channel is selected by writing 06h to ADCCH, the maximum voltage of OUTA0 to OUTH1 is recorded into ADC\_OUT register. The maximum channel output voltage is available after at least one output PWM cycle is completed.

Based on the measured maximum output voltage and supply voltage, microcontroller can regulate supply voltage from previous power stage to minimize the power consumption on the NEX1316X-Q100. Basically, a microcontroller needs to program the output voltage of previous power stage to be just higher than the measured maximum channel output voltage plus the required dropout voltage  $V_{OUT\_drop}$  of NEX1316X-Q100. In this way, NEX1316X-Q100 can achieve minimum power consumption, and overall power efficiency is optimized.

Table 17. ADC channel definition

Channel	ADCCH	Name	ADC calculation parameter (a)	ADC calculation parameter (k)	Comment
0	00h	REF	0.007 V	0.0101 V/LSB	reference voltage
1	01h	VS	0.1346 V	0.1608 V/LSB	supply voltage
2	02h	VLDO	0.0465 V	0.022 V/LSB	5 V VLDO output voltage
3	03h	TEMPSNS	-270.312 °C	2.688 °C/LSB	internal temperature sensor
4	04h	IREF	0.9969 μA	0.9969 μA/LSB	reference current
5	05h	VBAT	0.1346 V	0.1608 V/LSB	Vbat pin voltage
6	06h	MAXOUT	0.0673 V	0.0804 V/LSB	maximum channel output voltage
7	07h	NTC	0.0465 V	0.022 V/LSB	NTC pin voltage
8	08h	OUTA0	0.0673 V	0.0804 V/LSB	output voltage channel A0
9	09h	OUTA1			output voltage channel A1
10	0Ah	reserved			reserved
11	0Bh	OUTB0			output voltage channel B0
12	0Ch	OUTB1			output voltage channel B1
13	0Dh	reserved			reserved
14	0Eh	OUTC0			output voltage channel C0
15	0Fh	OUTC1			output voltage channel C1
16	10h	reserved			reserved
17	11h	OUTD0			output voltage channel D0
18	12h	OUTD1			output voltage channel D1
19	13h	reserved			reserved
20	14h	OUTE0			output voltage channel E0
21	15h	OUTE1			output voltage channel E1
22	16h	reserved			reserved
23	17h	OUTF0			output voltage channel F0
24	18h	OUTF1			output voltage channel F1
25	19h	reserved			reserved
26	1Ah	OUTG0			output voltage channel G0
27	1Bh	OUTG1			output voltage channel G1
28	1Ch	reserved			reserved
29	1Dh	OUTH0			output voltage channel H0
30	1Eh	OUTH1			output voltage channel H1
31	1Fh	reserved			reserved

### 15.3.5.1. Minimum on-time for ADC measurement

Since NEX1316X-Q100 supports PWM control for adjusting LED brightness, the voltage on OUTXn is like a pulse waveform. When the current output is enabled by setting ENOUTXn to 1, the ADC measures the voltage on assigned OUTXn after the output is turned on with  $t_{\text{BLANK}}$  delay time, which is programmable by 4-bit register BLANK. The minimum current output pulse on assigned OUTXn must be longer than  $t_{\text{BLANK}} + 3 \times t_{\text{CONV}}$  to make sure the correct measured result for OUTXn at ON state. When the output is disabled by setting ENOUTXn to 0, the ADC samples the voltage on assigned OUTXn at OFF state.

Nexperia recommends setting 100% duty cycle on assigned OUTXn for ADC measurement by writing FFh to PWMOUTXn and 0Fh to PWMLOWOUTXn register when the PWM dimming period  $t_{\text{DIM\_cycle}}$  has to be less than  $t_{\text{BLANK}} + 3 \times t_{\text{CONV}}$ .

### 15.3.5.2. ADC auto scan and ADC error

#### ADC auto scan

In ADC auto scan mode, if the MAXOUT channel is selected by writing 06h to ADCCHSEL, the maximum voltage of OUTXn is recorded into ADC\_OUT register. The maximum channel output voltage is available after at least nine output PWM cycles are completed.

The ADC measures every three outputs as one group when the group is turned on and moved to measure the next group in next PWM dimming cycle until all eight groups are completed no matter in PWM dimming mode or phase shift PWM dimming mode.

The device sets FLAG\_ADCDONE to 1 and stops ADC auto scan after the measurements for all eight groups are done. The FLAG\_ADCDONE is cleared to 0 by reading the ADC\_OUT, and ADC auto scan restarts again if the data of ADCCHSEL is still 06h. FLAG\_ADCDONE is also cleared to 0 by writing ADCCHSEL register, and ADC restarts after FLAG\_ADCDONE is cleared. The minimum current pulse for each output must be longer than  $t_{BLANK} + 3 \times t_{CONV}$  in auto scan mode. The channel is skipped if it is disabled in auto scan mode.

Based on the measured maximum output voltage and supply voltage, the microcontroller can regulate supply voltage from previous power stage to minimize the power consumption on the NEX1316X-Q100. Basically, the microcontroller must program the output voltage of previous power stage to be just higher than the measured maximum channel output voltage plus the required dropout voltage  $V_{OUT\_drop}$  of the NEX1316X-Q100. In this way, NEX1316X-Q100 takes minimum power consumption, and overall power efficiency is optimized.

#### ADC error

NEX1316X-Q100 integrates a digital comparator to measure the PWM dimming period  $t_{DIM\_cycle}$  and  $t_{BLANK} + 3 \times t_{CONV}$  at real time when ADC is started by writing ADCCHSEL register or reading ADC\_OUT register. The device stops the ADC measurement and sets the FLAG\_ADCERR register to 1 if the  $t_{DIM\_cycle}$  is measured less than  $t_{BLANK} + 3 \times t_{CONV}$  time. The FLAG\_ADCERR register is cleared to 0 by writing 1 to the CLRFAULT register.

### 15.3.6. NTC thermistor input

NEX1316X-Q100 provides an external Negative Temperature Coefficient (NTC) thermistor interface with integrated 5.1 k $\Omega$  pull-up resistor connected between a 5 V rail and the NTC pin. When the ADCCHSEL is configured to 07h, the ADC initiates voltage sampling on the NTC pin.

The conversion result is stored in the ADC\_OUT register upon the FLAG\_ADCDONE is set to 1, indicating completed analog-to-digital conversion. Nexperia recommends grounding the NTC pin through a low-impedance path ( $< 1 \Omega$ ) when the thermistor functionality is not used.

### 15.3.7. Diagnostic and protection in NORMAL state

NEX1316X-Q100 has a full diagnostic coverage for supply voltage, current output, and junction temperature.

In NORMAL state, the device detects all failures and reports the status out through the  $\overline{FLT}$  pin or FLAG registers, without any actions taken by the device except Vbat UVLO,  $V_{Vs}$  undervoltage and overtemperature protection. The master controller must handle all fault actions, for example, retry several times and shut down the outputs if the error still exists.

#### $V_{Vbat}$ and $V_{VLDO}$ undervoltage lockout diagnostics in NORMAL state

When  $V_{Vbat}$  or  $V_{VLDO}$  drops below its UVLO threshold, the device enters POR state. Upon voltage recovery, the device automatically switches to INIT state with FLAG\_POR and FLAG\_ERR set to 1. The master controller can write 1 to register CLR\_POR to clear the FLAG\_POR, write 1 to CLRFAULT to clear FLAG\_ERR, and the CLR\_POR, CLRFAULT bit automatically returns to 0.

#### Low-supply warning diagnostics in NORMAL state

NEX1316X-Q100 continuously monitors the  $V_{Vs}$  and compares the results with internal threshold  $V_{LOWVSTH}$  set by LOWVSTH for low-supply voltage warning. If the supply voltage is lower than threshold, the device pulls  $\overline{FLT}$  pin down with

one pulsed current sink for 50  $\mu$ s to report the fault and set flag registers including FLAG\_LOWVS and FLAG\_ERR to 1. The fault is latched in flag registers.

- When the  $V_{VS}$  rises above low-supply warning threshold, the master controller must write 1 to register CLRFAULT to clear FLAG\_LOWVS and FLAG\_ERR. The CLRFAULT bit automatically returns to 0. The low-supply warning is also used to disable the LED open-circuit detection and single-LED short-circuit detection.
- When the voltage applied on Vs pin is higher than the threshold  $V_{LOWVSTH}$ , NEX1316X-Q100 enables LED open-circuit and single-LED short-circuit diagnosis. When  $V_{VS}$  is lower than the threshold  $V_{LOWVSTH}$ , the device disables LED-open-circuit detection and single-LED short-circuit diagnosis.

Since when  $V_{VS}$  drops below the maximum total LED forward voltage plus required  $V_{OUT\_drop}$  at required current, NEX1316X-Q100 is not able to deliver sufficient current output. The device pulls the voltage of each output channel as close as possible to the Vs. In this condition, the LED open-circuit fault or single-LED short-circuit fault can be detected and reported mistakenly. Setting the low-supply warning threshold high enough can prevent the LED open-circuit and single LED short-circuit fault being detected when  $V_{VS}$  drops to low. The  $V_{LOWVSTH}$  is programmable from 4 V to 35 V at 1-V interval.

### Supply undervoltage diagnostics in NORMAL state

NEX1316X-Q100 provides an internal analog comparator to monitor the  $V_{VS}$  for undervoltage protection. If the  $V_{VS}$  falls below the internal threshold,  $V_{VS\_th\_fall}$ , the device pulls the  $\overline{FLT}$  pin low with constant current sink to report the fault and set flag registers including FLAG\_VSUV and FLAG\_ERR to 1. The supply undervoltage detection is used to disable all current output.

When the voltage applied on the Vs pin is higher than the threshold  $V_{VS\_th\_rise}$ , NEX1316X-Q100 enables all current outputs. When  $V_{VS}$  is lower than the threshold  $V_{VS\_th\_fall}$ , the device disables every output to avoid the unwanted LED flickering or output fault triggered improperly.

The fault is latched in flag registers. When the supply voltage rises above  $V_{VS\_th\_rise}$ , the master controller must write register CLRFAULT to 1 to clear FLAG\_VSUV and FLAG\_ERR. The CLRFAULT bit automatically returns to 0.

### Reference diagnostics in NORMAL state

NEX1316X-Q100 integrates diagnostics for REF resistor open and short fault in NORMAL state. The device monitors the reference current  $I_{REF}$  set by external resistor  $R_{REF}$ . Use equation (6) to calculate the  $I_{REF}$ .

$$I_{REF} = \frac{V_{REF}}{R_{REF}} \quad (6)$$

$V_{REF}$  typically is 1.235 V.

If the current output from REF pin  $I_{REF}$  is lower than  $I_{REF\_OPEN\_th}$ , the reference resistor open-circuit fault is reported. The reference resistor short-circuit fault is reported if the voltage of REF pin  $V_{REF}$  is lower than  $V_{REF\_SHORT\_th}$ . The device pulls the  $\overline{FLT}$  pin down with constant current sink and sets flag registers including FLAG\_REF and FLAG\_ERR to 1.

The fault is latched in flag registers. After the REF pin  $I_{REF}$  and  $V_{REF\_SHORT\_th}$  recover to normal, the device releases  $\overline{FLT}$  pin pull-down automatically and the master controller must send CLRFAULT to clear FLAG\_REF and FLAG\_ERR. CLRFAULT automatically returns to 0.

In NORMAL state, the device does not perform any actions automatically when reference resistor fault is detected. However, the output may not work properly, and the output current may be operating at high current level. Nexperia recommends for master controller to shut down the device outputs and report error to upper level control system such as body control module (BCM).

### Pre-thermal warning in NORMAL state

NEX1316X-Q100 has pre-thermal warning at typical 135 °C. When the junction temperature,  $T_j$ , of NEX1316X-Q100 rises above pre-thermal warning threshold, the device reports pre-thermal warning, pulls  $\overline{FLT}$  pin with pulsed current sink for 50  $\mu$ s and sets the flag registers including FLAG\_PRETSD and FLAG\_ERR to 1.

The fault is latched in flag registers. When the junction temperature of NEX1316X-Q100 falls below pre-thermal warning threshold, the master controller must write 1 to CLRFAULT register to clear FLAG\_PRETSD and FLAG\_ERR. The

CLRFAULT bit automatically returns to 0. When more accurate thermal measurement on LED unit is required, one current output channel can be sacrificed to provide current bias to external thermal resistor such as PTC or NTC.

The voltage of external thermal resistor can be measured by integrated ADC to acquire the temperature information of the thermal resistor located area. The master controller can determine actions based on the acquired temperature information to turn off or reduce current output.

### Overtemperature protection in NORMAL state

NEX1316X-Q100 has overtemperature protection at  $T_{TSD1}$ , typical 175 °C. When device junction temperature  $T_j$  further rises above overtemperature protection threshold, the device turns off all output drivers, pulls the FLT pin low with constant current sink to report fault, and sets the flag registers including FLAG\_TSD and FLAG\_ERR to 1.

The fault is latched in flag registers. When the junction temperature falls below  $T_{TSD1} - T_{TSD1\_HYS}$ , the device resumes all outputs and releases FLT pin pull-down. The master controller must write 1 to CLRFAULT to clear FLAG\_TSD and FLAG\_ERR. The CLRFAULT bit automatically returns to 0.

### Overtemperature shutdown in NORMAL state

When the  $T_j$  rises too high above  $T_{TSD2}$ , 185 °C typically, NEX1316X-Q100 turns off the internal linear regulator, VLDO output to shut down all the analog and digital circuit.

The FLT pin is pulled down by constant current sink to report the fault, and the FLAG\_POR and FLAG\_ERR are all set to 1. When the  $T_j$  drops below  $T_{TSD2} - T_{TSD2\_HYS}$ , NEX1316X-Q100 restarts from POR state with all the registers cleared to default value and FLT pin released. The master controller must write 1 to CLR\_POR to clear both FLAG\_POR and FLAG\_ERR after fault removal. The CLR\_POR bit automatically returns to 0.

### Communication loss diagnostic in NORMAL state

NEX1316X-Q100 monitors the UART interface for communication with an internal watchdog timer. Any successful non-broadcast communication with correct CRC and address matching target device automatically resets the timer.

If the watchdog timer overflows, the device automatically switches to Fail-Safe state as indicated by external FM input.

- If FM = 0, the device switches to Fail-Safe state 0.
- If FM = 1, the device switches to Fail-Safe state 1.

The watchdog timer is programmable by 4-bit register WDTIMER. NEX1316X-Q100 can directly enter Fail-Safe states from normal mode by burning WDTIMER to 0xFh. Disabling the watchdog timer by setting WDTIMER to 0x0h prevents the device from getting into Fail-Safe state.

### LED open-circuit diagnostics in NORMAL state

NEX1316X-Q100 integrates LED open-circuit diagnostics to allow users to monitor LED status in real time. The device monitors voltage difference between  $V_s$  and  $OUTX_n$  to judge if there is any open-circuit failure. The  $V_{Vs}$  is also monitored in parallel with programmable threshold to determine if  $V_{Vs}$  is high enough for open-circuit diagnostics.

The open-circuit monitor is only effective during PWM-ON state with programmable minimal pulse width greater than  $t_{BLANK}$ . The  $t_{BLANK}$  is programmed by register BLANK.

If PWM on-time is less than  $t_{BLANK}$ , the device does not report any open-circuit fault.

- When the device supply voltage  $V_{Vs}$  is below the threshold  $V_{LOWVSTH}$  set by register LOWVSTH, the LED open-circuit is not detected nor reported.
- When the voltage difference  $V_{Vs} - V_{OUTX_n}$  is below threshold  $V_{OPEN\_th\_rise}$  with duration longer than  $t_{BLANK}$ , and the device supply voltage  $V_{Vs}$  is above the threshold  $V_{LOWVSTH}$  set by register LOWVSTH, NEX1316X-Q100 pulls the FLT pin down with one pulsed current sink for 50  $\mu$ s to report fault and set flag registers including FLAG\_OPENOUTXn, FLAG\_OUT and FLAG\_ERR to 1.

In NORMAL state, the device does not take any actions in response to the LED open-circuit fault and waits for the master controller to determine the protection behavior. The fault is latched in flag registers. When the voltage difference  $V_{Vs} - V_{OUTX_n}$  rises above threshold  $V_{OPEN\_th\_rise}$  with duration longer than  $t_{BLANK}$ , or the device's  $V_{Vs}$  is below the threshold

$V_{LOWVSTH}$ , the master controller must write 1 to CLRFAULT to clear FLAG\_OPENOUTXn, FLAG\_OUT and FLAG\_ERR. The CLRFAULT bit automatically returns to 0.

To minimize the limitations of the open threshold on system design, users can configure OPENTH bit to set the most suitable threshold, the setting as below:

- OPENTH=0 LED OPEN, rising threshold:  $V_{Vs} - V_{OUT} < 200 \text{ mV}$ ; falling threshold:  $V_{Vs} - V_{OUT} > 300 \text{ mV}$
- OPENTH=1 LED OPEN, rising threshold:  $V_{Vs} - V_{OUT} < 300 \text{ mV}$ ; falling threshold:  $V_{Vs} - V_{OUT} > 400 \text{ mV}$

### LED short-circuit diagnostics in NORMAL state

NEX1316X-Q100 has internal analog comparators to monitor all channel outputs with respect to a fixed threshold for reporting OUTXn short to GND fault. The short-circuit detection is only effective during PWM-ON state with programmable minimal pulse width of  $t_{BLANK}$ . The  $t_{BLANK}$  is programmable by register BLANK.

If PWM on-time is less than  $t_{BLANK}$  the device cannot report any short-circuit fault. When the voltage  $V_{OUTXn}$  is below threshold  $V_{SG\_th\_fall}$  with duration longer than deglitch timer length of  $t_{BLANK}$ , the device pulls the FLT pin down with pulsed current sink for 50  $\mu\text{s}$  to report fault and set flag registers including FLAG\_SHORTCHXn, FLAG\_OUT and FLAG\_ERR.

In NORMAL state, the device does not take any actions in response to the LED short-circuit fault and waits for the master controller to determine the protection behavior. The fault is latched in flag registers. When the voltage  $V_{OUTXn}$  rises above threshold  $V_{SG\_th\_rise}$  with duration longer than deglitch timer length of  $t_{BLANK}$ , the master controller must write 1 to CLRFAULT to clear FLAG\_SHORTCHXn, FLAG\_OUT and FLAG\_ERR. The CLRFAULT bit automatically returns to 0.

### Single-LED short-circuit detection in NORMAL state (auto scan)

NEX1316X-Q100 integrates analog comparators to monitor all outputs with respect to two alternative threshold for single-LED short-circuit diagnosis. Setting the register SLSSEN to 1 enables the single-LED short-circuit detection.

The single-LED, short-circuit detection is only effective during PWM-ON state with programmable minimal pulse width of  $t_{BLANK} + t_{SLS\_deg}$ . The  $t_{BLANK}$  is programmable by register BLANK. If PWM on-time is less than  $t_{BLANK} + t_{SLS\_deg}$ , the device cannot report any single-LED short-circuit fault. When the device supply voltage  $V_s$  is below the threshold  $V_{LOWSUPTH}$  set by register LOWSUPTH, the single-LED short-circuit is not detected nor reported.

When the voltage  $V_{OUTXn}$  is below threshold  $V_{SLSTHx}$  with duration longer than deglitch timer length of  $t_{BLANK} + t_{SLS\_deg}$ , and the device supply voltage  $V_{SUPPLY}$  is above the threshold  $V_{LOWSUPTH}$  set by register LOWSUPTH, the device pulls the ERR pin down with pulsed current sink for 50  $\mu\text{s}$  to report fault and set flag registers including FLAG\_SLSOUTXn, FLAG\_OUT and FLAG\_ERR.

NEX1316X-Q100 provides two alternative thresholds  $V_{SLSTH0}$  and  $V_{SLSTH1}$  for single-LED short-circuit detection selected by SLSTHOUTXn independently for each current output. The  $V_{SLSTH0}$  is selected for current OUTXn when SLSTHOUTXn is set to 0, however  $V_{SLSTH1}$  is selected when SLSTHOUTXn is set to 1. The actual voltage value for  $V_{SLSTH0}$  and  $V_{SLSTH1}$  is programmable by two 7-bit registers SLSTH0 and SLSTH1 from 2.5 V to 18.375 V at 125 mV interval.

In NORMAL state, the device does not take any actions in response to the single-LED short-circuit fault and waits for the master controller to determine the protection behavior.

The fault is latched in flag registers. When the voltage  $V_{OUTXn}$  rises above threshold  $V_{SLSTHx} + 275 \text{ mV}$  with duration longer than deglitch timer length of  $t_{BLANK} + t_{SLS\_deg}$ , or the device supply voltage  $V_{Vs}$  is below the threshold  $V_{LOWSUPTH}$ , the master controller must write 1 to register CLRFAULT to clear FLAG\_SLSOUTXn, FLAG\_OUT and FLAG\_ERR. The CLRFAULT automatically returns to 0.

### MTP CRC error in NORMAL state

NEX1316X-Q100 implements MTP CRC check after loading the MTP code to configuration register in NORMAL state. The calculated CRC result is sent to register CALC\_MTPCRC and compared to the data in register MTPCRC, which stores the CRC code for all MTP registers.

If the code in register CALC\_MTPCRC is not matched to the code in register MTPCRC, NEX1316X-Q100 pulls the FLT pin down with pulsed current sink for 50  $\mu\text{s}$  to report the fault and set the registers including FLAG\_MTPCRC and FLAG\_ERR to 1. NEX1316X-Q100 only loads MTP to corresponding registers one time during initialization state.

Reloading the MTP triggers the MTP CRC check. The master controller must write CLRFAULT to 1 to clear the fault flags, and the CLRFAULT bit automatically returns to 0. The CRC code algorithm for multiple bytes of binary data is based on the polynomial,  $X^8 + X^5 + X^4 + 1$ . The CRC code contains 8-bit binary code, and the initial value is FFh.

All bits code shift to MSB direction for 1 bit with three exclusive-OR calculation. A new CRC code for one byte input can be generated after repeating the 1-bit shift and three exclusive-OR calculation for eight times. Based on this logic, the CRC code can be calculated for all the MTP register byte.

When the MTP design for production is finalized, the corresponding CRC code based on the calculation must be burnt to MTP register MTPCRC together with other MTP registers at the end of production line. If the DC current for each output channel must be calibrated at the end of production for different LED brightness bin, the CRC code for each production devices must be calculated independent and burnt during the calibration. The CRC algorithm must be implemented into the LED calibration system at the end of production line.

**Table 18. CRC calculation range**

Register	Calculation range
CALC_MTPCRC	00h to 17h, 20h to 37h, 40h to 44h, 50h to 67h, 6Ah to 6Ch, 70h to 7Eh, 80h to 86h
CALC_CONFRC	00h to 17h, 20h to 37h, 40h to 44h, 50h to 67h, 6Ah to 6Ch, 70h to 7Eh, 80h to 86h

### Low $V_{bat}$ warning detection in NORMAL state

When (AUTOSS=1) and LOWVBAT\_FD= 1, NEX1316X-Q100 will compare ADC sample  $V_{bat}$  value with  $V_{bat}$  threshold, the threshold is set by register LOWVBATTH ( the range is 4 V to 35 V, low  $V_{bat}$  threshold x 0.25 V + 4 V). When sampled  $V_{bat} < V_{bat}$  threshold, NEX1316X-Q100 will pull the FLT pin down with pulsed current sink for 50  $\mu$ s to report fault and set flag registers including FLAG\_LOWVBAT and FLAG\_ERR. When LOWBAT\_FD = 0, the device does not report this fault.

### Communication loss diagnostic in NORMAL state

NEX1316X-Q100 monitors the UART interface for communication with an internal watchdog timer. Any successful non-broadcast communication with correct CRC and address matching target device automatically resets the timer.

If the watchdog timer overflows, device automatically switches to Fail-Safe state and sets the FLAG\_FS to 1. The master controller can access NEX1316X-Q100 and writes 1 to CLR\_FS to set the device to NORMAL state again when the communication recovers. The watchdog timer is programmable by 4-bit register WDTIMER. NEX1316X-Q100 can directly enter Fail-Safe state from NORMAL state by burning MTP of WDTIMER to Fh. Disabling the watchdog timer by setting WDTIMER to 0h prevents the device from getting into Fail-Safe state.

### Fault masking

NEX1316X-Q100 provides fault masking capability using masking registers. The device is capable of masking faults by channels or by fault types. The fault masking does not disable diagnostics features but only prevents fault reporting to FLAG\_OUT register, FLAG\_ERR register, and ERR output.

[Table 19](#) lists the detailed description for each fault mask register in NORMAL state. To disable diagnostics on a single channel, setting DIAGENOUTXn registers to 0 disables open-circuit, LED short-circuit and single-LED short circuit diagnostics of channel n and thus no fault of this channel is reported to FLAG\_OPENOUTXn, FLAG\_SHORTCHXn, FLAG\_SLSOUTXn, FLAG\_OUT or FLAG\_ERR registers, or to the ERR pin output.

Fault mask function is the same under normal mode and Fail-Safe mode.

**Table 19. Fault masking in NORMAL state**

Fault detected	Mask register	FLAG name	FLT pin
$V_{Vs}$ low warning	MASKLOWVS=1	FLAG_LOWVS=1	no action
	MASKLOWVS=0	FLAG_LOWVS=1 FLAG_ERR=1	one pulse pulled down for 50 $\mu$ s
$V_{Vs}$ undervoltage	MASKVSUV=1	FLAG_VSUV=1	no action
	MASKVSUV=0	FLAG_VSUV=1 FLAG_ERR=1	constant pulled down

Fault detected	Mask register	FLAG name	FLT pin
Reference fault	MASKREF=1	FLAG_REF=1	no action
	MASKREF=0	FLAG_REF=1 FLAG_ERR=1	constant pulled down
Pre-thermal warning	MASKPRETSD=1	FLAG_PRETSD=1	no action
	MASKPRETSD=0	FLAG_PRETSD=1 FLAG_ERR=1	one pulse pulled down for 50 $\mu$ s
Overtemperature protection	MASKTSD=1	FLAG_TSD=1	no action
	MASKTSD=0	FLAG_TSD=1 FLAG_ERR=1	constant pulled down
MTPCRC error	MASKMTPCRC=1	FLAG_MTPCRC=1	no action
	MASKMTPCRC=0	FLAG_MTPCRC=1 FLAG_ERR=1	one pulse pulled down for 50 $\mu$ s
LED open-circuit fault	MASKOPEN=1	FLAG_OPENOUTn=1	no action
	MASKOPEN=0	FLAG_OPENOUTn=1 FLAG_OUT=1 FLAG_ERR=1	one pulse pulled down for 50 $\mu$ s
LED short-circuit fault	MASKSHORT=1	FLAG_SHORTCHXn = 1	no action
	MASKSHORT=0	FLAG_SHORTCHXn=1 FLAG_OUT=1 FLAG_ERR=1	one pulse pulled down for 50 $\mu$ s
Single-LED short-circuit fault	MASKSLS=1	FLAG_SLSOUTXn=1	no action
	MASKSLS=0	FLAG_SLSOUTXn=1 FLAG_OUT=1 FLAG_ERR=1	one pulse pulled down for 50 $\mu$ s

Table 20. Diagnostics table in NORMAL state

Fault type	Detection criteria	Conditions and method	Fault actions	Fault output	FLT pin	Recovery
V <sub>Vbat</sub> UVLO based on comparator	$V_{Vbat} < V_{POR\_fall}$	comparator	device switch to POR state	FLAG_POR FLAG_ERR	constant pulled down	device switch to INIT state when all voltage rails are good; clears fault flag with CLR_POR
VLDO UVLO based on comparator	$V_{VLDO} < V_{VLDO\_POR\_fall}$	comparator	device switch to POR state	FLAG_POR FLAG_ERR	constant pulled down	device switch to INIT state when all voltage rails are good; clears fault flag with CLR_POR
VLDO OV	$V_{VLDO} > V_{VLDO\_OV\_rise}$	comparator	no action	FLAG_LDOOV FLAG_ERR	constant pulled down	automatically recovers upon fault removal; clears fault flag with CLRFAULT
Low V <sub>Vbat</sub> warning	$V_{Vbat} < V_{LOWVBATTH}$	ADC(AUTOSS=1) & LOWVBAT_FD=1	no action	FLAG_LOWVBAT (optional disable) FLAG_ERR(optional disable)	one pulse pulled down for 50 μs (optional disable)	clears fault flag with CLRFAULT
Low V <sub>Vs</sub> warning	$V_{Vs} < V_{ADCLOWVSTH}$	ADC	disable fault type	FLAG_LOWVVS FLAG_ERR (maskable)	one pulse pulled down for 50 μs (maskable)	clears fault flag with CLRFAULT
V <sub>Vs</sub> undervoltage	$V_{Vs} < V_{Vs\_th\_fall}$	comparator or ADC(AUTOSS=1)	turn off all outputs	FLAG_VSUUV FLAG_LOWVVS FLAG_ERR (maskable)	constant pulled down (maskable)	automatically recovers and releases $\overline{FLT}$ pin upon fault removal; clears fault flag with CLRFAULT
Reference fault	$V_{REF} < V_{REF\_SHORT\_th}$ or $I_{REF} < I_{REF\_OPEN\_th}$	comparator or ADC(AUTOSS=1)	no action	FLAG_REF FLAG_ERR (maskable)	constant pulled down (maskable)	automatically recovers and releases $\overline{FLT}$ pin upon fault removal; clears fault flags with CLRFAULT
Pre-thermal warning	$T_j > T_{PRETSD}$	comparator or ADC(AUTOSS=1)	no action	FLAG_PRETSD	one pulse pulled down for 50 μs (maskable)	clears fault flags with CLRFAULT
Overtemperature protection	$T_j > T_{TSD1}$	comparator	turn off all outputs	FLAG_PRETSD FLAG_TSD FLAG_ERR (maskable)	constant pulled down (maskable)	automatically recovers and releases $\overline{FLT}$ pin upon fault removal; clears fault flags with CLRFAULT
Overtemperature shutdown	$T_j > T_{TSD2}$	comparator	turn off VLDO	FLAG_POR FLAG_ERR	constant pulled down	device switch to INIT state when all voltage rails are good; clears fault flag with CLR_POR

Fault type	Detection criteria	Conditions and method	Fault actions	Fault output	FLT pin	Recovery
LED open-circuit fault (disable fault type)	$V_{Vs} - V_{OUTXn} < V_{OPEN\_th\_rise}$ $V_{Vs} > V_{LOWVSTH}$	PWM pulse width greater than $t_{(BLANK)}$ ENOUTXn=1 DIAGENOUTXn=1 comparator or ADC(AUTOSS=1)	no action	FLAG_OPENOUTn FLAG_OUT(maskable) FLAG_ERR (maskable)	one pulse pulled down for 50 $\mu$ s (maskable)	automatically recovers and releases $\overline{FLT}$ pin upon fault removal; clears fault flags with CLRFAULT
Single-LED short circuit (disable fault type)	$V_{OUTXn} < V_{ADCSHORTTH}$ $V_{SUPPLY} > V_{ADCLOWVSTH}$	PWM pulse width greater than $T_{(BLANK)} + 3 \times T_{(CONV)}$ ENOUTXn=1 DIAGENOUTXn=1 ADC (AUTOSS=1)	no action	FLAG_ODDIAGCHn FLAG_OUT(maskable) FLAG_ERR (maskable)	one pulse pulled down for 50 $\mu$ s (maskable)	clears fault flag with CLRFAULT
MTP-ROM CRC error	CALC_MTPCRC is different from MTPCRC	-	no action	FLAG_MTPCRC FLAG_ERR (maskable)	one pulse pulled down for 50 $\mu$ s (maskable)	clears fault flag with CLRFAULT
Communication loss fault	$T_{WDTIMER}$ overflows	-	enters Fail-Safe states	FLAG_FS	no action	set CLRFS to 1 to set the device to NORMAL state
Unexpected $V_{OUT}$ during channel disable	during channel disable time, $V_{OUTXn} > V_{SG\_th\_rise}$	OFFOUT_FD=1 ADC(AUTOSS=1)	no action	FLAG_OFFOUT (OFFOUT_FD=1) FLAG_ERR (OFFOUT_FD= 1)	one pulse pulled down for 50 $\mu$ s (OFFOUT_FD = 1)	clears fault flag with CLRFAULT

### 15.3.8. Diagnostic and protection in Fail-Safe state

In Fail-Safe state, NEX1316X-Q100 also detects failures and reports the status out by  $\overline{\text{FLT}}$  pin or FLAG registers.

[Table 22](#) lists the summary of the fault detection criteria and the device behavior after the fault is detected. Basically, NEX1316X-Q100 actively takes the action to turn off the failed output channels, retry on the failed channels, or restart the device to keep device operating without controlled by the master. The MTP register NV\_OFAP can be used to set the fault behavior for LED open-circuit, LED short-circuit, and single-LED short-circuit faults.

The one-fails-all-fail behavior is selected when the register NV\_OFAP is burnt to 1; otherwise, the one-fails-others-on behavior is chosen. NEX1316X-Q100 turns off all output channels when any type of LED fault is detected on any one of output channels for one-fails-all-fail behavior.

On the other hand, NEX1316X-Q100 only turns off the failed channel and keeps all other normal channels on. In Fail-Safe state, the fault flag registers of NEX1316X-Q100 still can be accessed again through UART interface in case the communication is rebuilt.

### $V_{\text{bat}}$ and $V_{\text{LDO}}$ undervoltage lockout diagnostics in Fail-Safe state

When  $V_{\text{bat}}$  or  $V_{\text{LDO}}$  drops below its UVLO threshold, the device enters POR state. Upon voltage recovery, the device automatically switches to INIT state with FLAG\_POR and FLAG\_ERR set to 1. The master controller can write 1 to register CLRPOP to clear the FLAG\_POR and FLAG\_ERR, and the CLRPOP bit automatically returns to 0.

### Low-supply warning diagnostics in Fail-Safe state

NEX1316X-Q100 continuously monitors the  $V_{\text{Vs}}$  and compares the results with internal threshold  $V_{\text{LOWVSTH}}$  set by LOWVSTH for low supply voltage warning.

If the supply voltage is lower than threshold, the device sets flag registers including FLAG\_LOWVS and FLAG\_ERR to 1. The fault is latched in flag registers.

- When the supply voltage rises above low-supply warning threshold, the master controller must write register CLRFAULT to 1 to reset FLAG\_LOWVS and FLAG\_ERR. The CLRFAULT bit automatically returns to 0. The low-supply warning is also used to disable the LED open-circuit detection and single-LED short-circuit detection.
- When the voltage applied on Vs pin is higher than the threshold  $V_{\text{LOWVSTH}}$ , NEX1316X-Q100 enables LED open-circuit and single-LED short-circuit diagnosis.
- When  $V_{\text{Vs}}$  is lower than the threshold  $V_{\text{LOWVSTH}}$ , the device disables LED-open-circuit detection and single-LED short-circuit diagnosis.

Since when  $V_{\text{Vs}}$  drops below the maximum total LED forward voltage plus required  $V_{\text{OUT\_drop}}$  at required current, NEX1316X-Q100 is not able to deliver sufficient current output to pull the voltage of each output channel as close as possible to the pin Vs. In this condition, the LED open-circuit fault or single-LED short circuit fault might be detected and reported by mistake. Setting the low-supply warning threshold high enough can prevent the LED open-circuit and single LED short-circuit fault being detected when  $V_{\text{Vs}}$  drops too low. The  $V_{\text{LOWVSTH}}$  is programmable from 4 V to 35 V at 1 V interval.

### $V_{\text{Vs}}$ undervoltage diagnostics in Fail-Safe state

NEX1316X-Q100 provides internal analog comparator to monitor the supply voltage for undervoltage protection in Fail-Safe state. If the supply voltage falls below the internal threshold,  $V_{\text{Vs\_th\_fall}}$ , the device pulls the  $\overline{\text{FLT}}$  pin low with constant current sink to report the fault and set flag registers including FLAG\_VSUV and FLAG\_ERR to 1.

The supply undervoltage detection is used to disable all current output.

- When  $V_{\text{Vs}}$  is lower than the threshold  $V_{\text{Vs\_th\_fall}}$ , the device disables every output to avoid the unwanted LED flickering or output fault triggered improperly.
- When the voltage applied on Vs pin rises above the threshold  $V_{\text{Vs\_th\_rise}}$ , NEX1316X-Q100 enables all current outputs automatically. The fault is latched in flag registers.
- When the supply voltage rises above  $V_{\text{Vs\_th\_rise}}$ , NEX1316X-Q100 releases  $\overline{\text{FLT}}$  pin and the master controller must write register CLRFAULT to 1 to clear FLAG\_VSUV and FLAG\_ERR. The CLRFAULT bit automatically returns to 0.

### Reference diagnostics in Fail-Safe state

NEX1316X-Q100 integrates diagnostics for REF resistor open and short fault in Fail-Safe state. The device monitors the reference current  $I_{REF}$  set by external resistor  $R_{REF}$ .

Use equation (6) to calculate the  $I_{REF}$ . If the current output from REF pin  $I_{REF}$  is lower than  $I_{REF\_OPEN\_th}$ , the reference resistor open-circuit fault is reported. The reference resistor short-circuit fault is reported if the voltage of REF pin  $V_{REF}$  is lower than  $V_{REF\_SHORT\_th}$ . The device pulls the  $\overline{FLT}$  pin down with constant current sink and sets flag registers including FLAG\_REF and FLAG\_ERR to 1. The fault is latched in flag registers.

After the REF pin  $I_{REF}$  and  $V_{REF\_SHORT\_th}$  recover to normal, the device releases  $\overline{FLT}$  pin pull-down automatically and the master controller must send CLRFAULT to clear FLAG\_REF and FLAG\_ERR. The CLRFAULT automatically returns to 0. In Fail-Safe state, the device turns off all output channels when reference fault is detected. The device automatically recovers and turns on all enabled channels after fault removal.

### Pre-thermal warning in Fail-Safe state

NEX1316X-Q100 has pre-thermal warning at typical 135 °C in Fail-Safe state.

- When the junction temperature  $T_j$  of NEX1316X-Q100 rises above pre-thermal warning threshold, the device reports pre-thermal warning and sets the flag registers including FLAG\_PRETSD and FLAG\_ERR to 1. The fault is latched in flag registers.
- When the junction temperature of NEX1316X-Q100 falls below pre-thermal warning threshold, the master controller must write 1 to CLRFAULT register to clear FLAG\_PRETSD and FLAG\_ERR. The CLRFAULT bit automatically returns to 0.

### Overtemperature protection in Fail-Safe state

NEX1316X-Q100 has overtemperature protection at  $T_{TSD1}$ , typical 175 °C in Fail-Safe state. When the device junction temperature  $T_j$  further rises above overtemperature protection threshold, the device turns off all output drivers, pulls the  $\overline{FLT}$  pin low with constant current sink to report fault, and sets the flag registers including FLAG\_TSD and FLAG\_ERR to 1. The fault is latched in flag registers.

When the junction temperature falls below  $T_{TSD1} - T_{TSD1\_HYS}$ , the device resumes all outputs and releases  $\overline{FLT}$  pin pull-down. The master controller must write 1 to CLRFAULT to clear FLAG\_TSD and FLAG\_ERR. The CLRFAULT bit automatically returns to 0.

### Overtemperature shutdown in Fail-Safe state

When the  $T_j$  rises too high above  $T_{TSD2}$ , typically 185 °C, NEX1316X-Q100 turns off the internal linear regulator, VLDO output to shut down all the analog and digital circuits. The  $\overline{FLT}$  pin is pulled down by constant current sink to report the fault, and the FLAG\_POR and FLAG\_ERR are all set to 1.

When the  $T_j$  drops below  $T_{TSD2} - T_{TSD2\_HYS}$ , NEX1316X-Q100 restarts from POR state with all the registers cleared to default value and  $\overline{FLT}$  pin released. The master controller must write 1 to CLR\_POR to clear both FLAG\_POR and FLAG\_ERR after fault removal. The CLR\_POR bit automatically returns to 0.

### LED open-circuit diagnostics in Fail-Safe state

NEX1316X-Q100 integrates LED open-circuit diagnostics to allow users to monitor LED status real time in Fail-Safe state. The device monitors voltage difference between  $V_s$  and  $OUTX_n$  to judge if there is any open-circuit failure. The  $V_{Vs}$  is also monitored in parallel with programmable threshold to determine if supply voltage is high enough for open-circuit diagnostics. The open-circuit monitor is only effective during PWM-ON state with programmable minimal pulse width greater than  $t_{BLANK}$ .

The  $t_{BLANK}$  is programmed by register BLANK. If PWM on-time is less than  $t_{BLANK}$ , the device does not report any open-circuit fault. When the device supply voltage  $V_{Vs}$  is below the threshold  $V_{LOWVSTH}$  set by register ADCLOWVSTH, the LED open-circuit fault is not detected nor reported.

When the voltage difference  $V_{Vs} - V_{OUTX_n}$  is below threshold  $V_{OPEN\_th\_rise}$  with duration longer than  $t_{BLANK}$ , and the device supply voltage  $V_{Vs}$  is above the threshold  $V_{LOWVSTH}$ , NEX1316X-Q100 pulls the  $\overline{FLT}$  pin down with constant current sink to report fault and set flag registers including FLAG\_OPENOUTXn, FLAG\_OUT and FLAG\_ERR to 1.

In Fail-Safe state, NEX1316X-Q100 shuts down the normal current regulation and PWM duty cycle for the error output, then the device sources a current  $I_{\text{retry}}$  to faulty output every  $t_{\text{retry}}$ , typically 10 ms for retrying.  $I_{\text{retry}}$  is programmed by ODIOUT register. The current  $I_{\text{retry}}$  can be calculated with the equation (7).

When the voltage difference  $V_{V_s} - V_{\text{OUTXn}}$  of error output rises above threshold  $V_{\text{OPEN\_th\_rise}}$  with duration longer than  $t_{\text{BLANK}}$ , or the supply voltage  $V_{V_s}$  is above the threshold  $V_{\text{LOWVSTH}}$ , the device automatically resumes the normal current and PWM duty cycle setup and releases the  $\overline{\text{FLT}}$  pin.

$$I_{\text{retry}} = \frac{\text{CONF}_{\text{ODIOUT}} \times 4 + 4}{64} \times I_{\text{full\_range}} \quad (7)$$

$I_{\text{retry}}$  is programmable from 0 to 15.

Use equation (7) to calculate  $I_{\text{full\_range}}$ .

The fault is latched in flag registers. When the open-circuit failure is removed, the master controller must write 1 to CLRFAULT to clear FLAG\_OPENCHn, FLAG\_OUT and FLAG\_ERR. The CLRFAULT bit automatically returns to 0.

To meet the non-retry requirement for some application, NEX1316X-Q100 adds one CONF register option to close retry function as below, this function is applicable to all retry scenarios.

- DISRETRY: Fail-Safe mode retry function enable bit
- DISRETRY=0: under Fail-Safe mode, when LED OPEN or LED SHORT appears, NEX1316X-Q100 will auto retry to open the channel.
- DISRETRY=1: under Fail-Safe mode, when LED OPEN or LED SHORT appears, NEX1316X-Q100 will keep the channel off, and latch the status, unless the communication recovery and the fault flag is cleared.

### LED short-circuit diagnostics in Fail-Safe state

NEX1316X-Q100 has internal analog comparators to monitor all channel outputs with respect to a fixed threshold for reporting OUTXn short to GND fault in Fail-Safe state. The short-circuit detection is only effective during PWM-ON state with programmable minimal pulse width of  $t_{\text{BLANK}}$ . The  $t_{\text{BLANK}}$  is programmable by register BLANK. If PWM on-time is less than  $t_{\text{BLANK}}$ , the device cannot report any short-circuit fault.

When the voltage  $V_{\text{OUTXn}}$  is below threshold  $V_{\text{SG\_th\_fall}}$  with duration longer than deglitch timer length of  $t_{\text{BLANK}}$ , the device pulls  $\overline{\text{FLT}}$  pin down with constant current sink to report fault and set flag registers including FLAG\_SHORTCHn, FLAG\_OUT and FLAG\_ERR.

In Fail-Safe state, NEX1316X-Q100 shuts down the normal current regulation and PWM duty cycle for the faulty output, then the device sources a pulse current to faulty output every  $t_{\text{retry}}$ , 10 ms for retrying.  $I_{\text{retry}}$  is programmed by ODIOUT register. Use equation (7) to calculate the current  $I_{\text{retry}}$ .

When the voltage  $V_{\text{OUTXn}}$  of error output rises above threshold  $V_{\text{SG\_th\_rise}}$  with duration longer than  $t_{\text{BLANK}}$ , the device automatically resumes the normal current and PWM duty cycle setup and releases the  $\overline{\text{FLT}}$  pin. The fault is latched in flag registers. When the short-circuit failure is removed, the master controller must write 1 to CLRFAULT to clear FLAG\_SHORTOUTXn, FLAG\_OUT and FLAG\_ERR. The CLRFAULT bit automatically returns to 0.

### Single-LED short-circuit detection in Fail-Safe state

NEX1316X-Q100 integrates analog comparators to monitor all outputs with respect to two alternative threshold for single-LED short-circuit diagnostic in Fail-Safe state. Setting the register SLSSEN to 1 enables the single-LED short-circuit detection.

The single-LED short-circuit detection is only effective during PWM-ON state with programmable minimal pulse width of  $t_{\text{BLANK}}$ . The  $t_{\text{BLANK}}$  is programmable by register BLANK.

If PWM on-time is less than  $t_{\text{BLANK}}$ , the device cannot report any single-LED short-circuit fault.

When the device supply voltage  $V_{V_s}$  is below the threshold  $V_{\text{LOWVSTH}}$  set by register ADCLOWVSTH, the single-LED short-circuit is not detected nor reported.

When the voltage  $V_{\text{OUTXn}}$  is below threshold  $V_{\text{SLSTHOUTXn}}$  with duration longer than deglitch timer length of  $t_{\text{BLANK}}$ , and the device supply voltage  $V_{V_s}$  is above the threshold  $V_{\text{LOWVSTH}}$ , the device pulls the  $\overline{\text{FLT}}$  pin down with constant current sink to report fault and set flag registers including FLAG\_SLSTHOUTXn, FLAG\_OUT and FLAG\_ERR.

NEX1316X-Q100 provides two alternative threshold  $V_{\text{ADCSHORTTH0}}$  and  $V_{\text{ADCSHORTTH1}}$  for single-LED short-circuit detection selected by SLSTHOUTXn independently for each current output. The  $V_{\text{ADCSHORTTH0}}$  is selected for current OUTXn when SLSTHOUTXn is set to 0, however  $V_{\text{ADCSHORTTH1}}$  is selected when SLSTHOUTXn is set to 1.

The actual voltage value for  $V_{\text{SLSTH0}}$  and  $V_{\text{SLSTH1}}$  is programmable by two 7-bit registers SLSTH0 and SLSTH1 from 2.5 V to 15.875 V at 125 mV interval. In Fail-Safe state, NEX1316X-Q100 shuts down the normal current regulation and PWM duty cycle for the faulty output, then the device sources a pulse current,  $I_{\text{OUTXn}}$  programed by IOOUTXn register to the faulty output every  $t_{\text{SLS\_Retry}}$ , 10 ms for retrying.

When the voltage  $V_{\text{OUTXn}}$  of error output rises above threshold  $V_{\text{SLSTHx}} + 275$  mV with duration longer than  $t_{\text{BLANK}} + t_{\text{SLS\_deg}}$  during retrying, or the supply voltage  $V_{\text{Vs}}$  is below the threshold  $V_{\text{LOWSUPTH}}$ , the device automatically resumes the normal current and PWM dutycycle setup and releases the FLT pin.

The fault is latched in flag registers. When the single-LED short-circuit fault is removed, the master controller must write 1 to register CLRFAULT to clear FLAG\_SLSOUTXn, FLAG\_OUT and FLAG\_ERR. The CLRFAULT automatically returns to 0.

### MTP CRC error in Fail-Safe state

NEX1316X-Q100 automatically reloads all MTP code into the corresponding configuration registers every time after entering the Fail-Safe state. NEX1316X-Q100 implements a MTPCRC check after loading the MTP code to configuration register in Fail-Safe state.

The calculated CRC results are sent to register CALC\_MTPCRC and compared to the data in MTP register NV\_CRC, which stores the CRC code for all MTP registers. If the code in register CALC\_MTPCRC is not matched with the code in register NV\_CRC, NEX1316X-Q100 turns off all channels output, pulls the FLT pin down with constant current sink to report the fault, and sets the registers including FLAG\_MTPCRC and FLAG\_ERR to 1. The CRC code for all the MTP registers must be burnt into MTP register MTPCRC at the end of production line. The CRC code algorithm is described in MTP CRC Error in NORMAL state.

### Fault masking in Fail-Safe state

To disable diagnostics on a single channel in Fail-Safe state, burning MTP of DIAGENOUTXn registers to 0 disables open-circuit, LED short-circuit and single-LED short-circuit diagnostics of channel x, and thus no fault of this channel is reported to FLAG\_OPENOUTXn, FLAG\_SHORTCHXn, FLAG\_SLSOUTXn, FLAG\_OUT or FLAG\_ERR registers, or to the ERR output.

**Table 21. Fault masking register in NORMAL state**

Fault detected	Mask register	FLAG name	FLT pin
Low-supply warning	MASKLOWVS = 1	FLAG_LOWVS = 1	no action
	MASKLOWVS = 0	FLAG_LOWVS = 1 FLAG_ERR = 1	no action
Supply undervoltage	MASKSUPUV = 1	FLAG_SUPUV = 1	no action
	MASKSUPUV = 0	FLAG_SUPUV = 1 FLAG_ERR = 1	constant pulled down
Reference fault	MASKREF = 1	FLAG_REF = 1	no action
	MASKREF = 0	FLAG_REF = 1 FLAG_ERR = 1	constant pulled down
Pre-thermal warning	MASKPRETSD = 1	FLAG_PRETSD = 1	no action
	MASKPRETSD = 0	FLAG_PRETSD = 1 FLAG_ERR = 1	no action
Overtemperature protection	MASKTSD = 1	FLAG_TSD = 1	no action
	MASKTSD = 0	FLAG_TSD = 1 FLAG_ERR = 1	constant pulled down
MTPCRC error	MASKMTPCRC = 1	FLAG_MTPCRC = 1	no action
	MASKMTPCRC = 0	FLAG_MTPCRC = 1 FLAG_ERR = 1	constant pulled down

Fault detected	Mask register	FLAG name	FLT pin
LED open-circuit fault	MASKOPEN = 1	FLAG_OPENOUTXn = 1	no action
	MASKOPEN = 0	FLAG_OPENOUTXn = 1 FLAG_OUT = 1 FLAG_ERR = 1	constant pulled down
LED short-circuit fault	MASKSHORT= 1	FLAG_SHORTOUTXn= 1	no action
	MASKSHORT= 0	FLAG_SHORTOUTXn= 1 FLAG_OUT = 1 FLAG_ERR = 1	constant pulled down
Single-LED short-circuit fault	MASKSLS = 1	FLAG_SLSOUTXn = 1	no action
	MASKSLS = 0	FLAG_SLSOUTXn = 1 FLAG_OUT = 1 FLAG_ERR = 1	Constant pulled down

Table 22. Diagnostics table in Fail-Safe state

Fault type	Detection criteria	Conditions and method	Fault actions	Fault output	FLT pin	Recovery
$V_{Vbat}$ UVLO Based on comparator	$V_{Vbat} < V_{POR\_fall}$	comparator	device switch to POR state	FLAG_POR FLAG_ERR	constant pulled down	device switch to INIT state when all voltage rails are good; clears fault flag with CLR_POR
VLDO UVLO Based on comparator	$V_{VLDO} < V_{VLDO\_POR\_fall}$	comparator	device switch to POR state	FLAG_POR FLAG_ERR	constant pulled down	device switch to INIT state when all voltage rails are good; clears fault flag with CLR_POR
Low-supply warning	$V_{Vs} < V_{LOWVSTH}$	ADC	disable fault type	FLAG_LOWVS FLAG_ERR (maskable)	no action	clears fault flag with CLRFAULT
$V_{Vs}$ undervoltage	$V_{Vs} < V_{Vs\_th\_fall}$	comparator	turn off all outputs	FLAG_VSUV FLAG_ERR (maskable)	constant pulled down (maskable)	automatically recovers and releases $\overline{FLT}$ pin upon fault removal; clears fault flag with CLRFAULT
Reference fault	$V_{REF} < V_{REF\_SHORT\_th}$ or $I_{REF} < I_{REF\_OPEN\_th}$	comparator	turn off all outputs	FLAG_REF FLAG_ERR (maskable)	constant pulled down (maskable)	automatically recovers and releases $\overline{FLT}$ pin upon fault removal; clears fault flags with CLRFAULT
Pre-thermal warning	$T_j > T_{PRETSD}$	comparator	no action	FLAG_PRETSD FLAG_ERR(maskable)	no action	clears fault flags with CLRFAULT
Overtemperature protection	$T_j > T_{TSD1}$	comparator	turn off all outputs	FLAG_TSD FLAG_ERR (maskable)	constant pulled down (maskable)	automatically recovers and releases $\overline{FLT}$ pin upon fault removal; clears fault flags with CLRFAULT
Overtemperature shutdown	$T_j > T_{TSD2}$	comparator	turn off VLDO	FLAG_POR FLAG_ERR	constant pulled down	device switch to INIT state when all voltage rails are good; clears fault flag with CLR_POR
LED open-circuit fault (disable fault type)	$V_{Vs} - V_{OUTXn} < V_{OPEN\_th\_rise}$ $V_{Vs} > V_{LOWVSTH}$	PWM pulse width greater than $t_{(BLANK)}$ ENOUTXn=1 DIAGENOUTXn=1	turn off the failed outputs and retry every 10 ms	FLAG_OPENOUTn FLAG_OUT(maskable) FLAG_ERR (maskable)	constant pulled down (maskable)	automatically recovers and releases $\overline{FLT}$ pin upon fault removal; clears fault flags with CLRFAULT
Single-LED short circuit (disable fault type)	$V_{OUTXn} < V_{ADCSHORTTH}$ $V_{SUPPLY} > V_{ADCLOWVSTH}$	PWM pulse width greater than $T_{(BLANK)} + 3 \times T_{(CONV)}$ ENOUTXn=1 DIAGENOUTXn=1 SLSSEN=1	no action	FLAG_SLSOUTXn FLAG_OUT(maskable) FLAG_ERR (maskable)	constant pulled down(maskable)	automatically recovers and releases $\overline{FLT}$ pin upon fault removal; clears fault flag with CLRFAULT

Fault type	Detection criteria	Conditions and method	Fault actions	Fault output	FLT pin	Recovery
LED short-circuit fault	$V_{OUTXn} < V_{SG\_th\_rise}$	PWM pulse width greater than $t_{(BLANK)}$ ENOUTXn=1 DIAGENOUTXn=1	turn off the failed outputs and retry every 10 ms	FLAG_SHORTOUTXn FLAG_OUT(maskable) FLAG_ERR (maskable)	constant pulled down(maskable)	automatically recovers and releases FLT pin upon fault removal; clears fault flags with CLRFAULT
MTP CRC error	CALC_MTPCRC is different MTPCRC		turn off all outputs	FLAG_MTPCRC FLAG_ERR (maskable)	constant pulled down (maskable)	clears fault flags with CLRFAULT

### 15.3.9. OFAF setup in Fail-Safe state

NEX1316X-Q100 has a unique setup for failure behaviors in Fail-Safe state. If there is a failure detected in Fail-Safe state, NEX1316X-Q100 automatically reacts to the failure. The register OFAF determines whether the result behavior of output failure is one-fails-all-fail or one-fails-others-on.

In Fail-Safe state, NEX1316X-Q100 shuts down all enabled current outputs except the faulty output when OFAF is set to 1. Otherwise, NEX1316X-Q100 keeps regulation for all enable current outputs except the faulty output when OFAF is set to 0. Refer to [Table 23](#) for more details.

### 15.3.10. $\overline{\text{FLT}}$ output

The  $\overline{\text{FLT}}$  pin is a programmable fault indicator pin. This pin can be used as an interrupted output to master controller in case there is any fault in NORMAL state. In Fail-Safe states, the  $\overline{\text{FLT}}$  pin can be used as an output to other  $\overline{\text{FLT}}$  pin of other NEX1316X-Q100 to achieve one-fails-all-fail at system level. The  $\overline{\text{FLT}}$  pin is an open-drain output with current limit up to  $I_{\text{PD(ERR)}}$ . Nexperia recommends a  $< 10 \text{ k}\Omega$  external pull-up resistor from the  $\overline{\text{FLT}}$  pin to the same IO voltage of the master controller.

In NORMAL state, when a fault is triggered, depending on the fault type, the  $\overline{\text{FLT}}$  pin is either pulled down constantly or pulled down for a single pulse. After an  $\overline{\text{FLT}}$  output is triggered, the master controller must take action to deal with the failure and reset the fault flag. For non-critical faults, NEX1316X-Q100 pulls down the  $\overline{\text{FLT}}$  pin with a duration of  $50 \mu\text{s}$  and release; for critical faults, device constantly pulls down  $\overline{\text{FLT}}$  as described in [Table 20](#). In NORMAL state, basically, NEX1316X-Q100 only reports the faults to the master controller for most of the failure and takes no actions except supply or LDO UVLO, reference fault, and overtemperature. The master controller determines what action to take according to the type of failure.

NEX1316X-Q100 provides a forced-error feature to validate the error feedback-loop integrity in NORMAL state. In NORMAL state, if the microcontroller sets FORCEERR to 1, the FLAG\_ERR is set 1 and pulls down  $\overline{\text{FLT}}$  output with a pulse of  $50 \mu\text{s}$  accordingly. The FORCEERR automatically returns to 0.

In Fail-Safe states, the  $\overline{\text{FLT}}$  pin is used as fault bus. When there is any output failure reported, the  $\overline{\text{FLT}}$  is pulled down by internal current sink  $I_{\text{PD(ERR)}}$ . NEX1316X-Q100 monitors the voltage of the  $\overline{\text{FLT}}$  pin. If the one-fails-all-fail diagnostics is enabled by setting register OFAF to 1, all current output channels are turned off, as well as diagnostics, when the  $\overline{\text{FLT}}$  pin voltage is low. If register OFAF is 0, the device only turns off the failed channel with alive channels diagnostics enabled.

**Table 23. One-Fails-All-Fail feature in Fail-Safe state**

$\overline{\text{FLT}}$ pin	OFAF = 1	OFAF = 0
$\overline{\text{FLT}}$ pulled low internally	all OUT channels OFF except failure detected OUT retries every 10 ms	only failure detected OUT OFF
$\overline{\text{FLT}}$ pulled low externally	all OUT channels OFF	all OUT channels ON

If multiple NEX1316X-Q100 devices are used in one application, tying the  $\overline{\text{FLT}}$  pins together achieves the one-fails-all-fail behavior in Fail-Safe states without master controlling. Any one of NEX1316X-Q100 reports fault by pulling the  $\overline{\text{FLT}}$  pin to low, and the low voltage on ERR bus is detected by other NEX1316X-Q100 as [Fig. 41](#) illustrates. If the register OFAF is set to 1 for all NEX1316X-Q100 devices having the  $\overline{\text{FLT}}$  pins tied together, all NEX1316X-Q100 devices turn off current for all output channels.

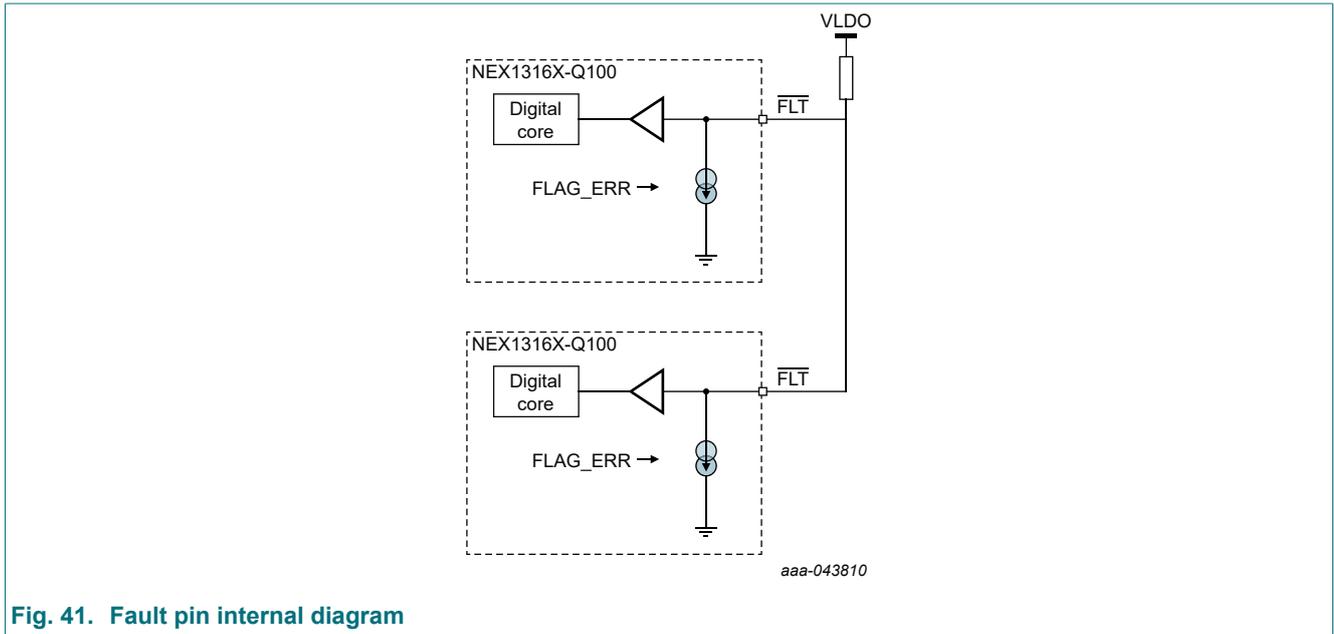


Fig. 41. Fault pin internal diagram

### 15.4. Device functional modes

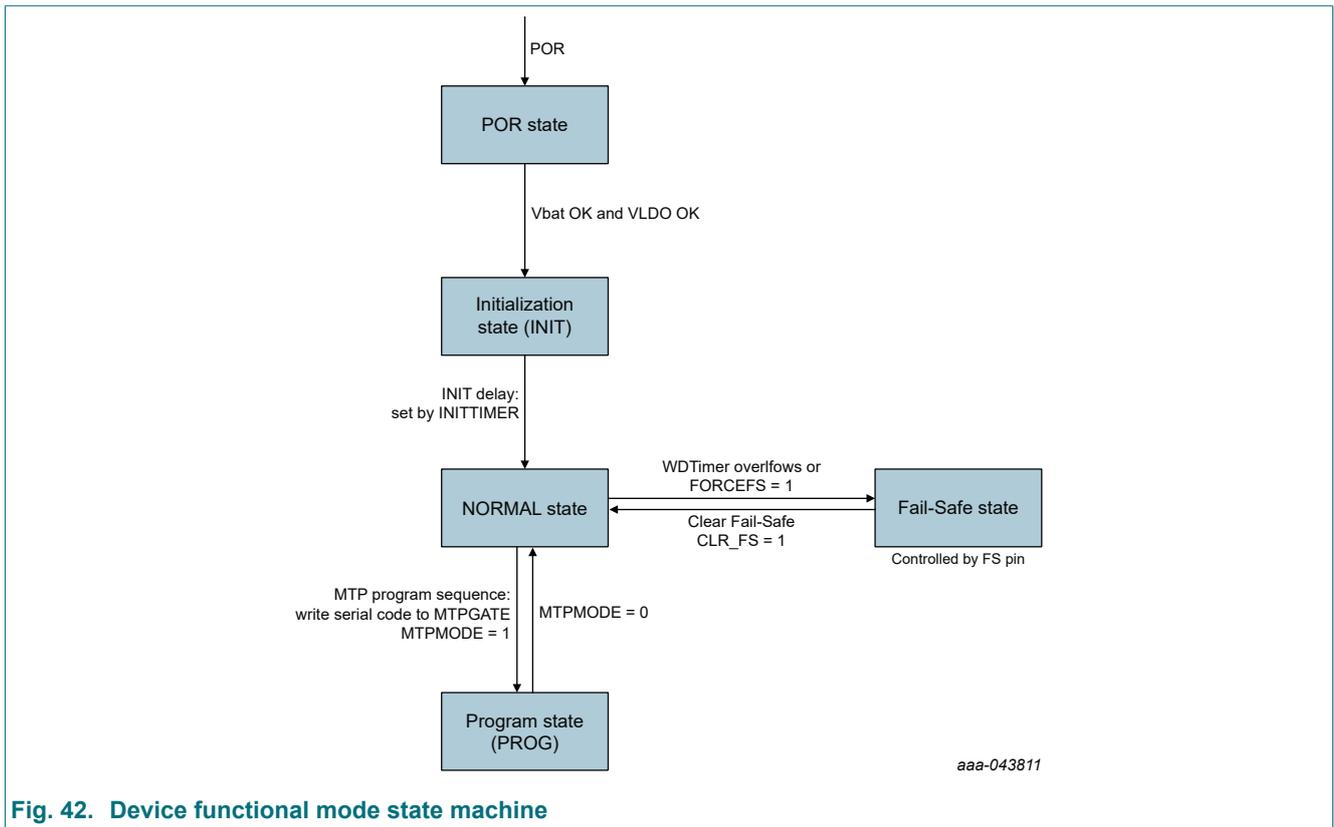


Fig. 42. Device functional mode state machine

#### 15.4.1. POR state

Upon powering up, NEX1316X-Q100 enters POWER\_ON\_RESET (POR) state. In this state, registers are cleared to default value, outputs are disabled, and the device cannot be accessed through the differential data interface (UART). After both Vbat input and the VLDO output are above their UVLO threshold, the device switches to INITIALIZATION state (INIT). If any of the supply fails below UVLO threshold in other states, the device immediately switches to POR state.

### 15.4.2. INITIALIZATION state

The INITIALIZATION state is designed to allow master controller to have enough time to power up before the device automatically gets into Fail-Safe states. INIT mode has a configurable delay programmed by 4-bit register NV\_INITTIMER. After the delay counter is reached, the device changes to NORMAL state.

In INIT state, the communication between master controller and NEX1316X-Q100 is enabled through the differential data interface (UART). In INITIALIZATION state, the device automatically loads register map default values, which can be programmed in corresponding MTP. The master controller sets CLR\_POR to 1 in INITIALIZATION state, the device immediately switches to NORMAL state. Only write CLR\_POR to NEX1316X-Q100 in INITIALIZATION state.

### 15.4.3. NORMAL state

After NEX1316X-Q100 is in NORMAL state, the device operates under master control for LED animation and diagnostics using UART interface. NEX1316X-Q100 integrates a watchdog timer to monitor the communication on the differential data interface (UART). The watchdog timer is programmable by a 4-bit register WDTIMER for 13 options. The timer in NEX1316X-Q100 starts to count when there is no instruction received from the master controller.

NEX1316X-Q100 enters Fail-Safe states when the timer overflows. The device can be also forced into Fail-Safe states anytime in NORMAL state by setting FORCEFS to 1. The FORCEFS register automatically returns to 0.

### 15.4.4. Fail-Safe state

When NEX1316X-Q100 is entering Fail-Safe state from NORMAL state, all the registers are set to default value or reloaded from MTP. The differential data interface (UART) keeps alive in Fail-Safe state. Setting FORCEFS to 1 forces the device into Fail-Safe state from NORMAL state. NEX1316X-Q100 can quit from Fail-Safe state to NORMAL state by setting CLR\_FS to 1 with FLAG\_FS register cleared.

### 15.4.5. PROGRAM state

NEX1316X-Q100 can enter MTP PROGRAM state by writing multiple configuration registers to MTPGATE and setting 1 to MTPMODE. For details of getting into PROGRAM state, refer to [Section 15.4.5.2](#).

#### 15.4.5.1. UART over CAN protocol

NEX13160-Q100 integrates UART compliant controller, while NEX13161-Q100 integrates a CAN transceiver, the structure is showed in [Fig. 43](#). NEX13160-Q100 is compliant with the UART, the data format is similar to UART. The signal input to NEX13161-Q100 is at the differential CAN physical electrical level, and the protocol is UART-based.

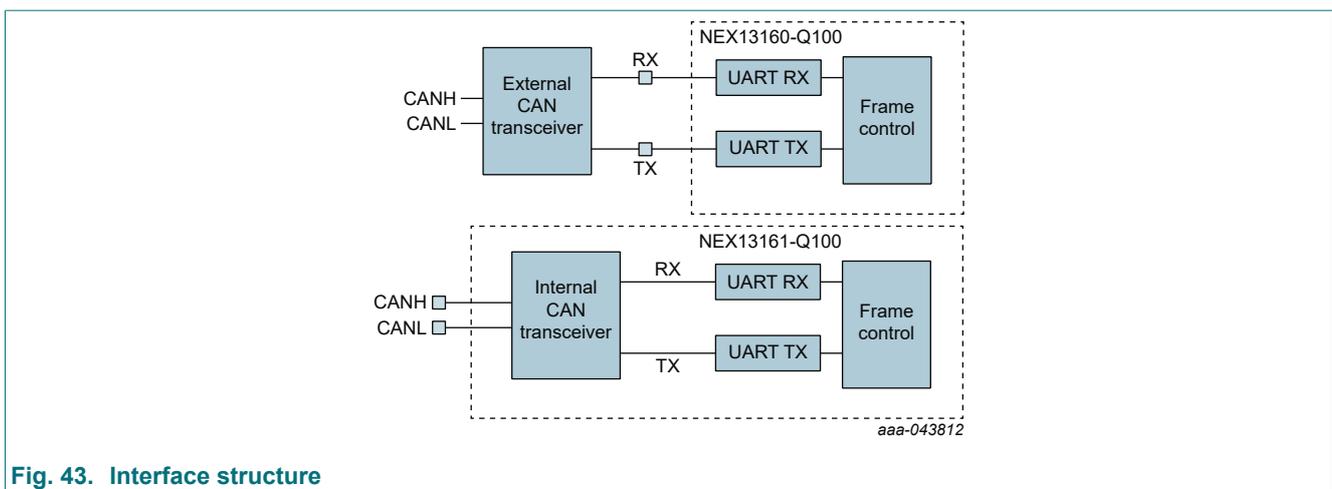


Fig. 43. Interface structure

### Differential data interface (UART) address setting

NEX1316X-Q100 supports a maximum of 27 slave devices. NEX1316X-Q100 has four pin-outs including ADDR3, ADDR2, ADDR1, and ADDR0 for slave address configuration. Different configurations allow each pin to support three statuses as shown in [Table 24](#).

If EXTADDR = 0, the device uses external inputs on ADDR3, ADDR2, ADDR1 and ADDR0 as shown in [Table 25](#), and ignores M status.

If EXTADDR = 1, the device uses external inputs on ADDR2, ADDR1 and ADDR0 to set 27 slaves as shown in [Table 26](#). In this mode, ADDR2, ADDR1 and ADDR0 can support M status.

**Table 24. Address pin status assessment**

Status	Settings
0	tie directly (0 $\Omega$ ) to GND
M	tie 30 k $\Omega$ to GND
1	option 1: tie 90 k $\Omega$ to GND option 2: tie directly to VCC

**Table 25. Address setting: EXTADDR = 0**

Address setting (EXTADDR = 0)				
Address (Decimal)	Bit 3	Bit 2	Bit 1	Bit 0
	ADDR3	ADDR2	ADDR1	ADDR0
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0
13	1	1	0	1
14	1	1	1	0
15	1	1	1	1

**Table 26. Address setting: EXTADDR = 1**

Address setting (EXTADDR = 1)				
Slave address	Address (Decimal)	ADDR2	ADDR1	ADDR0
0	0	0	0	0
1	1	0	0	1
2	2	0	1	0
3	3	0	1	1
4	4	1	0	0
5	5	1	0	1
6	6	1	1	0
7	7	1	1	1

Slave address	Address setting (EXTADDR = 1)			
	Address (Decimal)	ADDR2	ADDR1	ADDR0
8	8	0	0	M
9	9	0	1	M
10	10	1	0	M
11	11	1	1	M
12	12	0	M	0
13	13	0	M	1
14	14	1	M	0
15	15	1	M	1
16	16	M	0	0
17	17	M	0	1
18	18	M	1	0
19	19	M	1	1
20	20	0	M	M
21	21	1	M	M
22	22	M	0	M
23	23	M	1	M
24	24	M	M	0
25	25	M	M	1
26	26	M	M	M

### Status response

When NEX1316X-Q100 works as a slave device receiving a non-broadcast frame, it first verifies the CRC byte. After CRC check is succeeded, NEX1316X-Q100 sends out the device status of FLAG\_ERR register byte followed by CRC byte. The response is disabled by setting register ACKEN to 0. The response sent from NEX1316X-Q100 is enabled by default.

Every communication requires CRC verification to ensure the integrity of the data transaction. In broadcast mode, NEX1316X-Q100 does not send out a response.

### Synchronization byte

The first byte data sent from the master controller to NEX1316X-Q100 is synchronization frame (SYNC). The master controller sends the clock signal to V through outputting 01010101 binary code in first frame.

NEX1316X-Q100 adaptively uses the same clock to communicate with master by synchronization of internal high frequency clock. To prevent clock drift over time, the synchronization byte is always required for each new message.

### Device address byte

The device address byte, DEV\_ADDR frame follows the SYNC frame. There is total 8-bit binary code in the device address byte. [Table 27](#) provides detailed definition for each bit function. The DEVICE\_ADDR register is required to set to 0000b for broadcast mode, otherwise the broadcast mode cannot be enabled. The broadcast mode is only effective for the writing mode. The READ/WRITE bit must be 1 for the broadcast mode.

Table 27. DEV\_ADDR byte

Bit	Field	Description
3-0	DEVICE_ADDR	target device address
5-4	DATA_LENGTH	00b: single-byte mode with 1 byte of data 01b: burst mode with 4 bytes of data 10b: burst mode with 16 bytes of data 11b: burst mode with 24 bytes of data
6	BROADCAST	broadcast mode 1: broadcast (DEVICE_ADDR = 0000b) 0: single-device only
7	READ/WRITE	read/write mode 1: write mode 0: read mode

To support more than 16 slaves, we will use the broadcast bit as address bit when the amount of slave address is higher than 15, the details of DEV\_ADDR byte for different slaves are listed in [Table 28](#).

Table 28. Device address byte

DEV_ADDR byte				
Read/Write[7]	Broadcast[6]	Data length[5:4]	Device_ADDR[3:0]	Read/Write slave
Write: 1 Read: 0	0	00: 1 byte 01: 4 bytes 10: 16 bytes 11: 24 bytes	0	slave 0
	0		1	slave 1
	0		2	slave 2
	0		3	slave 3
	0		4	slave 4
	0		5	slave 5
	0		6	slave 6
	0		7	slave 7
	0		8	slave 8
	0		9	slave 9
	0		A	slave 10
	0		B	slave 11
	0		C	slave 12
	0		D	slave 13
	0		E	slave 14
	0		F	slave 15
	1		0	broadcast mode
	1		1	slave 16
	1		2	slave 17
	1		3	slave 18
	1		4	slave 19
	1		5	slave 20
	1		6	slave 21
	1		7	slave 22
1	8	slave 23		

DEV_ADDR byte				
	1		9	slave 24
	1		A	slave 25
	1		B	slave 26

## Registers lock

NEX1316X-Q100 provides registers content lock feature to prevent unintended modification of registers. There are four register lock bits for different types of registers covering all registers as [Table 29](#) specifies. Nexperia recommends locking the register after the register writes operations.

**Table 29. Registers lock table**

Register IP name	Address	Lock register name	Lock register default
BRT (PWMMx)	00h to 17h	BRTLOCK	0 (unlock)
BRT (PWMLx)	20h to 37h		
BRT	40h to 44h		
IOUT	50h to 67h	IOUTLOCK	1 (lock)
CONF_FD	6Ah to 6Ch	CONFLOCK	1 (lock)
CONF	70h to 83h	CONFLOCK	1 (lock)
CONF	84h to 87h	always locked except in EEPROM program state	
CTRL (ADCCH and CLR)	90h and 91h	no lock register	-
CTRL	92h to 95h	unlock by sending serial code to CTRLGATE register	
CTRL (CTRLGATE)	96h	no lock register	-
CTRL (EEP)	97h	unlock by sending serial code to EEPGATE register	
CTRL (EEPGATE)	98h	no lock register	-

Below instructions are required to access and exit the CTRL (92h to 95h) register.

- Write 43h, 4Fh, 44h, 45h to 8-bit register CTRLGATE one-byte by one-byte sequentially to access.
- Write any 8-bit data to register CTRLGATE to exit active mode of the CTRL register.
- Write any data to register CTRLGATE also reset LOCK register (93h) to default value.

## Register default data

NEX1316X-Q100 has three types of registers. The register IP name BRT with address between 00h to 17h, 20h to 37h and 40h to 44h, have the same set of MTP. These registers reset to 00h from POR or setting 1 to REGDEFAULT, and they load the code from the corresponding MTP value by the following operations:

- NEX1316X-Q100 enters Fail-Safe state by watchdog timer overflow.
- Writing FORCEFS to 1 to force NEX1316X-Q100 into Fail-Safe state.
- Writing MTPLOAD to 1 to load all corresponding MTP content.
- Writing MTPMODE to 1 to enter MTP program state.

The register IP name IOUT and CONF with address between 50h to approximately 67h and 70h to approximately 87h, have the same set of MTP. These registers always load MTP value through following operations:

- NEX1316X-Q100 starts from POR.
- NEX1316X-Q100 restarts from Vbat or LDO UVLO triggered.
- NEX1316X-Q100 enters Fail-Safe state by watchdog timer overflow.
- Writing FORCEFS to 1 to force NEX1316X-Q100 into Fail-Safe state.
- Writing MTPLOAD to 1 to load all corresponding MTP content.
- Writing REGDEFAULT to 1 to reset all registers to default code.

- Writing MTPMODE to 1 to enter MTP program state.

The register IP name CTRL and FLAG with address between 90h to 98h and A0h to approximately AFh have no corresponding MTP cells. These registers always set to manufacture default value by following operation:

- NEX1316X-Q100 starts from POR.
- NEX1316X-Q100 restarts from Vbat or LDO UVLO triggered.

**Table 30. Registers default value table**

Register IP name	Register address	POR default and soft reset	REG Default	EEPLOAD	Fail-Safe state	EEPMODE
BRT (PWMMx)	00h to 17h	00h	00h	Load EEPROM	Load EEPROM	Load EEPROM
BRT (PWMLx)	20h to 37h	00h	00h	Load EEPROM	Load EEPROM	Load EEPROM
BRT	40h to 44h	00h	00h	Load EEPROM	Load EEPROM	Load EEPROM
IOUT	50 to 67h	Load EEPROM	Load EEPROM	Load EEPROM	Load EEPROM	Load EEPROM
CONF_FD	6Ah to 6Ch	Load EEPROM	Load EEPROM	Load EEPROM	Load EEPROM	Load EEPROM
CONF	70h to 87h	Load EEPROM	Load EEPROM	Load EEPROM	Load EEPROM	Load EEPROM
CTRL	90h to 98h	default	no action	no action	only reset 93h to 03h, no action on other registers	set 93h to 00h
FLAG	A0 to AFh	default / Manufacture	only clear FLAG_POR to 00h no action on other registers	no action	no action	no action
FLAG_FD	B1h to B3h	default / manufacture	only clear FLAG_POR to 00h no action on other registers	no action	no action	no action

### 15.4.5.2. MTP Programming

NEX1316X-Q100 has a user-programmable MTP with high reliability for automotive applications. All the MTP registers can be burnt through writing the target data into its corresponding register. NEX1316X-Q100 supports two solutions for individual chip selection through pulling the REF pin high or through device address configuration by address pin.

#### Chip selection by pulling REF pin high

NEX1316X-Q100 supports using REF pin as chip-select during MTP programming. Considering multiple NEX1316X-Q100 devices connected on one UART bus before burning MTP, the slave address for all NEX1316X-Q100 is all same before programming in case internal MTP register DEVADDR is used for slave address setup.

The MTP burning instruction can be sent to target NEX1316X-Q100 by pulling the REF pin of the target NEX1316X-Q100 to 5 V. After the REF pin is pulled up to 5 V, NEX1316X-Q100 ignores the device address setup by ADDR2/ADDR1/ADDR0 pins or MTP programmed device address in DEVADDR.

The master controller must send out data to target NEX1316X-Q100 with device address as 0h and not in broadcast mode.

#### Chip selection by ADDR pins configuration

NEX1316X-Q100 also supports using configuration on ADDR2/ADDR1/ADDR0 pins to determine the slave address for NEX1316X-Q100 if multiple NEX1316X-Q100 devices are connected on the same differential data bus.

Nexperia recommends using this approach for applications of multiple NEX1316X-Q100 in the same differential data bus. The master controller can send out register data to target NEX1316X-Q100 with device address matched to the ADDR2/ADDR1/ADDR0 pins configuration and not in broadcast mode.

### MTP register access and burn

After selecting the target NEX1316X-Q100 for MTP burning, the master controller must send a serial of data bytes to register MTPGATE, set 1 to MTPMODE one by one in below sequence to finally enable the MTP register access. Each data written must be a single-byte operation instead of burst-mode operation. For detailed program sequence, refer to NEX1316X-Q100 configuration guide and [Section 15.5](#).

### MTP program state exit

The REF pin can be released after MTP burning if it is pulled high to 5 V for chip selection. The REF pin must be kept high during all MTP program state. NEX1316X-Q100 can quit the MTP program state to normal state after burning by writing 0 to register MTPMODE. Nexperia recommends reloading the MTP data to the registers after MTP burning by setting 1 to REGDEFAULT.

## 15.5. Register map

Table 31. Register map

ADDR	Name	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0	Default	EEPROM default
00h	PWMMMA0				PWMOUTA0					00h	FFh
01h	PWMMMA1				PWMOUTA1					00h	FFh
02h	PWMMB0				PWMOUTB0					00h	FFh
03h	PWMMB1				PWMOUTB2					00h	FFh
04h	PWMMC0				PWMOUTC0					00h	FFh
05h	PWMMC1				PWMOUTC1					00h	FFh
06h	PWMMD0				PWMOUTD0					00h	FFh
07h	PWMMD1				PWMOUTD1					00h	FFh
08h	PWMME0				PWMOUTE0					00h	FFh
09h	PWMME1				PWMOUTE1					00h	FFh
0Ah	PWMMF0				PWMOUTF0					00h	FFh
0Bh	PWMMF1				PWMOUTF1					00h	FFh
0Ch	PWMMG0				PWMOUTG0					00h	FFh
0Dh	PWMMG1				PWMOUTG1					00h	FFh
0Eh	PWMMH0				PWMOUTH0					00h	FFh
0Fh	PWMMH1				PWMOUTH1					00h	FFh
10h	PWMMR0				<b>RESERVED</b>					00h	FFh
11h	PWMMR1				<b>RESERVED</b>					00h	FFh
12h	PWMMR2				<b>RESERVED</b>					00h	FFh
13h	PWMMR3				<b>RESERVED</b>					00h	FFh
14h	PWMMR4				<b>RESERVED</b>					00h	FFh
15h	PWMMR5				<b>RESERVED</b>					00h	FFh
16h	PWMMR6				<b>RESERVED</b>					00h	FFh
17h	PWMMR7				<b>RESERVED</b>					00h	FFh

ADDR	Name	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0	Default	EEPROM default
20h	PWMLA0	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTA0				00h	0Fh
21h	PWMLA1	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTA1				00h	0Fh
22h	PWMLB0	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTB0				00h	0Fh
23h	PWMLB1	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTB1				00h	0Fh
24h	PWMLC0	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTC0				00h	0Fh
25h	PWMLC1	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTC1				00h	0Fh
26h	PWMLD0	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTD0				00h	0Fh
27h	PWMLD1	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTD1				00h	0Fh
28h	PWMLE0	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTE0				00h	0Fh
29h	PWMLE1	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTE1				00h	0Fh
2Ah	PWMLF0	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTF0				00h	0Fh
2Bh	PWMLF1	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTF1				00h	0Fh
2Ch	PWMLG0	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTG0				00h	0Fh
2Dh	PWMLG1	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTG1				00h	0Fh
2Eh	PWMLH0	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTH0				00h	0Fh
2Fh	PWMLH1	RESERVED	RESERVED	RESERVED	RESERVED	PWMLOWOUTH1				00h	0Fh
30h	PWMLR0	RESERVED								00h	0Fh
31h	PWMLR1	RESERVED								00h	0Fh
32h	PWMLR2	RESERVED								00h	0Fh
33h	PWMLR3	RESERVED								00h	0Fh
34h	PWMLR4	RESERVED								00h	0Fh
35h	PWMLR5	RESERVED								00h	0Fh
36h	PWMLR6	RESERVED								00h	0Fh
37h	PWMLR7	RESERVED								00h	0Fh
40h	OUTEN0	RESERVED	RESERVED	ENOUTB1	ENOUTB0	RESERVED	RESERVED	ENOUTA1	ENOUTA0	00h	33h
41h	OUTEN1	RESERVED	RESERVED	ENOUTD1	ENOUTD0	RESERVED	RESERVED	ENOUTC1	ENOUTC0	00h	33h
42h	OUTEN2	RESERVED	RESERVED	ENOUTF1	ENOUTF0	RESERVED	RESERVED	ENOUTE1	ENOUTE0	00h	33h

ADDR	Name	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0	Default	EEPROM default
43h	OUTEN3	RESERVED	RESERVED	ENOUTH1	ENOUTH0	RESERVED	RESERVED	ENOUTG1	ENOUTG0	00h	33h
44h	PWMSHARE	RESERVED	RESERVED	RESERVED	RESERVED	SHAREPWM				00h	00h
50h	IOUTA0	RESERVED	RESERVED				IOUTA0			EEPROM	3Fh
51h	IOUTA1	RESERVED	RESERVED				IOUTA1			EEPROM	3Fh
52h	IOUTB0	RESERVED	RESERVED				IOUTB0			EEPROM	3Fh
53h	IOUTB1	RESERVED	RESERVED				IOUTB1			EEPROM	3Fh
54h	IOUTC0	RESERVED	RESERVED				IOUTC0			EEPROM	3Fh
55h	IOUTC1	RESERVED	RESERVED				IOUTC1			EEPROM	3Fh
56h	IOUTD0	RESERVED	RESERVED				IOUTD0			EEPROM	3Fh
57h	IOUTD1	RESERVED	RESERVED				IOUTD1			EEPROM	3Fh
58h	IOUTE0	RESERVED	RESERVED				IOUTE0			EEPROM	3Fh
59h	IOUTE1	RESERVED	RESERVED				IOUTE1			EEPROM	3Fh
5Ah	IOUTF0	RESERVED	RESERVED				IOUTF0			EEPROM	3Fh
5Bh	IOUTF1	RESERVED	RESERVED				IOUTF1			EEPROM	3Fh
5Ch	IOUTG0	RESERVED	RESERVED				IOUTG0			EEPROM	3Fh
5Dh	IOUTG1	RESERVED	RESERVED				IOUTG1			EEPROM	3Fh
5Eh	IOUTH0	RESERVED	RESERVED				IOUTH0			EEPROM	3Fh
5Fh	IOUTH1	RESERVED	RESERVED				IOUTH1			EEPROM	3Fh
60h	IOUR0	RESERVED								EEPROM	3Fh
61h	IOUR1	RESERVED								EEPROM	3Fh
62h	IOUR2	RESERVED								EEPROM	3Fh
63h	IOUR3	RESERVED								EEPROM	3Fh
64h	IOUR4	RESERVED								EEPROM	3Fh
65h	IOUR5	RESERVED								EEPROM	3Fh
66h	IOUR6	RESERVED								EEPROM	3Fh
67h	IOUR7	RESERVED								EEPROM	3Fh
6Ah	LOWBAT	RESERVED	LOWVBATTH[6:0]							EEPROM	00h

ADDR	Name	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0	Default	EEPROM default	
6Bh	CONF_FD1	AUTOSS	LOWVBAT_FD	OPENTH	DISRETRY	PS0[1:0]		OFFDelay	OFFOUT_FD	EEPROM	00h	
6Ch	CONF_FD2	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	EEPROM	00h	
70h	DIAGEN0	RESERVED	RESERVED	DIAGEN_OUTB1	DIAGEN_OUTB0	RESERVED	RESERVED	DIAGEN_OUTA1	DIAGEN_OUTA0	EEPROM	33h	
71h	DIAGEN1	RESERVED	RESERVED	DIAGEN_OUTD1	DIAGEN_OUTD0	RESERVED	RESERVED	DIAGEN_OUTC1	DIAGEN_OUTC0	EEPROM	33h	
72h	DIAGEN2	RESERVED	RESERVED	DIAGEN_OUTF1	DIAGEN_OUTF0	RESERVED	RESERVED	DIAGEN_OUTE1	DIAGEN_OUTE0	EEPROM	33h	
73h	DIAGEN3	RESERVED	RESERVED	DIAGEN_OUTH1	DIAGEN_OUTH0	RESERVED	RESERVED	DIAGEN_OUTG1	DIAGEN_OUTG0	EEPROM	33h	
74h	SLSTHSEL0	RESERVED	RESERVED	SLSTHOUTB1	SLSTHOUTB0	RESERVED	RESERVED	SLSTHOUTA1	SLSTHOUTA0	EEPROM	00h	
75h	SLSTHSEL1	RESERVED	RESERVED	SLSTHOUTD1	SLSTHOUTD0	RESERVED	RESERVED	SLSTHOUTC1	SLSTHOUTC0	EEPROM	00h	
76h	SLSTHSEL2	RESERVED	RESERVED	SLSTHOUTF1	SLSTHOUTF0	RESERVED	RESERVED	SLSTHOUTE1	SLSTHOUTE0	EEPROM	00h	
77h	SLSTHSEL3	RESERVED	RESERVED	SLSTHOUTH1	SLSTHOUTH0	RESERVED	RESERVED	SLSTHOUTG1	SLSTHOUTG0	EEPROM	00h	
78h	SLSDAC0	RESERVED	SLSTH0							EEPROM	00h	
79h	SLSDAC1	RESERVED	SLSTH1							EEPROM	00h	
7Ah	REFERENCE	SLSEN	REFRANGE			LOWVSTH				EEPROM	60h	
7Bh	DIAG	IRETRY					BLANK				EEPROM	00h
7Ch	DIAGMASK	MASKLOWSUP	MASKVSUV	MASKREF	MASKPRETSD	MASKTSD	MASKMTPCRC	RESERVED	RESERVED	EEPROM	00h	
7Dh	OUTMASK	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	MASKOPEN	MASKSHORT	MASKSLS	EEPROM	00h	
7Eh	DIM	EXPEN	PSEN	12BIT	PSMEN	PWMFREQ				EEPROM	30h	
80h	FSMAP0	RESERVED	RESERVED	FSOUTB1	FSOUTB0	RESERVED	RESERVED	FSOUTA1	FSOUTA0	EEPROM	00h	
81h	FSMAP1	RESERVED	RESERVED	FSOUTD1	FSOUTD0	RESERVED	RESERVED	FSOUTC1	FSOUTC0	EEPROM	00h	
82h	FSMAP2	RESERVED	RESERVED	FSOUTF1	FSOUTF0	RESERVED	RESERVED	FSOUTE1	FSOUTE0	EEPROM	00h	
83h	FSMAP3	RESERVED	RESERVED	FSOUTH1	FSOUTH0	RESERVED	RESERVED	FSOUTG1	FSOUTG0	EEPROM	00h	
84h	FLEXWIRE0	WDTIMER					DBWTIMER			ACKEN	EEPROM	01h
85h	FLEXWIRE1	RESERVED	RESERVED	DEVADDR [4]	EXTADDR	DEVADDR				EEPROM	10h	
86h	FLEXWIRE2	RESERVED	RESERVED	RESERVED	OFAF	INITTIMER				EEPROM	10h	

ADDR	Name	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0	Default	EEPROM default
87h	CRC	MTPCRC								EEPROM	B0h[1]

ADDR	Name	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0	Default	
90h	ADCCH	RESERVED	RESERVED	RESERVED	ADCCHSEL						00h
91h	CLR	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	CLRFS	CLRFALT	CLRPOR	00h	
92h	DEBUG	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	FORCEFS	FORCEERR	00h	
93h	LOCK	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	BRTLOCK	CONFLOCK	IOUTLOCK	03h	
94h	CLRREG	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	SOFTRESET	EEPLOAD	REGDEFAULT	00h	
95h	CTRL-R	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	00h	
96h	CTRLGATE	CTRLGATE								00h	
97h	EEP	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	EEPProg	EEPMode	00h	
98h	EEPGATE	EEPGATE								00h	
A0h	FLAG_ERR	FLAG_LOWSUP	FLAG_VSUUV	FLAG_REF	FLAG_PRETSD	FLAG_TSD	FLAG_EEPCRC	FLAG_OUT	FLAG_ERR	01h	
A1h	FLAG_STATUS	RESERVED	FLAG_EXTFS1	FLAG_EXTFS0	FLAG_PROGDONE	FLAG_FS	FLAG_ADCDONE	FLAG_ADCERR	FLAG_POR	01h	
A2h	FLAG_ADC	ADC_OUT								00h	
A3h	FLAG_SLS0	RESERVED	RESERVED	FLAG_SLSOUTB1	FLAG_SLSOUTB0	RESERVED	RESERVED	FLAG_SLSOUTA1	FLAG_SLSOUTA0	00h	
A4h	FLAG_SLS1	RESERVED	RESERVED	FLAG_SLSOUTD1	FLAG_SLSOUTD0	RESERVED	RESERVED	FLAG_SLSOUTC1	FLAG_SLSOUTC0	00h	
A5h	FLAG_SLS2	RESERVED	RESERVED	FLAG_SLSOUTF1	FLAG_SLSOUTF0	RESERVED	RESERVED	FLAG_SLSOUTE1	FLAG_SLSOUTE0	00h	
A6h	FLAG_SLS3	RESERVED	RESERVED	FLAG_SLSOUTH1	FLAG_SLSOUTH0	RESERVED	RESERVED	FLAG_SLSOUTG1	FLAG_SLSOUTG0	00h	
A7h	FLAG_OPEN0	RESERVED	RESERVED	FLAG_OPENOUTB1	FLAG_OPENOUTB0	RESERVED	RESERVED	FLAG_OPENOUTA1	FLAG_OPENOUTA0	00h	
A8h	FLAG_OPEN1	RESERVED	RESERVED	FLAG_OPENOUTD1	FLAG_OPENOUTD0	RESERVED	RESERVED	FLAG_OPENOUTC1	FLAG_OPENOUTC0	00h	
A9h	FLAG_OPEN2	RESERVED	RESERVED	FLAG_OPENOUTF1	FLAG_OPENOUTF0	RESERVED	RESERVED	FLAG_OPENOUTE1	FLAG_OPENOUTE0	00h	
AAh	FLAG_OPEN3	RESERVED	RESERVED	FLAG_OPENOUTH1	FLAG_OPENOUTH0	RESERVED	RESERVED	FLAG_OPENOUTG1	FLAG_OPENOUTG0	00h	
ABh	FLAG_SHORT0	RESERVED	RESERVED	FLAG_SHORTOUTB1	FLAG_SHORTOUTB0	RESERVED	RESERVED	FLAG_SHORTOUTA1	FLAG_SHORTOUTA0	00h	
ACH	FLAG_SHORT1	RESERVED	RESERVED	FLAG_SHORTOUTD1	FLAG_SHORTOUTD0	RESERVED	RESERVED	FLAG_SHORTOUTC1	FLAG_SHORTOUTC0	00h	
ADh	FLAG_SHORT2	RESERVED	RESERVED	FLAG_SHORTOUTF1	FLAG_SHORTOUTF0	RESERVED	RESERVED	FLAG_SHORTOUTE1	FLAG_SHORTOUTE0	00h	
Aeh	FLAG_SHORT3	RESERVED	RESERVED	FLAG_SHORTOUTH1	FLAG_SHORTOUTH0	RESERVED	RESERVED	FLAG_SHORTOUTG1	FLAG_SHORTOUTG0	00h	

ADDR	Name	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0	Default
AFh	FLAG_EEPCRC	CALC_EEPCRC								00h
B0h	FLAG_CONFCRC	CALC_CONFCRC								00h
B1h	FLAG_FD	RESERVED	RESERVED	RESERVED	FLAG_LOWVBAT	FLAG_ECC	FLAG_CMP	FLAG_OFFOUT	FLAG_LDOOV	00h
B2h	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	RESERVED	00h
B3h	ADC_IREF	ADC_IREF								00h

[1] Factory default value; subsequent calculations follow the MTPCRC formula.

### 16. Package outline

plastic, thermal enhanced thin shrink small outline package;  
38 leads; 0.5mm pitch; 9.7mm × 4.4mm × 1.2mm body

SOT8106-1

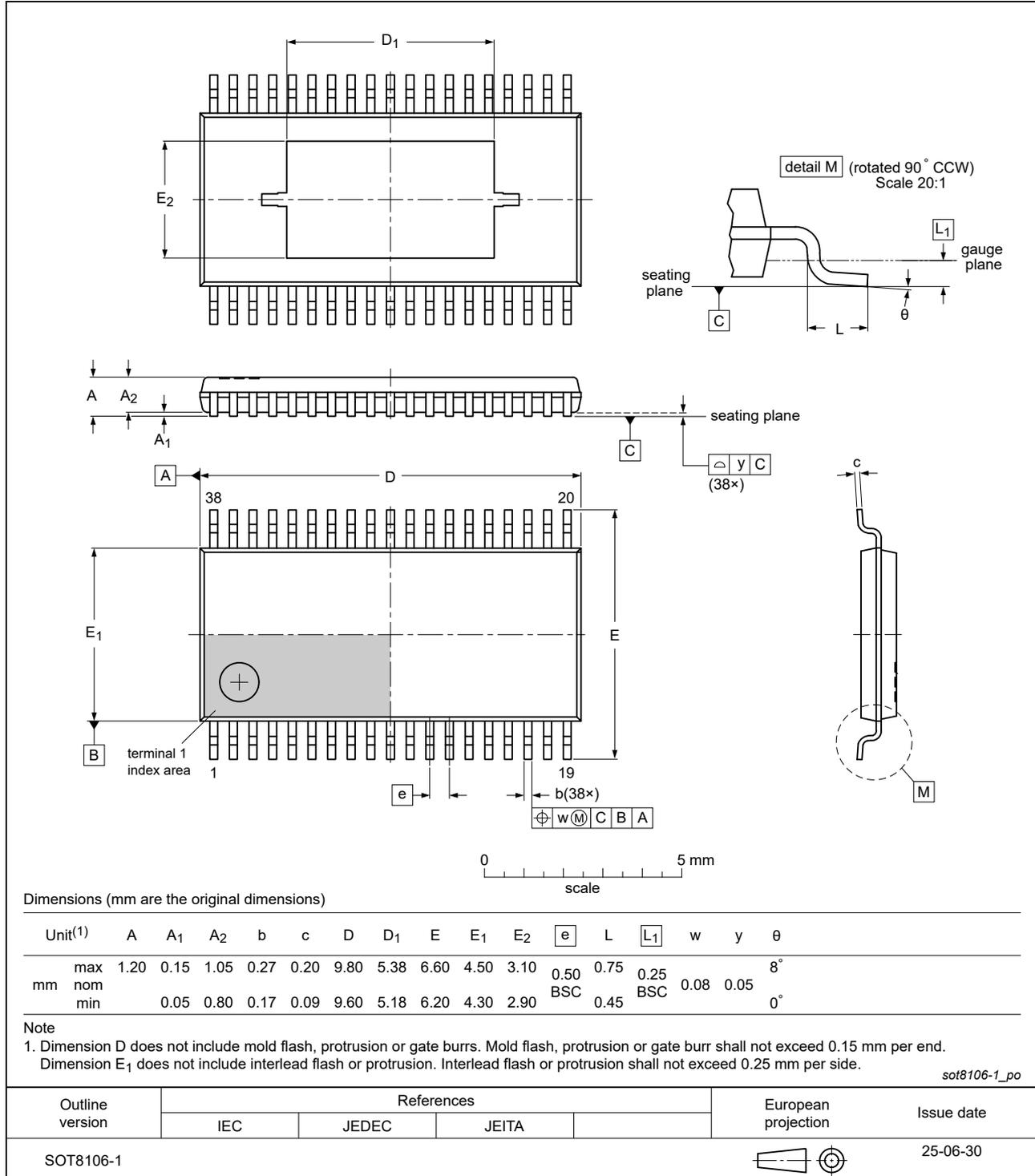


Fig. 44. Package outline SOT8106-1 (HTSSOP38)

## 17. Abbreviations

Table 32. Abbreviations

Acronym	Description
ADC	Analog-to-Digital Converter
AEC	Automotive Electronics Council
ANSI	American National Standards Institute
ASIL	Automotive Safety Integrity Levels
BCM	Body Control Module
CAN	Controller Area Network
CDM	Charged Device Model
CRC	Cyclic Redundancy Check
DC	Dot Correction
ECC	Error Correction Code
ESD	ElectroStatic Discharge
ESDA	ElectroStatic Discharge Association
FS	Fail-Safe
HBM	Human Body Model
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
JEDEC	Joint Electron Device Engineering Council
LED	Light Emitting Diode
MTP	Multi-Time Programming
PCB	Printed Circuit Board
POR	Power-On-Reset
PWM	Pulse-Width Modulation
UART	Universal Asynchronous Receiver/Transmitter
UVLO	Undervoltage Lockout

## 18. Revision history

Table 33. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
NEX1316X_Q100 v.1.2	20251023	Product data sheet	-	NEX1316X_Q100 v.1.1
Modifications:	<ul style="list-style-type: none"> <li>• <a href="#">Section 2</a> and <a href="#">Table 9</a> updated.</li> </ul>			
NEX1316X_Q100 v.1.1	20250929	Product data sheet	-	NEX1316X_Q100 v.1
Modifications:	<ul style="list-style-type: none"> <li>• The document status changed from Preliminary to Product.</li> <li>• <a href="#">Section 14</a> added.</li> <li>• <a href="#">Section 2</a> and <a href="#">Table 7</a> updated.</li> </ul>			
NEX1316X_Q100 v.1	20250825	Preliminary data sheet	-	-

## 19. Legal information

### Data sheet status

Document status [1][2]	Product status [3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

- [1] Please consult the most recently issued document before initiating or completing a design.
- [2] The term 'short data sheet' is explained in section "Definitions".
- [3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the internet at <https://www.nexperia.com>.

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