MLX80124

Code-free LIN RGB ambient light controller – MLX80124KDC-AAC-000-RE

Datasheet

1. Features

Main configurable features

- Control of RGB LED
- Configurable LED channel assignment
- Configurable LED current per LED color channel (5-60mA, 5mA step size)
- ~500Hz PWM frequency
- 16-bit PWM resolution
- Staggered PWM
- Local intensity multiplier
- Configurable filter for LED temperature measurements
- Melexis color control
- Conversion from RGBI values (input from LIN) to 16-Bit PWM duty cycles
- Color/Intensity fading
- LED temperature compensation
- Configurable LED calibration data
- LED temperature derating
- LED Calibration Mode
- ADC measurement (VS, IC temperature, LED forward voltage, internal voltages)
- Low standby current consumption of typ. 25 µA in sleep mode
- Integrated battery monitor including over and under-voltage detection

LIN Features

- LIN physical Layer compliant to ISO17987-4
- LIN Protocol controller compliant to ISO17987-6
- Support for auto-addressing according to bus shunt method

Diagnostic Features

- Under/over-voltage detection of VS
- Under/over-temperature detection of IC and LED
- Open/Short detection of LED channels

Automotive Standard

- Developed following ISO26262 supporting safety related system implementations up to ASIL-B
    - Integrated monitors to support functional safety applications
- AECQ-100 qualified
- Automotive temperature range of -40 °C to 150 °C
- 28 V jump start compliant
- SOIC-8 (DC) RoHS-compliant package with exposed pad

2. Applications

- Connected interior light
- Ambient light applications

3. Abbreviations

AA	Auto-Addressing
AC	Alternating Current
ADC	Analog Digital converter
AEC	Automotive Electronics Council
ANSI	American National Standards Institute
ASIL	Automotive Safety Integrity Level
BSM	Bus Shunt Method
CC	Current Controlled
CRC	Cyclic Redundancy Code
DC	Direct Current
DMA	Direct Memory Access
ECC	Error Correction Code
ECU	Electronic Control Unit (with µ-Controller/µ-Processor)
EMC	Electromagnetic Compatibility
ESD	Electrostatic discharge
ESDA	Electrostatic Discharge Association
GND	Ground, reference point in an electrical circuit
GPIO	General Purpose In-/Output
HPOR	Power-on reset for normal supply voltage range
HV	High Voltage Pin
IC	Integrated Circuit
ID	Identifier
IO	Input Output
IP	Intellectual Property
ISO	International Organization for Standardization
IUM	Internal user memory
JA	Junction to Ambient
JC	Junction to Case
JEDEC	Joint Electron Device Engineering Council
LIN	Local Interconnect Network
LSB	Least Significant Bit
LED	Light-Emitting Diode
LPOR	Power-on reset for low supply voltage range
MRB	Master Reset Block
MSB	Most Significant Bit
NB	Narrow Body
PHY	Physical Layer
POR	Power-On Reset
PWM	Pulse Width Modulator
RC	Resistor-Capacitor
REF	Reference Voltage
RGB	Red-Green-Blue color model
RxD	Receive Data Signal
SAE	Society of Automotive Engineers
SMD	Surface Mount Device
SNPD	Responder Node Position Detection
SOIC	Small Outline Integrated Circuit (IC package type)
SW	Switch
TBD	To Be Defined
TJ	Junction temperature
TxD	Transmit Data Signal
UV	Under Voltage
VBG	Bandgap Voltage

4. Contents

5. References

Following documents are referred to in this document:

This documentation as well as application notes, SW tools, libraries and descriptions is not scope of this specification and can be found under http://softdist.melexis.com/.
Please contact your Melexis Sales channel for getting access.

[1] ISO 17987:2016 Road vehicles – Local Interconnect Network (LIN)
[2] Melexis guidelines for IC handling and assembly https://www.melexis.com/en/tech-info/ic-handling-and-assembly
[3] Automotive Electronics Council, “Stress test qualification standard AEC-Q100,” rev. F2, 2003-07-18.
[4] LIN consortium, “LIN Slave Node Position Detection Implementation Note” rev. 1.0, 2008
[5] Melexis Application note, LIN-AA according Bus Shunt Method (BSM) Slave Node Position Detection (SNPD)

The descriptions in this document overrule the descriptions in the referred documents.

6. Ordering Information

Order Code	Temperature Range	Package	Option 1	Option 2	Packing Form
MLX80124KDC-XYZ-123-RE	K	DC	AAC	000	RE

Legend:

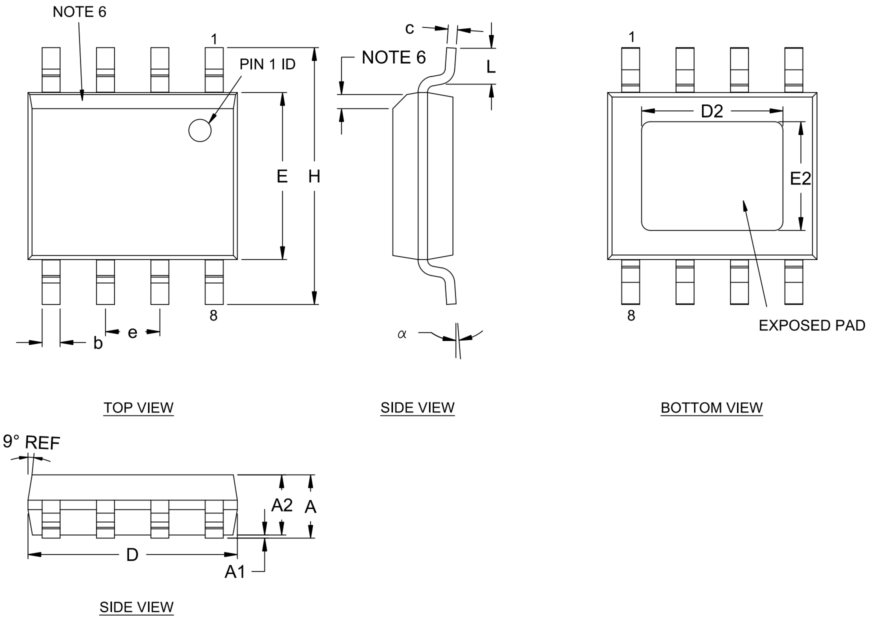
Temperature Code:	K: from -40°C to 125°C
Package Code:	DC = SOIC package
Option Code:	XYZ-123 XYZ: Design Revision XYZ 123: Melexis Reserved
Packing Form:	RE = Reel
Ordering Example:	MLX80124KDC-AAC-000-RE

7. Technical description

The chip will be assembled in a SOIC8 with exposed pad.

A guideline for landing pattern can be found in [2].

7.1. Package data SOIC8 with exposed pad



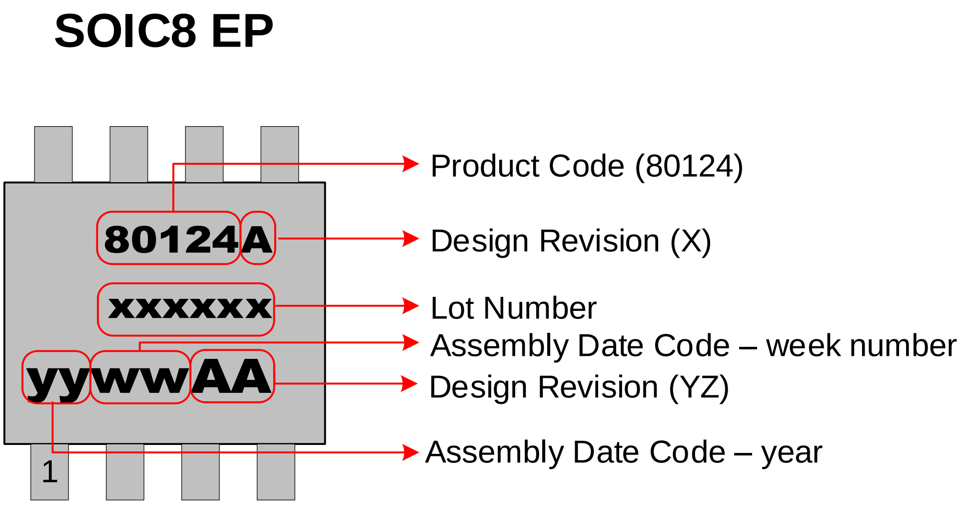
SYMBOL	MINIMUM	NOMINAL	MAXIMUM
A	1.40	---	1.68
A1	0.00	---	0.13
A2	1.37	---	1.58
D	4.80	4.90	5.00
E	3.81	3.90	3.99
D2	3.00	3.30	3.55
E2	2.29	2.50	2.79
H	5.80	6.00	6.20
L	0.41	---	1.27
b	0.36	0.41	0.46
c	0.19	---	0.25
e	1.27 BSC		
α	0°	---	8°

NOTE :

1. ALL DIMENSIONS IN MILLIMETERS (mm) UNLESS OTHERWISE STATED.
2. DIMENSION D DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS OF MAX 0.15 mm PER SIDE.
3. DIMENSION E DOES NOT INCLUDE INTERLEADS FLASH OR PROTRUSIONS OF MAX 0.25 mm PER SIDE.
4. DIMENSION b DOES NOT INCLUDE DAMBAR PROTRUSION OF MAX 0.10 mm.
5. LEAD TO LEAD COPLANARITY MAX 0.100 mm.
6. MOLD CHAMFER ANGLE CAN DIFFER. DEPENDING ON MOLD TOOLING IT IS POSSIBLE TO HAVE NO CHAMFER OR A 45 DEGREE CHAMFER WITH TYPICAL WIDTH OF 0.33 mm. CONTACT MELEXIS IN CASE OF QUESTIONS.
7. DAMBAR CUT PORTION AT THE LEAD SHOULDER CAN HAVE TRACES OF EXPOSED COPPER. CONTACT MELEXIS IN CASE OF QUESTIONS.

Figure 1 – Package Drawing SOIC8 with exposed pad

7.2. IC Marking



7.3. Package View

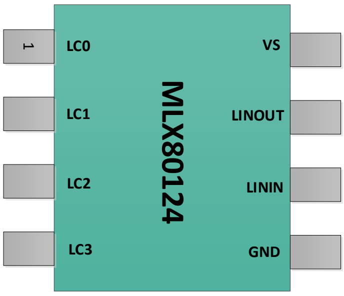


Figure 2 – Pinout SOIC8

7.4. Pin out description

Pin No. SOIC8	Pin name	Type	Remarks and description
1	LC0	Output	low side current source output up to 60mA / Melexis Test Interface (Full duplex Mode)
2	LC1	Output	low side current source output up to 60mA
3	LC2	Output	low side current source output up to 60mA
4	LC3	Output	low side current source output up to 60mA
5	GND	Ground	ground, internal star connection of power/digital/analog grounds
6	LININ	BiDi	LIN physical interface
7	LINOUT	BiDi	LIN auto addressing shunt connection
8	VS	Supply Input	high voltage supply input
	EXP	Exposed pad	Must be connected to GND[1]

Table 1 – Pin description for MLX80124

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[1] *To achieve suitable in application thermal performance it is necessary to connect the exposed pad of the package to a sizable copper plane acting as a heatsink. The heatsink and exposed pad must be connected to GND.*

7.5. Electrical characteristics

7.5.1. Absolute maximum ratings

All voltages are referenced to ground (GND). Positive currents flow into the IC. The absolute maximum ratings given in the table below are limiting values that do not lead to a permanent damage of the device but exceeding any of these limits may do so. Long term exposure to limiting values may affect the reliability of the device. Reliable operation of the IC is only specified within the limits shown in “Operating conditions”.

The application circuitry and components values used for evaluating the maximum ratings can be found in chapter 15.5.

Parameter	Symbol	Condition	Limit Min	Limit Max	Unit
Input Supply voltage	VS_non_op	ISO17987-4, device passive	-0.3	+40	V
LIN DC voltage vs. GND	VLIN		-40	+40	V
DC Voltage on LC IOs	V_LC		-0.3	+40	V
Maximum latch–up free current at any pin	ILATCH	according to JEDEC JESD78, AEC-Q100-004	-500	+500	mA
ESD immunity at VS versus GND	ESDHBM_VS	Human Body Model [1]	-6	+6	kV
ESD at LIN versus GND	ESDHBM_LIN	Human Body Model [1]	-8	+8	kV
ESD handling capability of any other pin, except VS/LIN	ESDHBM	Human Body Model [1]	-4	+4	kV
ESD capability at any pin	ESDCDM	Charge Device Model [2]	-750	+750	V
Storage temperature	Tstg		-55	150	°C
Junction Temperature	TJ		-40	175	°C
Thermal resistance SOIC8 with exposed pad	Rthjc	Junction Case	7 (typical)		K/W

Table 2 – MLX80124 Absolute maximum ratings

[1] Equivalent to discharging a 100pF capacitor via 1.5kΩ resistor according AEC-Q100-002
[2] ESD is applied according to joint standard ANSI/ESDA/JEDEC JS-002

7.5.2. Operating conditions

Parameter	Symbol	Conditions	Limit Min	Typ	Max	Unit
Supply Voltage Range	VS	nominal battery voltage range according LIN ISO 17987-4 - full analog performance	7		18	V
Supply Voltage Range	VS	extended battery voltage range - full analog performance, LIN communication functional	5.5		28	V
Supply Voltage Range	VS	low battery voltage range ▪ reduced analog and full digital performance, no LIN communication ▪ LCIO minimum drop out voltage VLC can be increased by +200mV	4.5		5.5	V
Supply Voltage Range	VS	no operation, IC is in reset state	0		4.5	V
Junction Temperature	Tj[2]		-40		150	°C

Table 3 – Recommended operation conditions

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[2] *The maximum Tj=150°C is guaranteed by design, characterization and qualification. Not subject to production test.*

7.5.3. Electrical parameter specification

Following characteristics are valid over the full temperature range of Tj = -40°C to +150°C, a supply range of 5.5V ≤ VS ≤ 28V unless otherwise noted.
All voltages refer to ground of IC, which is built by short of all existing ground pins, which were split to meet EMC performance and lowest possible noise influence.

Parameter	Symbol	Conditions	Limits			Unit
			Min	Typ	Max	
Currents no DC loads, all pins are inputs						
Normal operating current[3]	Inom	PWM=32MHz		7.5	9	mA
SLEEP MODE current	Isleep	Chip in SLEEP MODE VS=14V, Tj=35degC	8	13	18	µA
STOP MODE current	Istop	Chip in STOP MODE Tj<125degC	230	365	500	µA
Frequencies						
Tolerance of RC oscillator	frc_32M	fRC=32MHz	-5		+5	%
Short Term stability RC-oscillator[4]			-1		+1	%
Frequency separate 10kHz RC oscillator	frc_10k		5	10	20	kHz
Startup time of the system after Power On	tstartup_POR	Not tested in production; for information only; time until internal dig reset is inactive			300	µs
Tolerance of separate 1MHz RC oscillator	frc_1M		-10		+10	%
Startup time of the system after Release of SLEEP MODE	tstartup_SLEEP	Not tested in production; for information only; time until internal dig reset is inactive			250	µs

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[3] *not measured in production*

[4] *Stability during sending one frame*

Parameter	Symbol	Conditions	Limits Min	 Typ	 Max	Unit
Startup time until main()-loop is reached after Power On					10	ms
VS – Programmable under voltage interrupt parameters						
Undervoltage detection ON	Vuv_lh_VS	PRUV_VS=0	3.5	4	4.5	V
		PRUV_VS=1	4.5	5	5.5	V
		PRUV_VS=2	5.5	6	6.5	V
		PRUV_VS=3	6.5	7	7.5	V
		PRUV_VS=4	7.5	8	8.5	V
		PRUV_VS=5	8.5	9	9.5	V
Hysteresis for undervoltage detection	Vhyst_uv_VS	guaranteed by design	0.1	0.5	1.0	V
Debouncing UV_VS	tuv_VS		1	3	10	µs
VS – Over Voltage (Load dump) interrupt related parameters						
Overvoltage detection ON	Vov_lh_VS	PROV_VS=0	20	22	24	V
		PROV_VS=1	22	24	26	V
		PROV_VS=2	37	40	42	V
Overvoltage detection OFF	Vov_hl_VS	PROV_VS=0	18	20	22	V
		PROV_VS=1	20	22	24	V
		PROV_VS=2	36	38	40	V
Hysteresis for overvoltage detection	Vhyst_ov_VS	guaranteed by design	1	2	3	V
Debouncing OV_VS	tov_VS		1	3	10	µs
ADC (12Bit) related parameters						
Effective number of bits	ADCERR	fully differential mode		10.7		bit
Differential nonlinearity	DNL	differential mode, no production test	-1	0.5	1	LSB12
Integral nonlinearity	INL	differential mode	-3	0.4	3	LSB12 rms

Parameter	Symbol	Conditions	Limits			Unit
			Min	Typ	Max	
Output resolution	RESADC	differential mode	6.0	12.0	13.0	bit
Minimum conversion Time	Tconv	ADC_CLK=16MHz, 14 ADC clocks		780		ns
Reference Voltage	VRH0		1.62	1.65[5]	1.68	V
Input range differential	VIR_D	differential mode	-1.0		1.0	VREF
Input range single ended	VIR_S	single ended mode (VIN - GNDA)	0.0		1.0	VREF
Gain error	G_ERR	Max. deviation at full scale	-0.5		0.5	%FS
ADC input divider			-2		+2	%
Low Side Current Source IOs (LC0 … 3)						
output current	ILC		5		60	mA
output current step size	ILCstep			5		mA
Voltage drop LCIO[6]	VLC_drop	LC_LOW_CUR_EN = 0	1.5	2.0	28.0	V
Voltage drop LCIO[6] in low current mode[6]	VLC_drop_low	LC_LOW_CUR_EN = 1	0.95	2.0	28.0	V
output current relative error	ILCerr1	Tj = 35°C, VS = 6V, VLC = 2V, trimming condition	-3		+3	%
output current absolute accuracy	ILCerr2	Tj = 35°C, VS = 6V, VLC = 2V, ILC=50mA, trimming condition	-1		+1	%
output current relative voltage error	ILCVerr	VLC = VLC_drop, all current steps	-1		+1	%
output current relative temperature error	ILCTerr	VLC = VLC_drop, all current steps	-3		+3	%

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[5] *For replacing the MLX81113 a compatibility mode is implemented. Further information can be found in the Application Note.*

[6] *The minimum drop-out voltage is required for the specified accuracy of the output currents.*
The operation up to Tj=150°C is guaranteed by design & characterization and not tested in production. At this temperature the minimum drop-out voltage can be increased by +200mV.

Parameter	Symbol	Conditions	Limits			Unit
			Min	Typ	Max	
output current in half output current mode	ILC_lowC	LC_LOW_CUR_EN = 1	2.5	15	30	mA
output current step size	ILCstep_lowC	LC_LOW_CUR_EN = 1		2.5		mA
output current relative error	ILCerr_lowC1	Tj = 35°C VS = 6V VLC = 2V trimming condition all current steps except 10mA LC_LOW_CUR_EN = 1	-3		+3	%
output current relative error	ILCerr_lowC2	Tj = 35°C VS = 6V VLC = 2V ILC=10mA trimming condition LC_LOW_CUR_EN = 1	-1		+1	%
output current relative voltage error	ILCVerr_lowC	VLC = VLC_drop_low, all current steps	-1		+1	%
output current relative temperature error	ILCTerr_lowC	VLC = VLC_drop_low, all current steps LC_LOW_CUR_EN = 1	-3		+3	%
pull up resistor vs. VS for leakage compensation	Rpu_VS		65	100	145	kΩ
LC output leakage current[7]	ILCleak	Tj < 135°C, VS = 14V VLC = 0 / 14V LC_DISPU=1 normal & sleep mode	-1		1	uA
configurable LC diagnosis - output current ILCdiag range	ILCdiag	1.5V < VLC <VS, VS > 4.5V	125		1000	uA
LC diagnosis - output current ILCdiag stepsize	ILCdiag_step	1.5V < VLC <VS, VS > 4.5V		125		uA

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[7] *The leakage current can be increased up to 2uA for 135°C < Tj < 150°C*

Parameter	Symbol	Conditions	Limits Min	 Typ	 Max	Unit
LC diagnosis - output current trimm accuracy	ILCdiag_trim	Tj=35°C, VS=6V, VLC=2V trimming condition	-3		+3	%
LC diagnosis – output current relative voltage error	ILCdiagVerr	1.5V < VLC < VS, VS > 4.5V	-1		+1	%
LC diagnosis – output current relative temperature error	ILCdiagTerr	1.5V < VLC < VS, VS > 4.5V	-3		+3	%
Differential Amplifier for RGB diagnosis						
HV differential amplifier - gain0	Gain0	0.1V < Vout < VREF, LCIO selected, MS_SELSC_GAIN=0	0.995	1.0	1.005	
HV differential amplifier - gain1	Gain1	0.1V < Vout < VREF, LCIO selected,MS_SELSC_GAIN=1	0.4975	0.5	0.5025	
HV differential amplifier - gain2	Gain2	0.1V < Vout < VREF, LCIO selected, MS_SELSC_GAIN=2	0.3313	0.333	0.3346	
HV differential amplifier - gain3	Gain3	0.1V < Vout < VREF, LCIO selected, MS_SELSC_GAIN=3	0.126	0.125	0.124	
HV differential amplifier - gain4	Gain4	0.1V < Vout < VREF, LINAA channel selected, MS_SELSC_GAIN=0	19.9	20.0	20.1	
HV differential amplifier - gain5	Gain5	0.1V < Vout < VREF, LINAA channel selected, MS_SELSC_GAIN=1	38.8	40.0	40.2	
HV differential amplifier - gain6	Gain6	0.1V < Vout < VREF, LINAA channel selected, MS_SELSC_GAIN=2		80		
HV differential amplifier - gain7	Gain7	0.1V < Vout < VREF, LINAA channel selected, MS_SELSC_GAIN=3		160		

Parameter	Symbol	Conditions	Limits			Unit
			Min	Typ	Max	
HV differential amplifier - maximum differential input voltage	VHVdiff_in_max	defined by vout/gain, gain = 1/8			13.2	V
HV differential amplifier - minimum differential input voltage	VHVdiff_in_min	defined by vout/gain, gain = 1/8	-13.2			V
HV differential amplifier - differential output voltage	Vout	VOUP-VOUTN	-1.65		1.65	V
HV differential amplifier - output voltage noise	Vout_noise1	Gain=1, Sampled Noise (CDS), referring to 12Bit ADC, VREF=1.65V, 1LSB=0.4mV, RMS value	-1.0		1.0	LSB
HV differential amplifier - output voltage noise	Vout_noise40	Gain=40, Sampled Noise (CDS), referring to 12Bit ADC, VREF=1.65V, 1LSB=0.4mV, RMS value	-40.0		40.0	LSB
HV differential amplifier - settling time	tsettleHVdiff1	configurable via ADC DMA interface, selected	20.0			us
HV differential amplifier - settling time	tsettleHVdiff0	configurable via ADC DMA interface, LCIO[3:0] selected			5.0	us
HV differential amplifier - start up time	tstartHVdiff	power on, change of input channel or VRH value configurable via ADC DMA interface			7.5	us
Temperature Sensor (for ADC measurement)						
Temperature Coefficient	TC_Tj		-2.2	-2	-1.8	mV/K
Accuracy	Tj_acc[8]	For information only	-5.0	0.0	5.0	°C

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[8] *Guaranteed by design & characterization, not tested in production.*

Parameter	Symbol	Conditions	Limits			Unit
			Min	Typ	Max	
Voltage temperature sensor	Vtemp_m40	@ -40°C	0.813	0.82	0.827	V

Table 4 – Electrical parameter specification

LIN related static parameters (according to ISO17987-4, SAE J2602-1)

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Transmitter internal capacitance[1]	CLIN	Response on 14V pulse via 1K		30	40	pF
Bus short circuit current	IBUS_LIM	VLIN = VS =27V	40		200	mA
Pull up resistance bus	RSLAVE	trimmed	27.66	35	40	kΩ
Pull up current bus, sleep mode	ISLAVE_SLEEP	VLIN = 0V, Sleep Mode	-50	-20	-5	µA
Dominant input leakage current including pull up resistor	IBUS_PAS_dom	VLIN = 0V, VS =12V,	-600		-185	µA
Recessive input leakage current	IBUS_PAS_rec	VLIN > VS		7	20	µA
Device Bus Leakage Current Vbatt Disconnected [2]	IBUS_NO_BAT	VS = 0V, 0V < VLIN < 27V		0.25	20	µA
Device Bus Leakage Current Ground Disconnected [2]	IBUS_NO_GND	VS = VGND = 12V, 0 < VLIN < 27V	-100		1	µA
Transmitter dominant output voltage [2]	VolBUS	Rload = 500Ω	0		0.2	VS
Transmitter recessive output voltage [2]	VohBUS	sleep mode	0.8		1	VS
Receiver dominant voltage	VBUSdom				0.4	VS
Receiver recessive voltage	VBUSrec		0.6			VS
Center point of receiver threshold	VBUS_CNT	VBUS_cnt = (Vth_dom+ Vth_rec)/2	0.475	0.5	0.525	VS
Receiver hysteresis	VHYS	VHYS = (Vth_rec – Vth_dom)			0.175	VS

[1] No production test, guaranteed by design and qualification
[2] In accordance to SAE J2602

LIN related dynamic parameters (according to ISO17987-4, SAE J2602-1)

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Propagation delay receiver [1] [2]	trx_pdf	CRxD =25pF falling edge			6	µs
Propagation delay receiver [1] [2]	trx_pdr	CRxD =25pF rising edge			6	µs
Propagation delay receiver symmetry	trx_sym	Calculate trx_pdf - trx_pdr	-2		2	µs
Receiver debounce time	trx_deb	LIN rising & falling edge	0.5		4	µs
LIN duty cycle 1 [2] [3]	D1	20kbps operation, normal mode	0.396			
LIN duty cycle 2 [2] [3]	D2	20kbps operation, normal mode			0.581	
LIN duty cycle 3 [2] [3]	D3	10.4kbs operation, low speed mode	0.417			
LIN duty cycle 4 [2] [3]	D4	10.4kbs operation, low speed mode			0.590	
tREC(MAX) – tDOM(MIN) [4]	Δt3	10.4kbs operation, low speed mode			15.9	µs
tDOM(MAX) – tREC(MIN) [4] [5]	Δt4	10.4kbs operation, low speed mode			17.28	µs
Remote Wake-up filter time	twu_remote	sleep mode, LIN dominant time before rising edge	28		150	µs
Slew rate on pin LIN normal mode, untrimmed		dV/dt between duty cycle measurement points, Vs=12V		1.7		V/ µs
Slew rate on pin LIN low speed mode untrimmed		dV/dt between duty cycle measurement points, Vs=12V		0.85		V/ µs
TxD dominant timeout			10		20	ms
Supported baud rate according ISO17987-4		auto-baud rate detection enabled	9.6		20	kBaud

[1] This parameter is tested by applying a square wave signal to the LIN. The minimum slew rate for the LIN rising and falling edges is 50V/us

[2] See Figure 3 – LIN timing diagram in accordance to ISO17987-4

[3] Standard loads for duty cycle measurements are 1KΩ/1nF, 660Ω/6.8nF, 500Ω/10nF, internal commander termination disabled

[4] See Figure 4 – Timing diagram in accordance to SAE J2602

7.5.3.1. LIN Duty Cycle Calculation

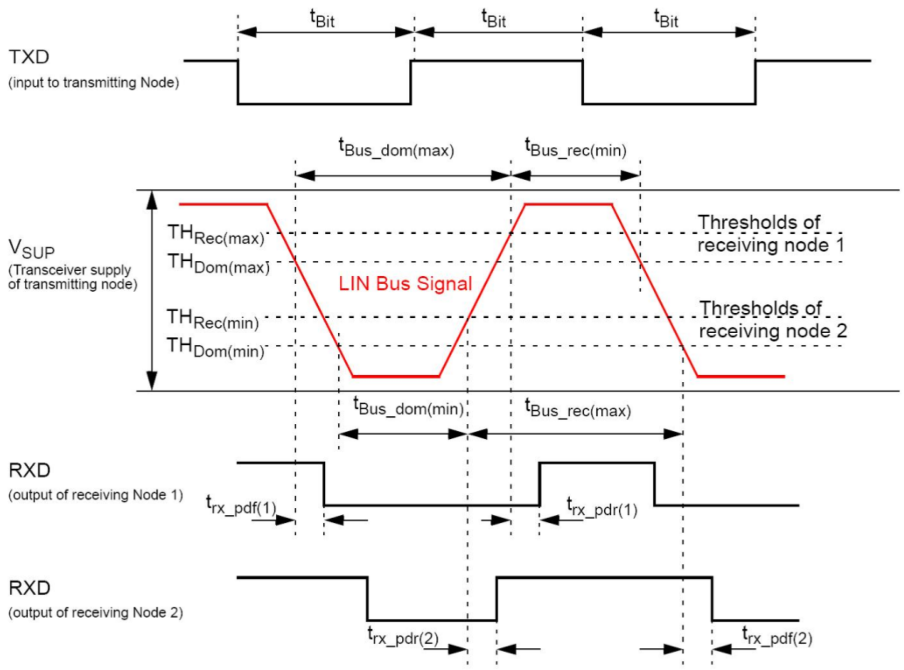

Figure 3 – LIN timing diagram (reference ISO17987-4 specification)

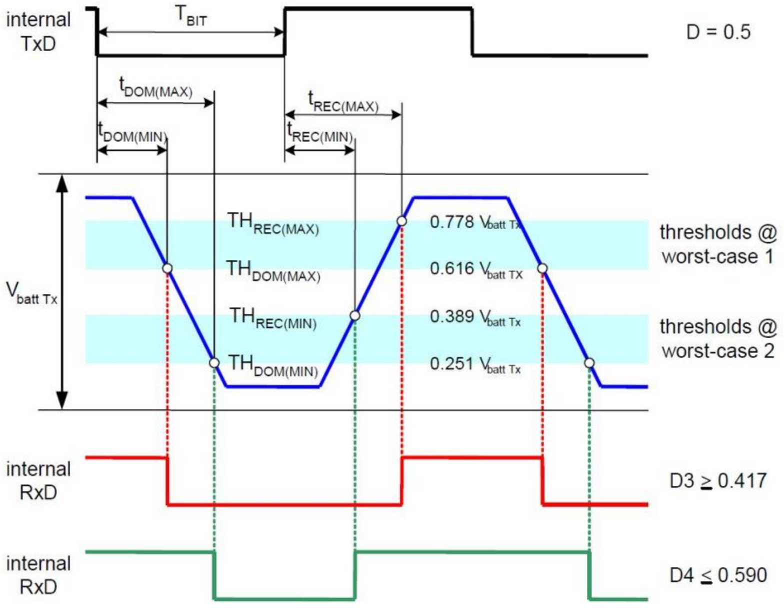

Figure 4 – LIN timing diagram (reference SAE J2602-1 specification)

As shown in Figure 3, both worst case duty cycles and both transmitter propagation delays can be calculated as follows:

$$Dwc1 = tBUS\_rec(min) / (2\ tBit)$$
$$Dwc2 = tBUS\_rec(max) / (2\ tBit)$$

$$\Delta t3 = tBit - tBUS\_rec(min)$$
$$\Delta t4 = tBUS\_rec(max) - tBit$$

In accordance to Figure 4 these parameters are calculated in the following way:

$$Dwc1 = (TBIT - tREC\ (MAX) + tDOM\ (MIN)) / (2\ TBIT)$$
$$Dwc2 = (TBIT - tREC\ (MIN) + tDOM\ (MAX)) / (2\ TBIT)$$

$$\Delta t3 = tREC\ (MAX) - tDOM\ (MIN)$$
$$\Delta t4 = tDOM\ (MAX) - tREC\ (MIN)$$

Thresholds for duty cycle calculation for the plug & play specification in accordance to ISO17987-4 / SAE J2602:

Baud rate	20kBd	10.4kBd
TBIT	50µs	96µs
Dwc1	D1	D3
Dwc2	D2	D4
THREC(MAX)	0.744 × VS_TX	0.778 × VS_TX
THDOM(MAX)	0.581 × VS_TX	0.616 × VS_TX
THREC(MIN)	0.422 × VS_TX	0.389 × VS_TX
THDOM(MIN)	0.284 × VS_TX	0.251 × VS_TX

Table 5 – Data Transmission Rates

Parameter	Symbol	Conditions	Limits			Unit
			Min	Typ	Max	
LIN auto-configuration LININ/LINOUT						
Functional range LIN auto-addressing	VS		9	-	15	V
LIN responder pull up resistance	RLIN,SLAVE		27.66	-	40	kΩ
Bus pull-up source 1 for auto-addressing PRE-Selection Phase (OPTION1)	IPU,AA,PRE,1	VBUS=0V … 2.5V VS > VBUS + 6V	VS,MAX / RLIN, SLAVE, MIN	-	VS,MIN / RLIN, SLAVE, MAX	mA
Bus pull-up source 2 for auto-addressing Selection Phase	IPU,AA,SEL	VBUS=0V … 2.5V VS > VBUS + 6V	2.26	-	1.84	mA
BUS voltage range	VBUS		0	-	2.5	V
PRE-Selection phase current threshold	ITH_PRE				1.2	mA
Selection phase current threshold	ITH_SEL				1.2	mA
LIN shunt resistor	Rshunt (internal)	Tj=35°C	0.61	0.78	0.96	Ω

Table 6 – LIN related parameters

7.5.3.2. Internal supply parameters for diagnosis

The following voltages can be used to diagnose the internal IC status, as they can be measured by the ADC.

The accuracy of the measurement system needs to be considered.

If the values are used for diagnostic decisions a safety margin needs to be taken into account. Please refer to the safety manual for the details.

Voltage	Symbol	Condition	Min	Typ	Max	Unit
Digital supply voltage	VDDD	bandgap and 1.55V regulator trimmed	1.47	1.55	1.63	V
3.6V supply voltage	VDDA	bandgap and VDDA regulator trimmed	3.5	3.6	3.7	V
3.6V flash supply voltage	VDD3V6	bandgap and regulator trimmed	3.5	3.6	3.7	V
Bandgap voltage	VBG	trimmed	1.2	1.23	1.24	V
Auxiliary supply voltage	VAUX		2.0	3.8	5.0	V

Table 7 – Internal supply parameters for diagnosis

8. Block Diagram

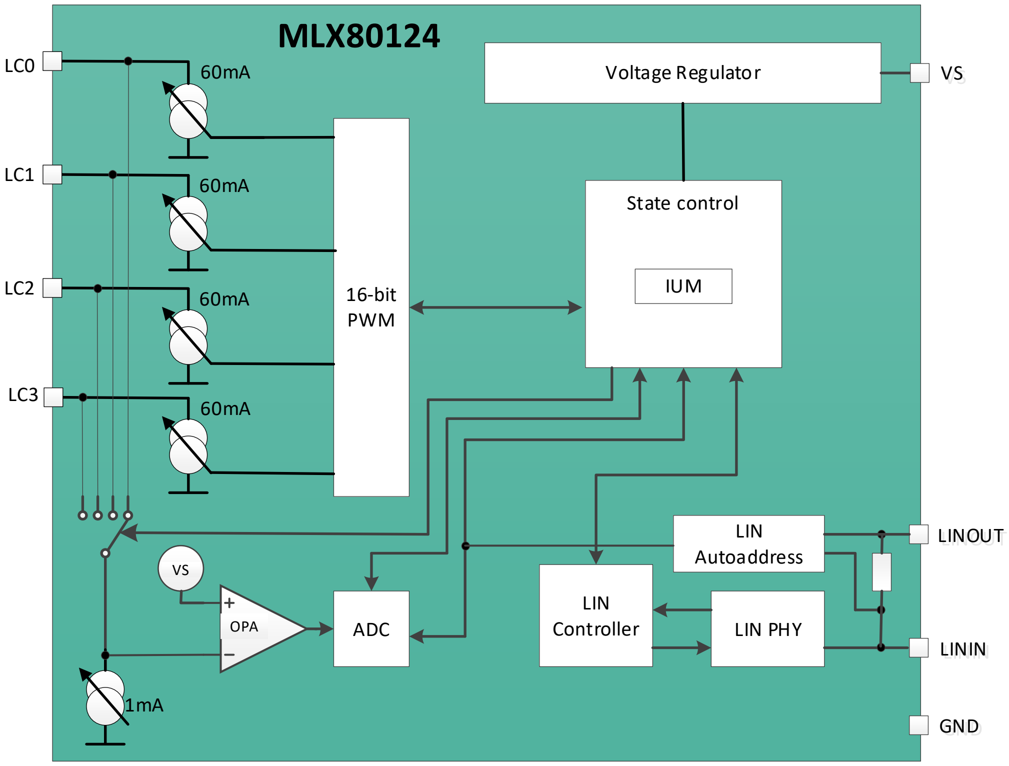

Figure 5 – Block Diagram

9. Typical application example

The MLX80124 has all components integrated to control one RGB LED and one single color LED with one integrated circuit for typical automotive ambient lighting applications. All currents are regulated and programmable up to 60mA per single LED. The integrated LIN communication interface secures simple and across the car communication possibility. For easy production configuration an auto-configuration possibility based on bus shunt method is foreseen as well.

Any RGB LED fitting to the current requirements can be used within that application. All RGB LEDs can be temperature monitored and any temperature drift can be compensated. For increased safety requirements the connected LEDs as well as the IC itself are diagnosable and the IC is developed according ASIL-B requirements.

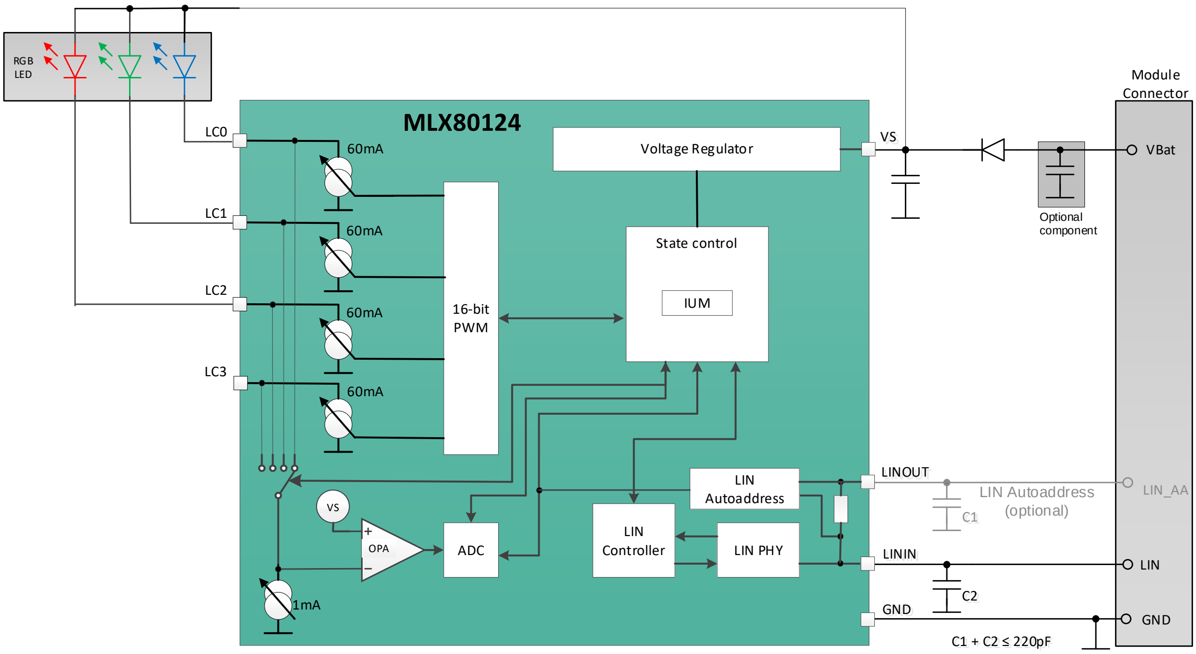

Figure 6 – Typical application example to drive one RGB-LED plus optional a white one

10. MLX80124 - Standard Features

10.1. General features

- Control RGB LED
  - Configurable LED channel assignment
  - Configurable LED current per LED color channel (5…60mA)
  - ~500Hz PWM frequency
  - 16bit PWM resolution
  - Staggered PWM (see section Staggered PWM)
  - Local intensity multiplier
  - Configurable filter for LED temperature measurements
- Melexis color control
  - Conversion from RGBI values (input from LIN) to 16-Bit PWM duty cycles
  - Color/Intensity fading
  - LED temperature compensation
- LIN node selection via NAD or via group ID (see section LIN node selection)
- Configurable application parameter (see section IUM handling)
- Configurable LED calibration data (see section IUM handling)
  - RGB LED from different suppliers can be used
  - no limitation for dedicated suppliers or RGB LEDs
  - easy exchange of the used RGB LED and target color gamut
- LED temperature derating (see section LED derating)
- LED Calibration Mode
- ADC measurement (VS, IC temperature, LED forward voltage (VS<>LC0, VS<>LC1, VS<>LC2), internal voltages (VDDD, VDDA, VBG_D, VAUX))

10.2. LIN features

- LIN auto-addressing
- LIN transport layer
- LIN communication error
- Configurable LIN parameter (see section IUM handling)

10.3. Diagnostic features

- Diagnostic features (see section Diagnostic features)
  - Under/over-voltage detection of VS
  - Under/over-temperature detection of IC and LED
  - Open/Short detection of LED channels

10.4. LIN node selection

10.4.1. via NAD

The selection of the MLX80124 via LIN can be handled the conventional way based on its NAD. In this case, the LIN master has to set the LIN signal “SigUse_NAD” to 1 and the LIN signal “SigNAD_Group1” must match either the value 0x7F (wildcard) or the configured NAD of the MLX80124.

10.4.2. via group ID

The MLX80124 can also be selected based on a group ID which consists of 20 bits and is stored in the IUM.

Group ID area	Size	IUM parameter	related LIN signal
Group ID[7:0]	8 bit	EE_STATIC_GROUP_ID1_2[7:0]	SigNAD_Group1
Group ID[15:8]	8 bit	EE_STATIC_GROUP_ID1_2[15:8]	SigGroup2

Group ID area	Size	IUM parameter	related LIN signal
Group ID[19:16]	4 bit	EE_STATIC_RGB_CHANNEL_GROUP_ID3[3:0]	SigGroup3

Table 8 - Group ID overview

The usage of the group ID allows the selection and control of several MLX80124 nodes at the same time with one single LIN message. Each bit of the group ID can be interpreted as a separate group of MLX80124 nodes or a separate zone inside the vehicle (for example left door, right door, dashboard etc.).

To select the MLX80124 via its group ID, the LIN master has to set the LIN signal “SigUse_NAD” to 0. In addition, the group ID has to be selected by the corresponding LIN signals. A selection is given when at least one bit of both the LIN signal and group ID is set to 1 at the same bit position.

Group ID setting	LIN signal setting	Result	Remark
Group ID[7:0] = 0x00 Group ID[15:8] = 0x00 Group ID[19:16] = 0x0	SigNAD_Group1 = 0x00 SigGroup2 = 0x55 SigGroup3 = 0xA	Ignore LIN message	
Group ID[7:0] = 0xFF Group ID[15:8] = 0x55 Group ID[19:16] = 0xA	SigNAD_Group1 = 0x00 SigGroup2 = 0xAA SigGroup3 = 0x5	Ignore LIN message	
Group ID[7:0] = 0x01 Group ID[15:8] = 0x00 Group ID[19:16] = 0x0	SigNAD_Group1 = 0x0F SigGroup2 = 0x00 SigGroup3 = 0x0	Accept LIN message	• group ID[0] selected by SigNAD_Group1[0]
Group ID[7:0] = 0x00 Group ID[15:8] = 0x80 Group ID[19:16] = 0x0	SigNAD_Group1 = 0x0F SigGroup2 = 0xAF SigGroup3 = 0x0	Accept LIN message	• group ID[15] selected by SigGroup2[7]
Group ID[7:0] = 0x0F Group ID[15:8] = 0xFF Group ID[19:16] = 0x2	SigNAD_Group1 = 0x0F SigGroup2 = 0x00 SigGroup3 = 0x3	Accept LIN message	• group ID[3:0] selected by SigNAD_Group1[3:0] • group ID[17] selected by SigGroup3[1]

Table 9 - Examples of Group ID settings

10.5. Feature activation/deactivation

The following application features can be activated/deactivated depending on the IUM parameter “EE_STATIC_SWITCHES” located at address 0x09C2.

Bit position	Feature	Description
EE_STATIC_ SWITCHES[0]	---	reserved
EE_STATIC_ SWITCHES[1]	LED temperature compensation	0: Disable RGB LED output correction over temperature 1: Enable RGB LED output correction based on current LED temperature
EE_STATIC_ SWITCHES[2]	LED derating	0: Disable RGB LED output derating during over-temperature 1: Enable RGB LED output derating during over-temperature based on the given IUM settings (see section LED derating)
EE_STATIC_ SWITCHES[3]	LIN sleep timeout	0: Enable switch to sleep mode after ~4s LIN bus inactivity 1: Disable switch to sleep mode after ~4s LIN bus inactivity
EE_STATIC_ SWITCHES[15:4]	---	reserved

Table 10 - Structure of IUM parameter EE_STATIC_SWITCHES (address 0x09C2)

10.6. LED derating

The MLX80124 provides an LED derating feature which is dimming the LED in case of over-temperature of the LED. If the LED temperature exceeds the defined limit, the application reduces the output of the LED in order to prevent a further increase of the temperature. All parameters which have an impact on the LED derating are listed in the following table.

IUM parameter	IUM address	min	typ	max
EE_STATIC_SWITCHES[2] (LED derating)	0x09C2	0 (disabled)		1 (enabled)
EE_STATIC_TEMP_DER_MULTIPLIER_MIN	0x09C4	0	50	65535
EE_STATIC_TEMP_DER_MULTIPLIER_NORM	0x09C6	1	100	65535
EE_STATIC_TEMP_DER_POINT_P1	0x09C8	0	80	65535
EE_STATIC_TEMP_DER_POINT_P2	0x09CA	0	125	65535
EE_STATIC_PWM_DERATING_ITERATIONS	0x09D0	0	1	65535

Table 11 - IUM parameters used by LED derating module

10.6.1. Activation/Deactivation

The LED derating feature becomes active if the corresponding bit EE_STATIC_SWITCHES[2] inside the IUM is set to 1 and the measured LED temperature exceeds the defined value of EE_STATIC_TEMP_DER_POINT_P1.

In return, the LED derating feature becomes inactive if the measured LED temperature falls below EE_STATIC_TEMP_DER_POINT_P1.

In case bit EE_STATIC_SWITCHES[2] is set to 0, the LED derating module is deactivated permanently without taking the LED temperature into account.

10.6.2. Functional principle

The general principle of the LED derating module is shown in Figure 7.

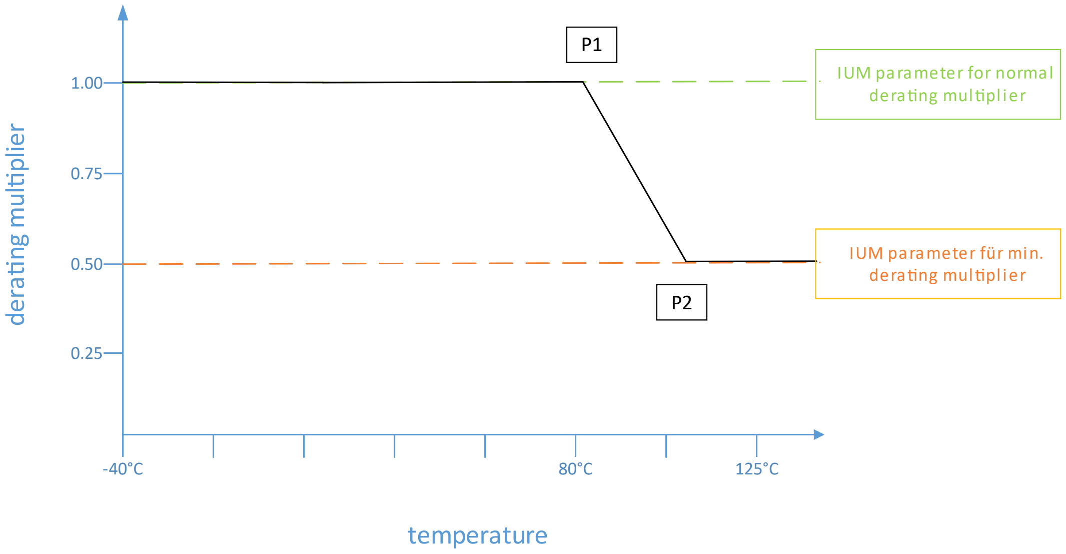

Figure 7 - LED derating

The temperature points P1 and P2 will be defined via the IUM parameters *EE_STATIC_TEMP_DER_POINT_P1* and *EE_STATIC_TEMP_DER_POINT_P2*.

In case the temperature is below P1, the temperature derating multiplier is (*EE_STATIC_TEMP_DER_MULTIPLIER_NORM* / 100).

In case the temperature equals or exceeds P2, the temperature derating multiplier is (*EE_STATIC_TEMP_DER_MULTIPLIER_MIN* / 100).

In case the temperature is between P1 and P2, the temperature derating multiplier will be calculated based on an interpolation between P1 and P2.

The execution of the LED derating module is triggered by the PWM Master1 END interrupt which is called at the end of every PWM period. The parameter *EE_STATIC_PWM_DERATING_ITERATIONS* defines the number of PWM Master1 END ISR executions before the next derating step shall be done based on the actual LED temperature.

10.7. Staggered PWM

The MLX80124 provides a staggered PWM feature which activates the three LED channels at various times within one PWM period (see Figure 8).

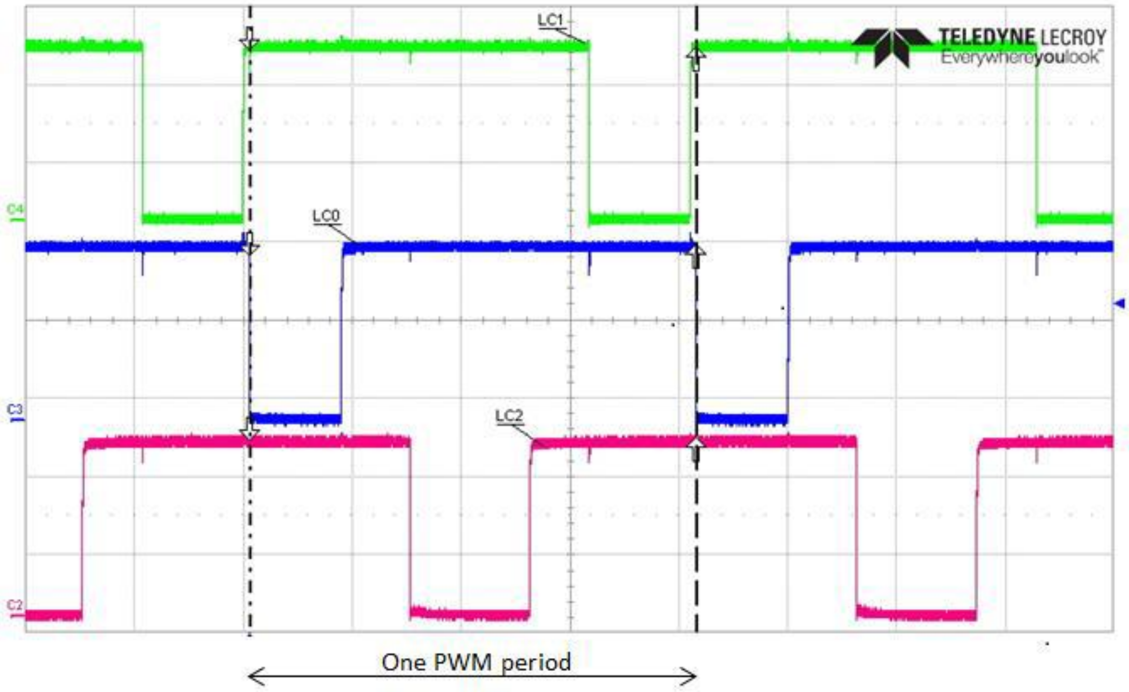

Figure 8 - Staggered PWM duty cycles

The staggered PWM feature always sets the PWM low phase at LC0 at the beginning of the PWM period while the PWM low phase at LC1 is set at the end of the PWM period. The PWM low phase at LC2 is set in the middle of the PWM period. This leads to a separation of the currents driven through the LED which improves the EMC performance of the MLX80124.

Furthermore, there is a time interval at the end of each PWM period where all 3 PWM duty cycles are at high state. This time interval can be used to switch the current source SW settings of the LED channels (for example from 5mA to 30 mA) while the LED is inactive in order to avoid blinking effects.

10.8. Diagnostic features details

The MLX80124 provides the following diagnostic features. Certain features can be configured by dedicated IUM parameters as described in the following.

- Open/Short detection of each RGB LED channel
  - periodical VS<>LC differential measurement to get LED forward voltage
  - IUM parameters:

        - EE_STATIC_VS_LCx_OPEN_THRESHOLD (Voltage threshold in [mV] to detect ‘OPEN’ of the LED connected to the selected LC pin)
        - EE_STATIC_VS_LCx_SHORT_THRESHOLD (Voltage threshold in [mV] to detect ‘SHORT’ of the LED connected to the selected LC pin)
        - EE_STATIC_VS_LCX_ERROR_CNT_LIMIT (number of ‘OPEN’/‘SHORT’ detections leading to the deactivation of the RGB LED)
- VS over/under-voltage detection
    - periodical ADC measurement of VS channel
    - ADC resolution: 10 bits; Reference voltage: 2.5 V
    - IUM parameters:
        - EE_STATIC_VS_UNDERVOLT (Voltage threshold in [ADC digits] to detect VS under-voltage)
        - EE_STATIC_VS_OVERVOLT (Voltage threshold in [ADC digits] to detect VS over-voltage)
        - EE_STATIC_VS_HYSTERESIS (Voltage hysteresis in [ADC digits])
- IC over/under-temperature detection
    - periodical ADC measurement of internal temperature sensor
    - ADC resolution: 10 bits; Reference voltage: 2.5 V
    - IUM parameters:
        - EE_STATIC_IC_TEMP_LOW_LIMIT (Temperature threshold in [°C] to detect IC under-temperature)
        - EE_STATIC_IC_TEMP_HIGH_LIMIT (Temperature threshold in [°C] to detect IC over-temperature)
        - EE_STATIC_IC_TEMP_HYSTERESIS (IC temperature hysteresis in [K])
- LED over/under-temperature detection
    - periodical VS<>LC differential measurement to get LED forward voltage
    - indirect measurement of LED temperature based on LED forward voltage evaluation
    - IUM parameters:
        - EE_STATIC_LED_TEMP_LOW_LIMIT (Temperature threshold in [°C] to detect LED under-temperature)
        - EE_STATIC_LED_TEMP_HIGH_LIMIT (Temperature threshold in [°C] to detect LED over-temperature)
        - EE_STATIC_LED_TEMP_HYSTERESIS (LED temperature hysteresis in [K])
- Monitoring of internal IC voltages (VDDD, VDDA, VBG_D, VAUX)

10.9. Error codes

The current status of the application can be monitored by a 15-bit application error code which can be requested via the unconditional LIN S2M message “Slave status” (see also Table 14). The available error codes are summarized in Table 12. Please note that several bits inside the error register can be set in case more than one error is present at the same time.

Error code	Description
0x0000	No error
0x0001	VS under-voltage
0x0002	VS over-voltage
0x0004	reserved
0x0008	LED failsafe
0x0010	reserved
0x0020	IC over-temperature
0x0040	IC under-temperature
0x0080	LED over-temperature
0x0100	LED under-temperature
0x0200	LIN auto-addressing error
0x0400	VDDD
0x0800	VDDA

Error code	Description
0x1000	VBG_D
0x2000	VAUX
0x4000	reserved

Table 12 - Error codes

11. LIN communication

11.1. Application frames

11.1.1. LED control (Master to Slave)

This LIN frame is used to send new color data to the LIN slave to control the RGB LED.

Signal name	Bit position	Size	Description
SigNAD_Group1	[7:0]	8 bit	• NAD of the slave (if signal “SigUse_NAD” is 1) • ID of Group 1 (if signal “SigUse_NAD” is 0; IUM parameter “EE_STATIC_GROUP_ID1_2[7:0]”)
SigGroup2	[15:8]	8 bit	ID of Group 2 (IUM parameter “EE_STATIC_GROUP_ID1_2[15:8]”)
SigGroup3	[19:16]	4 bit	ID of Group 3 (IUM parameter “EE_STATIC_RGB_CHANNEL_GROUP_ID3[3:0]”)
SigUse_NAD	[21]	1 bit	0: slave recognizes frame only if ID of Group 1, 2 or 3 matches 1: slave recognizes frame only if NAD matches
SigUse_RGBI	[22]	1 bit	0: use predefined color 1: use color values from signals “SigColorR_Predef”, “SigColorG” and “SigColorB”
SigEnable_LED	[23]	1 bit	0: LED off 1: LED on
SigFadingTime	[29:24]	6 bit	Fading time in 100 ms steps: 0: 100 ms 1: 200 ms … 63: 6400 ms
SigUpdateColor	[31:30]	2 bit	0: immediate update 1: store new color, but do not update LED output 2: update LED output based on already stored color 3: discard received color values
SigIntensity	[38:32]	7 bit	LED intensity in % (maximum is limited to 100)
SigEnableFading	[39]	1 bit	0: LED output fading off 1: LED output fading on
SigColorR_Predef	[47:40]	8 bit	• Color value for red LED channel (in case signal “SigUse_RGBI” is 1) • Index of predefined color (in case signal “SigUse_RGBI” is 0)
SigColorG	[55:48]	8 bit	Color value for green LED channel
SigColorB	[63:56]	8 bit	Color value for blue LED channel

Table 13 - Signal description: LIN frame “LED control” (ID 0x24)

11.1.2. Slave status (Slave to Master)

This LIN frame is used to send several basic information from the LIN slave to the master.

Signal name	Bit position	Size	Description
SigADCIntVS	[15:0]	16 bit	ADC-measured VS voltage in mV
SigADCIntTemp	[31:16]	16 bit	filtered ADC-measured IC temperature in degC
SigAppError	[46:32]	15 bit	Application error status
SigCommErr	[47]	1 bit	LIN response error
SigM2sMsgCounter	[55:48]	8 bit	number of received M2S messages range 0x01-0xFE (set to 0x01 if 0xFF is reached)
SigS2mMsgCounter	[63:56]	8 bit	number of transmitted S2M messages range 0x01-0xFE (set to 0x01 if 0xFF is reached)

Table 14 - Signal description: LIN frame “Slave status” (ID 0x05)

11.1.3. FauCo status (Slave to Master)

This LIN frame is used to send several Fault collector status flags from the LIN slave to the master. Each error status consists of 2 bits which is decoded in Table 16.

Signal name	Bit position	Size	Description
SigFauCo_VDDD	[1:0]	2 bit	ADC-measured VDDD is outside the allowed limits (+/-5% on top of the min/max limits in the datasheet)
SigFauCo_VDDA	[3:2]	2 bit	ADC-measured VDDA is outside the allowed limits (+/-5% on top of the min/max limits in the datasheet)
SigFauCo_VBG_D	[5:4]	2 bit	ADC-measured VBG_D is outside the allowed limits (+/-5% on top of the min/max limits in the datasheet)
SigFauCo_VAUX	[7:6]	2 bit	ADC-measured VAUX is outside the allowed limits (+/-5% on top of the min/max limits in the datasheet)
SigFauCo_OV_VS_INT	[9:8]	2 bit	VS overvoltage interrupt occurred due to 20V <= VS <= 24V (see datasheet parameter “PROV_VS”)
SigFauCo_UV_VS_INT	[11:10]	2 bit	VS undervoltage interrupt occurred due to 3.5V <= VS <= 4.5V (see datasheet parameter “PRUV_VS”)
SigFauCo_VDDA_INT	[13:12]	2 bit	VDDA undervoltage interrupt occurred due to VDDA of typ. <= 3.15V
SigFauCo_OV_VS	[15:14]	2 bit	VS voltage exceeds IUM parameter “EE_STATIC_VS_OVERVOLT”
SigFauCo_UV_VS	[17:16]	2 bit	VS voltage deceeds IUM parameter “EE_STATIC_VS_UNDERVOLT”
SigFauCo_SafetyError	[19:18]	2 bit	Presence of least one of the following errors: VDDD, VDDA, VBG_D, VAUX, VDDA_INT, OV_VS_INT, UV_VS_INT
SigFauCo_OT_IC	[21:20]	2 bit	IC temperature exceeds IUM parameter “EE_STATIC_IC_TEMP_HIGH_LIMIT”
SigFauCo_UT_IC	[23:22]	2 bit	IC temperature deceeds IUM parameter “EE_STATIC_IC_TEMP_LOW_LIMIT”
SigFauCo_OT_LED	[25:24]	2 bit	LED temperature exceeds IUM parameter “EE_STATIC_LED_TEMP_HIGH_LIMIT”
SigFauCo_UT_LED	[27:26]	2 bit	LED temperature deceeds IUM parameter “EE_STATIC_LED_TEMP_LOW_LIMIT”
SigFauCo_LINSum	[29:28]	2 bit	LIN transmission timeout occurred due to permanent dominant level at TxD (see also “TxD dominant Timeout”)

Signal name	Bit position	Size	Description
SigFauCo_LINAA_Twisted	[31:30]	2 bit	detection of twisted LIN_IN/LIN_OUT connection during LIN auto-addressing
SigFauCo_EEPROM	[33:32]	2 bit	Incomplete and/or corrupted IUM content detected
SigFauCo_Open_Ch00	[35:34]	2 bit	LED voltage at LC0 exceeds IUM parameter “EE_STATIC_VS_LC0_OPEN_THRESHOLD” (maximum error counter “EE_STATIC_VS_LCX_ERROR_CNT_LIMIT” not yet reached)
SigFauCo_Open_Ch01	[37:36]	2 bit	LED voltage at LC1 exceeds IUM parameter “EE_STATIC_VS_LC1_OPEN_THRESHOLD” (maximum error counter “EE_STATIC_VS_LCX_ERROR_CNT_LIMIT” not yet reached)
SigFauCo_Open_Ch02	[39:38]	2 bit	LED voltage at LC2 exceeds IUM parameter “EE_STATIC_VS_LC2_OPEN_THRESHOLD” (maximum error counter “EE_STATIC_VS_LCX_ERROR_CNT_LIMIT” not yet reached)
SigFauCo_Short_Ch00	[41:40]	2 bit	LED voltage at LC0 deceeds IUM parameter “EE_STATIC_VS_LC0_SHORT_THRESHOLD” (maximum error counter “EE_STATIC_VS_LCX_ERROR_CNT_LIMIT” not yet reached)
SigFauCo_Short_Ch01	[43:42]	2 bit	LED voltage at LC1 deceeds IUM parameter “EE_STATIC_VS_LC1_SHORT_THRESHOLD” (maximum error counter “EE_STATIC_VS_LCX_ERROR_CNT_LIMIT” not yet reached)
SigFauCo_Short_Ch02	[45:44]	2 bit	LED voltage at LC2 deceeds IUM parameter “EE_STATIC_VS_LC2_SHORT_THRESHOLD” (maximum error counter “EE_STATIC_VS_LCX_ERROR_CNT_LIMIT” not yet reached)
SigFauCo_Failsafe_Ch00	[47:46]	2 bit	Failsafe mode (deactivated RGB LED) due to detected LED Open/Short at LC0 for at least “EE_STATIC_VS_LCX_ERROR_CNT_LIMIT” times
SigFauCo_Failsafe_Ch01	[49:48]	2 bit	Failsafe mode (deactivated RGB LED) due to detected LED Open/Short at LC1 for at least “EE_STATIC_VS_LCX_ERROR_CNT_LIMIT” times
SigFauCo_Failsafe_Ch02	[51:50]	2 bit	Failsafe mode (deactivated RGB LED) due to detected LED Open/Short at LC2 for at least “EE_STATIC_VS_LCX_ERROR_CNT_LIMIT” times
SigFauCo_MaxFaultCh00	[53:52]	2 bit	IUM parameter “EE_STATIC_VS_LCX_ERROR_CNT_LIMIT” reached/exceeded by LED at LC0
SigFauCo_MaxFaultCh01	[55:54]	2 bit	IUM parameter “EE_STATIC_VS_LCX_ERROR_CNT_LIMIT” reached/exceeded by LED at LC1
SigFauCo_MaxFaultCh02	[57:56]	2 bit	IUM parameter “EE_STATIC_VS_LCX_ERROR_CNT_LIMIT” reached/exceeded by LED at LC2

Table 15 - Signal description: LIN frame “FauCo status” (ID 0x03)

Status value	Status description
0	Initial status
1	No Error status

Status value	Status description
2	Error status

Table 16 - Signal decoding of LIN frame “FauCo status”

11.2. Diagnostic frames

11.2.1. User-defined Read-by-Identifiers

The MLX80124 supports several user-defined identifiers which are summarized in Table 17. The Table 18 to Table 31 describe the content of the response messages after the corresponding Read-by-Identifier request.

Identifier	Description
0x21	Enable configuration mode
0x22	Disable configuration mode
0x24	LC0-3 current source settings
0x32	Application error code and PWM duty cycle at LC0
0x33	PWM duty cycles at LC1 and LC2
0x34	Unfiltered VS voltage and IC temperature
0x36	Filtered and unfiltered IC temperature
0x37	RGB LED status and filtered RGB LED temperature
0x38	Application error code and filtered LED VF at LC0
0x39	Filtered LED VF at LC1 and LC2
0x3A	Application error code and unfiltered LED VF at LC0
0x3B	Unfiltered LED VF at LC1 and LC2
0x3C	Status of single LED channel at LC0, LC1 and LC2
0x3D	LED error counter for LC0, LC1 and LC2

Table 17 - Supported user-defined identifiers

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	Function ID LSB	Function ID MSB	IUM configuration map revision LSB	IUM configuration map revision MSB	0x01

Table 18 - Response of identifier “Enable configuration mode” (0x21)

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	Function ID LSB	Function ID MSB	IUM configuration map revision LSB	IUM configuration map revision MSB	0x00

Table 19 - Response of identifier “Disable configuration mode” (0x22)

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	CS setting LC0	CS setting LC1	CS setting LC2	CS setting LC3	0xFF

Table 20 - Response of identifier “LC0-3 current source settings” (0x24)

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	App error code LSB	App error code MSB	PWM duty cycle LC0 LSB	PWM duty cycle LC0 MSB	0xFF

Table 21 - Response of identifier “Application error code and PWM duty cycle at LC0” (0x32)

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	PWM duty cycle LC1 LSB	PWM duty cycle LC1 MSB	PWM duty cycle LC2 LSB	PWM duty cycle LC2 MSB	0xFF

Table 22 - Response of identifier “PWM duty cycles at LC1 and LC2” (0x33)

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	VS voltage in ADC digits LSB	VS voltage in ADC digits MSB	IC temperature in degC LSB	IC temperature in degC MSB	0xFF

Table 23 - Response of identifier “Unfiltered VS voltage and IC temperature” (0x34)

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	filtered IC temperature in degC LSB	filtered IC temperature in degC MSB	unfiltered IC temperature in degC LSB	unfiltered IC temperature in degC MSB	0xFF

Table 24 - Response of identifier “Filtered and unfiltered IC temperature” (0x36)

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	RGB LED status LSB	RGB LED status MSB	filtered RGB LED temperature in degC LSB	filtered RGB LED temperature in degC MSB	0xFF

Table 25 - Response of identifier “RGB LED status and filtered RGB LED temperature” (0x37)

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	App error code LSB	App error code MSB	filtered LED VF at LC0 in mV LSB	filtered LED VF at LC0 in mV MSB	0xFF

Table 26 - Response of identifier “Application error code and filtered LED VF at LC0” (0x38)

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	filtered LED VF at LC1 in mV LSB	filtered LED VF at LC1 in mV MSB	filtered LED VF at LC2 in mV LSB	filtered LED VF at LC2 in mV MSB	0xFF

Table 27 - Response of identifier “Filtered LED VF at LC1 and LC2” (0x39)

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	App error code LSB	App error code MSB	unfiltered LED VF at LC0 in mV LSB	unfiltered LED VF at LC0 in mV MSB	0xFF

Table 28 - Response of identifier “Application error code and unfiltered LED VF at LC0” (0x3A)

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	unfiltered LED VF at LC1 in mV LSB	unfiltered LED VF at LC1 in mV MSB	unfiltered LED VF at LC2 in mV LSB	unfiltered LED VF at LC2 in mV MSB	0xFF

Table 29 - Response of identifier “Unfiltered LED VF at LC1 and LC2” (0x3B)

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	Status LED LC0	Status LED LC1	Status LED LC2	0xFF	0xFF

Table 30 - Response of identifier “Status of single LED channel at LC0, LC1 and LC2” (0x3C)

NAD	PCI	RSID	D1	D2	D3	D4	D5
NAD	0x06	0xF2	LED error counter LC0	LED error counter LC1	LED error counter LC2	0xFF	0xFF

Table 31 - Response of identifier “LED error counter for LC0, LC1 and LC2” (0x3D)

11.2.2. Configuration messages

There are additional diagnostic messages available which can be used to configure the MLX80124. These messages use the Service Identifier 0xB4 (Data dump request). Table 33 shows the commands which are available in order to select the desired configuration message.

Note: The usage of the following configuration messages is only possible if the application has been set into configuration mode via the following LIN Read-by-Identifier message.

NAD	PCI	SID	D1	D2	D3	D4	D5
NAD	0x06	0xB2	0x21	Supplier ID LSB	Supplier ID MSB	Function ID LSB	Function ID MSB

Table 32 - “Enable configuration mode” request

Command	Description
0x08	Read IUM
0xD3	Write IUM
0x55	Set current sources and PWM duty cycles
0x66	Delete LED temperature data
0xAA	Set local intensity
0xAB	Get local intensity

Table 33 - Configuration message commands

11.2.2.1. Read IUM

This LIN message is used to read the content of the IUM.

NAD	PCI	SID	D1	D2	D3	D4	D5
NAD	0x05	0xB4	0x08	OFFSET LSB	OFFSET MSB	LEN	0xFF

Table 34 - Read IUM request

Table 34 shows the structure of the Read IUM request with the following parameters:

- *OFFSET*: A 16 bits word offset to select the start address of the IUM to be read (Offset “0” corresponds to IUM address 0x0880)
- *LEN*: An 8 bits length to declare the number of data bytes to be read

11.2.2.2. Write IUM

This LIN message is used to write the IUM. Please note that the IUM will be written page-wise where one page consists of 128 bytes.

NAD	PCI	SID	D1	D2	D3	D4	D5
NAD	PCI	0xB4	0xD3	OFFSET LSB	OFFSET MSB	W0	W1

Table 35 - Write IUM request (SF)

If there are 2 bytes of data or less to send, the single frame message can be used as shown in Table 35. This message contains the following parameters:

- *OFFSET*: A 16 bits word offset to select the start address of the IUM to be written (Offset “0” corresponds to IUM address 0x0880)
- *Wx*: The data bytes to be written into the IUM where W1 is the MSB and W0 is the LSB

NAD	PCI	LEN	SID	D1	D2	D3	D4
NAD	PCI	LEN	0xB4	0xD3	OFFSET LSB	OFFSET MSB	W0

Table 36 - Write IUM request (FF)

If there are more than 2 bytes of data to send, a first frame message is needed followed by consecutive frame messages. The first frame contains the first data byte to be written into the IUM. The structure of the first frame message is shown in Table 36 with the following parameters:

- *LEN*: Length information (number of data bytes)
- *OFFSET*: A 16 bits word offset to select the start address of the IUM to be written (Offset “0” corresponds to IUM address 0x0880)
- *W0*: First data byte to be written into the IUM

NAD	PCI	D1	D2	D3	D4	D5	D6
NAD	PCI	W1	W2	W3	W4	W5	W6

Table 37 - Write IUM request (CF)

Table 37 shows the structure of the consecutive frame message which contains 6 bytes to be written into the IUM. If there is insufficient data to complete a frame, it has to be filled with 0xFF.

11.2.2.3. Set current sources and PWM duty cycles

This LIN message is used to set the current sources and the PWM duty cycles at the MLX80124 pins LC0, LC1 and LC2 for LED calibration purposes. This message consists of 3 separate messages with the following parameters:

- *PWM LCx*: 16 bits PWM duty cycle to be output at the corresponding LC pin
- *CS LCx*: 16 bits current source selection to be used at the corresponding LC pin (5 mA … 60 mA); Only the 4 LSB of this signal are used as shown in Table 38.

CS LCx[3:0]	Current source value
0	5 mA
1	10 mA
2	15 mA
3	20 mA
4	25 mA
5	30 mA
6	35 mA
7	40 mA
8	25 mA
9	30 mA
10	35 mA
11	40 mA
12	45 mA
13	50 mA
14	55 mA
15	60 mA

Table 38 - Current source selection

NAD	PCI	LEN	SID	D1	D2	D3	D4
NAD	0x10	0x0E	0xB4	0x55	PWM LC0 LSB	PWM LC0 MSB	PWM LC1 LSB

Table 39 - Set current sources and PWM duty cycles (FF)

NAD	PCI	D1	D2	D3	D4	D5	D6
NAD	0x21	PWM LC1 MSB	PWM LC2 LSB	PWM LC2 MSB	CS LC0 LSB	CS LC0 MSB	CS LC1 LSB

Table 40 - Set current sources and PWM duty cycles (CF1)

NAD	PCI	D1	D2	D3	D4	D5	D6
NAD	0x22	CS LC1 MSB	CS LC2 LSB	CS LC2 MSB	0xFF	0xFF	0xFF

Table 41 - Set current sources and PWM duty cycles (CF2)

11.2.2.4. Delete LED temperature data

This LIN message is used to delete the complete content of the LED temperature data area (see Table 48). Table 42 shows the structure of the Delete LED temperature data request.

NAD	PCI	SID	D1	D2	D3	D4	D5
NAD	0x02	0xB4	0x66	0xFF	0xFF	0xFF	0xFF

Table 42 - Delete LED temperature data request

11.2.2.5. Set local intensity

This LIN message is used to set the local intensity in [%] of the RGB LED connected to the MLX80124. This value will be multiplied by the global intensity which is part of the M2S LIN frame “LED control” to set a new color (see also Table 13).

NAD	PCI	SID	D1	D2	D3	D4	D5
NAD	0x03	0xB4	0xAA	INTENSITY	0xFF	0xFF	0xFF

Table 43 - Set local intensity request

Table 43 shows the structure of the Set local LED intensity request with the following parameter:

- INTENSITY: new local LED intensity in [%]

11.2.2.6. Read local intensity

This LIN message is used to read the local intensity in [%] of the RGB LED connected to the MLX80124. This value will be multiplied by the global intensity which is part of the M2S LIN frame “LED control” to set a new color (see also Table 13).

NAD	PCI	SID	D1	D2	D3	D4	D5
NAD	0x02	0xB4	0xAB	0xFF	0xFF	0xFF	0xFF

Table 44 - Read local intensity request

12. IUM handling

12.1. IUM areas

The IUM area for the MLX80124 is split into a static area and a dynamic area where the static area is again split into 3 sub-areas. The static area and the dynamic area are non-overlapping in terms of IUM pages. That means, in case something is going wrong inside one area then the other area will not be affected.

The first static area consists of the LED calibration section.

The second static area consists of application parameters as for example overvoltage/undervoltage limits, the activation/deactivation of certain features or which current source shall be used for LED forward measurements.

The third static area consists of LED temperature data.

Each static section is secured via its own valid signature pattern, its revision number and checksum. The intention of the complete static section is that it will be written only during end of line process. It will not be written when the application is running.

On the other hand, there is the dynamic area. This section is secured via its own signature, revision number and checksum. Its intention is that it can be written by LIN master request in case a new node address has to be stored for example.

The following tables are showing the static and dynamic sections of the IUM in general and in detail, respectively.

Address	Content	Remark
0x0880 - 0x097F	LED calibration data	Static section
0x0980 - 0x09FF	Application parameters	Static section
0x0A00 - 0x0A7F	LED temperature data	Static section
0x0A80 - 0x0AFF	LIN data (NAD, frame IDs), local intensity	Dynamic section

Table 45 - Overview of static and dynamic data sections in IUM

Address offset in bytes	Content	Size in bytes	Remark
0	CFL_OFFSET_COLORGAMUT	12	Offsets of color gamut triangle
12	CFL_SLOPE_COLORGAMUT	12	Slopes of color gamut triangle
24	CFL_M_SLOPE	36	XYZ slope for single current of RGB LED
60	CFL_CALIB_TEMP	2	LED calibration temperature
62	CFL_M_REDTEMPN	12	linearly negative temperature compensation for red LED
74	CFL_M_REDTEMPP	12	linearly positive temperature compensation for red LED
86	CFL_M_GREENTEMPN	12	linearly negative temperature compensation for green LED
98	CFL_M_GREENTEMPP	12	linearly positive temperature compensation for green LED
110	CFL_M_BLUETEMPN	12	linearly negative temperature compensation for blue LED
122	CFL_M_BLUETEMPP	12	linearly positive temperature compensation for blue LED
134	CFL_SRGB_TO_XYZ_SCALED	36	transformation matrix RGB to XYZ
170	CFL_MAX_INTENSITY	12	maximum intensities for RGB in [lm]
182	CFL_SCALE_RGB	4	RGB scaling factor

Address offset in bytes	Content	Size in bytes	Remark
186	CFL_LIMIT_MAX_OUTPUT	4	maximum allowed PWM output
190	EE_STATIC_LED_CAL_VALID_PATTERN	2	valid pattern
192	EE_STATIC_LED_CAL_REVISION	2	section structure revision
194	EE_STATIC_LED_CAL_CRC9	2	checksum
196	---	60	reserved

Table 46 - Content of static IUM section "LED calibration data"

Address offset in bytes	Content	Size in bytes	Remark
0	EE_STATIC_PREDEF_COLOR_AREA_START	30	10 predefined colors in RGB format
30	EE_STATIC_VS_UNDERVOLT	2	VS undervoltage limit in ADC digits
32	EE_STATIC_VS_OVERVOLT	2	VS overvoltage limit in ADC digits
34	EE_STATIC_VS_HYSTERESIS	2	Hysteresis for VS undervoltage/overvoltage in ADC digits
36	EE_STATIC_VS_LC0_OPEN_THRESHOLD	2	Voltage threshold at LC0 in mV to detect 'OPEN'
38	EE_STATIC_VS_LC1_OPEN_THRESHOLD	2	Voltage threshold at LC1 in mV to detect 'OPEN'
40	EE_STATIC_VS_LC2_OPEN_THRESHOLD	2	Voltage threshold at LC2 in mV to detect 'OPEN'
42	EE_STATIC_VS_LC0_SHORT_THRESHOLD	2	Voltage threshold at LC0 in mV to detect 'SHORT'
44	EE_STATIC_VS_LC1_SHORT_THRESHOLD	2	Voltage threshold at LC1 in mV to detect 'SHORT'
46	EE_STATIC_VS_LC2_SHORT_THRESHOLD	2	Voltage threshold at LC2 in mV to detect 'SHORT'
48	EE_STATIC_VS_LCX_ERROR_CNT_LIMIT	2	Limit for 'OPEN'/'SHORT' error counter
50	EE_STATIC_GROUP_ID1_2	2	group ID1 and group ID2
52	EE_STATIC_RGB_CHANNEL_GROUP_ID3	2	group ID3 and RGB LED channel assignment
54	EE_STATIC_IC_TEMP_LOW_LIMIT	2	IC undertemperature limit in degC
56	EE_STATIC_IC_TEMP_HIGH_LIMIT	2	IC overtemperature limit in degC
58	EE_STATIC_IC_TEMP_HYSTERESIS	2	Hysteresis for IC undertemperature/overtemperature in K
60	EE_STATIC_LED_TEMP_LOW_LIMIT	2	LED undertemperature limit in degC
62	EE_STATIC_LED_TEMP_HIGH_LIMIT	2	LED overtemperature limit in degC
64	EE_STATIC_LED_TEMP_HYSTERESIS	2	Hysteresis for LED undertemperature/overtemperature in K
66	EE_STATIC_SWITCHES	2	Application switches to activate/deactivate SW features

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9 See *section* CRC calculation

Address offset in bytes	Content	Size in bytes	Remark
68	EE_STATIC_TEMP_DER_MULTIPLIER_MIN	2	Minimum temperature derating multiplier
70	EE_STATIC_TEMP_DER_MULTIPLIER_NORM	2	Normal temperature derating multiplier
72	EE_STATIC_TEMP_DER_POINT_P1	2	Temperature point P1 in degC for interpolation
74	EE_STATIC_TEMP_DER_POINT_P2	2	Temperature point P2 in degC for interpolation
76	reserved	2	
78	reserved	2	
80	EE_STATIC_PWM_DERATING_ITERATIONS	2	number of PWM iterations for temperature derating
82	EE_STATIC_IIR_TIC_TLED	2	IIR filter: - IC temperature (LSB) - RGB LED temperature (MSB)
84	EE_STATIC_IIR_VS_LCDIFF	2	IIR filter: - VS (LSB) - LC differential voltage (MSB)
86	EE_STATIC_LC_CURRENT_CFG	2	RGB current settings: - [3:0]-> LC0 - [7:4]-> LC1 - [11:8]-> LC2 - [15:12]-> LC3 - 0 -> 0mA - 1 -> 5mA - 2 -> 10mA - 3 -> 15mA - 4 -> 20mA - 5 -> 25mA - 6 -> 30mA - 7 -> 35mA - 8 -> 40mA - 9 -> 45mA - 10 -> 50mA - 11 -> 55mA - 12 -> 60mA
88	EE_STATIC_LED_TEMP_SLOPE_0	2	LED temperature gradient for LED at LC0 in mV/K (prescaled by factor 1024)
90	EE_STATIC_LED_TEMP_SLOPE_1	2	LED temperature gradient for LED at LC1 in mV/K (prescaled by factor 1024)
92	EE_STATIC_LED_TEMP_SLOPE_2	2	LED temperature gradient for LED at LC2 in mV/K (prescaled by factor 1024)
94	EE_STATIC_APP_PARAM_VALID_PATTERN	2	valid pattern
96	EE_STATIC_APP_PARAM_REVISION	2	section structure revision
98	EE_STATIC_APP_PARAM_CRC10	2	checksum
100	---	28	reserved

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10 See *section* CRC calculation

Table 47 - Content of static IUM section “Application parameters”

Address offset in bytes	Content	Size in bytes	Remark
0	EE_STATIC_LED_TEMP_B_OFFSET_0C	6	LED voltage offset in mV at 0 degC
6	EE_STATIC_LED_TEMP_VALID_PATTERN	2	valid pattern
8	EE_STATIC_LED_TEMP_REVISION	2	section structure revision
10	EE_STATIC_LED_TEMP_CRC[11]	2	checksum
12	---	116	reserved

Table 48 - Content of static IUM section “LED temperature data”

Address offset in bytes	Content	Size in bytes	Remark
0	EE_DYNAMIC_VALID_PATTERN	2	valid IUM pattern
2	EE_DYNAMIC_REV	2	IUM revision
4	EE_DYNAMIC_LED_LOCAL_INTENSITY	1	Local LED intensity in %
5	NAD	1	LIN node address
6	Frame ID 1	1	Frame ID of unconditional LIN message “Slave_Status”
7	Frame ID 2	1	Frame ID of unconditional LIN message “LED_Control”
8	Frame ID 3	1	Frame ID of unconditional LIN message “FauCo_Status”
9	---	1	reserved
10	EE_DYNAMIC_CRC[12]	2	checksum
12	---	116	reserved

Table 49 - Content of dynamic IUM section “LIN data”

12.2. CRC calculation

The data content of all IUM areas mentioned in *section* IUM areas is protected by dedicated checksums which are stored at the following positions.

Address	Parameter	Remark
0x0942 - 0x0943	EE_STATIC_LED_CAL_CRC	CRC for LED calibration data
0x09E2 - 0x09E3	EE_STATIC_APP_PARAM_CRC	CRC for Application parameters
0x0A0A - 0x0A0B	EE_STATIC_LED_TEMP_CRC	CRC for LED temperature data

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[11] See *section* CRC calculation
[12] See *section* CRC calculation

Address	Parameter	Remark
0x0A8A - 0x0A8B	EE_DYNAMIC_CRC	CRC for LIN data and local intensity

Table 50 - IUM checksum parameters

The checksum values are calculated based on the following conditions:

- Polynomial: **0x1021**
- Initial seed value: **1**

13. Memories

13.1. IUM – Internal User Memory

The controller has one IUM block with 1024Byte. The IUM is organized in 8 pages a 16x72bit (64 user bits per 72bit, the remaining 8bits will be used to store the CRC).

With this IUM it is possible to store non-volatile information of the user application data that can be programmed by the configuration messages described in chapter Write IUM.

The IUM has built-in error detection and a single bit error correction.

Data retention **after**	
up to 10,000 programming / erase cycles at Tj,av ≤ 125°C[13]	min. 2000h at Tj ≤ 150°C[14]

Table 51 – IUM Cycles and data retention

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[13] *The total amount of program/erase cycles used in the application should be recalculated with the mission profile from the customer application.*

[14] *The high temperature equivalent hours are equivalent hours calculated with the mission profile from the customer application.*

14. IC Behavior during fault case

14.1. Loss of battery

If the ECU is disconnected from the battery, the LIN_IN / LIN_OUT pins are in high impedance state. There is no impact to the LIN-bus traffic and to the ECU itself.

14.2. Loss of Ground

In case of an interrupted ECU ground connection there is no influence to the LIN bus line.

14.3. Short circuit to battery

The LIN transmitter output current is limited to the specified value in case of short circuit to battery in order to protect the controller itself against high current densities.

14.4. Short circuit to ground

If the bus line is shorted to negative shifted ground levels, there is no current flow from the ECU ground to the LIN-bus and no distortion of the bus traffic.
If the controller detects a short circuit of the LIN-bus to ground the controller switches to sleep mode. The internal responder termination resistor will be switched off and only a high impedance termination of typical 20uA is applied to the bus. The failure current of the whole system can be reduced significant to prevent a fast discharge of the car battery.
If the failure disappears, the bus level will become recessive again and will wake-up the system even if no local wake-up is present or possible.

After valid wake-up or Power-ON the standard LIN responder termination is reconnected.

14.5. Under-voltage Vs

If the ECU battery supply voltage is missing or decreases under the specified value, the LIN pin behaves passive.

14.6. TxD dominant Timeout

In case of a faulty blocked permanent dominant level on pin TxD the transmit path will be disabled after a specified time (typ. 20ms). The data transmission is released again as soon as the failure disappears by the next rising edge of TxD.

15. EMC requirements of Transient Immunity

In order to minimize EMC influences, the PCB has to be designed according to EMC guidelines. The IC is an EMC sensitive device and has to be handled according to the rules in IEC61340-5-2. The IC will apply the requirements in the application according to the specifications ISO7637-2, -3 and ISO 16750-2.
Prototype samples of IC will be evaluated according AEC-Q100-002. The result will be published after qualification.

The automotive test pulses are applied to the module in the application environment using recommended external circuitry. Therefore attention must be taken, that the test pulses shall be applied on global pins only.
For the LININ and LINOUT pins the specification ISO 17987-4 is valid.
Supply Pin VS is protected via the reverse polarity diode and the supply capacitors. No damage will occur for defined test pulses. A deviation of characteristics is allowed during pulse 1 and 5b; but the module shall recover to the normal function after each pulse. During test pulses 2a, 3a and 3b the module shall work within characteristic limits.
Test pulses are used according to ISO 7637-2, 3 and ISO 16750-2. To fulfil other requirements or test pulse definitions changes in the values of the external circuitries might be mandatory.

Description of functional status:

A: All functions of the device are performed as designed during and after the disturbance occurs.

B: All functions of the device are performed as designed during the disturbance occurs. One or more functions can violate the specified tolerances. All functions return automatically within their normal limits after the disturbance is removed.

C: A function of a device does not perform as designed during the disturbance occurs but returns automatically to the normal operation after the disturbances is removed

D: A function of a device does not perform as designed during the disturbance occurs and does not return automatically to the normal operation after the disturbances is removed. The device needs to be reset by a simple operation/action to return to the specified limits/function.

15.1. Test on Supply Lines directly connected to Car Battery – Evaluation of Communication and Function

Test Pulse	Symbol	Value	Dim	Coupling	Test Duration, Functional Status
Transient test pulses according to ISO7637-2 (supply lines), U_A=13.5V, T=(23 ± 5)°C					
1	U_S	-100	V	Direct	5000 pulses, functional state C
2a	U_S	+75	V	Direct	5000 pulses, functional state C
3a	U_S	-150	V	Direct	1h, functional state A
3b	U_S	+100	V	Direct	1h, functional state A
Test pulses according to ISO16750-2, U_A =13V, T=(23 ± 5)°C					
Load dump Test B	U_S	+100	V	Direct	10 pulses clamped to +40 V (U_S*), functional state C

Table 52 – Test pulses Supply Line

15.2. Test pulses on LININ and LINOUT lines – Evaluation of Damage

Test Pulse	Symbol	Value	Dim	Coupling	Test Condition, Functional Status
Transient test pulses according to ISO7637-2 , U_A=0V, T=(23 ± 5)°C & requirements according to IEC 62228-2					
1	U_S	-100	V	Direct capacitive coupled: 1nF	1000 pulses, functional state D
2a	U_S	+75	V	Direct capacitive coupled: 1nF	1000 pulses, functional state D
3a	U_S	-150	V	Direct capacitive coupled: 1nF	10 min, functional state D
3b	U_S	+100	V	Direct capacitive coupled: 1nF	10 min, functional state D

Table 53 – Test pulses LIN

15.3. Test pulses on signal lines, incl. LININ, LINOUT – Evaluation of Communication and Function

Test Pulse	Symbol	Value	Dim	Coupling	test condition, functional status
Transient test pulses in accordance to ISO7637-3 (signal lines). T=(23 ± 5)°C					
DCC slow –	U_S	-30	V	Direct capacitive coupled: 100nF (1nF on LINin, LINout)	1000 pulses, functional state C
DCC slow +	U_S	+30	V	Direct capacitive coupled: 100nF (1nF on LINin, LINout)	1000 pulses, functional state A
DCC fast a	U_S	-60	V	Direct capacitive coupled: 100pF	10 min, functional state A
DCC fast b	U_S	40	V	Direct capacitive coupled: 100pF	10 min, functional state A

Table 54 – Test pulses signal lines

15.4. EMC Test pulse definition

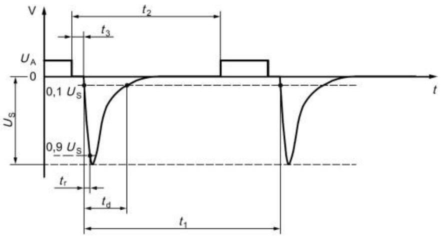
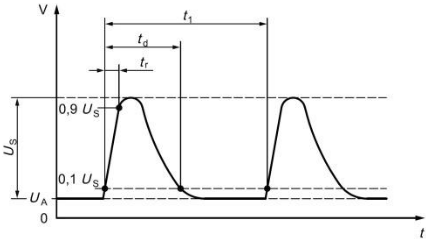
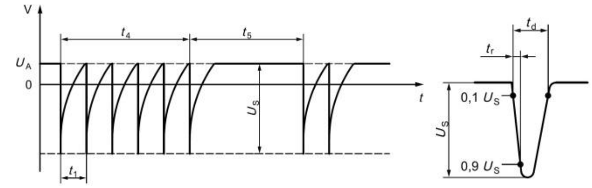
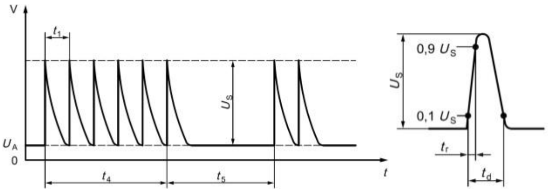
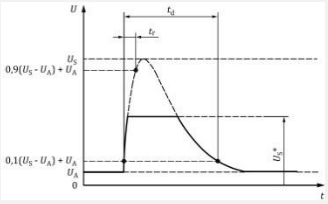
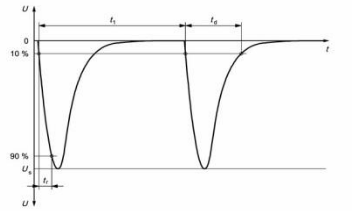
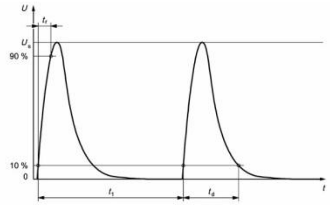
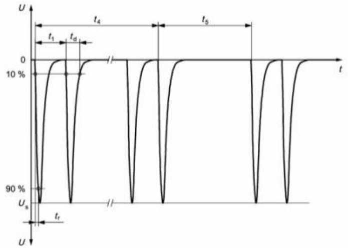
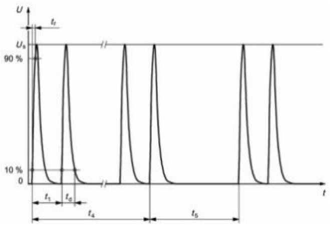
EMC Test Pulse shapes (ISO7637-2 (supply lines))	
Test Pulse 1 Ri = 10 Ohm	Test pulse 2a Ri = 2 Ohm
	
Test Pulse 3a Ri = 50 Ohm	Test Pulse 3b Ri = 50 Ohm
	
Test Pulse shapes (ISO16750-2 (supply lines))	
	Test Pulse 5b (Load Dump) Ri = 0.5 Ohm
	
EMC Test Pulse shapes (ISO7637-3 (non-supply lines))	
Test Pulse 'DCC slow -' Ri = 2 Ohm	Test pulse 'DCC slow +' Ri = 2 Ohm
	
Test Pulse 'Fast a, DCC' Ri = 50 Ohm	Test Pulse 'Fast b, DCC' Ri = 50 Ohm
	

Table 55 – Test pulses shapes ISO7637-2 and -3

15.5. Application Circuitry recommendations for improved ESD and EMC behavior

For best EMC performance, the following minimum application circuit is required.

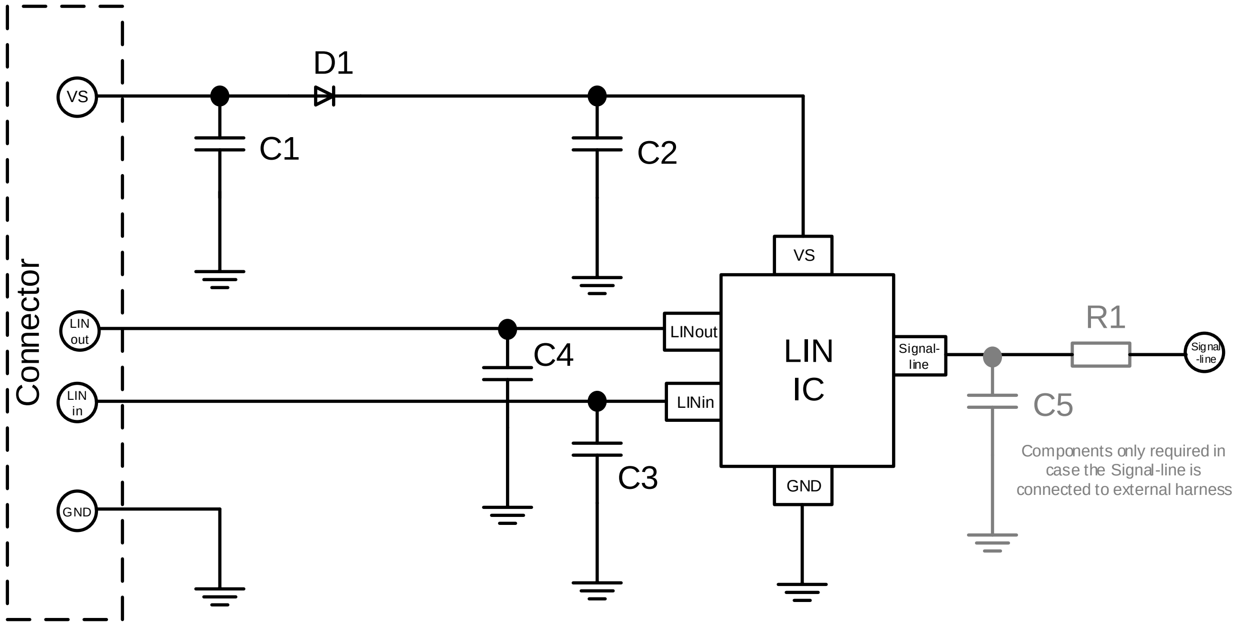


Figure 9 – Minimum required application circuit

15.5.1. External Circuitry on Supply Lines

Symbol	Value	Dim	Comment
C1	4.7	nF	Ceramic SMD: 10%, ≥50V
D1			Inverse-polarity protection diode
C2	4.7	µF	Recommendation: Ceramic SMD Murata X7R 4.7uF +-10% 50V GCM31CC71H475KA03[15]

Table 56 – Used components on supply lines

15.5.2. External Circuitry on LIN Lines

Symbol	Value	Dim	Comment
C3+C4	≤220	pF	Ceramic SMD: 10%, ≥50V; CSlave = C3+C4+ CLIN ≤250pF;

Table 57 – Used components on LIN

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[15] *During the test higher voltage than 50V can occur. It would be verified that neither the DUT nor the capacitor will be damaged.*

15.5.3. External Circuitry on Signal Lines

Components only required in case the Signal-line is connected to external harness.

Symbol	Value	Dim	Comment
C5	10	nF	Ceramic SMD: 10%, 0805, ≥50V;
R1	0	Ω	

Table 58 – Used component on signal line

16. ESD robustness according to procedure IEC62228-2

IC – level tests according to procedure IEC62228-2 (LIN products) will be performed by an external test house (IBEE Zwickau).
Part of the procedure IEC62228-2 is ESD robustness according to IEC61000-4-2. (150pF, 330Ohm).
Test results will be available in a separate report.

17. Contact

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18. History record

Datasheet Version	Changes	Release Date
001	Initial release	October 2025
002	LED Derating feature added Chapter “Absolute maximum ratings” ▪ Max junction temperature increased to Tj=175°C Chapter “Operating conditions” ▪ Max junction temperature in operation condition increased to Tj=150°C Chapter “Electrical parameter specification” ▪ Test condition changed to Tj=35°C ▪ min. VLC_drop voltage changed to 1.5V/0.95V	February 2026

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