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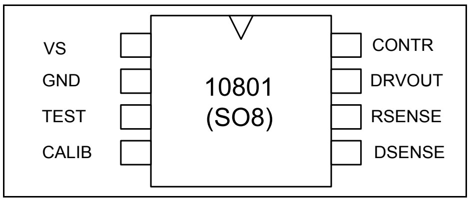
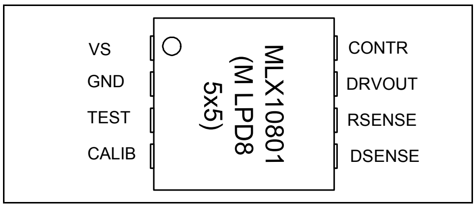
IC specification MLX10801
Power LED driver for automotive applications
Power saving low side coil driver
Electronic fuse

Features





General
- Minimum number of inexpensive external components
- Auto shutdown in case of over temperature with internal or external temperature sensor
- Small package allows compact module design with minimised wire runs and short connections to achieve improved EMI performance
- MLX10801 is offered in 2 package options: SOIC8 and MLPD8 5x5. The MLPD8 5x5 package option allows to take out a higher peak and average current than the SOIC8 package option

LED driver
- High energy efficiency
- Light control via PWM possible
- Light output has a minimized dependency on supply and temperature variations
- Adjustable LED parameters are stored in an internal NV memory

Coil driver
- Additional use for driving coils like relays and micro valves in a power saving mode
- Works with a wide range of coils

Electronic fuse
- Additional use as electronic fuse.
- Fuse current adjust possibility

Ordering Information

Part Nr	*Temperature Code*	*Package Code*
MLX10801	R (-40°C to 105°C)	DC (SOIC8)
MLX10801	R (-40°C to 105°C)	LDC (MLPD8 5x5)

General Description

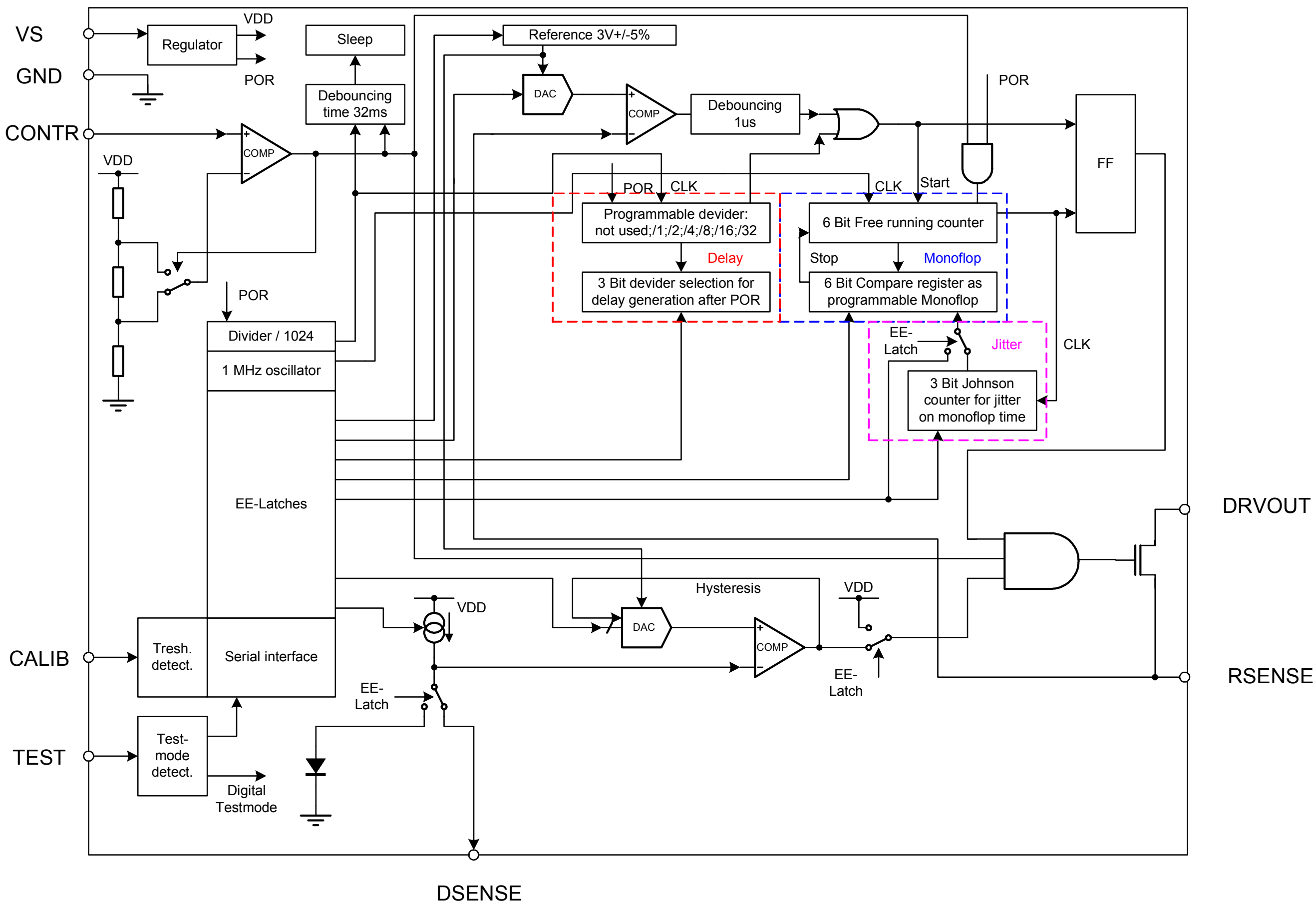
The MLX10801 is a multi-purpose LED driver for high power LEDs designed for automotive applications.
A lot of adjustment possibilities allow for the design of different LED applications using only a few external components.
The circuit is load dump protected for a 40V load dump pulse.

As a second use, a variety of coils like relays and micro valves can be driven in a very efficient power saving mode.

A third use is a simple electronic fuse, to protect circuits from overcurrent or overtemperature.

Table of content

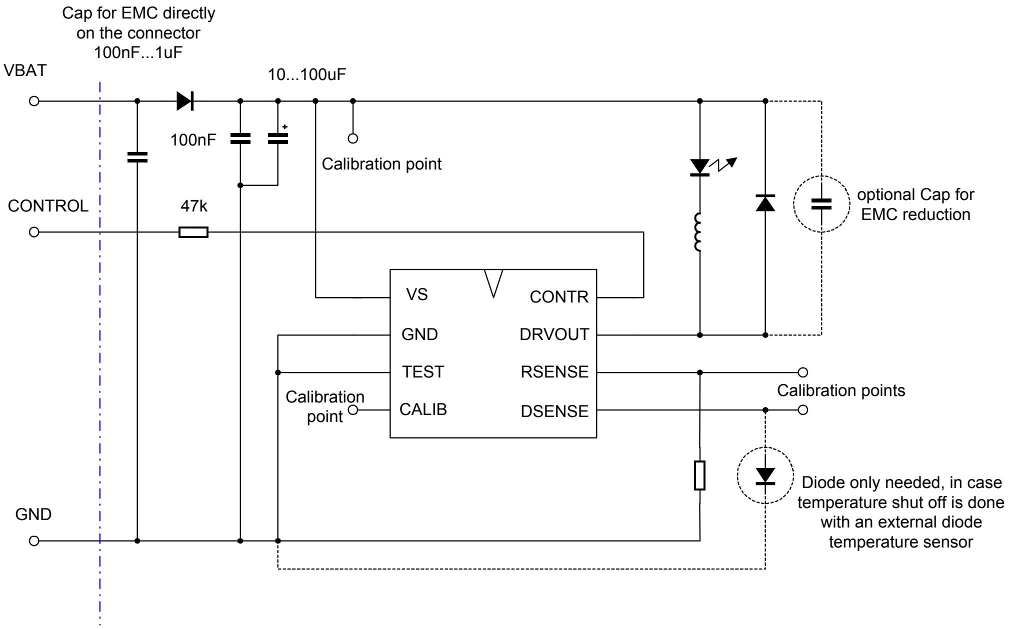
Block diagram



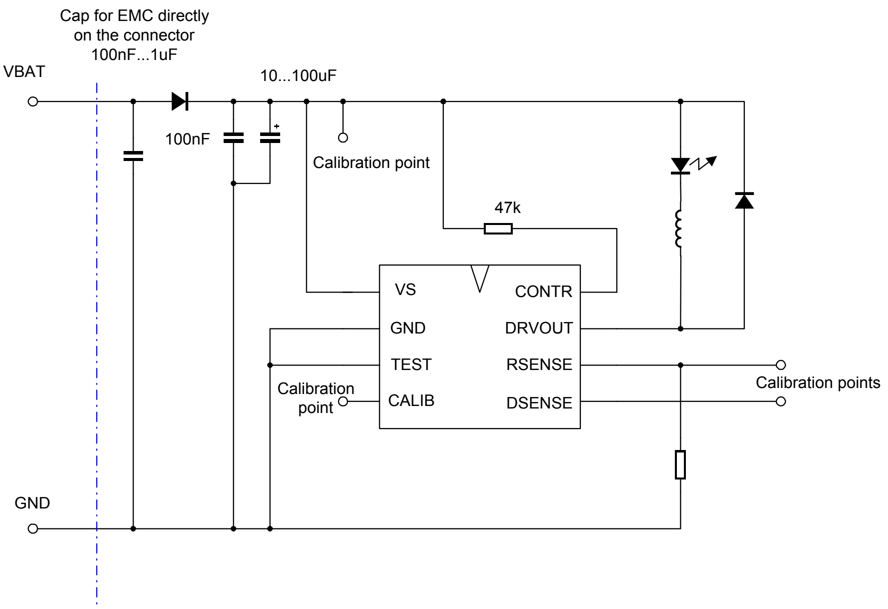
1. Typical application data

1.1. LED driver applications

1.1.1. Complete schematic LED driver diagram



1.1.2. Minimum schematic LED driver diagram



1.1.3. LED driver application notes

The MLX10801 is optimised for the use of low cost coils. For a standard application with 1 LED and an average current of 350mA a coil of about 100µH…470µH having ≤ 1R omic resistance should be chosen. The sense resistor should have a value between 0.47R…1R / 250mW.

As a general rule: the higher the load current, the lower the inductance of the coil should be, since higher currents lengthen the charging time of the coil. Switching frequencies lower than 20kHz are often not desired.
It is possible (without manipulating the internal IC trimming data) to set the peak current and the average current of the LED by a variation of sense resistor and coil value. The same can be achieved by programming a modified parameter set to the EEPROM of the IC.

The free wheel diode that carries the load current during the passive state (driver OFF) should be a very fast switching diode like ES1D or BYG80 with a recommended trr<30ns in order to avoid parasitic spikes on RSENSE. The diode must be able to carry the current flowing in the LED.

For applications that use an external temperature sensor, virtually any low cost diode with a temperature coefficient of -2mV/K can be used.

In case of longer lines between the IC and the coil (which should be avoided because of EMI), a capacitor might be placed in parallel to RSENSE to avoid crosstalk and parasitic switching.
A well chosen parameter set can help to avoid such a condition. The goal should be to unload the coil as much as possible during the selected monoflop time (see as well chapter 8.3).

The schematic diagram under 1.1.1 is used in applications, where the LED is controlled by external control electronics. A PWM with a frequency between 30Hz..4kHz can be applied to the CONTROL pin in order to dim the light output. This frequency is limited by the debouncing time for the sleep mode on the lower side and the selected monoflop time on the upper side of that range.
This function can be used to achieve different light outputs or also be used in a temperature down regulation.
It is recommended to have the PWM frequency at least 5-10 times lower than the selected driver switching frequency.

The minimum schematic diagram under 1.1.2 is sufficient for all applications with a constant light output. Nevertheless a dimming function could be achieved by a PWM driving directly on the module supply.
In this mode, the PWM frequency should be chosen between 0 and 1kHz. It is limited by the maximum IC settling time.

1.1.3.1.LED driver application notes for MLX10801 in MLPD8 5x5

The MLX10801 assembled in a MLPD8 5x5 package allows to take out of the IC a higher average and a higher peak current.

The pre calibration data of the MLX10801 in all types of packages is identical.

In order to take advantage of the bigger output current capability without changing the ICs pre trimmed parameter set, the user can change the values of the coil and the sense resistor.
A typical LED average current of approx. 700mA can be achieved by using a coil of 220uH and a sense resistor of 0,3 Ohm.

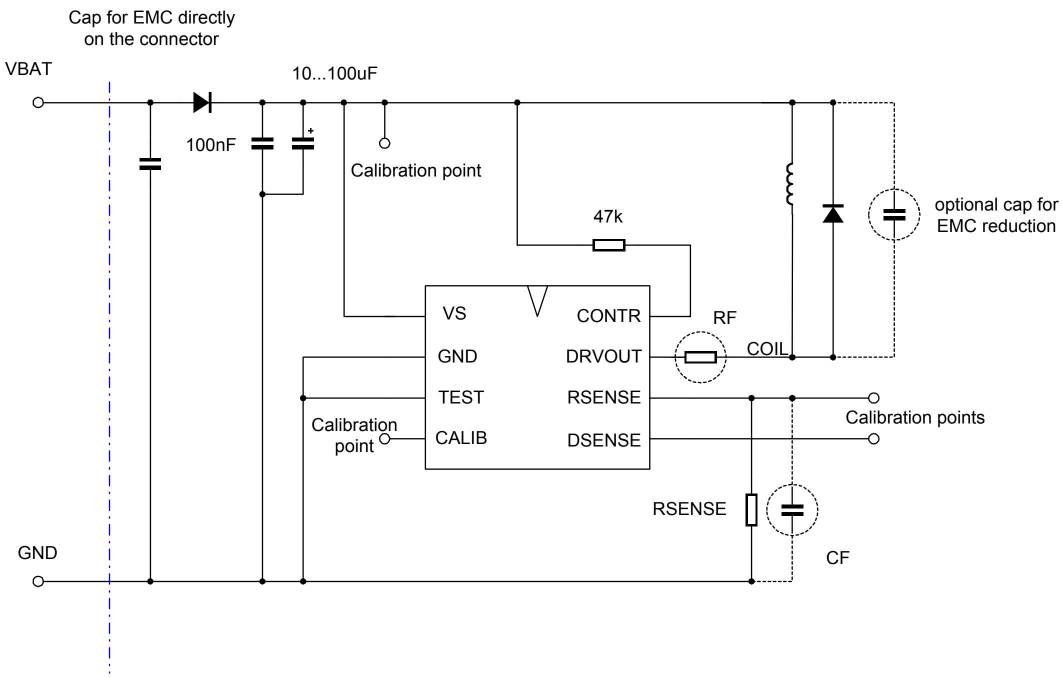
In case of such typical high current applications, the user must provide a suitable heat sink possibility on the PCB.

Changing the pre calibrated data, which is stored in the internal EEPROM, allows to tune the IC also to other coil and sense resistor values, the EMC performance can be influenced as well.

Please check as well out the MLX10801 application notes for different driving solutions, which allow to drive more than one high power LED on a single MLX10801.

1.2. Coil driver applications

1.2.1. Coil driver schematic diagram



1.2.2. Coil driver application notes

The purpose of this application is to drive a coil in a power saving efficient way using a switched mode power supply. Coils of 10mH…5H can be driven. Attention has to be drawn to the maximum allowed current which must not be exceeded.

In case of high inductive coils and/or longer cables between the IC and the coil, CF and RF might be needed for reducing electromagnetic emissions.

When the driver switches on, the coil still contains a certain amount of energy, which is connected to a high voltage on node COIL. Via the R_{DSon} of the driver this voltage together with switching oscillations is then coupled to RSENSE. If these switching oscillations do not disappear within the debouncing time of the comparator (typically 1µs) the driver is switched off immediately, an effect known as “parasitic switching”. A solution to that could be:

- CF, R_{DSon}+ RF form a filter
- CF only acts in case the driver switches ON (in the OFF state it is quickly discharged by RSENSE)
- R_{DSon} + RF should be larger than RSENSE
- RSENSE and CF must be directly connected to pin RSENSE
- CF and RF must be figured out in the application. However, typical start values are RF=0 (not used) and CF=1.5uF.

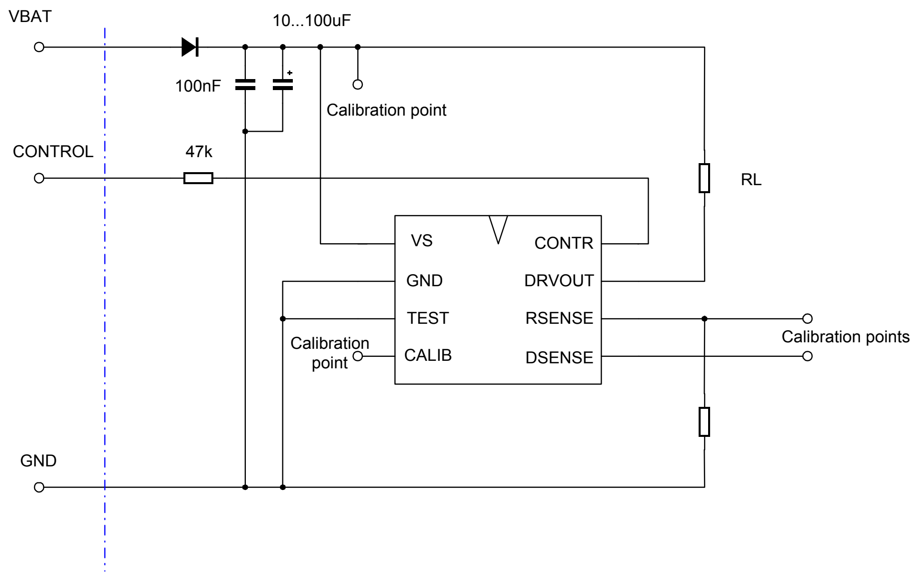
The idea is to decouple the node COIL from RSENSE so that the switch off voltage can not be reached. Thus, parasitic switching is avoided.

Instead of using RF and CF, “parasitic switching” can also be avoided by a well chosen parameter set (see also chapter 8.3) and a well designed PCB that avoids switching oscillations.

Note: Melexis designed in a debouncing time of 1µs to the internal comparator due to the fact that the MLX10801 can be used with a wide range of inductances.

1.3. Electronic fuse applications

1.3.1. Electronic fuse schematic diagram



1.3.2. Electronic fuse application notes

The purpose of this application is the protection of an external load against overcurrent. In this mode, the switch mode regulator is disabled. The driver is permanently ON as long as the current remains below a specified level. Once this level is reached, the driver switches OFF and remains OFF until a POR is given.

A shutdown of the module due to overtemperature is also achievable if the internal or external temperature sensor is used.

2. Application pins

Nr.	Name	Function
1	VS	Supply Voltage
2	GND	Ground
3	TEST	MELEXIS test pin for test modes enable
4	CALIB	Serial clock/data for end of line programming
5	DSENSE	External diode pin for temperature measurement and temperature shutdown condition
6	RSENSE	External sense resistor pin for peak current detection
7	DRVOUT	Driver output
8	CONTR	Light control input, ON/OFF or dimming via PWM signal, sleep mode possibility

3. Absolute maximum ratings

Parameter	Symbol	Condition	Min	Max	Unit
Power supply	vs	DC max. 2h max. 0.5s	-0.3 -0.3 -0.3	28 36 40	V V V
Maximum input current in protection circuitry on any pin	iprot	In case of maximum supply ratings	-10	10	mA
Maximum input voltage on CONTR	vicontr	without external resistor protected with external 47k resistor	-0.3 -40V (0.5s)	18 40 (0.5s)	V V
Maximum input voltage on RSENSE, DSENSE, TEST	vilv		-0.3	vdd+0,3	V
Maximum input voltage on CALIB	vicalib		-0.3	18	V
Maximum input voltage on DRVOUT	vdrvoutmax	with load DC max. 2h max. 0.5s	 -0.3 -0.3 -0.3	 28 36 40	 V V V
Maximum peak current on DRVOUT for MLX10801 in SOIC8	ipkdrvout			550	mA
Maximum average current on DRVOUT for MLX10801 in SOIC8	iavgdrvout			400	mA
Maximum peak current on DRVOUT for MLX10801 in MLPD8 5x5	ipkdrvout	*)		1.2	A
Maximum average current on DRVOUT for MLX10801 in MLPD8 5x5	iavgdrvout	*)		750	mA
Maximum junction temperature Lifetime Dynamic In case of EE Latch write Storage temperature	tjunc		 -40 -40 -40 -55	 130 150 85 125 150 (100h)	 C C C C C
Ambient temperature range	tambient	-40C		105	C

Thermal resistance junction to ambient for MLX10801 in SOIC8	rth			120	K/W
Thermal resistance junction to ambient for MLX10801 in MLPD8 5x5 (Under consideration of the thermal application notes for MLPD packages published under www.carsem.com)	rth	*)		37	K/W

*) The parameters are only valid, in case the specified rth is insured by having a suitable heat sink capability on the PCB.

4. Electrical characteristics

Following characteristics are valid
- for the full temperature range of T = -40°C to +105°C,
- a supply range of 28V ≥ VS > 6V
- and the IC settling time after power on reset

unless other conditions noted.

With 6V ≥ VS > vporh analog parameters can not be guaranteed.

Note: The correct operation of the MLX10801 as a switching mode power supply for voltages lower than the nominal supply voltage is dependent on the forward bias voltage of the used LED.
The user must ensure that at low supply voltage the peak current threshold voltage on the RSENSE pin can be reached in order to keep the switching principle working.

If several pins are charged with transients above VS and below GND, the sum of all substrate currents of the influenced pins should not exceed 10mA for correct operation of the device.

Normal operating supply voltage is supposed to be 13.8V.

Parameter	Symbol	Conditions		Limits		Units
			Min	Typ	Max	
Global parameters						
Maximum current during 40V load dump	ihv	VS=40V CONTR=H			10	mA
Normal supply current at highest DC voltage	inomdch	VS=28V CONTR=H			4	mA
Normal supply current	inom	VS=13.8V CONTR=H			2	mA
Sleep mode current	isleep	VS=13.8V Chip in sleep T=25C			105	µA
IC settling time						
IC settling time after power on reset	tsettle				300	µs
IC settling time after wake up	tssettle				300	µs
Oscillator related parameters The min/max specification influences directly all derived timings in the same deviation						
Oscillator frequency	fosc	(frequency can only be adjusted by Melexis during final parts test)	0.7	1.0	1.3	MHz
Debouncing time for sleep mode						
Debouncing time on CONTR for sleep mode	tdebsleep			32		ms
Wake up time	twakeup			8		µs

RESET related parameters						
Power on reset level, if VS is ramped up	vporh	(Reset is connected to the internal VDD, but vporh is measured on pin VS)			5.0	V
VDD related parameters (VDD stays only internal)						
5V supply voltage range	vdd	VS=13.8V	4.0		5.5	V
Monoflop related parameters						
Monoflop time	tmon	specified under 14.1				
Delay time generation for current reduction after power on reset						
Delay time	tdelay	specified under 14.1				
DAC reference related parameters						
DAC reference voltage	vdacref		2,75	3	3,25	V
RSENSE related parameters						
Input leakage current	ileakrsense	DRVOUT is switched off	-5		5	µA
Minimum threshold voltage on RSENSE of a given step	vrsensemin	specified under 14.1				
Maximum threshold voltage on RSENSE of a given step	vrsensemax	specified under 14.1				
Stability of a selected step due to temperature and supply influence and long term drift	vrsensestab		-3 [1]		3 [1]	%
DSENSE related parameters						
Output leakage current	ileakdsense	CONTR=0	-5		5	µA
Output current for temperature measure-ment	idsense	CONTR=1 (current can only be adjusted by Melexis during final parts test)	80		120	µA
Minimum temperature shutdown voltage on pin DSENSE of a given step	vdsensemin	specified under 14.1				
Maximum temperature shutdown voltage on pin DSENSE of a given step	vdsensemax	specified under 14.1				
Hysteresis between shutdown and switch on for a selected trimming step	vdsensehyst		13		35	mV
Stability of a selected step due to temperature and supply influence and long term drift	vdsensestab		-3 [1]		3 [1]	%

Temperature shutdown related parameters for the internal temperature sensor						
Forward bias voltage of internal diode at 25°C	vfwdrt	idsense trimmed	630	660	690	mV
Forward bias voltage of internal diode at 105°C	vfwdht	idsense trimmed	460	490	520	mV
CONTR related parameters						
Input leakage current	ileakcontr		-5		5	µA
Comparator digital threshold level L => H, switching point	vin5vhcontr	 vdd=5V	0.6*vdd 3	0.65*vdd 3.25	0.7*vdd 3.5	V V
Comparator digital threshold level H => L, switching point	vin5vlcontr	 vdd=5V	0.3*vdd 1.5	0.35*vdd 1.75	0.4*vdd 2	V V
DRVOUT related parameters						
Input leakage of DRVOUT when switched off	ileakdrvout		-5		5	µA
On resistance of DRVOUT @Tj=150C	rdsdrvout				1.4	Ω
CALIB related parameters						
Pull down resistance of pin CALIB	rpdcalib		5	10	20	k

[1)] Guaranteed by design

5. EE-Latch characteristics

The NV memory carrying the trimming information is composed of an EEPROM latch. The data, that is written to this latch during final parts programming at Melexis or by the customer, is permanently stored in this latch, even after the chip is powered down.

Data retention	
25°C permanent ambient	20 years
55°C permanent ambient	20 years
85°C permanent ambient	10 years
125°C permanent ambient	1 year

6. ESD/EMI recommendations for MLX10801

- In order to minimise EMI, the PCB has to be designed according to EMI guidelines. Additional components may be needed, other than what is shown in the application diagrams, in order to comply with the EMI requirements.
- The MLX10801 is an ESD sensitive device and has to be handled according to EN100015 part 1.
- The MLX10801 will fulfil the requirements in the application according to the specification and to DIN 40839 part 1.
- The MLX10801 is designed with ESD protection >1000V HBM according to MIL883D.
- After ESD stress, the sleep mode current (specified in chapter 4) of the component can not be guaranteed anymore.

7. *Automotive test pulses*

The following chapter is valid for a completely assembled module. That means, that automotive test pulses are applied to the module and not to the single IC.

In the recommended application according to chapter 1, the reverse polarity diode together with the capacitors on the supply and the load dump protected IC itself protects the module against the automotive test pulses listed below.
The exact values of the capacitors for the application have to be figured out according to the automotive and EMI requirements.

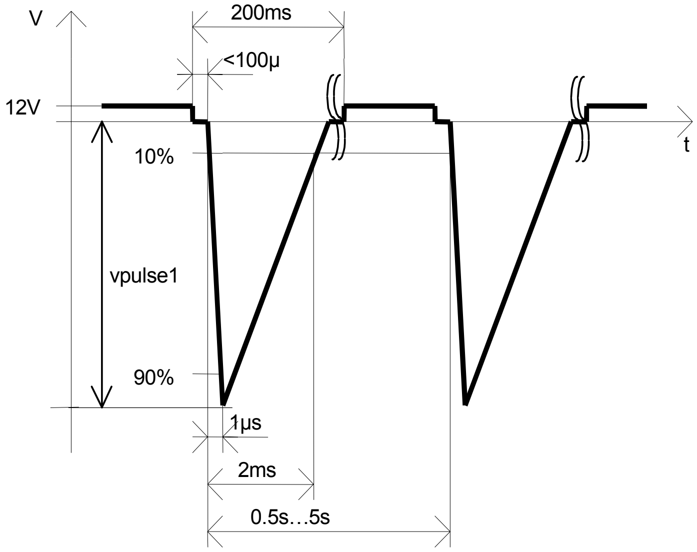
No damage occurs for any of the test pulses.
A deviation of characteristics is allowed during pulse 1, 2, 4; the module returns to normal operation after the pulse without any additional action.
During test pulse 3a, 3b, 5 the module operates within characteristic limits.

Parameter	Symbol	Min	Max	Dim	Test condition, Functional status
Transient test pulses in accordance to DIN40839 part 1&3 and ISO7637 part 1&3, IC pin CONTR connected to IC pin VS via 47k, module schematics are according to application notes. Module acts as a single light source					
Test pulse #1 at module pin VBAT, GND	vpulse1	-100	0	V	5000 pulses, functional state C
Test pulse #2 at module pin VBAT, GND	vpulse2	0	100	V	5000 pulses functional state C
Test pulse #3a at module pin VBAT, GND	vpulse3a	-150	0	V	1h, functional state A
Test pulse #3b at module pin VBAT, GND	vpulse3b	0	100	V	1h, functional state A
Test pulse #4 at module pin VBAT, GND	vspulse4 vapulse4	-6 -5	-4 -2,5	V V	1 pulse, functional state C
Test pulse #5 at module pin VBAT, GND	vpulse5	26,5	86,5	V	1 pulse clamped to <=40V functional state C,

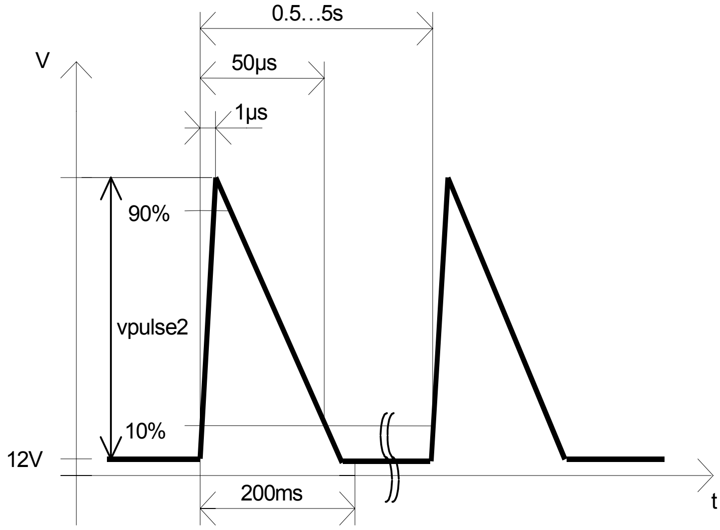
Description of functional status:
A: All functions of the module are performed as designed during and after the disturbance.
B: All functions of the module are performed as designed during and after the disturbance: However, one or more can deviate from specified tolerance. All functions return automatically to normal limits after exposure is removed. Memory functions shall remain class A.
C: A function of the module is not performed as designed during disturbance but returns automatically to a normal operation after the disturbance

7.1. Test pulse definition

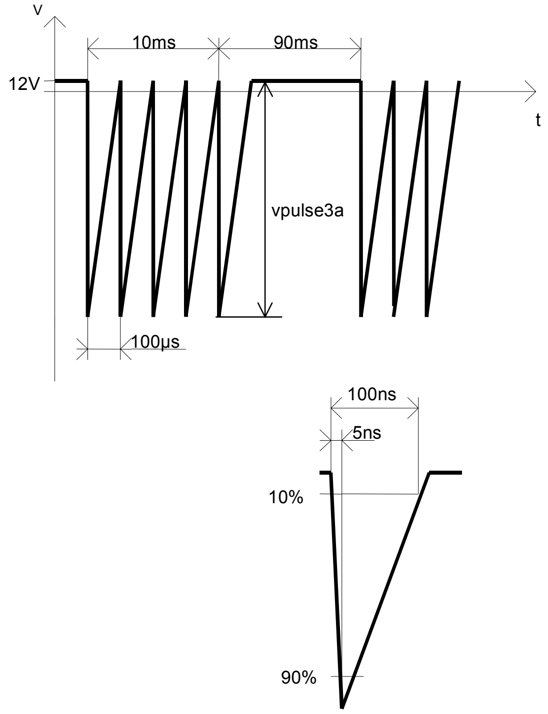
Test Pulse 1
Ri = 10R



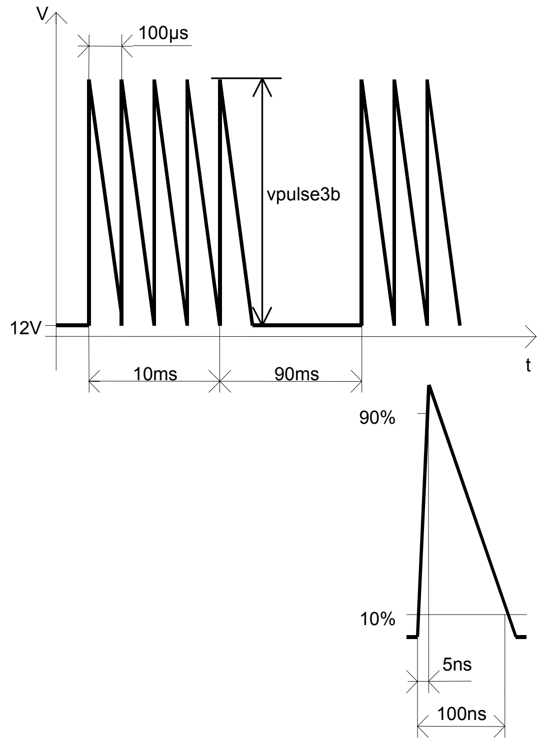
Test pulse 2
Ri=10R



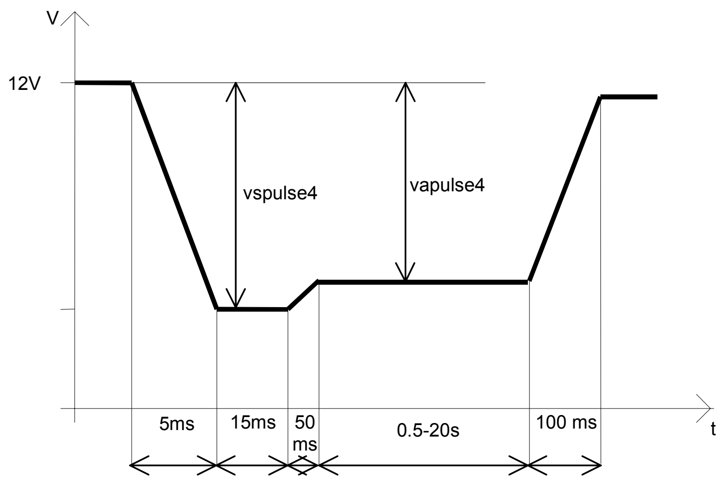
Test Pulse 3a
Ri = 50R



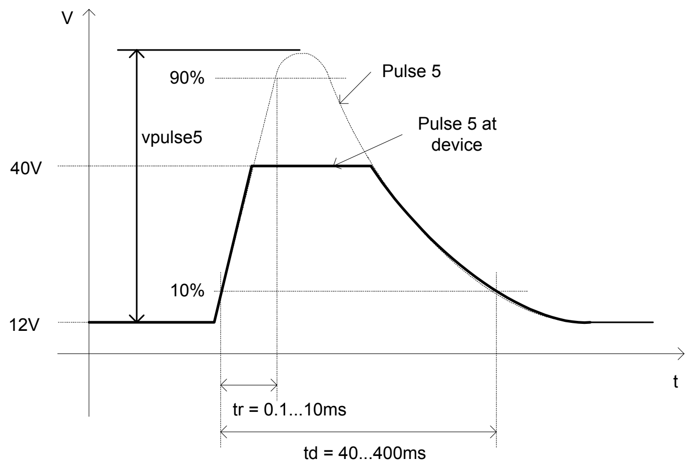
Test Pulse 3b
Ri = 50R



Test Pulse 4 (Cranking)
Ri = 0.01R



Test Pulse 5 (Load Dump)
Ri = 0.5…4R (clamped to 40V during test)



8. LED driving principle

8.1. General

The LED is driven by a switched mode power supply using an inductor as the energy storage element. This method has several advantages. The supply voltage has to be set down to the forward bias voltage of the LED. In ordinary applications this is achieved by a resistor with the following drawbacks:

- A resistor dissipates power which is transformed to heat
- Efficiency is reduced drastically
- The light output of the LED is dependent on the supply and the temperature of the resistor

The MLX10801 avoids this disadvantages as the following calculation shows (all values according to the Melexis demo board EVB10801,standard configuration with L=220µH, R_{SENSE} =0.47R):

Supposed:

V_{bat} = 13.8V
$V_{fLED} \approx$ 3.4V
$I_{fLED} \approx$ 350mA
$V_{f1} \approx$ 0.7V (reverse polarity diode)
$V_{f2} \approx$ 0.7V (free wheel diode)
$V_{RSENSE} \approx$ 0.4V (@I_{fLED}, R_{SENSE}=0.47R)
$V_{RDS\ ON} \approx$ 0.3V (@I_{fLED})
$V_{Coil} \approx$ 0.2V (@I_{fLED})

Efficiency using a simple resistor:

Efficiency n: $n = V_{fLED} / V_{bat} \approx$ **25%**

Efficiency using the MLX10801:

The following calculation is an approximation only, due to the fact the coil current is not constant. It is therefore calculated with average currents.

1) During OFF time, the coil acts as the storage element and puts its energy to the free wheel diode and the LED:
$n_1 = V_{fLED} / (V_{fLED} + V_{f2} + V_{Coil}) \approx 79\%$

2) During ON time, current flows through the reverse polarity diode, LED, coil , FET driver and RSENSE, which causes the following voltage drops:

$n_2 = V_{fLED} / (V_{fLED} + V_{f1} + V_{Coil} + V_{RDS\ ON} + V_{RSENSE}) \approx 68\%$

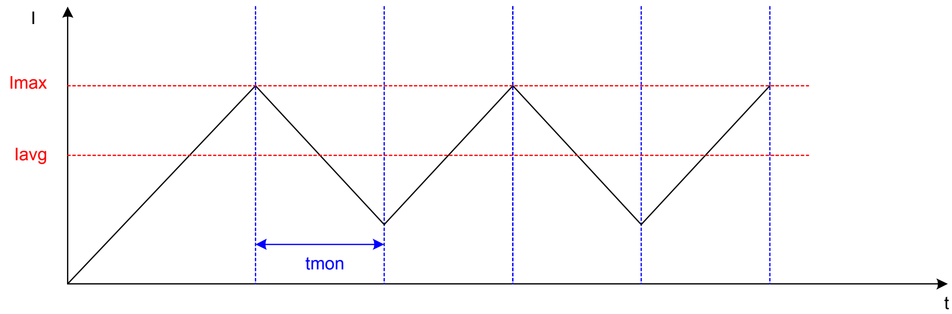
3) ON and OFF times are in ratio of roughly 40:60
Efficiency n:n = (n_1*0.4 + n_2*0.6) = **72.4%**

Measurements have given an efficiency of about 70% and confirm this estimation. Note, that the ratio of ON and OFF time depends on many factors like supply voltage, coil inductance, forward bias voltage etc. and is therefore an application specific value. For ordinary applications, efficiency ranges from about 65% - 75%.

8.2. The principle in detail

The driver is switched on until a maximum current through the LED is reached. This maximum current is programmable by the customer. After reaching the maximum current, the driver is switched off for an adjustable monoflop time that is formed by a counter compare unit. The monoflop time is also programmable by the customer. Both parameters, the peak current threshold voltage and the monoflop time, create an ON/OFF period to form an average current through the LED. By programming these parameters, an adjustment of the average load current is possible in a wide range.

Note: The current sense comparator has a typical debouncing time of 1µs as shown in the block diagram. This delay time prevents the driver from being switched off due to short term switching oscillations etc. When working with very short monoflop times this time has to be taken into account for calculations.



Note: The circuit is active only in case CONTR=H.

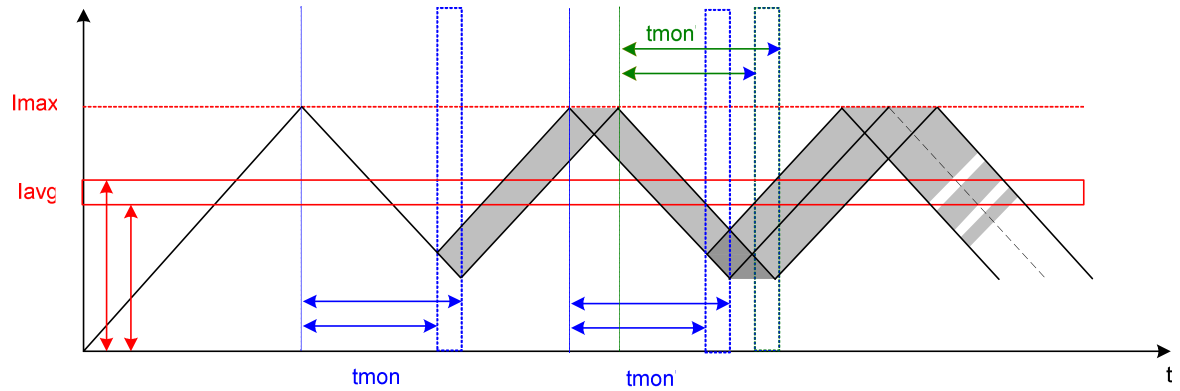
By applying a PWM signal on CONTR, the LED can be dimmed from 0% to 100%.

CONTR=0	LED with 0%
CONTR=PWM	LED dimmed with PWM
CONTR=H	LED with 100%

Dimming can also be achieved by applying a PWM directly to the module supply.

IC settling times have always to be considered in PWM mode. Please refer also to chapter 1.1.3 for additional PWM frequency considerations.

With a configuration bit, a pseudo random generator can be applied to the last 3 LSBs of the 6 setting bits for the monoflop time. The pseudo random generator runs with the clock derived out of the monoflop time and adds a random distribution on these 3 LSBs. Therefore, the monoflop time gets a **random** variation from its trimmed value. This occurs in every monoflop period. It will influence the average current in the same manner. By using this **jitter mode** feature, the EMI behaviour of the complete module is improved, due to the variation of the otherwise fixed switching frequency.
Please refer to 14.2 for additional information.



jitter mode

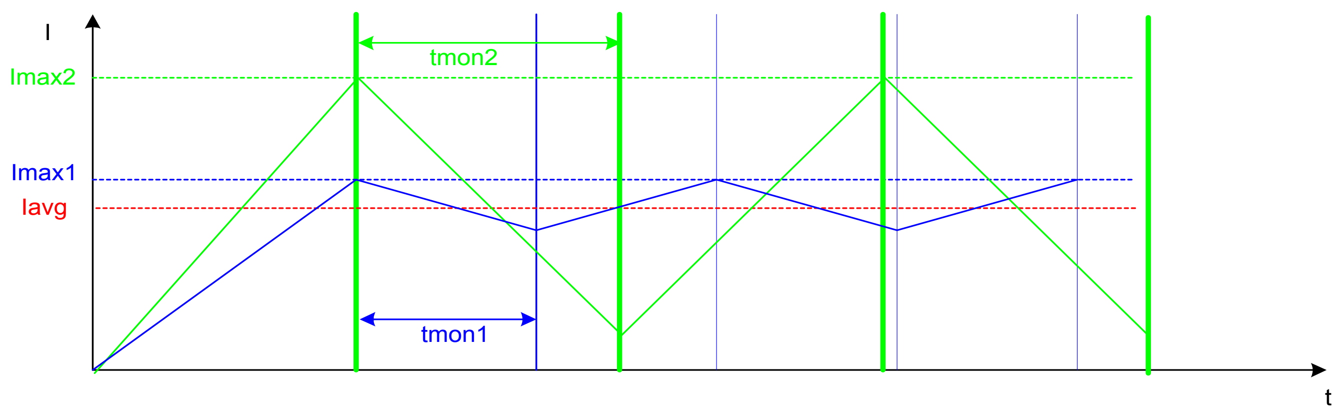
8.3. Coil inductance, EMI and selected parameter set

The inductance L of a coil describes the amount of magnetical energy that can be stored in it. Consequently, high inductive coils will be discharged less than low inductive coils in a given time.

Generally the coil can be driven in two different ways:

1) The coil will only be discharged partially. That means the coil still carries a significant amount of energy when going from discharging to charging. In that moment the charging current rises immediately to the coil current that was flowing just before switching. This is connected with large dI/dt transients on the RSENSE pin that have a negative impact on EMI.

2) The coil will be discharged completely. Thus, at the end of a discharging cycle, the coil doesn't carry energy anymore. With the next charging cycle, current increases steadily from around zero. This way, large dI/dt transients are completely avoided.
Care has to be taken when working in jitter mode. In this case, monoflop time (=discharging time) is not constant but varies in a certain range (see chapter 14.2 for details). It must be ensured that only the longest possible monoflop time completely discharges the coil. Otherwise the coil is discharged before the monflop time ends which results in a loss of efficiency.



Conclusion: In most cases the coil is driven in a combination of both ways. A tradeoff has to be made between EMI behaviour and maximum allowed LED current. By varying these parameters, an optimum can be found for virtually every application.

Below are some examples for typical parameter sets given for a 350mA LED current and the following application data:

Standard application used according to 1.1.1:

- RSENSE = 0.47R (1R)
- LED: Luxeon LXHL-MW1C
- L = 220µH, 470µH

L=470µH, RSENSE=1R

```
;Selection of temperature sensor (1-internal). Bit[19].
 1
;Jitter enabled (1-enabled). Bit [18].
 1
;Delay after POR. Bits [17:15].
 0 0 0
;Temperature shut off. Bits [14:10].
 0 1 0 0 1
;TMonoflop time. Bits [9:4].
 1 0 0 1 0 0
;Peak current. Bits [3:0].
 1 1 1 1
w
```

L=220µH, RSENSE=0.47R

```
;Selection of temperature sensor (1-internal). Bit[19].
 1
;Jitter enabled (1-enabled). Bit [18].
 1
;Delay after POR. Bits [17:15].
 0 0 0
;Temperature shut off. Bits [14:10].
 0 1 0 0 1
;TMonoflop time. Bits [9:4].
 0 1 1 1 0 0
;Peak current. Bits [3:0].
 0 1 1 1
w
```

L=100µH, RSENSE=0.47R

```
;Selection of temperature sensor (1-internal). Bit[19].
 1
;Jitter enabled (1-enabled). Bit [18].
 1
;Delay after POR. Bits [17:15].
 0 0 0
;Temperature shut off. Bits [14:10].
 0 1 0 0 1
;TMonoflop time. Bits [9:4].
 0 0 1 1 0 0
;Peak current. Bits [3:0].
 0 1 1 1
w
```

8.4. Switching frequency considerations and constant light output

As already shown, the switching frequency depends on the peak current as well as on the monoflop time for a given coil. Furthermore it depends on the coil inductance itself.

Due to the principle of switch mode power supplies, the current through the LED is kept constant for any supply changes. The parameter that changes in order to keep the current constant is the switching frequency itself. The lower the supply voltage, the lower the switching frequency. Furthermore, the supply current is affected by supply changes: with an increasing supply voltage the average supply current decreases.

Melexis delivers the MLX10801 with a pre-trimmed parameter set according to chapter 15, where an average switching frequency for a supply voltage of 13.8V is given.

The graph below shows the relative luminous flux versus the power supply for a **typical** application.
The luminous flux at 14V has been set to 100%. The graph indicates that the light output is not as dependent on supply changes.