Application Note
MLX10803 Boost/Buck EVA board
Power LED driver for automotive applications

1. Scope

This document describes the design and use of the ***MLX10803 Boost/Buck Evaluation Board***. For a general description about the functionality of the MLX10803 please refer to the MLX10803 data sheet.
Note: This document is valid for the *MLX10803 Boost/Buck Evalboard Rev.2.2* or higher!

2. Applications

The *MLX10803 Boost/Buck Evaluation Board* is intended to be used as an application example of the MLX10803 Power LED driver. It was developed to show the possibility of driving a serial chain of LEDs with a supply voltage that is lower than the total forward voltage of all LEDs. It works as a two stage step-up/step-down converter by using 2 MLX10803 ICs. The board is suitable to be used in prototypes and mock ups to allow quick implementation of the MLX10803 in a multiple LED lighting application.

3. Other Components Needed

The board is optimized for a chain of serially connected LEDs with a total forward voltage of 20-24V and an average LED current of 350mA. This corresponds to 6 white high brightness LEDs like Lumileds Luxeon I® , Cree XLamp™ 7090 or OSRAM Golden Dragon®. However, the board can be modified in order to suit other applications with less or more LEDs.

4. Application Schematic

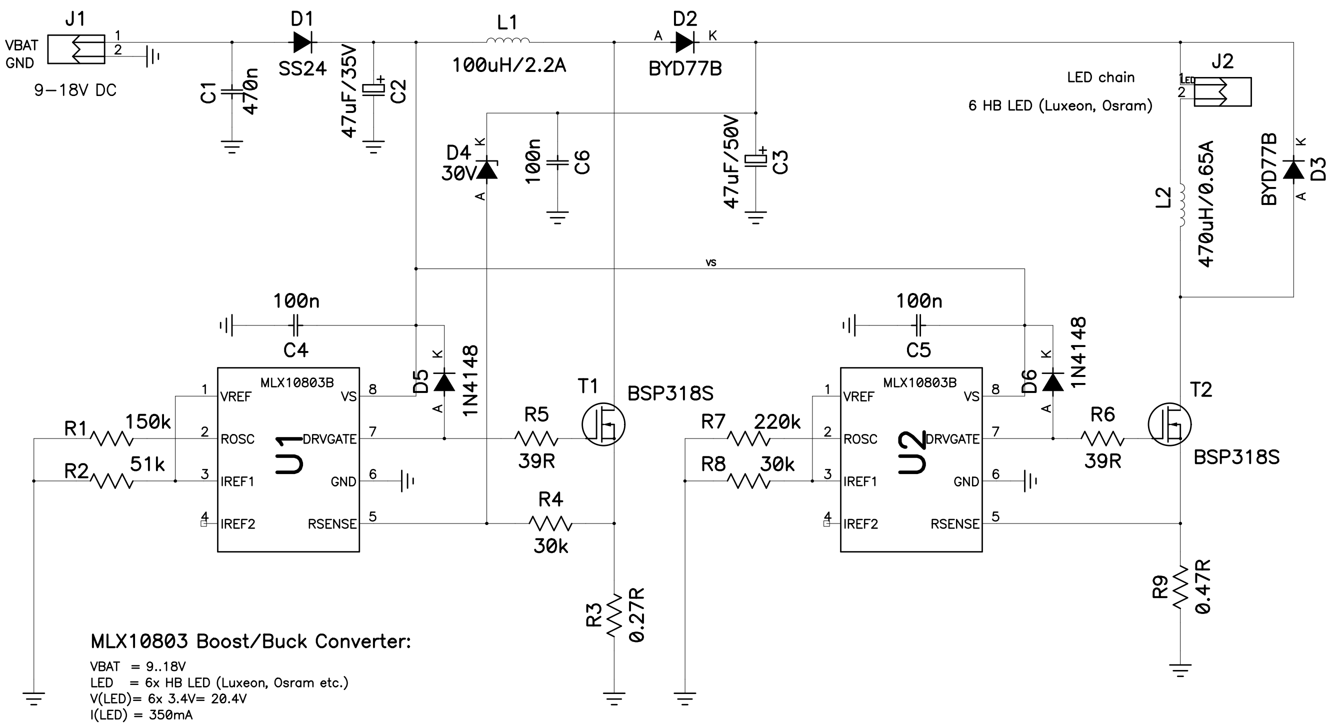

Figure 1: MLX10803 Boost/Buck Evaluation board schematic

5. Connector Pin Definitions

Connector J1 (VBAT)	**Signal**	**Connection**
Pin1	VBAT	LED and IC supply, 9..18V DC
Pin2	GND	Supply ground
Connector J2 (LED)	**Signal**	**Connection**
Pin1	LED+	High Brightness LEDs anode
Pin2	LED-	High Brightness LEDs cathode

6. PCB Layout

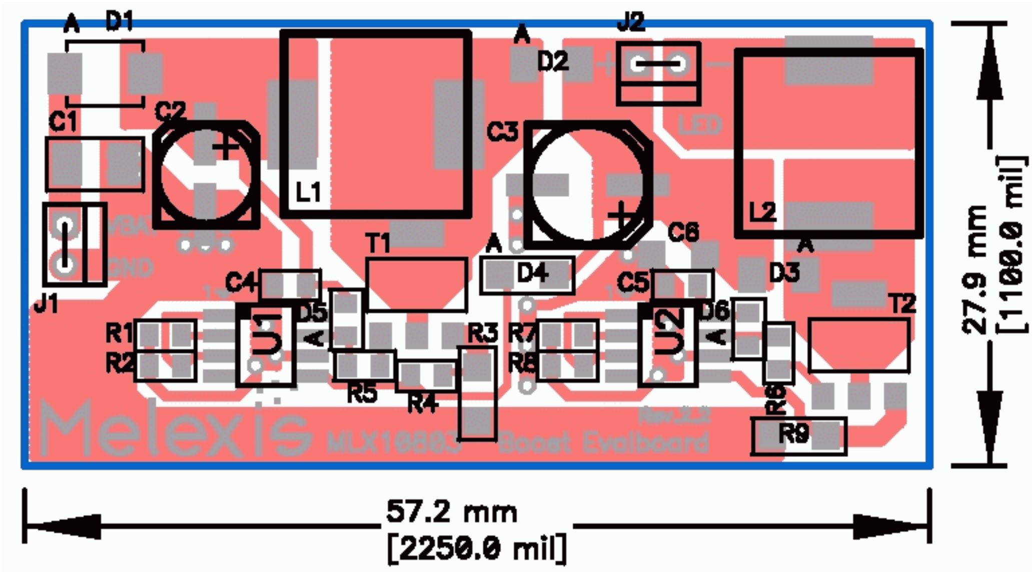

Figure 2: MLX10803 Boost/Buck Evaluation board, dimensions and layout (top view)

Note: Pin 1 of both connectors is marked with a square pad on the PCB. For connector J1 pin 1 is the upper pin, for connector J2 pin 1 is left (top view).

7. Minimal Board Connections

The supply line VBAT (J1) must be connected to any standard DC supply. The VBAT voltage should be in the range of 9..18V as the board is optimized for a 12V automotive net. The supply must be able to drive the peak current of the board. For the original board a supply with a minimum current of ≥1A is recommended.
The LEDs must be connected to the LED connector (J2) according to the symbols '+' (anode) and '-' (cathode).

8. Description

For details on the function of the LED driver circuit, please refer to the MLX10803 IC specification.

The board consists of 2 relatively independent stages of MLX10803 driver ICs that work in different modes. The 1st stage (U1) works as a pure voltage booster in order to generate the voltage that is necessary to drive the chain of LEDs in the 2nd stage. The 2nd stage (U2) gets that boosted voltage as input voltage and drives the LEDs with an average LED current of 350mA. This current is kept constant within the VBAT range of 9-18V.

8.1 Voltage Booster Stage

The 1st stage of the circuitry works as a voltage step-up converter. By switching ON transistor T1, inductor L1 is charged and the voltage is boosted. The zener diode D4 limits the boosted voltage to a maximum of about 30V. The input supply voltage is boosted to provide the necessary input voltage for the 2nd stage of the circuitry.
The sense resistor R3 (0.27Ω) and the setting resistor R2 (33kΩ) of the MLX10803 (U1) were selected in order to limit the maximum peak current of coil L1 which is necessary to remain within its safe operation area (saturation current I_{sat}). We get:

$$U_{IREF1} = IREF1 \cdot R2 = 50\mu A \cdot 33k\Omega = 1.65V$$

$$U_{THRESH\_RSENSE} = U_{IREF1} \div 5 = 330mV$$

$$I_{MAX\_RSENSE} = U_{THRESH\_RESNSE} \div R3 = \underline{\underline{1.22A}}$$

When the threshold level U_{THRESH_RSENSE} is reached, T1 is switched OFF. With resistor R1 the drivers OFF time (monoflop time T_{mon}) is set. During this time, energy is provided by the coil for supplying the 2nd stage of the circuitry. As both stages do not work synchronously (i.e. with the same switching frequency), capacitor C3 serves as a temporary energy buffer. This way, C3 is charged in case the 2nd stage is in OFF time (driver FET T2 is off) and discharged during T2 is ON.

Defining the value of R1 depends very much on the energy that is needed for the 2nd stage and thus on the number and current of the connected LEDs and the input voltage VBAT. For this board, a value of 150kΩ was chosen which generates a monoflop time of:

$$R_{OSC}[k\Omega] = 222.2 \cdot \frac{Tmon[\mu s]}{12.5} - 0.02$$ (equation according to MLX10803 datasheet, page 10)

$$Tmon[\mu s] = 12.5 \cdot \frac{R_{OSC}[k\Omega] + 4.44}{222.2} = 12.5 \cdot \frac{150 + 4.44}{222.2}$$

$$Tmon = \underline{\underline{8.7\mu s}}$$

8.2 LED Driver Stage

The LED driver stage works in the same way as the standard *MLX10803 EVA board;* as a switching regulator. The inductor L2 is charged until the desired threshold voltage on RSENSE (R9) is reached. This voltage is proportional to the peak current that flows through the LEDs. The peak current in this application is:

$$U_{IREF1} = IREF1 \cdot R2 = 50\mu A \cdot 30k\Omega = 1.5V$$

$$U_{THRESH\_RSENSE} = U_{IREF1} \div 5 = 300mV$$

$$I_{MAX\_RSENSE} = U_{THRESH\_RESNSE} \div R9 = \underline{\underline{638mA}}$$

As soon as U_{THRESH_RSENSE} is reached, the MLX10803 (U2) shuts off the transistor T2 for a time defined by the value of R_{OSC} (monoflop time T_{mon}). During the OFF time of the circuit, L2 provides the previously stored energy to the chain of LEDs via the flyback diode D3.
The OFF or monoflop time can be adjusted by R_{OSC} (R7) resistor. With the selected 220kΩ resistor the monoflop time is:

$$Tmon[\mu s] = 12.5 \cdot \frac{R_{OSC}[k\Omega] + 4.44}{222.2} = 12.5 \cdot \frac{220 + 4.44}{222.2}$$

$$\underline{\underline{Tmon = 12.6\mu s}}$$

With these both parameters -set by R7, R8 and R9- the *MLX10803 Boost EVA board* is currently optimized for 6 white high brightness LEDs (Luxeon®, Osram Golden Dragon® etc.) in series with a total forward voltage of 20-24V and a LED current of 350mA.

8.3 Efficiency

With this *MLX10803 Boost/Buck Evaluation Board* the following efficiency can be achieved (supply input power versus output power of LEDs) for the configurations below at different supply input voltages:

Configuration	Total $U_{F\ LEDs}$ [V]	Number of LEDs	$\eta_{@9V}$ [%]	$\eta_{@13.5V}$ [%]	$\eta_{@18V}$ [%]
1*	**20-24V**	**6**	**76**	**80**	**81**
2	13-16V	4	78	79	80
3	34-40V	10	70	75	76

* default setting of the board

The efficiency for a certain application depends on the exact adaptation of the 1st stage to the energy needs of the 2nd stage. Therefore, the booster voltage should always be in the range of 5-10V above the total forward voltage of the LED chain.

Furthermore, the efficiency can be increased by using peripheral components with low intrinsic power losses. Following components are subject for improvements in terms of efficiency:

- Inductors L1, L2 (DC resistance)

- Diodes D1, D2, D3 (forward voltage)
- RSENSE resistors R3, R9 (DC resistance)
- Transistors T1, T2 (R_{DSon})

8.4 User Modification of the board

As mentioned before, the board is optimized for a total LED forward voltage of 20-24V which corresponds to 6 white high brightness LEDs (Luxeon I®, Osram Golden Dragon® etc.).
However, the board can easily be modified to other customer requirements. The adaption is mainly accomplished by a modification of the setting resistors of the 2nd stage, R7 and R8 and –if necessary- R1, R2 and D4 of the 1st stage of the circuit.

Generally, the modification for a certain application should be accomplished in 2 steps. First, the 2nd stage should be adapted to the number and current of the LEDs to be driven. This can be done by the setting resistors ROSC (oscillator frequency, R7) and IREF1 (peak current, R8). For details about how to set the parameters please refer to the MLX10803 data sheet.
If the new load condition differs much from the default setting of the board it might also be necessary to modify the 1st stage in order to adapt the booster stage to these new conditions.

This will be, for example, the case if the total forward voltage of the LED chain will be close or higher than the boosted voltage of the 1st stage. As a general rule the boosted voltage should be around 5-10V higher than the total forward voltage of the LED chain (measured at the respective LED peak current!). In case a higher booster voltage is needed, the zener diode D4 must be adapted according to the desired booster voltage (e.g. U_z=43V for 43V booster voltage).

If the delivered energy of the 1st stage is not sufficient to maintain the boosted voltage for the 2nd stage, more energy has to be pumped into the inductor. This is possible by increasing the peak current of the inductor (IREF1 Resistor R2) and/or by increasing the inductance of the coil.

The table below shows the configuration for applications with 4 and 6 (default) LEDs, driven at 350mA, and 10 LEDs, driven at 250mA, respectively. Other configurations are possible and have to be worked out by the user. In such cases, attention has to be drawn to the maximum allowed parameters of peripheral components which must not exceed their respective limitations (e.g. inductor current, voltage class of the caps etc.). Furthermore, the thermal behaviour of the board must always be kept in mind.

Configuration	Total $U_{F\ LEDs}$ [V]	Number of LEDs	R7 [KΩ]	R8 [KΩ]	R1 [KΩ]	R2 [KΩ]	D4 [Uz/V]
1*	**20-24V**	**6**	**220**	**30**	**150**	**51**	**30**
2	13-16V	4	300	30	220	39	22
3	34-40V	10	200	27	100	68	47

* default configuration of the board

9. Used Components

Board Part Number	Type	Category	Part Name (Manufacturer)	Alternative Part (Manufacturer)	Data Sheet Download
D1	Rectifier	Schottky Diode	SS24 (FCH)	many	www.fairchildsemiconductor.com
D2, D3	Rectifier	Ultrafast Recovery Diode	BYD77B (PHI)	many, e.g. ES2D (FCH)	www.fairchildsemiconductor.com www.semiconductors.philips.com
D4	Zener Diode	30V Zener Diode	BZV55-C30 (PHI)	many	www.semiconductors.philips.com
D5, D6	Diode	Switching Diode	MCL4148 (VS)	many, e.g. 1N4148 (PHI)	www.vishay.com www.semiconductors.philips.com
T1, T2	Switching Transistor	n-channel MOSFET	BSP318S (INF)	many, e.g. NTF3055 (ON)	www.infineon.com www.onsemi.com
L1	Inductor	Power choke	WE-PD XL 100µH (WE)	many, e.g. MSS1278-104ML (CC)	www.wuerth-elektronik.de www.coilcraft.com
L2	Inductor	Power choke	WE-PD L 470µH (WE)	many, e.g. (CC)	www.wuerth-elektronik.de www.coilcraft.com
C1	Capacitor 470nF/50V	Ceramics 1210 type X7R	F3102X7R (KMT)	many, e.g. B37950 (EP)	www.kemet.com www.epcos.com
C2	Capacitor 47µF/35V	Electrolytic, low ESR	EEEFK1V470P (PS)	many	www.panasonic.com/industrial
C3	Capacitor 47µF/50V	Electrolytic, low ESR	EEEFK1H470P (PS)	many	www.panasonic.com/industrial
C4, C5,C6	Capacitor 100nF/50V	Ceramics 0805 type X7R	B37941 (EP)	many	www.epcos.com
R1, R2, R4, R7, R8	Resistor 5% tolerance R1: 150k, R2: 51k R4: 30k, R7: 220k R8: 30k	0805 type	D12CRCW (VS)	many, e.g. Yageo RC 0805 (YG)	www.vishay.com www.yageo.com
R3, R9	Resistor 0.5W 1% tolerance R3: 0.27R R9: 0.47R	1206 type	LR1206-R33FI (WW)	many	www.welwyn-tt.co.uk
R5, R6	Resistor 5% tolerance R5, R6: 39R	0805 type	D12CRCW (VS)	many, e.g. Yageo RC 0805 (YG)	www.vishay.com www.yageo.com

manufacturer codes:

FCH = Fairchild Semiconductor	PHI = Philips Semiconductor	PS = Panasonic
WE = Würth Elektronik	VS = Vishay	ON = On Semiconductor
INF = Infineon	CC = Coilcraft	EP = Epcos
YG = Yageo	WW = Welwyn	KMT = Kemet

10. EMI Measurement of the MLX10803 Boost/Buck EVA board

The *MLX10803 Boost/Buck Evaluation Board* is designed for good electromagnetic emission behaviour. The test was performed on the original board and the settings shown below. No additional filter components have been used. The conducted electromagnetic emission measurement was accomplished according to IEC 61967 part 4. The RF was decoupled from line VBAT.

Settings MLX10803_Boost/Buck Evalboard:

V_{BAT}	13.5V
LEDs:	6x Luxeon III @ I_{LED} = 350mA (average)
Board:	according to Figure 1

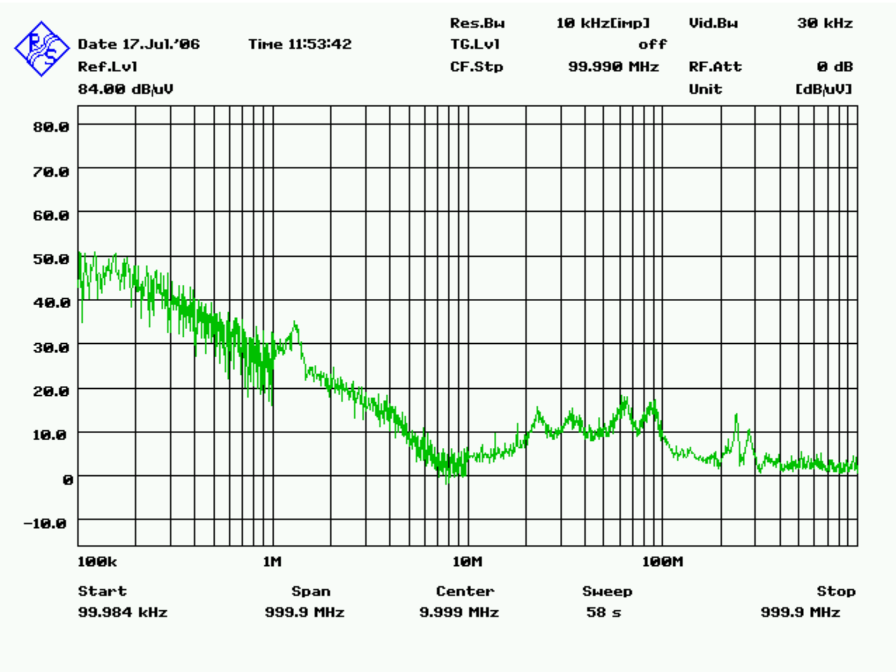

Figure 3: Conducted electromagnetic emission MLX10803 Boost/Buck Evaluation board

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