UM10478

High-efficiency UBA3070 4-channel DC-to-DC LED driver demo board

Rev. 1.1 — 8 August 2011 **User manual**

Document information

Info	Content
Keywords	UBA3070, street, high bay lighting
Abstract	This document explains the operation and application of the UBA3070 4-channel small form factor demo board. The demo board incorporates four independent DC-to-DC switch mode current drivers for LED strings with common input power stage. By default, the board is optimized to drive 12 LEDs at 1 A (typical) for street and high-bay lighting applications. Multiple user configuration options are available for the UBA3070 4-channel demo board however, some options require components changes.

Revision history

Rev	Date	Description
v.1.1	20110808	second issue
Modifications:		• Minor text changes. • Minor changes to Figure 7, Figure 8, Figure 9 and Figure 11.
v.1	20110803	first issue

Contact information

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1. Introduction

1.1 Scope of this document

WARNING

Lethal voltage and fire ignition hazard

The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire.

This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

The UBA3070 4-channel demo board demonstrates the LED driving capabilities of the UBA3070 device. Typical target applications for the 4-channel demo board include, LED street lighting, high and low bay and refrigeration lighting. Each channel is individually dimmable using Pulse Width Modulation (PWM) or an analog signal.

The circuit implements four Boundary Conduction Mode (BCM) buck converters and a common input power stage. The BCM buck converter is a true switch-mode current source. BCM is sometimes also referred to as Critical Conduction Mode (CCM).

Key features of the board include:

- Up to 98 % efficiency
- User configured output current (no custom made magnetic components needed)
- Intrinsically protected against short-circuit, open load and overtemperature conditions
- Boundary conduction buck converters operate as a true switch-mode current source
- Operates with input voltages ranging from 12 V to 600 V with some component changes
- Low-cost LED driver solution
- Small form factor
- PWM or analog dimming
- Independent or combined controls of channels
- No LED binning required

Applications:

- Street lighting
- High and low bay lighting
- Refrigeration lighting

Figure 1 shows the populated view of the demo board.

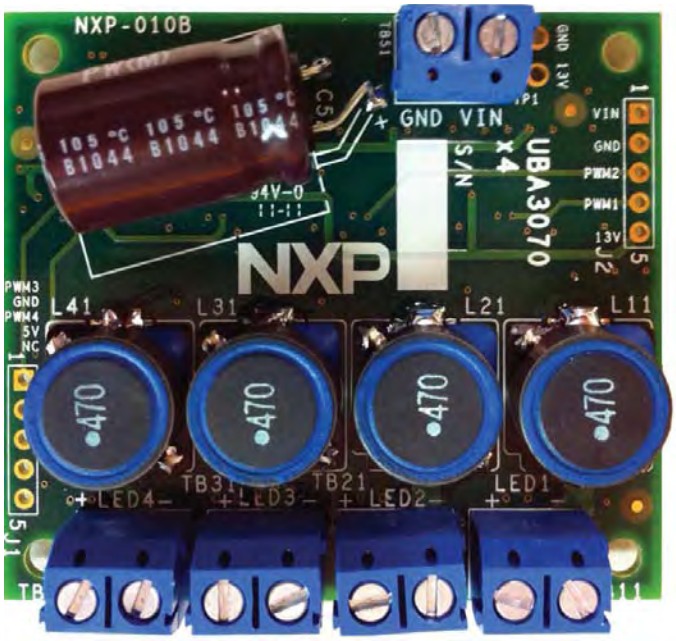
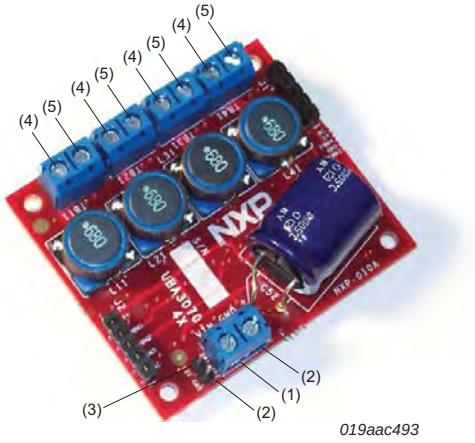


Fig 1. UBA3070 demo board

Figure 2 shows the connectivity of the demo board.



(1) Main supply (input voltage DC)
(2) Ground
(3) Auxiliary supply voltage (12 V to 20 V)
(4) LED string Anode
(5) LED string Cathode

Fig 2. Connectivity

2. Safety warning

The board needs to be connected to the mains voltage. Avoid touching the board while it is connected to the mains voltage. An isolated housing is obligatory when used in uncontrolled, non-laboratory environments. Galvanic isolation of the mains phase using a variable transformer is always recommended.

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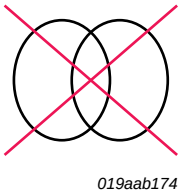
a. Isolated



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b. Not isolated

Fig 3. Variac isolation symbols

3. Specification

3.1 Demo board specification

Table 1. Specification

Parameter	Value	Comment
Output current	1 A	Each channel can be individually controlled and changed.
Supply voltage	48 V (DC) to 52 V (DC)	The demo board is optimized to drive 12 LEDs. However, the board can be used with any combinations of input/output voltage as long as the switching frequency stays in between 30 kHz and 145 kHz
Output voltage	up to 43 V	Depends on LED string length
Auxiliary supply voltage	12 V (DC) to 16 V (DC)	Typically 10 mA to 30 mA. It is suggested to use the primary side Auxiliary winding
Switching frequency	30 kHz to 145 kHz	Selectable see Ref. 1
Dimension	51 mm × 58.5 mm	L × W

4. Functional description

4.1 Introduction

The circuit on the UBA3070 multi-channel demo board consists of a general power input section and four UBA3070 current source sections. Each UBA3070 current source consists of the following sections: common power input, dimming input, switching, a current measurement/feedback and output. The default circuit diagram of the general power input section plus one UBA3070 current source section is shown in Figure 11. The component list is detailed in Table 2.

4.1.1 General power input section

The common power input section of the demo board's default configuration consists of one buffer capacitor (C52) and terminals TB1, TP1 and TP2. Terminal TB1 has two ports and must be connected to input mains DC voltage (48 V to 52 V) and ground as marked on the board. TP1 terminal must be connected to the auxiliary power supply (12 V (DC) to 20 V (DC)), TP2 must be connected to ground. The input mains voltage need not to be exactly as defined previously, it can go up to 600 V if the switch Qx1 is changed accordingly as long as the switching frequency stays in between 30 kHz and 145 kHz.

The mains power is predominantly used for providing power to the LED string. The auxiliary supply is used by the internal circuitry of the UBA3070 IC, to provide power for charging and discharging the gate of MOSFET Qx1. The current consumption of the auxiliary supply is determined by the amount of energy needed to charge and discharge of MOSFET Qx1. The current requirement can be as low as 2 mA (per channel) for a small MOSFET, with a large MOSFET it could be one order of magnitude higher.

4.1.2 Dimming section

The dimming input signal is supplied to the ports via connectors J1 and J2 as shown on the PCB (see Figure 2). The dimming signal passes via a low pass and current limiting network. The dimming input signal is supplied to the UBA3070 control pin (or PWM pin). Though the typical target application normally uses PWM dimming, there is also an option to use the analog dimming option via the same PWM pin.

When a high voltage (V_{high} > 2.5 V ≤ 5 V) is fed to the UBA3070 control pin (or PWM pin), the converter is effectively disabled (in cycle skipping mode). A low voltage (V_{low} < 0.5 V) on the same pin causes the UBA3070 to be fully enabled. The produced light output can be varied by toggling between low and high voltage. Typically, the light output is exactly proportional to the duty ratio of the PWM dimming signal.

In principle, any PWM frequency is acceptable for PWM dimming. In practice, a very low PWM frequency can give the impression that the LED string is flickering. A very high frequency can result in inaccurate dimming performance and interference with the UBA3070 circuit operating frequency (see Ref. 1). A PWM frequency in the range of 100 Hz to 1 kHz is usually recommended for most applications including general lighting and LCD TV backlighting. The relative light output intensity is given in Equation 1.

$$intensity = \frac{t_{low}}{t_{high} + t_{low}} \times 100\ \% \quad (1)$$

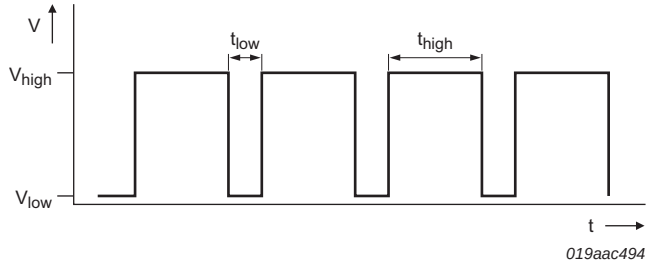

Fig 4. Typical PWM signal

By feeding an analog voltage signal to the UBA3070 control pin (PWM pin), the magnitude of the peak current that flows through the Lx1 inductor can be controlled. The analog control voltage on the control pin must be between 1 V and 2 V. Within this voltage range, the magnitude of the voltage is approximately inversely proportional to V_{SENSE} voltage of the UBA3070 IC. As a result, the light intensity control follows the curve shown in Figure 5. The default configuration has a 5 V supply is available on board from the auxiliary power supply for analog PWM dimming by connecting a voltage divider network between the 5 V supply and PWM pin of UBA3070.

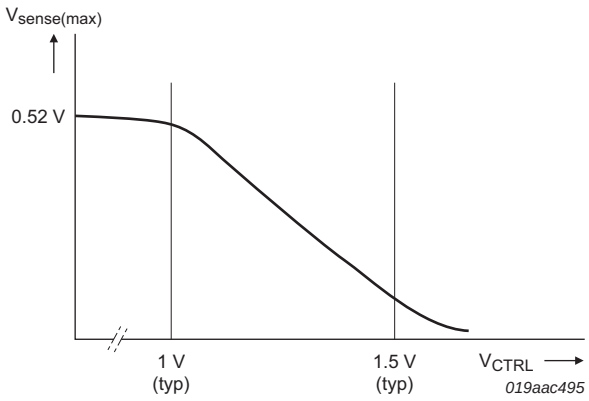

Fig 5. Typical analog control light intensity

4.1.3 Switching, feedback and current detection

UBA3070 ICx01 together with the power components Qx1, TB1, Lx01 and Rx1 forms the switching section. When the UBA3070 switches the MOSFET Qx1 on, the current in Lx1 ramps up. When UBA3070 switches off Qx1, the Lx1 current continues to flow through Dx1 (Dx0) and ramps down. A capacitor can be added in parallel to MOSFET Qx1 to limit the dV/dt when the MOSFET switches off. In many circumstances, this is needed to guarantee correct valley detection. R1 is a current sense resistor that is in the high current path. The peak inductor current is detected by measuring the voltage drop across Rx1. This voltage drop is applied to the UBA3070 SENSE pin, and the UBA3070 reacts to the detection of the peak current by switching off MOSFET Qx1.

The operation of the UBA3070 boundary mode buck converter relies on the measurement of two current levels:

- The detection of the peak inductor current level while MOSFET Qx1 is switch-on (primary stroke)
- The detection of zero inductor current while MOSFET Qx1 is switch-off and the current is flowing through Dx1 (secondary stroke)

As the current ramping up and ramping down is a constant slope, and no dead-time between two subsequent cycles exists, the average current supplied by the switching section is exactly half the inductor peak current.

4.1.4 Indirect demag detection

The default configuration of the UBA3070 4-channel demo board uses an alternative demag detection circuit that is cheaper and simpler than the standard direct demag detection option. The disadvantage of indirect demag detection is that its performance is lower with less accurate current regulation, and the possibility of false zero current detection in case of a dynamically changing load. For general lighting purposes, however, this demag detection option is generally adequate.

Indirect demag detection relies on the phenomenon that a ringing voltage (caused by resonance between inductor Lx1 and the (parasitic) capacitance CDS of Qx1) appears at the drain node of MOSFET Qx1 when the secondary stroke has finished. The resonating waveform propagates through capacitor Cx4 and resistor Rx2 to the Rx4, Rx3, Cx5, Dx2, Dx3 network and to the UBA3070 MASK pin. The first valley of the ringing signal causes the MASK pin voltage to drop lower than 100 mV and is therefore an indirect way of detecting demagnetization of the Lx01 inductor.

4.1.5 Direct demag detection

Direct demag detection zero inductor current is detected by measuring the inductor current by transferring the information via the (a-symmetric) current mirror to the network of Rx4, Rx3, Cx5, and dual diodes Dx2, Dx3. When the voltage supplied to the UBA3070 MASK pin drops lower than 100 mV, the UBA3070 IC reacts by switching on MOSFET Qx1. This method of detecting zero current (or demagnetization) of the inductor is called direct demag detection for further details see Ref. 1. This method of detection is implemented where high levels of accuracy are needed however, in general this type of detection is not needed for street lighting or high and low bay lighting applications.

4.1.6 Output section

The switching section produces a current waveform in the inductor that looks like a sawtooth; current ramps-up linearly from 0 A to I_{peak} and then ramps down linearly from I_{peak} to 0 A. This type of current waveform is not normally supplied to an LED string. For that reason, capacitor Cx2 is used in the output section to reduce the ripple on the LED current. For further details on dimensioning of the ripple filter see Ref. 1. The LED string is connected to connectors of TBx1.

4.1.7 Different voltage and current versions

In order for the UBA3070 multi-channel demo board driver to drive longer LED strings and operate from a higher supply voltage (for example, PF output voltage), some of the demo board's components must be changed to higher voltage types. The auxiliary supply voltage remains the same at 12 V to 15 V.

By changing the value of Rx1, Lx1 and Qx1, the output current of the UBA3070 current sources can be changed. For more details, on the calculation of component values see Ref. 1.

4.1.8 Combining options and features

Users can combine options and features as described in the other cross-reference sections. Any new combination of options and features must be checked against potential electrical conflicts. Assistance is available from application support if required.

4.2 Complete solution

The high efficiency 4-channel DC-to-DC LED driver demo board is optimally designed to work with NXP Semiconductors' 150 W high-bay lighting driver reference design which offers best in class performance, optimized size and low-cost solution to control multiple LED strings. The NXP Semiconductors solution combines the SSL4101 AC-to-DC SSL driver and UBA3070 DC-to-DC buck controller IC for maximum flexibility and performance. The overall efficiency for the unit from AC input to 4-channel DC output is 92 %. The complete solution meets all safety and EMI regulations. For more information, see Ref. 3. Assistance is available from application support if required.

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Fig 6. High efficiency complete solution

5. Performance data

5.1 Efficiency

The UBA3070 device and the UBA3070 4-channel demo board are suited to driving longer LED strings, driving short LED strings is an option. However, higher inductance may be required. High efficiency figures (> 98 %) are normally only obtained with relatively long LED strings. Figure 7 gives an indication of the typical efficiency that be expected from a UBA3070 LED current driver. The UBA3070 4-channel demo board efficiency is very consistent over a wide range of voltages as shown in Figure 7.

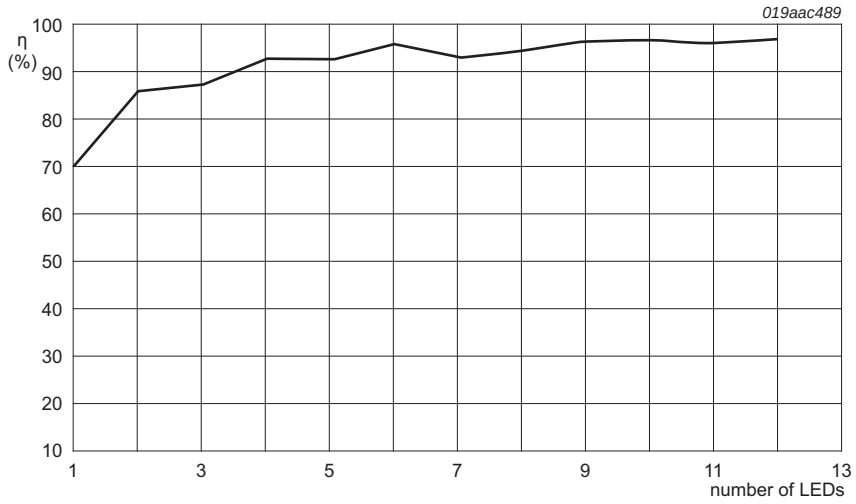


Fig 7. Efficiency Curve

The output current of the UBA3070 4-channel demo board varies slightly with the load and the supply voltage of the circuit. The curves shown in Figure 8 and Figure 9 show that the demo board has excellent load and line regulation properties which is ideal for general lighting purposes. Slight variations in light output intensity are hardly visible to the human eye however, for high accuracy applications (for example, back lighting applications for LCD) direct demagnetization detection can be implemented as explained in Section 4.1.5.

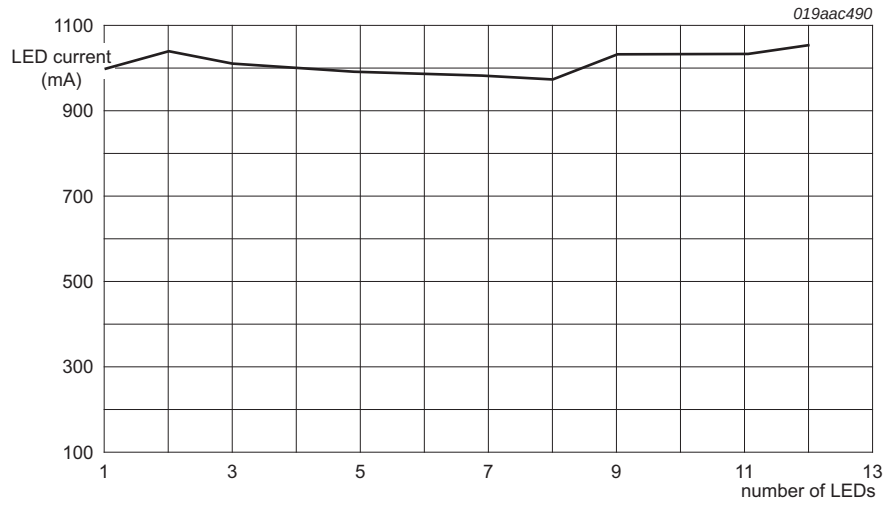


Fig 8. Load regulation

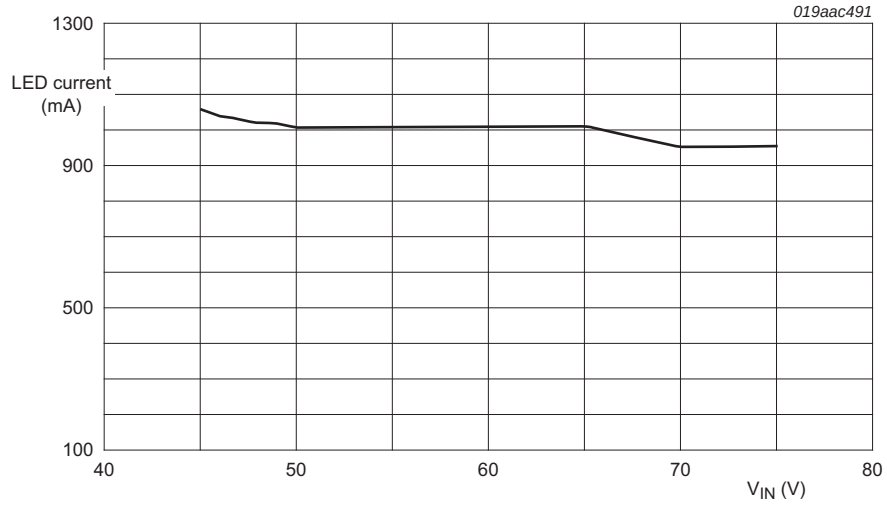


Fig 9. Line regulation

The value of the L1 inductor influences the operation of the UBA3070 circuit as detailed in Ref. 1. The main parameter affected is the switching frequency, although variations of the L1 inductance value have practically no influence on the LED output current value so that wide input voltage range can be achieved by changing the inductor to maintain the IC within operating switching frequency.

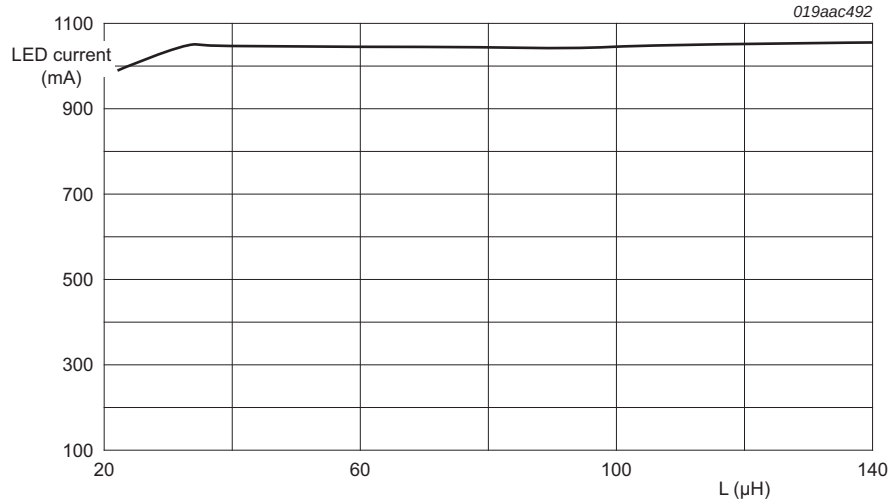
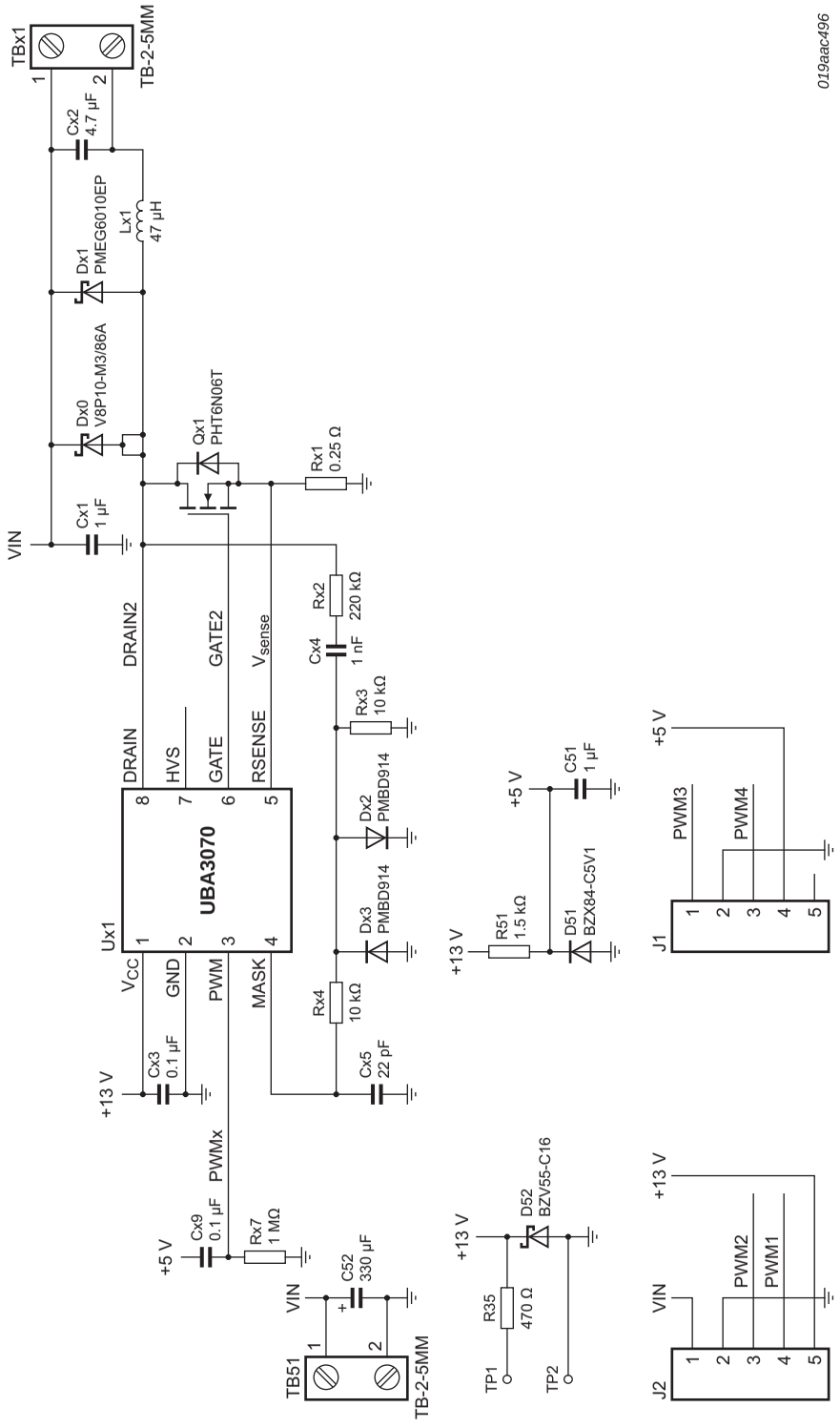


Fig 10. LED current versus inductance

6. EMI

The UBA3070 demo board is fully pre-compliant to EMC regulations.

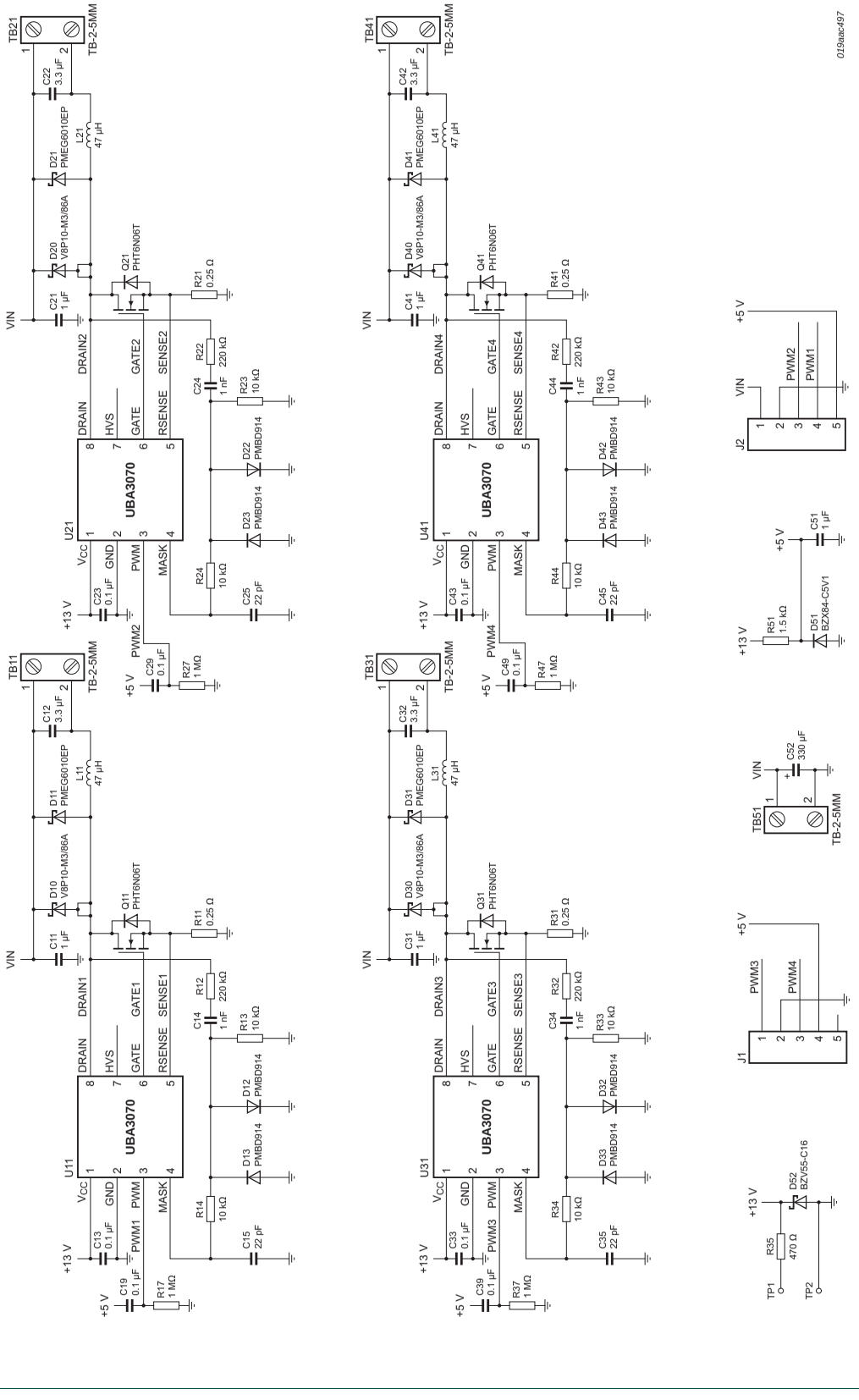
7. Circuit diagrams



Mount either Dx0 or Dx1. Dx0 is an optional free-wheeling diode for high currents greater than 1.2 A.

x represents the channel number, for example, if x = 1 then channel 1 is represented.

Fig 11. Default configuration: input section plus one UBA3070 channel



Mount either Dx0 or Dx1. Dx0 is an optional free-wheeling diode for high currents greater than 1.2 A.

x represents the channel number, for example, if x = 1 then channel 1 is represented.

Fig 12. Complete UBA3070 4-channel demo board schematic

8. Bill Of Materials (BOM)

Table 2 provides detailed component information for the UBA3070 demo board.

Table 2. BOM for the high efficiency UBA3070 demo board

Reference	Component	Package	Quantity	Part number	Remarks
C11	1.0 μF; 100 V; X7R	1206	1	C3216X7R2A105M	
C12	4.7 μF; 100 V; X7S 10 %	1210	1	C3225X7S2A475K	
C13	0.1 μF; 100 V; X7S	0805	1	08055C104KAT2A	
C14	1 nF; 100 V; X7R; 10 %	0805	1	C2012X7R2A102K	
C15	22 pF; 5 %; 100 V; NP0	0805	1	08051A220JAT2A	
C16	no part		1	-	
C17	no part		1	-	
C18	do not mount		1	-	
C19	0.1 μF; 10 %; 50 V; X7R	0805	1	08055C104KAT2A	
C21	1.0 μF; 100 V; X7R	1206	1	C3216X7R2A105M	
C22	3.3 μF; 100 V; X7S	1210	1	C3225X7S2A335M	
C23	0.1 μF; 100 V; X7S	0805	1	08055C104KAT2A	
C24	1 nF 100 V X7R; 10 %	0805	1	C2012X7R2A102K	
C25	22 pF 5 % 100 V; NPO	0805	1	08051A220JAT2A	
C26	no part		1	-	
C27	no part		1	-	
C28	no part		1	-	
C29	0.1 μF; 10 %; 50 V; X7R	0805	1	08055C104KAT2A	
C31	1.0 μF; 100 V; X7R	1206	1	C3216X7R2A105M	
C32	3.3 μF; 100 V; X7S	1210	1	C3225X7S2A335M	
C33	0.1 μF; 100 V; X7S	0805	1	08055C104KAT2A	
C34	1 nF; 100 V; X7R; 10 %	0805	1	C2012X7R2A102K	
C35	22 pF; 5 %; 100 V; NPO	0805	1	08051A220JAT2A	
C36	no part		1	-	
C37	no part		1	-	
C38	no part		1	-	
C39	0.1 μF; 10 %; 50 V; X7R	0805	1	08055C104KAT2A	
C41	1.0 μF; 100 V; X7R	1206	1	C3216X7R2A105M	
C42	3.3 μF; 100 V; X7S	1210	1	C3225X7S2A335M	
C43	0.1 μF; 100 V; X7S	0805	1	08055C104KAT2A	
C44	1 nF; 100 V; X7R; 10 %	0805	1	C2012X7R2A102K	
C45	22 pF; 5 %; 100 V; NPO	0805	1	08051A220JAT2A	
C46	no part		1	-	
C47	no part		1	-	
C48	no part		1	-	
C49	0.1 μF; 10 %; 50 V; X7R	0805	1	08055C104KAT2A	
C51	0.1 μF; 10 %; 50 V; X7R	0805	1	08055C104KAT2A	

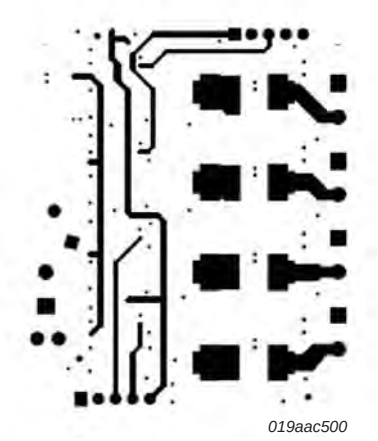
Table 2. BOM for the high efficiency UBA3070 demo board *…continued*

Reference	Component	Package	Quantity	Part number	Remarks
C52	330 μF; 63 V; ELECT; LXY	Radial	1	ELXY630ELL331ML20S	
D11	diode Schottky; 60 V; 3 A	SOD128	1	PMEG6030EP,115	
D12	diode hi-speed switching	SOT23	1	PMBD914,235	
D13	diode hi-speed switching	SOT23	1	PMBD914,235	
D21	diode Schottky 60 V; 3 A	SOD128	1	PMEG6030EP,115	
D22	diode hi-speed switching	SOT23	1	PMBD914,235	
D23	diode hi-speed switching	SOT23	1	PMBD914,235	
D31	diode Schottky; 60 V; 3 A	SOD128	1	PMEG6030EP,115	
D32	diode hi-speed switching	SOT23	1	PMBD914,235	
D33	diode hi-speed switching	SOT23	1	PMBD914,235	
D41	diode Schottky; 60 V; 3 A	SOD128	1	PMEG6030EP,115	
D42	diode hi-speed switching	SOT23	1	PMBD914,235	
D43	diode hi-speed switching	SOT23	1	PMBD914,235	
D51	diode Zener; 5.1 V; 250 mW	SOT23	1	BZX84-C5V1,215	
D52	diode Zener; 16 V; 500 mW	SOD80C	1		do not load
J1	CONN RCPT; 50 POS;100" SNGL GOLD		1	CES-150-01-S-S	
J2	CONN RCPT; 50 POS;100" SNGL GOLD		1	CES-150-01-S-S	
L11	inductor shield PWR; 47 μH		1	SLF12575T-470M2R7-PF/ 7447709470	
L21	inductor shield PWR; 47 μH		1	SLF12575T-470M2R7-PF/ 7447709470	
L31	inductor shield PWR; 47 μH		1	SLF12575T-470M2R7-PF/ 7447709470	
L41	inductor shield PWR; 47 μH		1	SLF12575T-470M2R7-PF/ 7447709470	
Q11	MOSFET N-CH; 100 V; 6.5 A	SOT223	1	PHT6NQ10T,135	
Q21	MOSFET N-CH; 100 V; 6.5 A	SOT223	1	PHT6NQ10T,135	
Q31	MOSFET N-CH; 100 V; 6.5 A	SOT223	1	PHT6NQ10T,135	
Q41	MOSFET N-CH; 100 V; 6.5 A	SOT223	1	PHT6NQ10T,135	
R11	0.25 Ω; 0.5 W; 1 %	1206 SMD	1	CSR1206FKR250	
R12	39 kΩ; 0.125 W; 5 %	0805 SMD	1	CRCW080539K0JNEA	
R13	10 kΩ; 0.125 W; 1 %	0805 SMD	1	RMCF0805FT10K0	
R14	10 kΩ; 0.125 W; 1 %	0805 SMD	1	RMCF0805FT10K0	
R17	1.0 MΩ; 0.125 W; 5 %	0805 SMD	1	ERJ-6GEYJ105V	
R21	0.25 Ω; 0.5 W; 1 %	1206 SMD	1	CSR1206FKR250	
R22	39 kΩ; 0.125 W; 5 %	0805 SMD	1	CRCW080539K0JNEA	
R23	10 kΩ; 0.125 W; 1 %	0805 SMD	1	RMCF0805FT10K0	
R24	10 kΩ; 0.125 W; 1 %	0805 SMD	1	RMCF0805FT10K0	
R27	1.0 MΩ; 0.125 W; 5 %	0805 SMD	1	ERJ-6GEYJ105V	
R31	0.25 Ω; 0.5 W; 1 %	1206 SMD	1	CSR1206FKR250	

Table 2. BOM for the high efficiency UBA3070 demo board *…continued*

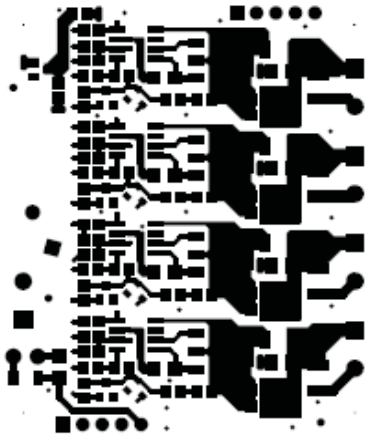
Reference	Component	Package	Quantity	Part number	Remarks
R32	39 kΩ; 0.125 W; 5 %	0805 SMD	1	CRCW080539K0JNEA	
R33	10 kΩ; 0.125 W; 1 %	0805 SMD	1	RMCF0805FT10K0	
R34	10 kΩ; 0.125 W; 1 %	0805 SMD	1	RMCF0805FT10K0	
R35	0.0 Ω; 0.5 W	1206 SMD	1	CRCW12060000Z0EAHP	
R37	1.0 MΩ; 0.125 W; 5 %	0805 SMD	1	ERJ-6GEYJ105V	
R41	0.25 Ω; 0.5 W; 1 %	1206 SMD	1	CSR1206FKR250	
R42	39 kΩ; 0.125 W; 5 %	0805 SMD	1	CRCW080539K0JNEA	
R43	10 kΩ; 0.125 W; 1 %	0805 SMD	1	RMCF0805FT10K0	
R44	10 kΩ; 0.125 W; 1 %	0805 SMD	1	RMCF0805FT10K0	
R47	1.0 MΩ; 0.125 W; 5 %	0805 SMD	1	ERJ-6GEYJ105V	
R51	1.5 kΩ; 0.125 W; 5 %	0805 SMD	1	ERJ-6GEYJ152V	
TB11	terminal block 5 mm vert 2POS PCB		1	OSTTC020162	
TB21	terminal block 5 mm vert 2POS PCB		1	OSTTC020163	
TB31	terminal block 5 mm vert 2POS PCB		1	OSTTC020164	
TB41	terminal block 5 mm vert 2POS PCB		1	OSTTC020165	
TB51	terminal block 5 mm vert 2POS PCB		1	OSTTC020162	
U11	IC LED driver; white backlight	8-SOIC	1	UBA3070	
U21	IC LED driver; white backlight	8-SOIC	1	UBA3070	
U31	IC LED driver; white backlight	8-SOIC	1	UBA3070	
U41	IC LED driver; white backlight	8-SOIC	1	UBA3070	

9. Demo board layout



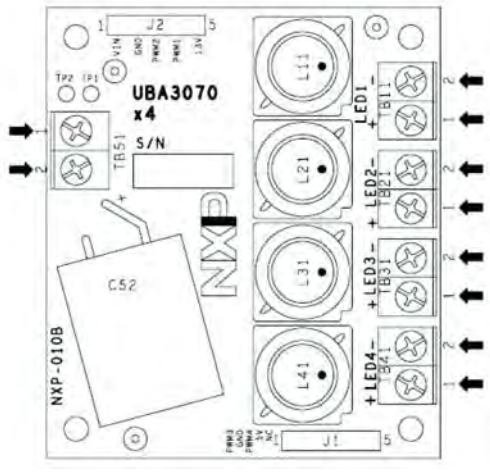
019aac500

Fig 13. Top layer



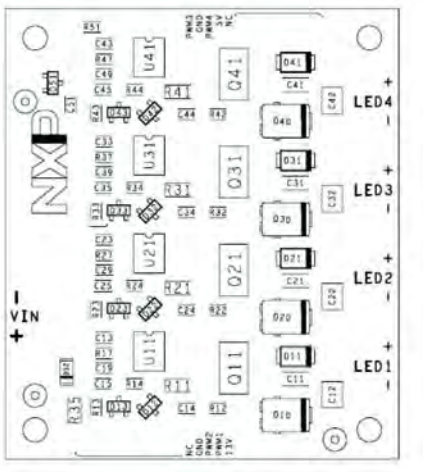
019aac499

Fig 14. Bottom layer



019aac504

Fig 15. Top silk



019aac501

Fig 16. Bottom silk

10. Abbreviations

Table 3. Abbreviations

Acronym	Description
BCM	Boundary Conduction Mode
DCM	Discontinuous Conduction Mode
EMC	ElectroMagnetic Compatibility
EMI	ElectroMagnetic Interference
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
PF	Power Factor
PWM	Pulse-Width Modulation

11. References

[1] AN10894 — Application note: Application aspects of the UBA3070 switch mode LED driver.

[2] UBA3070 — Data sheet: LED backlight driver IC

[3] SSL4101 — Data sheet: GreenChip III+ SMPS control IC

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Date of release: 8 August 2011
Document identifier: UM10478