UM10405

UBA3070 multi-channel demo board

Rev. 2 — 19 October 2011 **User manual**

Document information

Info	Content
Keywords	UBA3070, switch mode, current source, LED driver, PWM, dimming, analog dimming, multi-channel
Abstract	The NXP Semiconductors UBA3070 multi-channel demo board incorporates six independent switch mode current drivers for LED strings plus an optional common input power stage. By default, the board produces 300 mA output current while the maximum output voltage is around 170 V. Multiple user-configurable options are available for the UBA3070 multi-channel demo board. This user manual describes the UBA3070 multi-channel demo board version 1.01. Refer to the UBA3070 data sheet for details on the UBA3070 device and application note AN10894 for general application information.

Revision history

Rev	Date	Description
v.2	20111019	second issue
v.1	20102206	first issue

Contact information

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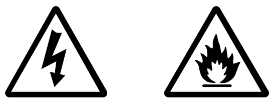
1. Introduction

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 NXP Semiconductors UBA3070 multi-channel demo board is intended to demonstrate the switch-mode current driving capabilities of the UBA3070 device. Typical target applications for this multi-channel demonstrator are LED backlighting for LCD monitors and televisions, panel backlighting and other (RGB) multi-channel general lighting applications. Each channel can typically drive an LED string up to a length of 45 white/green/blue LEDs or 60 red LEDs in series. Each channel is individually dimmable with PWM or an analog signal. In applications where the color temperature of the LED light sources is critical, the preferred way of dimming is generally PWM.

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

Remark: Unless otherwise stated all voltages are in V (DC).

2. Safety warning

This multi-channel demo board is connected to a high DC voltage (up to 190 V). Avoid touching the reference board during operation. An isolated housing is mandatory when used in uncontrolled, non-laboratory environments. Galvanic isolation of the mains phase using a fixed or variable transformer (Variac) is always recommended. These devices are recognized by the symbols shown in Figure 1.

a. Isolated

b. Not isolated

Fig 1. Variac isolation symbols

3. Features

- Boundary conduction buck converter operates as a true switch-mode current source
- Operates with input voltages from 12 V to 190 V and from 12 V to 600 V with some component changes
- User configurable output current
- No custom-made magnetic components required
- Intrinsically protected against short-circuit and open load operation
- Built-in over-temperature protection.

4. Technical specifications

The UBA3070 multi-channel demo board default configuration implements six 300 mA switch-mode current sources capable of driving LED strings. These strings can have a total voltage drop of up to 170 V which is equivalent to 60 red or 45 green/blue/white LEDs in series. These strings can be dimensioned individually and controlled independently. The maximum supply voltage is 190 V. The board can be reconfigured to meet specific application needs.

The application-specific requirements can be met changing the components listed in:

- Section 8 “Alternative circuit options” on page 11
- Section 9 “Schematics” on page 12
- Section 10 “Component lists” on page 15

See reference Ref. 1 and Ref. 2 for additional information.

Table 1. Default configuration main characteristics

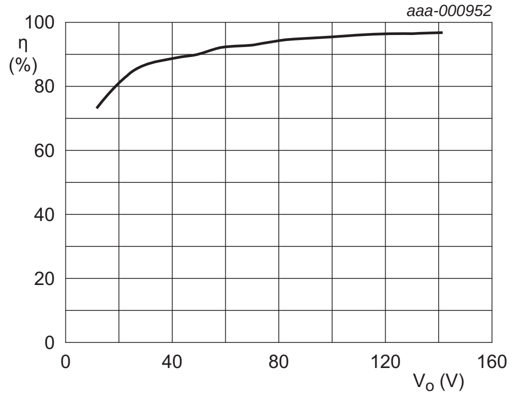
Property	Value	Remark
output current	300 mA	each channel selectable; see Ref. 2
supply voltage	12 V (DC) to 190 V (DC)	depends on maximum LED string length
AUX supply voltage	12 V (DC)	10 mA to 30 mA typical
switching frequency	30 kHz to 145 kHz	selectable; see Ref. 2

5. Performance data

5.1 Efficiency

The UBA3070 device and the UBA3070 multi-channel demo board are more suitable for driving longer LED strings. Although there is no fundamental objection to driving short LED strings, high efficiency figures are only obtainable with long LED strings. Figure 2 gives an indication of the typical efficiency that can be expected from a UBA3070 application.

In a modified UBA3070 application, a long LED string configuration of 80 LEDs in series at a 99 % efficiency can be achieved.



I_o = 330 mA.

Fig 2. Typical efficiency curve for the UBA3070 multi-channel demo board

5.2 Output current stability

The output current of the UBA3070 multi-channel demo board varies only slightly with load (that is, voltage drop across the LED string) and the circuit supply voltage. In most circumstances, the light output intensity variation is hardly visible to the human eye (if at all). If necessary, a compensation circuit can be added to the multi-channel demo board to correct for this output intensity variation. See Section 8 for more detailed information.

Figure 3 and Figure 4 show the standard output current stability of the UBA3070 multi-channel demo board.

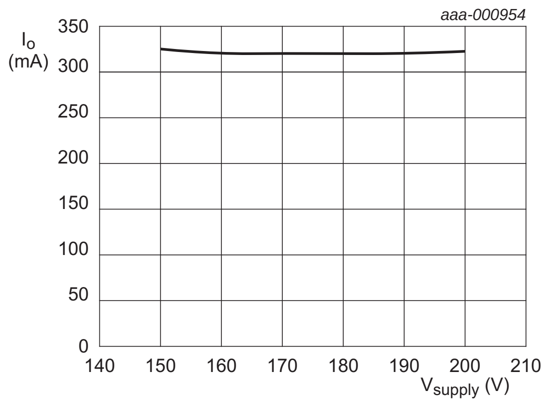


Fig 3. Typical output current stability for the UBA3070 multi-channel demo board under varying supply voltage conditions

The L1 inductor value (see circuit diagram in Figure 8) has an influence on the operation of the UBA3070 circuit. As can be concluded from application note AN10894, the main parameter affected is the switching frequency. Variations of up to ± 10 % of the L1 inductance value have practically no influence on the LED output current value.

The UBA3070 application is unaffected by production-related spread of the L1 inductor. Figure 4 gives an impression of this immunity.

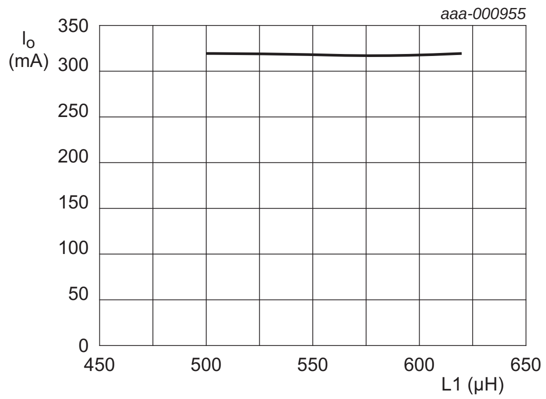


Fig 4. Typical output current stability for the UBA3070 multi-channel demo board under varying load condition

6. Connection of the multi-channel demo board

The UBA3070 multi-channel demo board connections are shown in Figure 5. When no connection is made to the dimming pin, the LEDs are at full intensity.

The AUX voltage is between 12 V and 15 V. The supply voltage can be between 12 V and 190 V. The supply voltage must be at least 10 % above the LED string voltage (at rated current). It is recommended a headroom of at least 20 % is allowed.

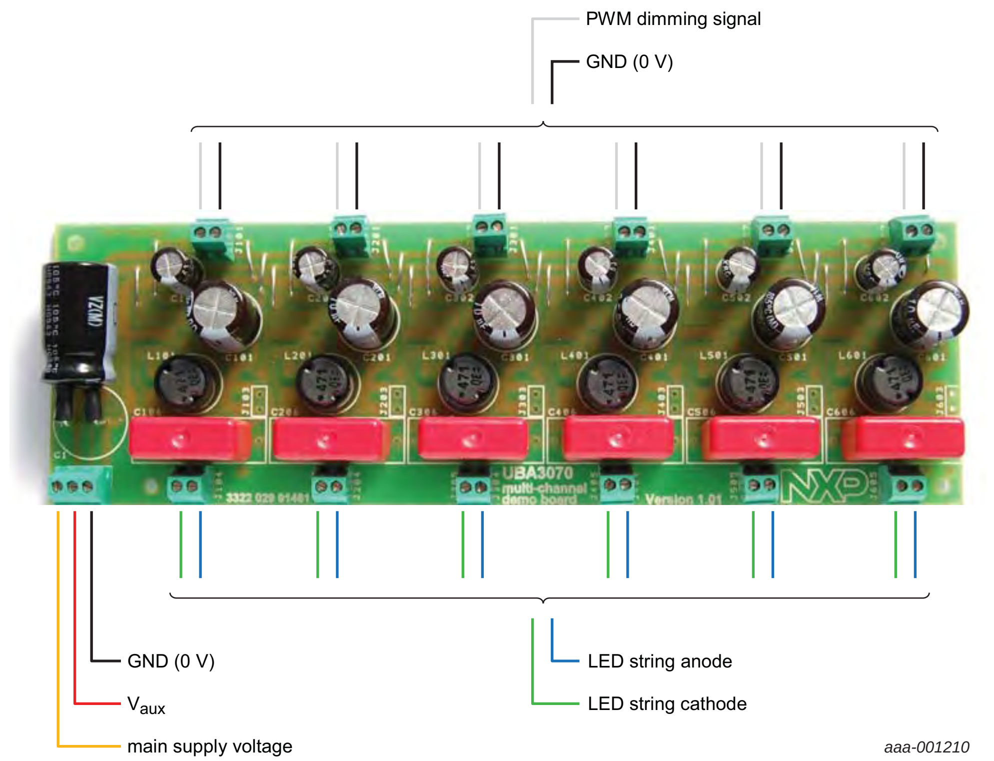


Fig 5. UBA3070 multi-channel demo board connections

7. Circuit description

The circuit on the UBA3070 multi-channel demo board consists of a general power Input section and six UBA3070 current source sections. Each UBA3070 current source consists of several sections: power supply input, dimming input, switching, 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 8. The components are listed in Table 2.

7.1 General power input section

In the default configuration, the general power input section consists of one buffer capacitor (C1) and three terminals (J1, J2, J3). J1 is the ground terminal, J2 is connected to the (12 V to 15 V) auxiliary power supply. J3 is connected to the high voltage (12 V to 190 V) main power supply.

The energy propagates from the general power input section to the six local power input sections (one for each individual UBA3070 current source). The general power Input section can be adapted in such a way that it is not necessary to use an external 12 V auxiliary supply. See Section 8.1 for details.

7.2 Local power supply input section

Each UBA3070 Current Source channel has an individual Local Power Input section. The power supply input section consists of two energy reservoirs and filters:

- The main supply voltage reservoir and noise filter: capacitors CX01 and CX10
- The auxiliary supply voltage reservoir and noise filter: capacitors CX02 and CX08

The main power is predominantly used for providing power to the LED string. The internal circuitry of the UBA3070 IC uses the auxiliary supply voltage (12 V to 15 V). This supply also provides the power to charging and discharging MOSFET QX01 gate.

The amount of energy required to charge and discharge C_{iss} of MOSFET QX01 determines the auxiliary supply current consumption. The current requirement can be as low as 2 mA for a small MOSFET. However, for a large MOSFET, it could be one order of magnitude higher.

7.3 Dimming input section

The dimming input signal is supplied to connectors JX01 (GND) and JX02 (PWM/signal). Using a low-pass and current limiting network (RX01, RX02, CX03), the dimming input signal is supplied to the UBA3070 PWM pin. The typical target application (backlighting) normally uses PWM dimming, however, there is an option to use the analog dimming option via the same PWM pin.

7.3.1 PWM dimming

When a high voltage (V_{high}, >2.5 V) is fed to the UBA3070 PWM pin, the converter is effectively disabled (It enters cycle skipping mode). A low voltage (V_{low}, <0.5 V) on the same pin causes the UBA3070 to be fully enabled. The light output produced can be varied by toggling between low voltage and high voltage. 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. However, in reality, a low PWM frequency can give the impression that the LED string is flickering. A high frequency can result in inaccurate dimming performance and interference with the UBA3070 circuit operating frequency (see Ref. 2).

A PWM frequency in the range of 100 Hz to 1 kHz is recommended for most applications including general lighting and LCD TV backlighting. The relative light output intensity is given in Equation 1

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

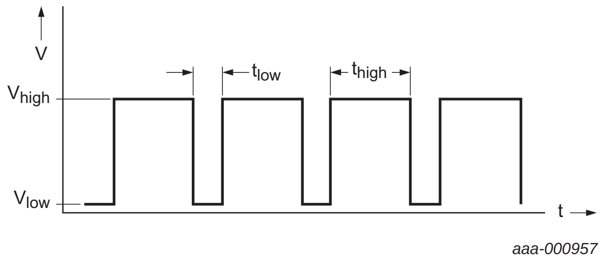


Fig 6. Typical PWM dimming signal

7.3.2 Analog dimming

By feeding an analog voltage signal to the UBA3070 PWM pin, the magnitude of the peak current flowing through the LX01 inductor can be controlled. The analog control voltage on the control pin is between 1 V and 2 V approximately. In this voltage range, the magnitude of the voltage is approximately inversely proportional to the V_{SENSE} voltage of the UBA3070 IC. Consequently, the light intensity control matches the curve shown in Figure 7.

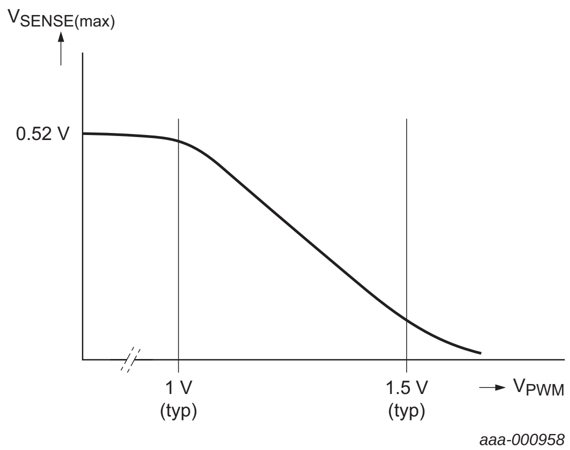


Fig 7. Typical analog control light intensity is proportional to the V_{SENSE} level

7.4 Switching section

The heart of the switching section is the UBA3070 IC (ICX01). Together with the power components QX01, DX03, LX01 and RX06, ICX01 forms the switching section. When the UBA3070 switches MOSFET QX01 on, the current in LX01 ramps up. When UBA3070 switches off QX01, the LX01 current continues to flow through DX02 and ramps down. Capacitor CX11 is added to the circuit to limit the dV/dt when MOSFET QX01 switches off. In many circumstances, this addition is necessary to guarantee correct valley detection (see UBA3070 data sheet (Ref. 1)). RX06 is a current sense resistor that is in the high current path. See Section 7.5 for further details.

7.5 Feedback section

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 QX01 is on (primary stroke)
- The detection of zero inductor current while MOSFET QX01 is off and the current is flowing through DX02 (secondary stroke)

The average current that is supplied by the switching section is exactly half the inductor peak current. This effect is because of the current ramping up and down with a constant slope and there is no dead-time between two subsequent cycles.

7.5.1 Peak current detection

The peak inductor current is detected by measuring the voltage drop across RX06. This voltage drop is presented to the UBA3070 SENSE pin. The UBA3070 reacts to the detection of the peak current by switching off MOSFET QX01.

7.5.2 Direct demagnetization detection

Zero inductor current is detected by measuring the inductor current with resistor RX04. The information is transferred using the a-symmetric current mirror QX02, QX03 and RX04, RX07 to the network RX03, RX05, CX04 and the dual diode DX01. When the voltage supplied to the UBA3070 MASK pin drops below 100 mV, the UBA3070 IC reacts by switching on MOSFET QX01. This way of detecting zero current (or demagnetization) of the inductor is called “direct demagnetization detection”. An alternative way of demagnetization detection is explained in Section 8.

7.6 Output section

The switching section produces a sawtooth current waveform in the inductor. Current ramps-up linearly from 0 A to I_{peak} and then ramps down linearly from I_{peak} to 0 A. In most circumstances, the current waveform must not be fed to an LED string. Capacitor CX06 is used in the output section to reduce the ripple on the LED current for that reason. See Ref. 2 for details about the dimensioning of the ripple filter.

The LED string is connected to connectors JX04 (anode of the LED string) and JX05 (cathode of the LED string).

8. Alternative circuit options

8.1 On-board V_{aux} generation

A linear voltage regulator is built by adding components Q1, D1, C2, R1, R2 and R3 that derives a stable V_{aux} voltage from the main supply voltage (terminal J3). When this circuit is added, do not apply the auxiliary supply voltage (12 V to 15 V) to terminal J2.

This option allows the UBA3070 multi-channel demo board to form a single (high voltage) power supply. The main disadvantage is the additional energy that is dissipated in the linear voltage regulator. Typically, the current supplied by the linear voltage regulator is between 10 mA to 30 mA. At 100 V supply voltage, this results in 1 W to 3 W of additional power dissipation (mainly in transistor Q1).

Make sure that the components can handle the extra dissipation. An example of the linear voltage regulator circuit is shown in Figure 9. The component changes are listed in Table 3.

8.2 Indirect demagnetization detection

The UBA3070 multi-channel demo board offers the possibility to implement a cheaper and simpler alternative demagnetization detection circuit than the standard direct demagnetization detection option. The disadvantages of indirect demagnetization detection are:

- its performance is lower with less accurate current regulation and
- the possibility of false zero current detection for a dynamically changing load.

However for general lighting purposes, this demagnetization detection option is adequate.

Indirect demagnetization detection relies on the phenomenon that a ringing voltage appears at the drain node of MOSFET QX01 when the secondary stroke has finished. Resonance between inductor LX01 and the (parasitic) capacitance C_{DS} of QX01 causes the ringing voltage.

The resonating waveform propagates through capacitor CX09 and resistor RX10 to the RX03, RX05, CX04, DX01 network and to the UBA3070 MASK pin. The first valley of the ringing signal causes the MASK pin voltage to drop below 100 mV. This voltage drop is therefore, an indirect way of detecting demagnetization of the LX01 inductor. The UBA3070 circuit using indirect demagnetization detection is shown in Figure 10. The component changes are listed in Table 4.

8.3 Rising slope compensation

The UBA3070 data sheet (Ref. 1) shows that there is always a time delay between peak current detection through the SENSE pin and the MOSFET switching off. This propagation delay is typically 140 ns and causes overshooting of the peak inductor current.

The steeper the slope of the rising current, the higher the overshoot. The slope-dependent overshoot is “neutralized” using a simple high-pass filter in the peak current detection circuit. Instead of using RX06 for peak current detection, a frequency-dependent divider (RX08, RX09, CX05) is added before the signal is fed back to the SENSE pin.

Depending on the UBA3070 driver circuit implementation, some recalculation and/or experimentation is required to find proper values for RX08, RX09 and CX05. The UBA3070 circuit diagram with rising slope compensation is shown in Figure 11. The component changes are listed in Table 5.

8.4 High voltage and higher or lower current versions

When some of the components of the UBA3070 multi-channel demo board are replaced with higher voltage types, the driver is able to drive longer strings. In addition, it is able to operate from a higher supply voltage while the auxiliary supply voltage remains at 12 V to 15 V. Examples of higher supply voltages are rectified mains or PFC output voltage.

Table 6 shows an example of the component changes for a 100 mA driver module capable of operating from a 400 V PFC voltage. See Ref. 2 for more details about the calculation of component values.

9. Schematics

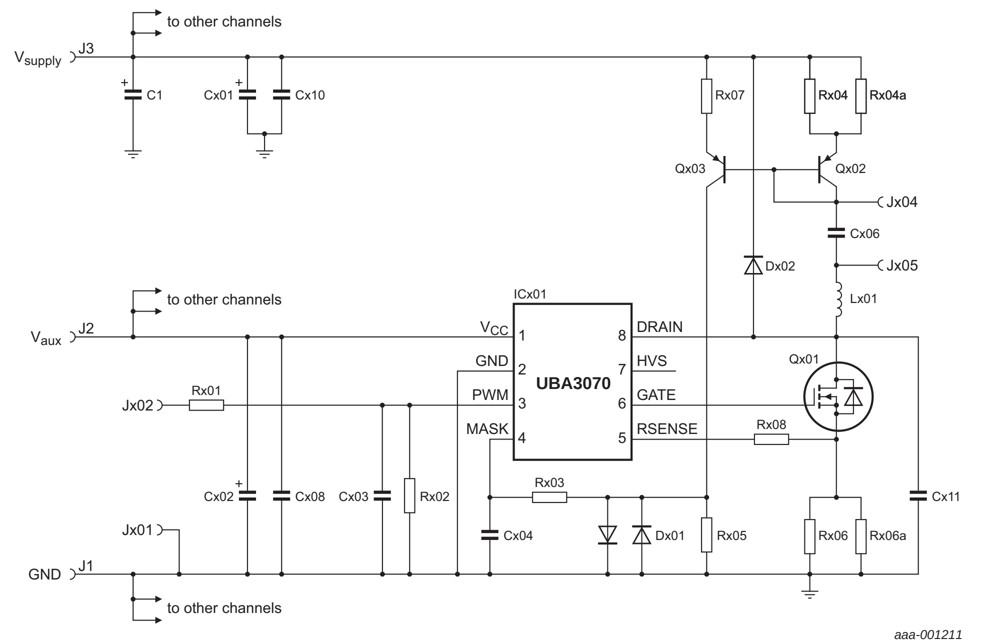


Fig 8. Default configuration UBA3070 multi-channel demo board circuit diagram with general power input and on channel

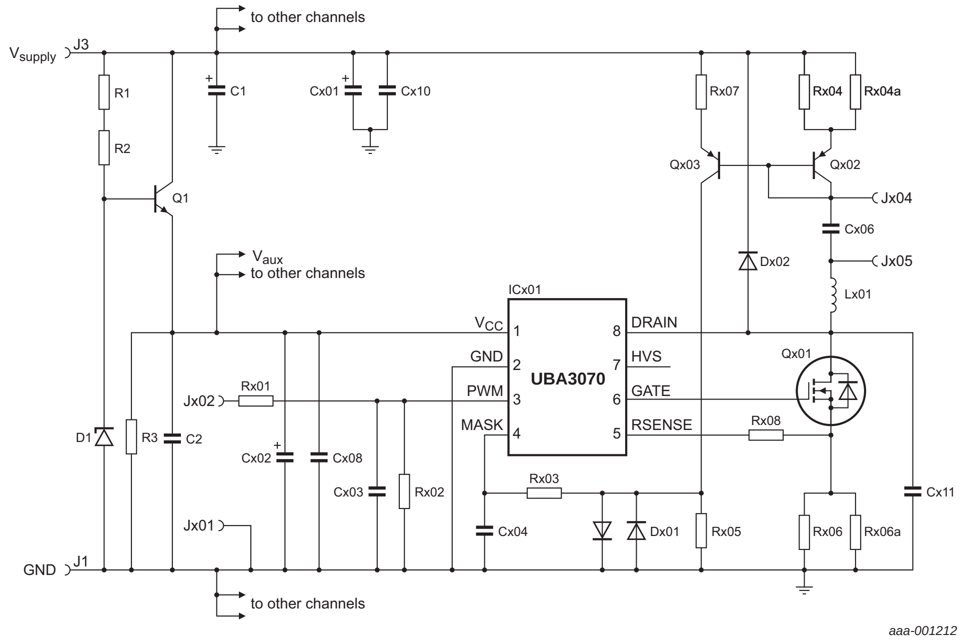


Fig 9. UBA3070 multi-channel demo board circuit diagram with modified general power input section: on-board V_{aux} generation

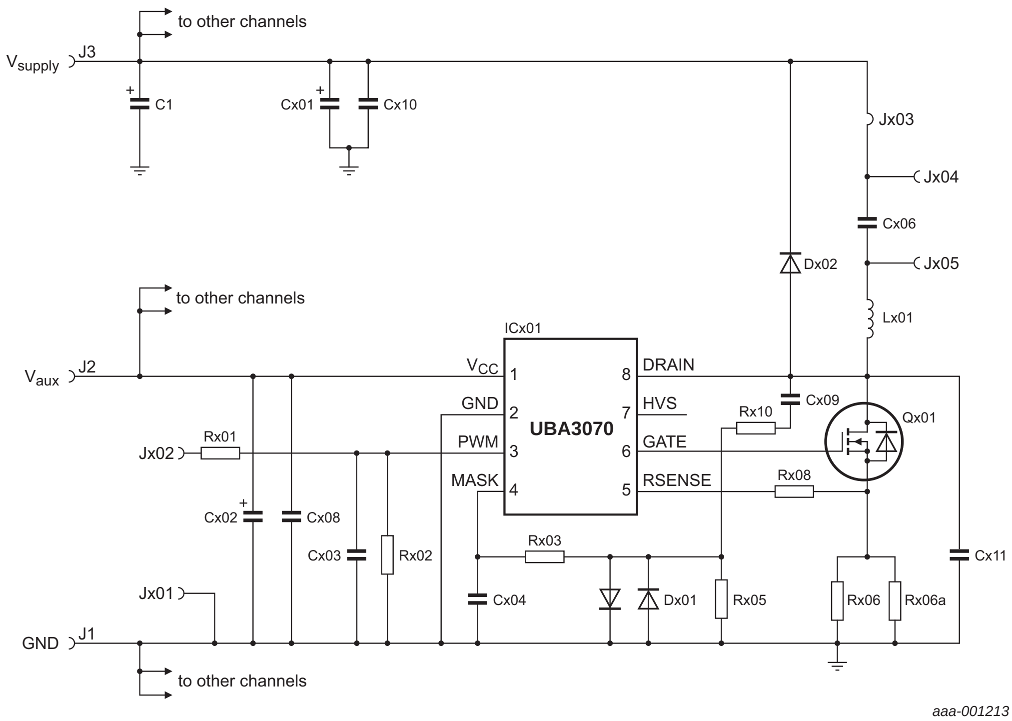


Fig 10. UBA3070 multi-channel demo board circuit diagram with indirect demagnetization detection

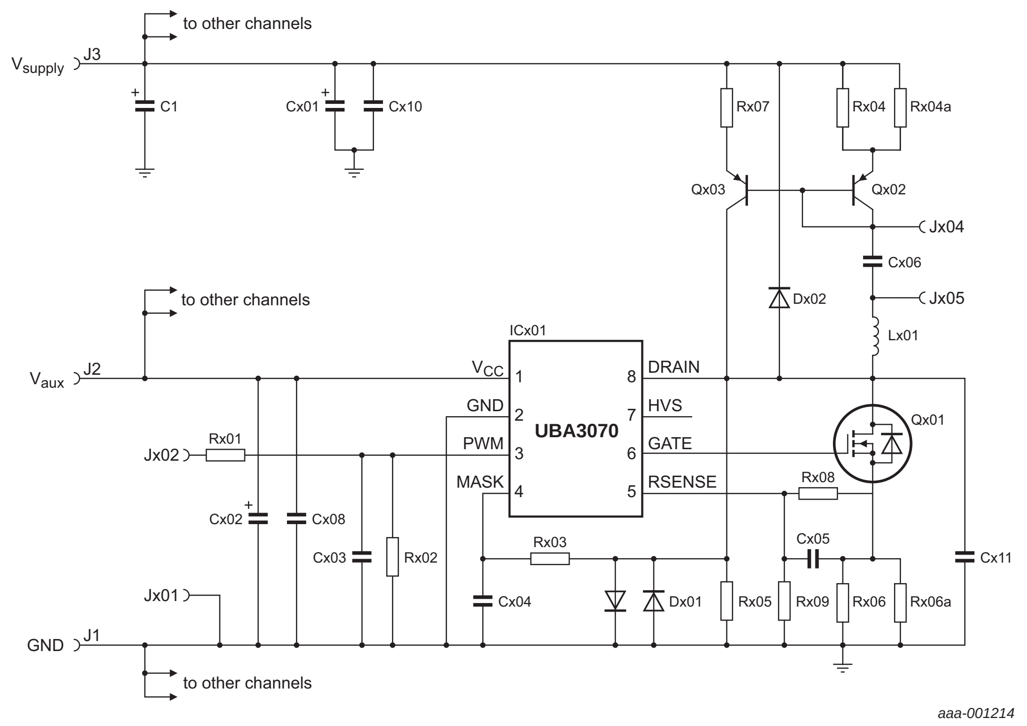


Fig 11. UBA3070 multi-channel demo board circuit diagram for rising slope compensation

10. Component lists

Table 2. Default component list

Part	Qty	Description and package	Manufacturer	Remarks
ICx01	6	UBA3070; SO8	NXP Semiconductors	-
Q1	0	BUJ103AD; DPAK	NXP Semiconductors	not mounted
Q1a	0	PBHV8540Z; SOT223	NXP Semiconductors	not mounted
Qx01	6	PHD9NQ20T; DPAK	NXP Semiconductors	-
Qx01a	0	BSP298; SOT223	Infineon	not mounted
Qx02	6	PBSS5230T; SOT23	NXP Semiconductors	-
Qx03	6	PBHV9040T; SOT23	NXP Semiconductors	-
D1	0	BZX384-C13; SOD323	NXP Semiconductors	not mounted
Dx01	6	BAV99; SOT23	NXP	dual-diode
Dx02	6	BYG20J; DO-214AC	Vishay	Farnell 1021747
Lx01	6	470 μH; ELC09D471F; 2E pitch	Panasonic	Farnell 8094969; ∅10 mm maximum
C1	1	47 μF, 200 V; 2E pitch	Vishay	Farnell 1165455; ∅13 mm maximum
C2	0	100 nF, 50 V; 0805	-	not mounted
Cx01	6	10 μF, 200 V; 2E pitch	Vishay	Farnell 1165453; ∅10 mm maximum
Cx02	6	47 μF, 25 V; 1E pitch	Vishay	Farnell 1165523; ∅10 mm maximum
Cx03	6	180 pF, 50 V; 0805	-	-
Cx04	6	22 pF, 50 V; 0805	-	-
Cx05	0	varies; 0805	-	not mounted
Cx06	6	680 nF, 250 V; 6E pitch	Vishay	Farnell 1413770; maximum size 22.5 mm × 7.5 mm
Cx07	0	varies; 1206	-	not mounted
Cx08	6	100 nF, 50 V; 0805	-	-
Cx09	0	330 pF, 250 V; 1206	-	not mounted
Cx10	6	10 nF, 500 V; 1206	-	-
Cx11	6	220 pF, 500 V; 0805	Yageo	Farnell 1284127
R1	0	100 kΩ; 1206	-	not mounted
R2	0	100 kΩ; 1206	-	not mounted
R3	0	100 kΩ; 1206	-	not mounted
Rx01	6	1 kΩ; 0805	-	-
Rx02	6	10 kΩ; 0805	-	-
Rx03	6	22 kΩ; 1206	-	-
Rx04	6	1.5 Ω, 0,25 W; 1206	-	-
Rx04a	6	1.5 Ω, 0.25 W; 1206	-	-
Rx05	6	10 kΩ; 0805	-	-
Rx06	6	1.5 Ω, 0.25 W; 1206	-	-
Rx06a	6	1.5 Ω, 0.25 W; 1206	-	-
Rx07	6	510 Ω; 1206	-	-
Rx08	6	0 Ω (jumper); 0805	-	-
Rx09	0	varies; 0805	-	not mounted

Table 2. Default component list *…continued*

Part	Qty	Description and package	Manufacturer	Remarks
Rx10	0	22 kΩ; 1206	-	not mounted
J1, J2, J3	1	3-pole terminal block; 1E pitch	Phoenix Contact	Phoenix: 1725669; Farnell: 3041360
Jx01, Jx02	6	2-pole terminal block; 1E pitch	Phoenix Contact	Phoenix: 1725656; Farnell: 3041359
Jx03	0	jumper wire	-	not mounted
Jx04, Jx05	6	2-pole terminal block; 1E pitch	Phoenix Contact	Phoenix: 1725656; Farnell: 3041359

Table 3. Component list modification for on-board V_{aux} generation

Part	Qty	Description and package	Manufacturer	Remarks
Q1	1	BUJ103AD; DPAK	NXP Semiconductors	-
D1	1	BZX384-C13; SOD323	NXP Semiconductors	-
C2	1	100 nF, 50 V; 0805	-	-
R1	1	100 kΩ; 1206	-	-
R2	1	100 kΩ; 1206	-	-
R3	1	100 kΩ; 1206	-	-
J1, J2, J3	1	3-pole terminal block	-	J2 not used

Table 4. Component list modification for indirect demagnetization detection

Part	Qty	Description and package	Manufacturer	Remarks
Qx02	0	PBSS5230T; SOT23	NXP Semiconductors	not mounted
Qx03	0	PBHV9040T; SOT23	NXP Semiconductors	not mounted
Cx09	6	330 pF, 250 V; 1206	-	-
Rx04	0	1.5 Ω, 0,25 W; 1206	-	not mounted
Rx04a	0	1.5 Ω, 0.25 W; 1206	-	not mounted
Rx05	6	1 kΩ; 0805	-	-
Rx07	0	510 Ω; 1206	-	not mounted
Rx10	6	22 kΩ; 1206	-	-
Jx03	6	jumper wire	-	-

Table 5. Component list modification for rising slope compensation

Part	Qty	Description and package	Manufacturer	Remarks
Cx05	6	varies; 0805	-	application dependent
Rx08	6	varies; 0805	-	application dependent
Rx09	6	varies; 0805	-	application dependent

Table 6. Component list modification for 400 V, 100 mA version

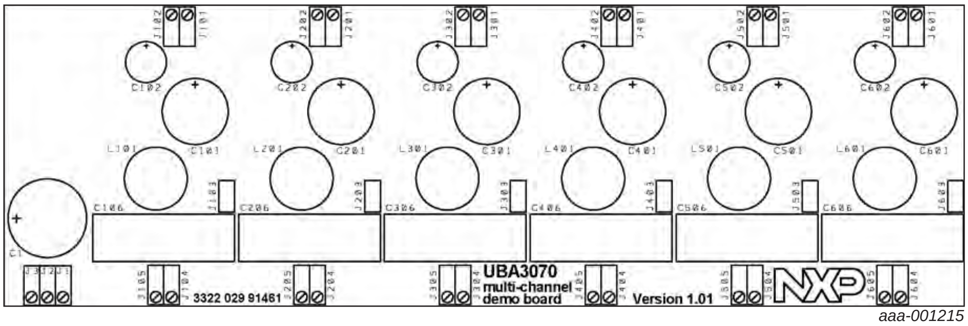
Part	Qty	Description	Manufacturer	Remarks
Qx01	0	PHD9NQ20T; DPAK	NXP Semiconductors	not mounted
Qx01a	6	BSP298; SOT223	Infineon	-
Lx01	6	4.7 mH, 200 mA; 2E pitch	-	∅10 mm maximum
C1	1	22 μF, 400 V; 2E pitch	-	∅13 mm maximum
Cx01	6	3.3 μF, 400 V; 2E pitch	-	∅10 mm maximum
Cx06	6	100 nF, 400 V; 2-6E pitch	-	maximum size 22.5 mm × 7.5 mm
Rx04	6	2.2 Ω, 0,25 W; 1206	-	-
Rx04a	0	1206	-	not mounted
Rx06	6	2.2 Ω, 0.25 W; 1206	-	-
Rx06a	0	1206	-	not mounted

11. Printed-Circuit Board (PCB)

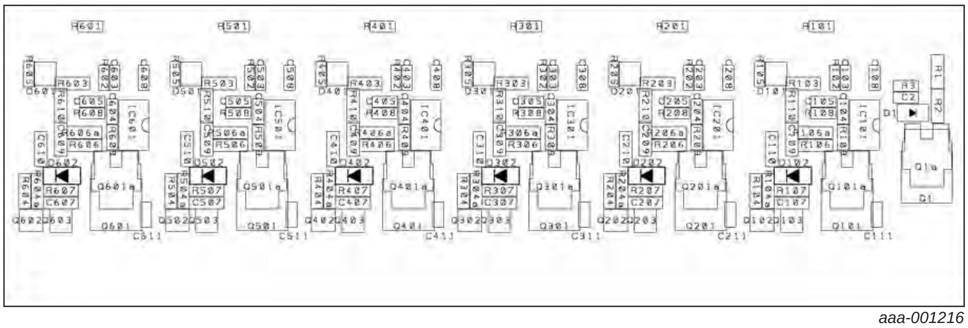
The UBA3070 multi-channel demo board PCB is a single-sided board. Dimensions are approximately 155 mm × 49 mm. The multi-channel demo boards are produced on 1.6 mm FR4 with single-sided 35 μm copper (1 oz.). FR2 can also be used as the PCB material.

The PCB can accommodate several implementations of the NXP Semiconductors UBA3070 multi-channel demo board as outlined in Section 7, Section 8, Section 9 and Section 10.

The Gerber File set for the production of the PCBs is available from NXP Semiconductors. The bottom silk is normally not used for PCB production. It is only a component position reference.



a. Top view



b. Bottom view

Fig 12. PCB silk screens

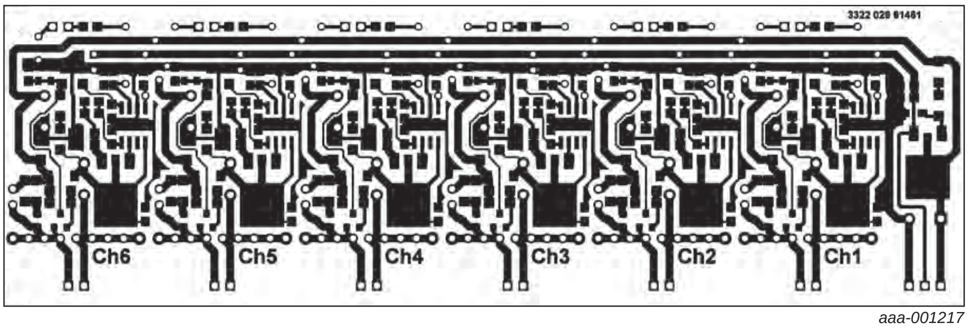


Fig 13. Bottom copper layer: bottom view

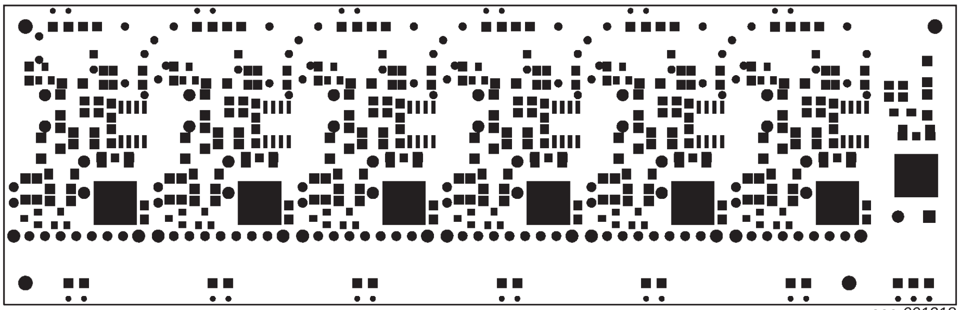


Fig 14. Bottom solder mask: bottom view

12. References

[1] **Data sheet —** UBA3070 LED backlight driver IC.

[2] **Application note —** AN10894 application aspects of the UBA3070 switch mode LED driver.

13. Legal information

13.1 Definitions

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14. Contents

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