UM10400

UBA3070 demo board

Rev. 2 — 10 October 2011 User manual

Document information

Info	Content
Keywords	UBA3070, switch mode, current source, LED driver, PWM, dimming, analog dimming
Abstract	The NXP Semiconductors UBA3070 demo board implements a switch-mode current driver for LED strings. By default the board produces 350 mA output current while the maximum output voltage is around 170 V. Multiple user-configurable options are available for the UBA3070 demo board. This user manual describes the UBA3070 demo board version 1.20. 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	20111010	second issue
v.1	20101204	first issue

Contact information

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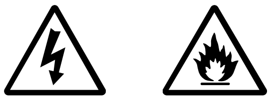
1. Introduction

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 demo board is intended to demonstrate the switch-mode current driving capabilities of the UBA3070 device. Emphasis is on driving LED strings of variable length and color. The LED intensity can be controlled in the following two ways:

- PWM dimming
- Analog dimming

The circuit implements a Boundary Conduction Mode (BCM), buck converter which is a classical text book example of 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 demo board is connected to a high DC voltage or to rectified AC Mains voltage. 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

UBA3070 demo board default configuration implements a 350 mA switch-mode current source 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. The maximum supply voltage is 190 V. The board can be reconfigured to meet specific application needs.

Some examples of application-specific implementation requirements can be met by changing the components listed in:

- Section 8 "Alternative circuit options" on page 12
- Section 9 "Schematics" on page 13
- Section 10 "Component lists" on page 16

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

Table 1. Default configuration main characteristics

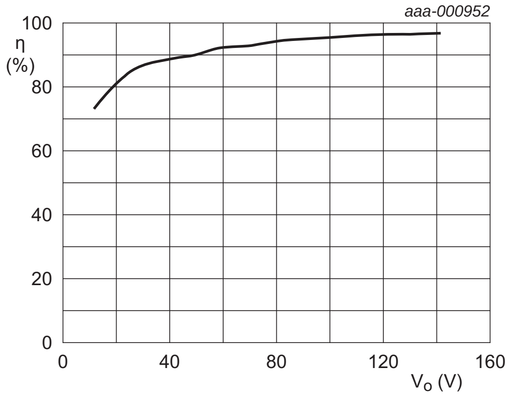
Property	Value	Remark
output current	350 mA	selectable; see Ref. 2
supply voltage	12 V to 190 V	depends on maximum LED string length
AUX supply voltage	12 V	2 mA to 5 mA typical
switching frequency	30 kHz to 145 kHz	selectable; see Ref. 2

5. Performance data

5.1 Efficiency

The UBA3070 device and the UBA3070 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 driving a string of 80 LEDs, 99 % efficiency can be achieved.



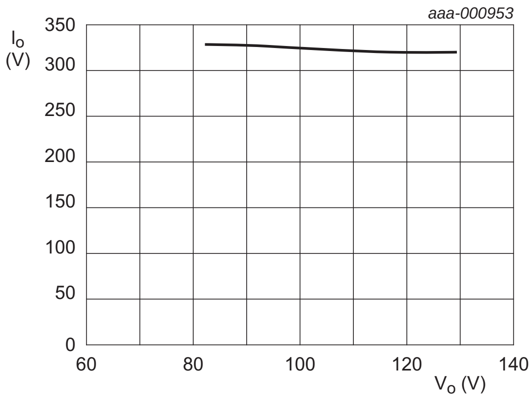
I_o = 330 mA.

Fig 2. Typical efficiency curve for the UBA3070 demo board

5.2 Output current stability

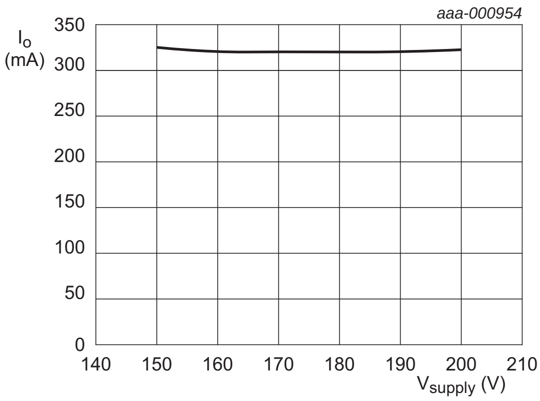
The output current varies only slightly with variation of the voltage drop across the LEDs and with variation of the circuit supply voltage. In most circumstances, the light output intensity variation is hardly visible to the human eye (if at all). If necessary, a compensation circuit can be added to the 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 demo board.



I_o = 320 mA typical.

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

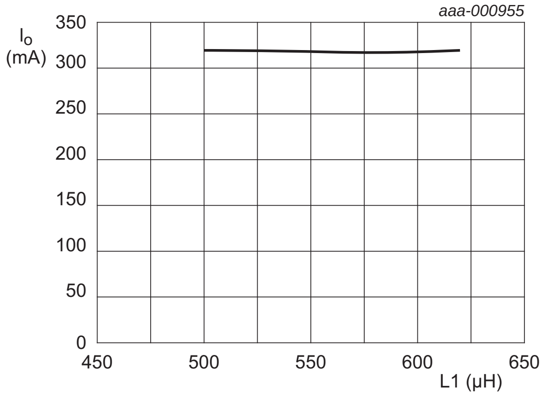


I_o = 320 mA typical.

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

The L1 inductor value (see circuit diagram in Figure 9) 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 up to ± 10 % of the L1 inductance value, however, have practically no influence on the LED output current value.

The UBA3070 application is minimally affected by production-related spread of the L1 inductor. Figure 5 gives an impression of this immunity.



I_o = 320 mA typical.

Fig 5. Typical output current variation of the UBA3070 demo board as a result of varying L1 value

6. Connection of the demo board

The UBA3070 demo board connections are shown in Figure 6. 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 headroom of at least 20 % is allowed.

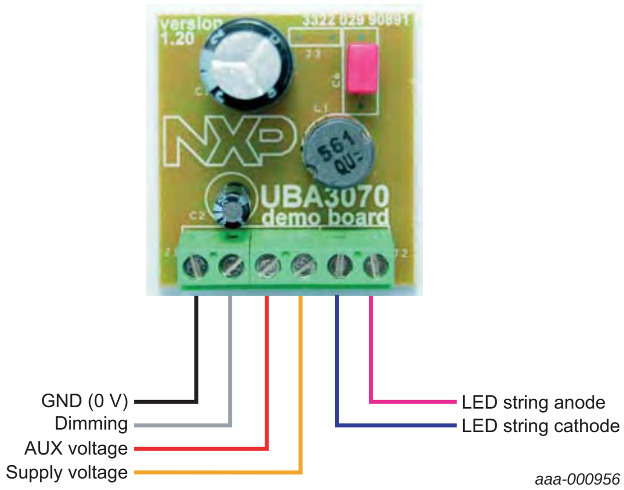


Fig 6. UBA3070 demo board connections

7. Circuit description

The circuit on the UBA3070 demo board consists of several sections: power supply input, dimming input, switching, current measurement/feedback and output.

The UBA3070 full default circuit diagram implemented on the demo board is shown in Figure 9. The component is shown in Table 3.

7.1 Power supply input section

The power supply input section consists of two energy reservoirs and filters:

- The main supply voltage reservoir and noise filter - capacitors C1 and C10
- The auxiliary supply voltage reservoir and noise filter - capacitors C2 and C8

The main supply power (12 V to 190 V) is connected to connectors J1.4 (positive) and J1.1 (negative/GND). The main power is predominantly used for providing power to the LED string. The auxiliary supply voltage (12 V to 15 V) is connected to connectors J1.3 (positive) and J1.1 (negative/GND). The auxiliary supply powers the internal circuitry of the UBA3070 IC. This supply also provides the power for charging and discharging MOSFET Q1 gate.

The amount of energy required to charge and discharge C_{iss} of MOSFET Q1 is the dominant factor which 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.

7.2 Dimming input section

The dimming input signal is supplied to connectors J1.2 (positive/signal) and J1.1 (GND). Using a low-pass and current limiting network (R1, R2, C3), the dimming input signal is supplied to the PWM pin. The dimming signal can be both a digital PWM signal and an analog signal.

7.2.1 PWM dimming

When a high voltage (V_{high}, >2.5 V) is fed to the 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 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

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

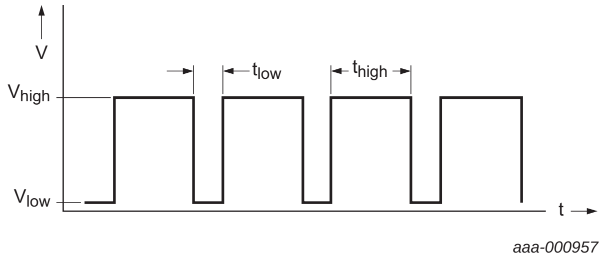


Fig 7. Typical PWM dimming signal

7.2.2 Analog dimming

By feeding an analog voltage signal to the PWM pin, the magnitude of the peak current flowing through the L1 inductor can be controlled. The analog control voltage on the control pin is between 1 V and 2 V approximately. In that voltage range, the magnitude of the voltage is roughly inversely proportional to the V_{SENSE} voltage of the UBA3070 IC. Consequently, the light intensity control matches the curve shown in Figure 8.

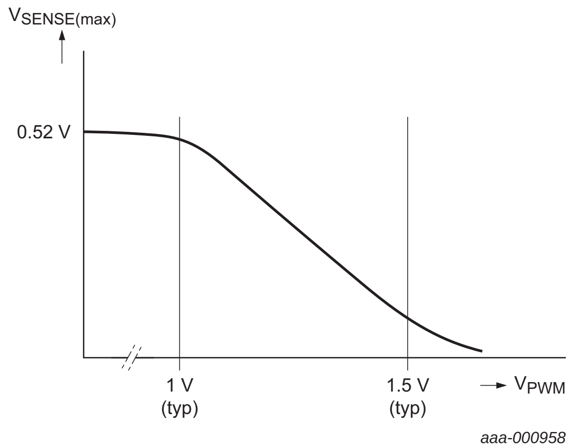


Fig 8. Typical analog control light intensity is proportional to the V_{SENSE} level

A simple circuit that could be used to experiment with analog dimming is shown in Figure 13.

7.3 Switching section

The heart of the switching section is the UBA3070 IC (IC1). Together with the power components Q1, D3, L1 and R6, IC1 forms the switching section. When the UBA3070 switches MOSFET Q1 on, the current in L1 ramps up. When UBA3070 switches off Q1, the L1 current continues to flow through D3 and ramps down. R6 is a current sense resistor that is in the high current path. See Section 7.4 for further details.

7.4 Current measurement and 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 Q1 is on (primary stroke)
- The detection of zero inductor current while MOSFET Q1 is off and the current is flowing through D3 (secondary stroke)

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

7.4.1 Peak current detection

The peak inductor current is detected by measuring the voltage drop across R6. This voltage drop is presented to the UBA3070 sense pin, and the UBA3070 reacts to the detection of the peak current by switching off MOSFET Q1.

7.4.2 Direct demagnetization detection

Zero inductor current is detected by measuring the inductor current with resistor R4. The information is transferred using the asymmetric current mirror Q2, Q3, R4 and R7 to the network R3, R5, C4, D1 and D2. When the voltage supplied to the UBA3070 MASK pin drops below 100 mV, the UBA3070 IC reacts by switching on MOSFET Q1. 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.

7.5 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, this current waveform is not fed directly to an LED string. Capacitor C6 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 J2.1 (cathode of the LED string) and J2.2 (anode of the LED string).

8. Alternative circuit options

8.1 Indirect demagnetization detection

The UBA3070 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 Q1 when the secondary stroke has finished. Resonance between inductor L1 and the (parasitic) capacitance C_{DS} of Q1 cause the ringing voltage.

The resonating waveform propagates through capacitor C9 and resistor R10 to the R3, R5, C4, D1, D2 network and to the UBA3070 MASK pin. The first valley of the ringing signal causes the MASK pin voltage to drop below 100 mV. In that sense, this method is an indirect way of detecting demagnetization of the L1 inductor. The UBA3070 circuit using indirect demagnetization detection is shown in Figure 10. The component changes are listed in Table 4.

8.2 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 R6 for peak current detection, a frequency-dependent divider (R8, R9, C5) 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 R8, R9 and C5. The UBA3070 circuit diagram with rising slope compensation is shown in Figure 11. The component changes are listed in Table 5.

8.3 Minimal application with relaxed noise immunity and protections

To save costs, some of the noise immunity and (current limiting) protection functions of the UBA3070 application can be sacrificed. In that way, a simple circuit with few components is obtained.

It is left to the judgment of the design engineer whether, in specific circumstances, these simplifications are acceptable. Figure 12 shows a minimal UBA3070 circuit diagram that is still fully functional. Take care how and under what circumstances it is operated. The component changes are listed in Table 6.

8.4 High voltage and higher or lower current versions

When some of the components of the UBA3070 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 7 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

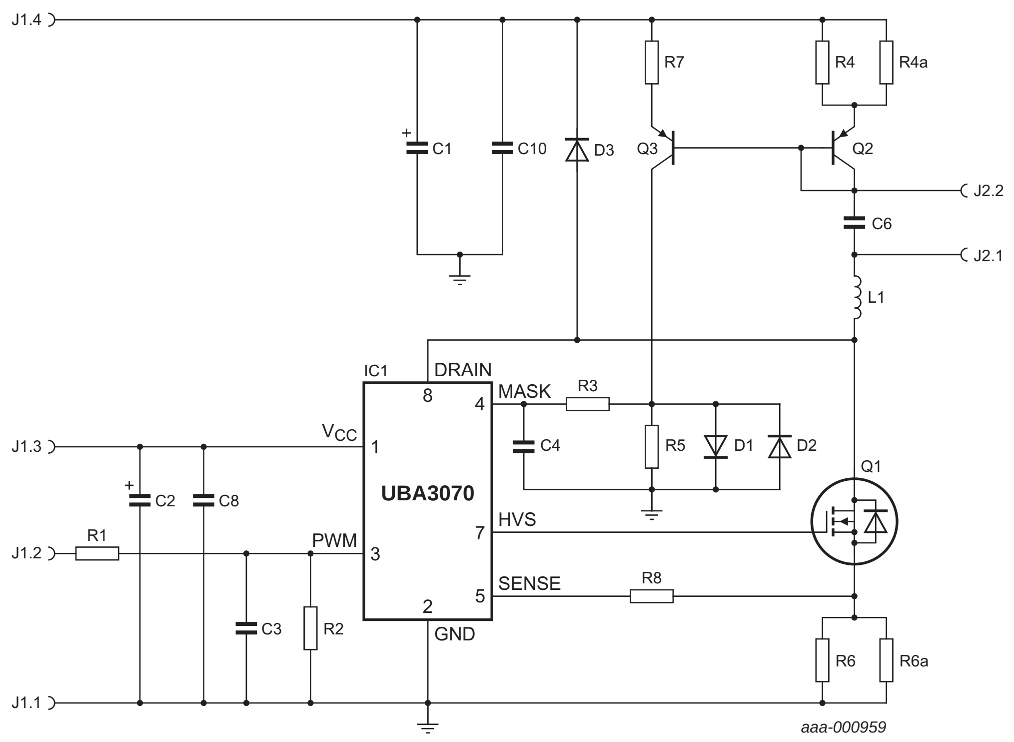


Fig 9. UBA3070 demo board circuit diagram with direct demagnetization detection (default implementation)

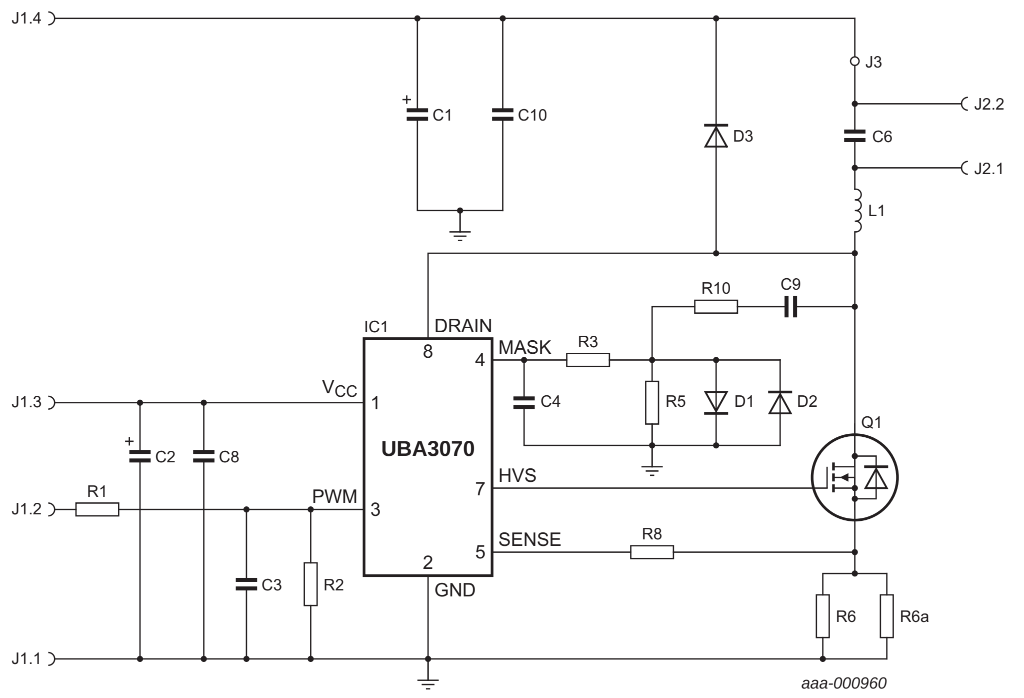


Fig 10. UBA3070 demo board circuit diagram with indirect demagnetization detection

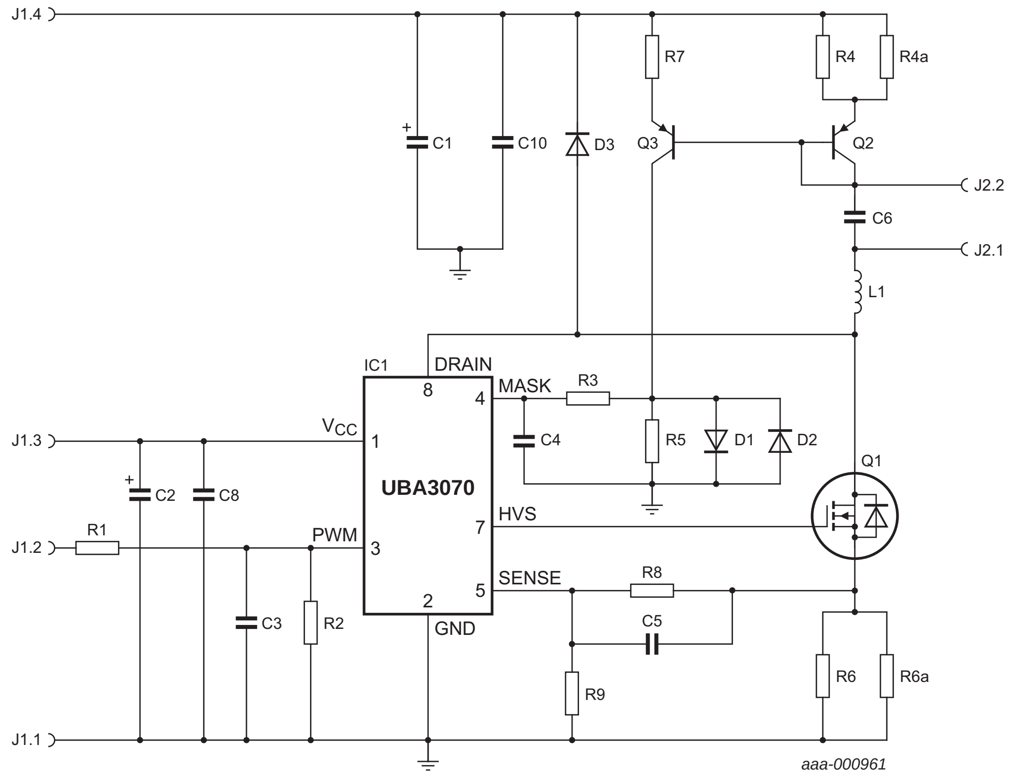


Fig 11. UBA3070 demo board circuit diagram with rising slope compensation

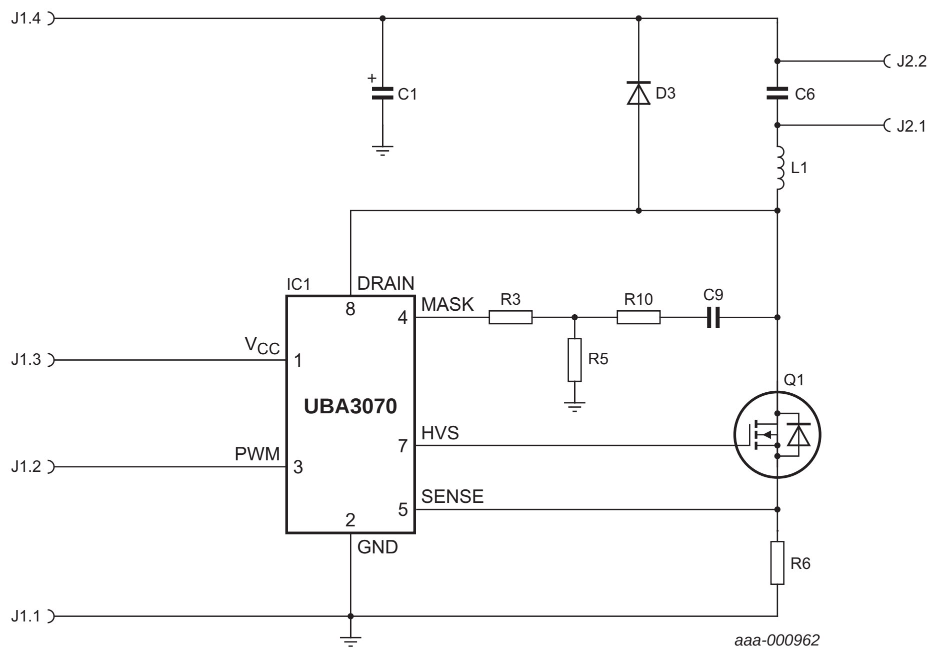


Fig 12. UBA3070 demo board circuit diagram for minimal application

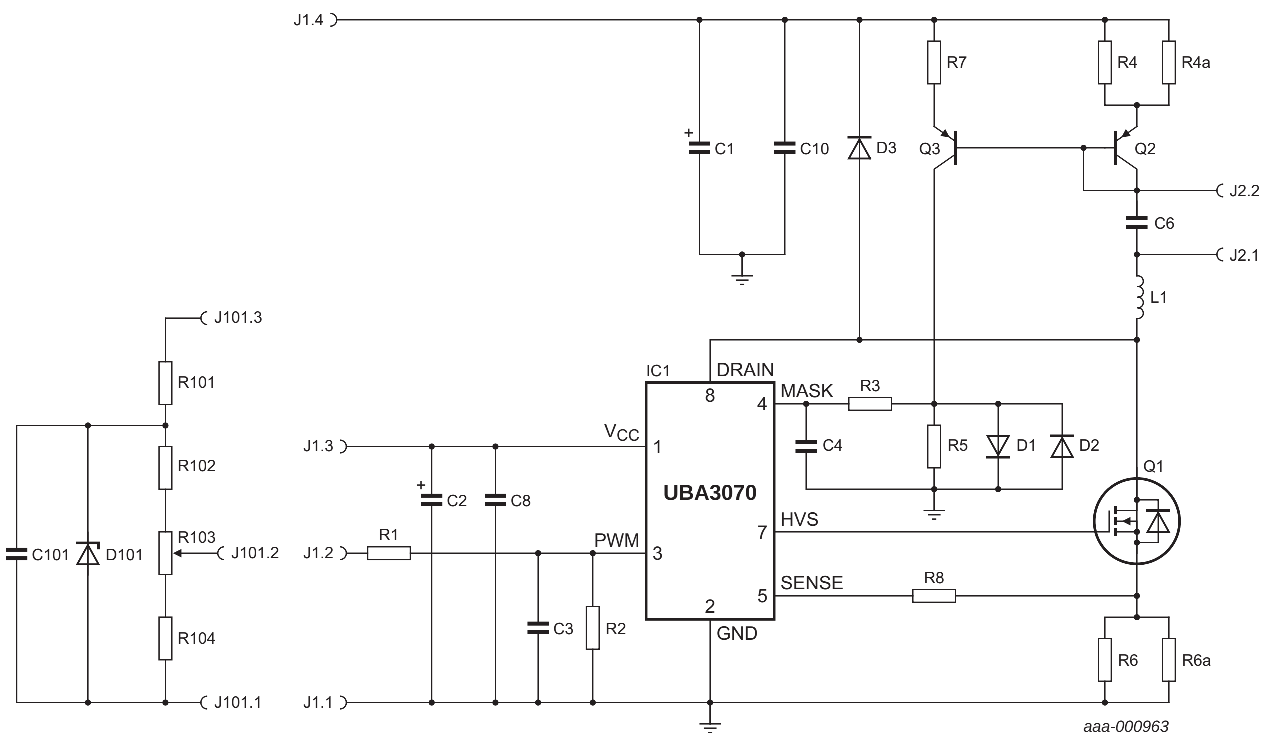


Fig 13. UBA3070 demo board circuit diagram with simple analog dimming extension

Connect terminal J101.3 to J1.3, J101.2 to J1.2 and J101.1 to J1.1 to use the simple analog dimming circuit: with all voltages applied to the UBA3070 module as described in Table 6 and Section 7.1. See Table 2 for suggested component values.

Table 2. Suggested component list for the simple analog dimming extension circuit

Ref.	Description and package	Manufacturer	Remarks
D101	BZX384C5V1; SOD323	NXP Semiconductors	-
C101	220 nF, 10 V	-	-
R101	12 kΩ	-	-
R102	4.7 kΩ	-	[1]
R103	2 kΩ	-	potentiometer
R104	1.5 kΩ	-	[1]

[1] To use the full range of the R103 potentiometer, the values of R102 and R104 may need adapting.

10. Component lists

Table 3. Default component list

Ref.	Description and package	Manufacturer	Remarks
IC1	UBA3070; SO8	NXP Semiconductors	-
Q1	PHD9NQ20T; DPAK	NXP Semiconductors	-
Q1a	varies; SOT223	varies	not mounted
Q2	BCP51; SOT223	NXP Semiconductors	-
Q3	BF723; SOT223	NXP Semiconductors	-
D1	BAS316; SOD323	NXP Semiconductors	-
D2	BAS316; SOD323	NXP Semiconductors	-
D3	BYG20J; DO-214AC	Vishay	-
L1	560 μH, 680 mA, ELC10D561E; 2E pitch	-	∅10 mm maximum
C1	22 μF, 200 V; 2E pitch	-	∅13 mm maximum
C2	100 μF, 25 V; 1E pitch	-	∅8 mm maximum
C3	180 pF, 50 V; 1206	-	-
C4	22 pF, 50 V; 1206	-	-
C5	varies; 1206	-	not mounted
C6	100 nF, 250 V; 2E pitch	-	maximum size 13 × 5 mm
C7	varies; 1206	-	not mounted
C8	100 nF, 50 V; 1206	-	-
C9	330 pF, 250 V; 1206	-	not mounted
C10	10 nF, 500 V; 1206	-	-
R1	1 kΩ; 1206	-	-
R2	10 k; 1206	-	-
R3	22 kΩ; 1206	-	-
R4	1.5 Ω, 0,25 W; 1206	-	-
R4a	1.5 Ω, 0.25 W; 1206	-	-

Table 3. Default component list

Ref.	Description and package	Manufacturer	Remarks
R5	10 kΩ; 1206	-	-
R6	1.5 Ω, 0.25 W; 1206	-	-
R6a	1.5 Ω, 0.25 W; 1206	-	-
R7	510 Ω; 1206	-	-
R8	0 Ω (jumper); 1206	-	-
R9	varies; 1206	-	not mounted
R10	22 kΩ; 1206	-	not mounted
J1	4-pole terminal block; 2E pitch	-	for example, Phoenix:1729144
J2	2-pole terminal block; 2E pitch	-	for example, Phoenix: 1729128
J3	jumper wire	-	not mounted

Table 4. Component list modification for indirect demagnetization detection

Ref.	Description and package	Manufacturer/Supplier	Remarks
Q2	BCP51; SOT223	NXP Semiconductors	not mounted
Q3	BF723; SOT223	NXP Semiconductors	not mounted
C9	330 pF, 250 V; 1206		
R4	1.5 Ω, 0,25 W; 1206		not mounted
R4a	1.5 Ω, 0.25 W; 1206		not mounted
R5	1 kΩ; 1206		
R7	510 Ω; 1206		not mounted
R10	22 kΩ; 1206		
J3	Jumper wire		install

Table 5. Component list modification rising slope compensation

Ref.	Description and package	Manufacturer	Remarks
C5	varies; 1206	-	[1]
R8	varies; 1206	-	[1]
R9	varies; 1206	-	[1]

[1] See application note AN10894 (Ref. 2) for guidelines.

Table 6. Component list modification for minimal application

Ref.	Description and package	Manufacturer	Remarks
Q2	BCP51; SOT223	NXP Semiconductors	not mounted
Q3	BF723; SOT223	NXP Semiconductors	not mounted
D1	BAS316; SOD323	NXP Semiconductors	not mounted
D2	BAS316; SOD323	NXP Semiconductors	not mounted
C2	100 μF, 25 V; 1E pitch	-	not mounted
C3	180 pF, 50 V; 1206	-	not mounted
C4	22 pF, 50 V; 1206	-	not mounted
C8	100 nF, 50 V; 1206	-	not mounted
C9	330 pF, 250 V; 1206	-	-
C10	10 nF, 500 V; 1206	-	not mounted
R1	0 Ω (short / jumper); 1206	-	-
R2	10 kΩ; 1206	-	not mounted
R4	1.5 Ω, 0,25 W; 1206	-	not mounted
R4a	1.5 Ω, 0.25 W; 1206	-	not mounted
R5	1 kΩ; 1206	-	-
R6	0.75 Ω, 0.25 W; 1206	-	-
R6a	1.5 Ω; 0.25 W; 1206	-	not mounted
R7	510 Ω; 1206	-	not mounted
R10	22 kΩ; 1206	-	-
J3	jumper wire	-	install

Table 7. Component list modification for 400 V, 100 mA driver

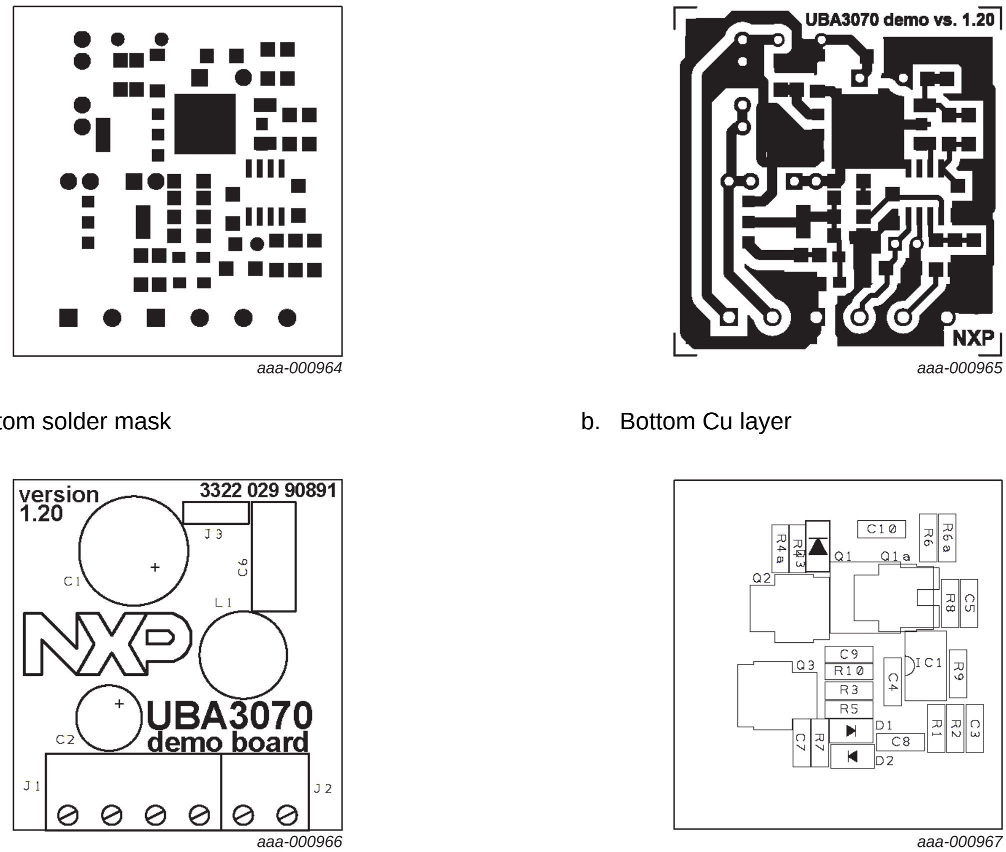
Ref.	Description and package	Manufacturer/ Supplier	Remarks
Q1	PHD9NQ20T; DPAK	-	not mounted
Q1a	BSP299; SOT223	Infineon	-
Q3	PBHV9040Z; SOT223	NXP Semiconductors	-
L1	4.7 mH, 200 mA, ELC11D472F; 2E pitch	-	∅12 mm maximum
C1	10 μF, 400 V; 2E pitch	-	∅13 mm maximum
C6	33 μF, 400 V; 2E to 4E pitch	-	maximum size 13 × 5 mm
R4	2.2 Ω, 0,25 W; 1206	-	-
R4a	1.5 Ω; 0.25 W; 1206	-	not mounted
R6	2.2 Ω, 0.25 W; 1206	-	-
R6a	1.5 Ω; 0.25 W; 1206	-	not mounted

11. Printed-Circuit Board (PCB)

The UBA3070 demo board PCB is a single-sided board. Dimensions are approximately 38 × 41 mm. The 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 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. Bottom solder mask

b. Bottom Cu layer

c. Top silk

d. Bottom silk

Fig 14. PCB layouts

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

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14. Contents

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