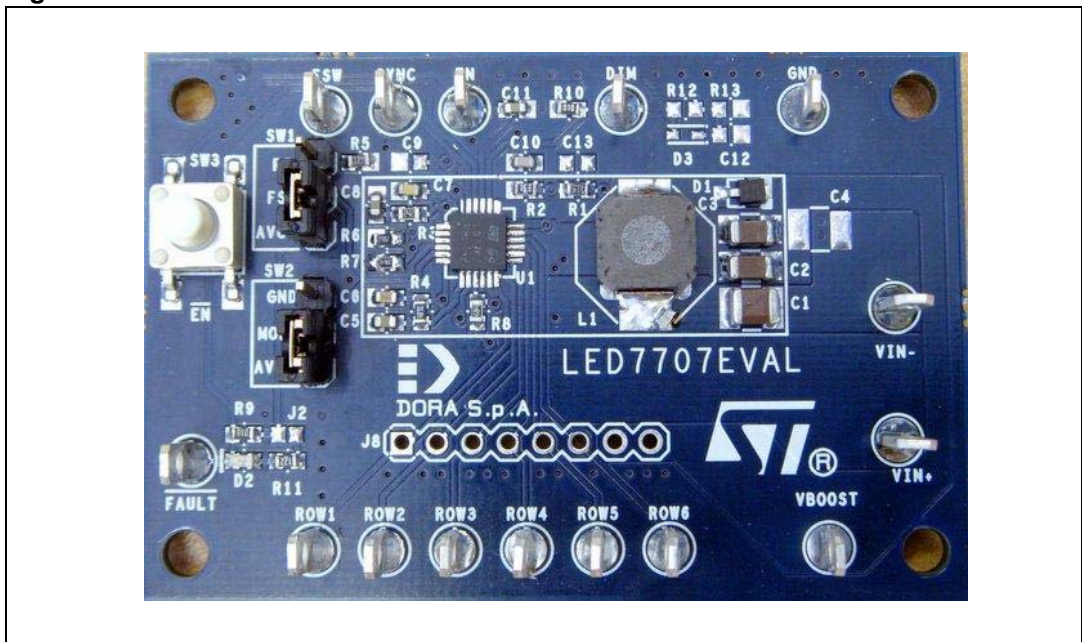


6-row 85 mA LED driver with boost converter for LCD panel backlighting

Introduction

The LED7707 LED driver from STMicroelectronics consists of a high-efficiency monolithic boost converter and six controlled current generators (rows), specifically designed to supply LED arrays used in the backlighting of LCD panels. The device can manage an output voltage up to 36 V (i.e. ten white-LEDs per row). The generators can be externally programmed to sink up to 85 mA and can be dimmed via a PWM signal (1% of minimum dimming duty-cycle at 1 kHz can be managed). The device allows detection and management of open and shorted LED faults, and permits unused rows to be left floating. Basic protections (output overvoltage, internal MOSFET overcurrent and thermal shutdown) are provided.

Figure 1. LED7707 demonstration board



Contents

- 1 LED7707 main features 4**
 - 1.1 Boost section 4
 - 1.2 Backlight driver section 4
- 2 LED7707 demonstration board 5**
- 3 Component list 6**
- 4 Component assembly and layout 7**
- 5 I/O interface 8**
- 6 Recommended equipment 8**
- 7 Configuration 8**
 - 7.1 SW1 fixed or adjustable switching frequency (FSW pin) 8
 - 7.2 SW2 fault management mode (MODE pin) 9
 - 7.3 SW3 enable function 10
- 8 Test setup 11**
- 9 Getting started 12**
 - 9.1 Quick startup 12
 - 9.2 Open and shorted WLEDs fault testing 13
 - 9.3 Device synchronization 13
 - 9.4 Efficiency measurements 14
- 10 Revision history 16**

List of figures

Figure 1.	LED7707 demonstration board	1
Figure 2.	LED7707 demonstration board schematic	5
Figure 3.	Top side component placement	7
Figure 4.	Bottom side test points	7
Figure 5.	SW1 (F_{SW}) setting	9
Figure 6.	SW2 (MODE) setting	9
Figure 7.	LED7707 demonstration board and white LED test board assembly	11
Figure 8.	LED7707 demonstration board test setup	11
Figure 9.	LED7707 synchronization setup	14
Figure 10.	Efficiency measurement setup	15
Figure 11.	Efficiency vs. DIM duty cycle, $V_{IN}=12$ V, 6 rows, 10 white LEDs in series, $I_{OUT} = 360$ mA	15
Figure 12.	Efficiency vs. DIM duty cycle, $V_{IN}=24$ V, 6 rows, 10 white LEDs in series, $I_{OUT} = 360$ mA	15

1 LED7707 main features

1.1 Boost section

- 4.5 V to 36 V input voltage range
- Internal power MOSFET
- Internal +5 V LDO for device supply
- Up to 36 V output voltage
- Constant frequency peak current-mode control
- 250 kHz to 1 MHz adjustable switching frequency
- External sync for multi-device application
- Pulse-skip power saving mode at light load
- Programmable soft-start
- Programmable OVP (overvoltage protection)
- Single ceramic output capacitor
- Non-latched thermal shutdown

1.2 Backlight driver section

- Six rows with 85 mA maximum current capability (adjustable)
- Up to 10 WLEDs per row
- Parallelable rows for higher current
- Row disable option
- Less than 10 μ s minimum dimming time
- $\pm 2\%$ current matching between rows
- LED failure (open and short-circuit) detection

2 LED7707 demonstration board

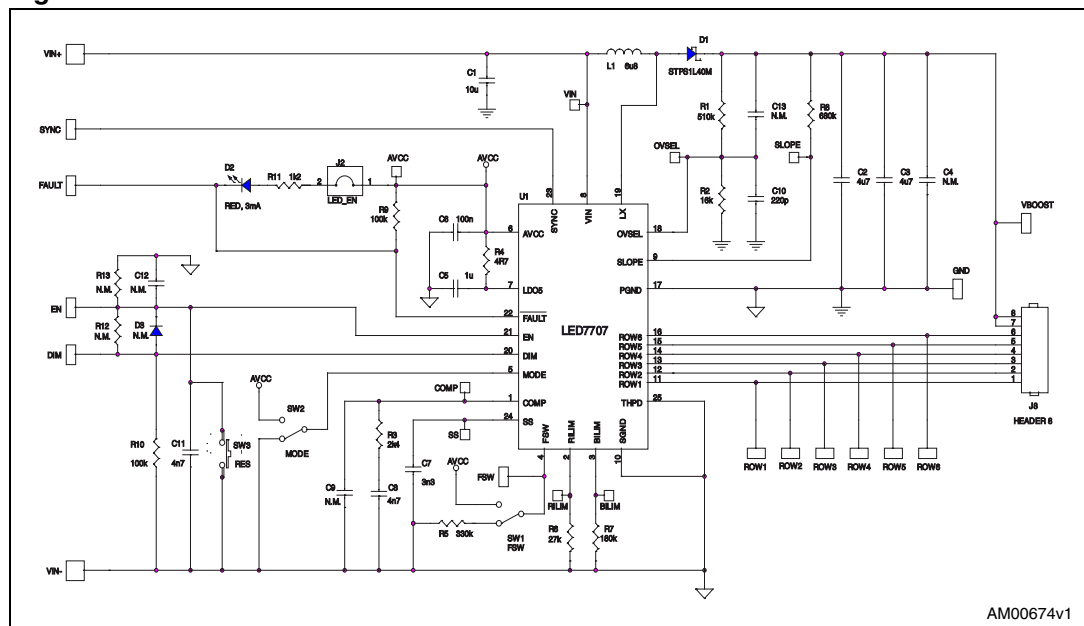
The LED7707 demonstration board has been designed to manage six strings of 8 to 10 white LEDs each.

Table 1 summarizes the board features and *Figure 2* shows the LED7707 demonstration board schematic. The input voltage range is limited to 32 V because of the 35 V rated input capacitor. An extended operating input voltage range (up to 36 V) can be achieved by using a 50 V-rated MLCC.

Table 1. LED7707 performance summary

Parameter	Conditions	Value
Minimum input voltage		6 V
Maximum input voltage		32 V
Output voltage		$V_{IN} < V_{BOOST} < 36 V$
Output OVP threshold	R1=510 kΩ, R2=16 kΩ	38 V
Internal MOSFET OCP	R7=360 kΩ	3.3 A
Boost section switching frequency	FSW pin to AVCC	660 kHz
	FSW pin to R5=330 kΩ	825 kHz
Minimum dimming on-time	400 Hz < FDIM < 20 kHz	10 μs
Output current (each row)	R6=24 kΩ	75 mA
Output current accuracy		±2%
Efficiency	$V_{IN}=12V, V_{BOOST}=34 V, FSW=660 kHz$	91%

Figure 2. LED7707 demonstration board schematic



AM00674v1

3 Component list

Table 2. LED7706 demonstration board component list

Qty	Component	Description	Package	Part-number	MFR	Value
1	C1	Ceramic, 35 V, X5R, 20%	SMD 1210	UMK325BJ106KM-T	Taiyo Yuden	10 μ F
2	C2,C3	Ceramic, 50 V, X7R, 20%	SMD 1206	GRM31CR71H475KA88B	Murata	4.7 μ F
1	C4	Ceramic, 50 V, X7R, 20%	SMD 1206			N.M.
1	C5	Ceramic, 25 V, X5R, 20%	SMD 0603		Standard	1 μ F
1	C6	Ceramic, 25V , X5R, 20%	SMD 0603		Standard	100 nF
1	C7	Ceramic, 25 V, X5R, 20%	SMD 0603		Standard	3.3 nF
1	C8	Ceramic, 25 V, X5R, 20%	SMD 0603		Standard	4.7 nF
1	C9	Ceramic, 25 V, X5R, 20%	SMD 0603		Standard	N.M.
1	C10	Ceramic, 25 V, X5R, 20%	SMD 0402		Standard	220 pF
1	C11	Ceramic, 25 V, X5R, 20%	SMD 0603		Standard	4.7 nF
1	C12	Ceramic, 25 V, X5R, 20%	SMD 0603		Standard	N.M.
1	C13	Ceramic, 25 V, X5R, 20%	SMD 0603		Standard	N.M.
1	R1	Chip resistor, 0.1 W, 1%	SMD 0603		Standard	510 k Ω
1	R2	Chip resistor, 0.1 W, 1%	SMD 0603		Standard	16 k Ω
1	R3	Chip resistor, 0.1 W, 1%	SMD 0603		Standard	2.4 k Ω
1	R4	Chip resistor, 0.1 W, 1%	SMD 0603		Standard	4.7 Ω
1	R5	Chip resistor, 0.1 W, 1%	SMD 0603		Standard	330 Ω
1	R6	Chip resistor, 0.1 W, 1%	SMD 0603		Standard	24 k Ω
1	R7	Chip resistor, 0.1 W, 1%	SMD 0603		Standard	360 k Ω
1	R8	Chip resistor, 0.1 W, 1%	SMD 0603		Standard	680 k Ω
2	R9, R10	Chip resistor, 0.1 W, 1%	SMD 0603		Standard	100 k Ω
1	R11	Chip resistor, 0.1 W, 1%	SMD 0603		Standard	1.2 k Ω
1	R12	Chip resistor, 0.1 W, 1%	SMD 0603		Standard	N.M.
1	R13	Chip resistor, 0.1 W, 1%	SMD 0603		Standard	N.M.
1	L1	68 μ H, 75 mH, 5.8 A	7x7mm	XPL7030-682ML	Coilcraft	6.8 μ H
1	D1	Schottky, 40 V, 1 A	DO216-AA	STPS1L40M	ST	STPS1L40M
1	D2	Red LED, 3 mA	SMD 0603		Standard	
1	D3	Signal Schottky	SOD-523	BAS69	ST	N.M.
1	U1	Integrated circuit	QFN4x4	LED7707	ST	LED7707
1	J2	PCB pad jumper				

Table 2. LED7706 demonstration board component list (continued)

Qty	Component	Description	Package	Part-number	MFR	Value
1	J8	Header 8	SIL 8		Standard	
1	SW1, SW2	Jumper 3	SIL 3		Standard	
1	SW3	Pushbutton	6x6mm	FSM4JSMAT	TYCO	

4 Component assembly and layout

Figure 3. Top side component placement

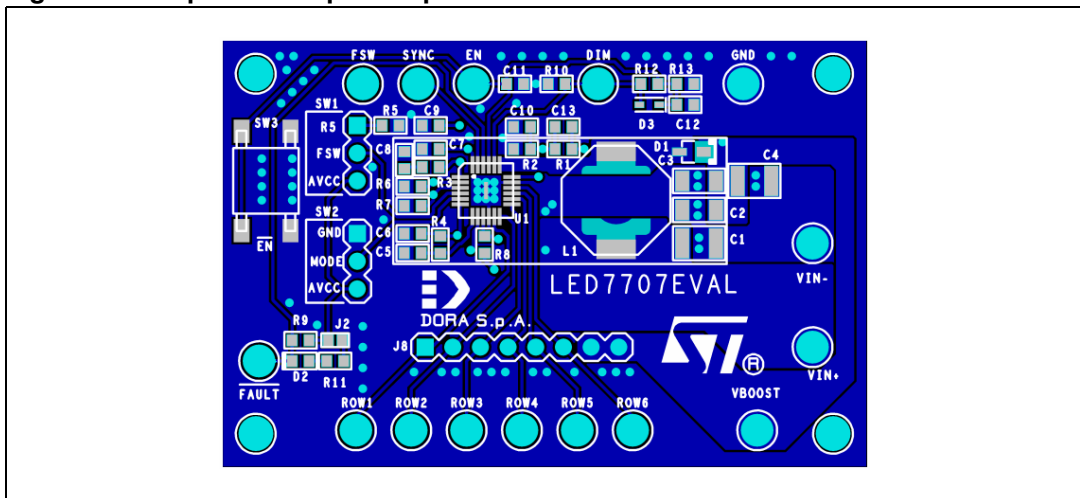
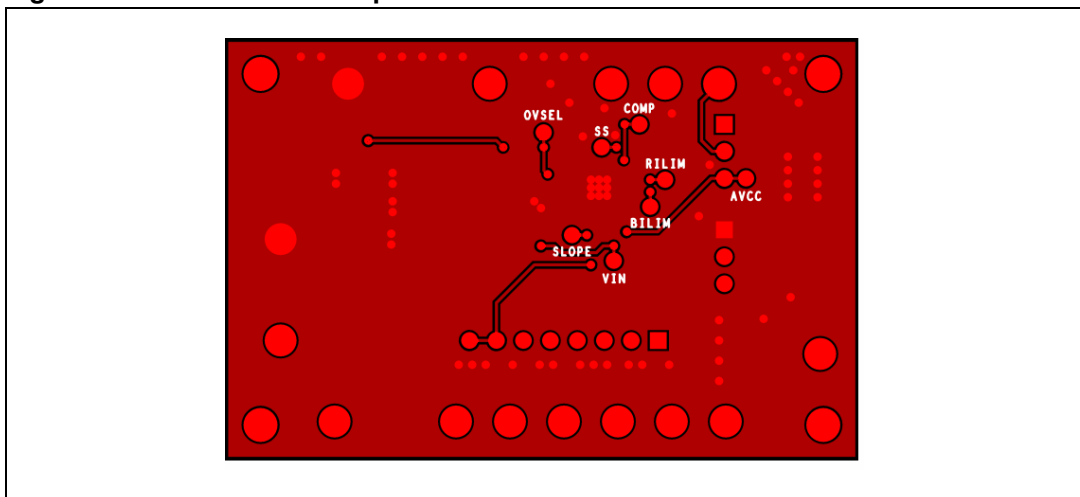


Figure 4. Bottom side test points



5 I/O interface

The LED7707 demonstration board is equipped with the test points described in [Table 3](#).

Table 3. LED7707 demonstration board test points description

Test point	Description
VIN+	Input voltage, positive terminal
VIN-	Input voltage, negative terminal
GND	Reference ground
ROW1 to ROW6	Current generator output
VBOOST	Boost regulator output voltage
DIM	PWM dimming input
EN	Enable input (active high)
SYNC	Synchronization output
FSW	Synchronization input
FAULT	Fault signal, active low

6 Recommended equipment

- 4.5 V to 32 V, 2 A capable power supply
- Digital multi-meters
- 20 MHz oscilloscope
- Signal generators for PWM dimming and synchronization clock (optional)

7 Configuration

The LED7707 demonstration board allows the user to choose the desired mode of operation using the SW1 and SW2 selectors (refer to the configuration description in the following paragraphs). A red LED is connected to the FAULT pin to easily monitor its status; if this option is not required, the monitor LED can be disconnected opening the J2 jumper.

7.1 SW1 fixed or adjustable switching frequency (FSW pin)

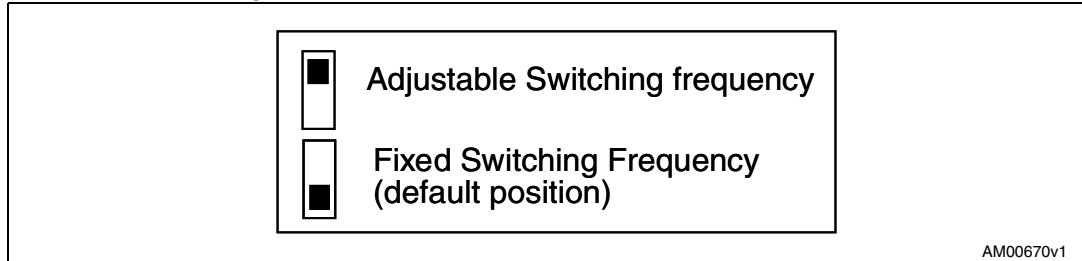
The SW1 selector is used to choose between the fixed switching frequency (660 kHz) and a user-defined switching frequency in the range 250 kHz to 1 MHz (see [Figure 5](#)). When placed in the “down” position, the fixed switching frequency is selected.

If SW1 is in the “up” position, the switching frequency is given by:

Equation 1

$$F_{SW} = 2.5 \cdot R_5$$

Figure 5. SW1 (F_{SW}) setting



The R5 resistor is set to 330 k Ω ($F_{SW} = 825$ kHz) and can be changed by the user.

7.2 SW2 fault management mode (MODE pin)

The SW2 selector is used to connect the MODE to AVCC or ground. When the jumper is set to the upper position, the MODE pin is connected to ground and the corresponding fault management is summarized in the first column of [Table 4](#).

Otherwise, when SW2 is set to the “down” position, the MODE pin is connected to AVCC and the corresponding fault management is summarized in the second column of [Table 4](#).

Figure 6. SW2 (MODE) setting

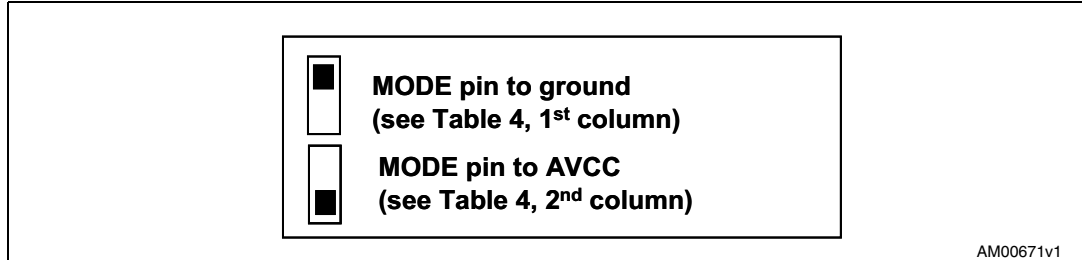


Table 4. Fault management summary

Fault	MODE to GND	MODE to VCC
Internal MOSFET overcurrent	Fault pin HIGH Power MOSFET turned off	
Output overvoltage	FAULT pin LOW Power MOSFET turned off (hysteretic regulation)	
Thermal shutdown	FAULT pin LOW. Device turned off. Automatic restart after 30 °C temperature drop.	
LED short-circuit	Fault pin LOW Device turned OFF (100 μA masking time), latched condition ($V_{th}=4.0\text{ V}$)	
Open row(s)	Fault pin LOW Device turned off at first occurrence, latched condition	FAULT pin HIGH Faulty row(s) disconnected (100 μs masking time)

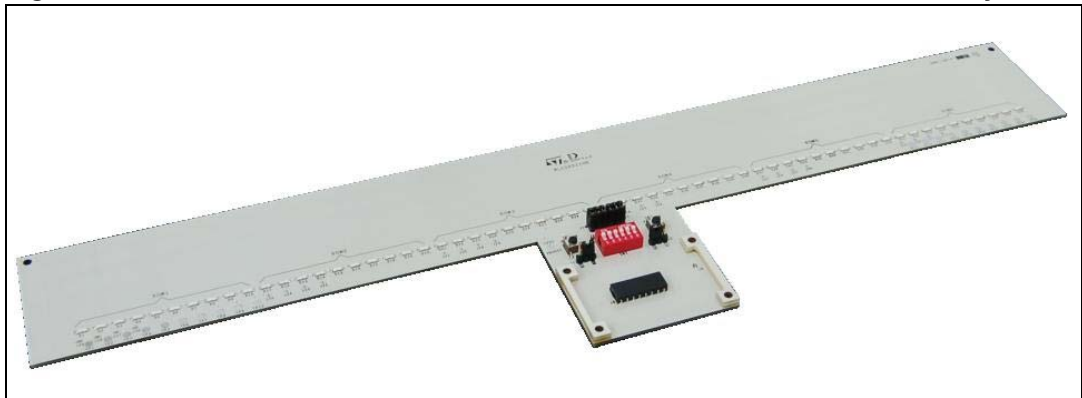
7.3 SW3 enable function

The terminals of switch SW3 are connected on one side to the EN pin and on the other side to ground. Therefore, when the switch is not pressed, the EN pin is floating, which implies that the device is working. Pressing the SW3 pin connects the EN pin to ground. When SW3 is released, the device re-starts (a soft-start is performed). The SW3 switch can be activated whenever a new startup is required or to escape a latched condition.

8 Test setup

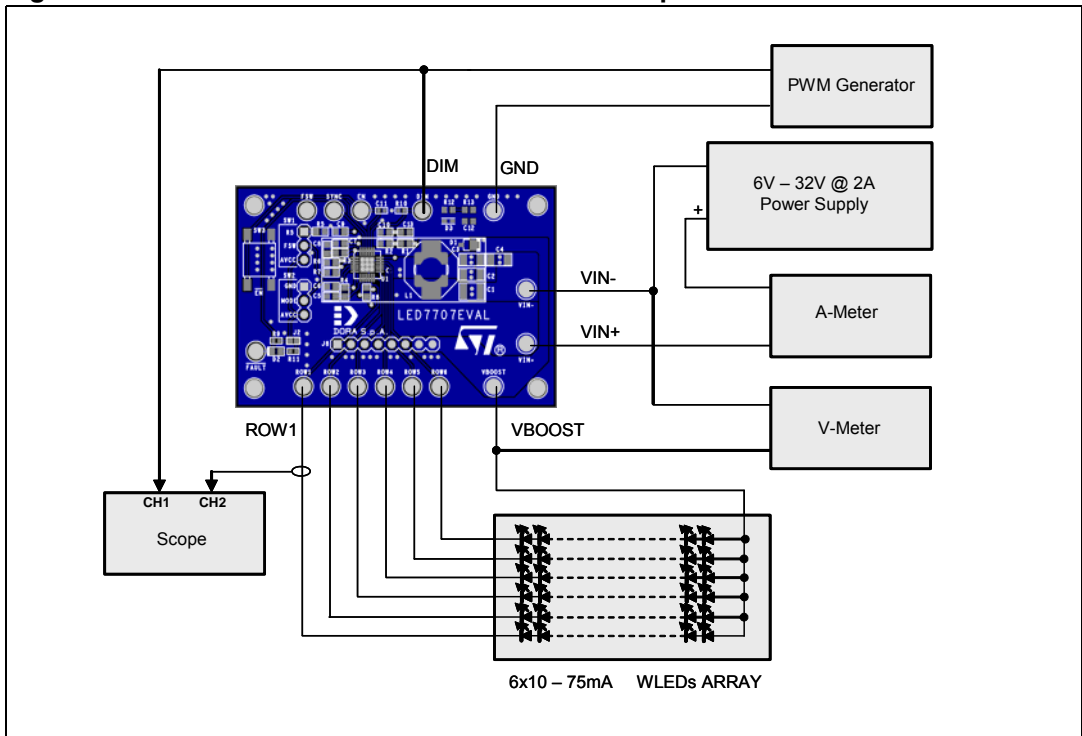
An appropriate white LED array is required as a load to correctly evaluate the LED7706. [Figure 7](#) shows a possible assembly of the LED7707 with a WLED test board. This demonstration board includes 60 white LEDs (150 mA), switches, jumpers and test points which can be used to easily perform functional testing of the LED7707.

Figure 7. LED7707 demonstration board and white LED test board assembly



[Figure 8](#) shows the complete test setup.

Figure 8. LED7707 demonstration board test setup



9 Getting started

The following step-by-step instructions are provided as a guide for quick evaluation of the performance of the LED7707 demonstration board.

9.1 Quick startup

1. Working in an ESD-protected environment is highly recommended. Check all wrist straps and ESD mat earth connections before handling the LED7707 board
2. Connect the power supply to the LED7707 board and insert the A-meter as shown in [Figure 8](#). Connect a V-meter between VBOOST and ground to monitor the output voltage
3. Connect the white LEDs array to the row1-row6 and VBOOST terminals of the LED7707 board
4. Set the PWM signal (500 Hz, 5% duty-cycle, 3.3 V CMOS logic levels) on a signal generator and connect it to the DIM input
5. Set SW1 and SW2 in the “down” position (fixed frequency and MODE to AVCC). Do not change jumpers settings when the board is powered
6. Set the input voltage to 12 V
7. Turn-on the PWM generator
8. Turn-on the VIN supply. The device turns on
9. Vary the input voltage within the range 6 V - 32 V
10. Set the input voltage to 12 V
11. Vary the dimming duty-cycle from 1% to 100%
12. Check the shape of the row current at 10 us dimming on-time

Note: *When used for rowx current measurement, some autoranging A-meters can trigger open-row or shorted-LED fault detection during the automatic scale selection procedure.*

Caution: Disabling the auto-ranging option on the A-meter is recommended.

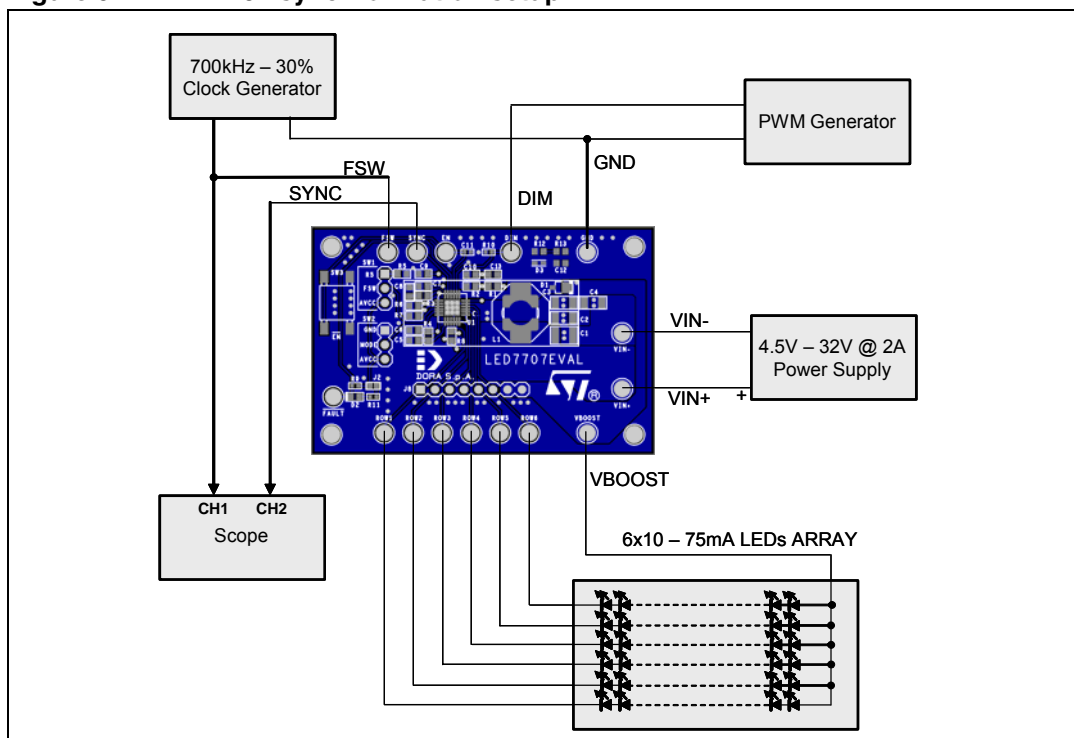
9.2 Open and shorted WLEDs fault testing

1. Set the input voltage to 12 V
2. Set the dimming duty-cycle to 20%
3. Set SW1 and SW2 in the “up” position
4. Turn-on the PWM generator and the supply in sequence
5. Disconnect the rows in sequence and compare the behavior of the LED7707 to [Table 4](#)
6. Restore all row connections and press the SW3 pushbutton on the LED7707 board to reset the device
7. Short one or more WLEDs and compare the LED7707 behavior to [Table 4](#)
8. Press the SW3 pushbutton on the LED7707 board
9. Turn-off the power supply and set the SW2 selector to the “up” position (MODE to ground)
10. Turn-on the power supply and repeat steps 5 through 8
11. Remove all shorted WLEDs and leave ROW1 and ROW2 floating
12. Turn-on the power supply. The floating rows are ignored
13. Turn-off the PWM generator
14. Turn-off the power supply

9.3 Device synchronization

1. Set the PWM dimming signal to 100%
2. Remove the jumper from the SW1 selector to leave the FSW pin floating
3. Connect an external 700 kHz clock generator (0 V-1 V logic levels, 30% duty-cycle) between the FSW test point and ground. Refer to [Figure 9](#)
4. Turn-on the PWM generator
5. Turn-on the power supply. The device remains off until the FSW pin is low
6. Turn-on the clock generator. The device turns on
7. Monitor the SYNC output and verify the synchronization (the SYNC output is a replica of the FSW signal)
8. Turn-off the PWM generator
9. Turn-off the clock generator
10. Turn-off the power supply

Figure 9. LED7707 synchronization setup



9.4 Efficiency measurements

Figure 10 shows the setup used to perform the efficiency measurements. The efficiency in this device is typically defined as the ratio between the power provided to the load (current flowing through the LEDs multiplied by the voltage across the LEDs) and the total input power. The power dissipated in the current generators is correctly considered as a power loss. This way of calculating the efficiency implies that the voltage across the LEDs is the same for all the strings. However this is not true. The power delivered to the load should be calculated as follows:

Equation 2

$$P_{LOAD} = \sum_{i=1}^6 V_{STRING_i} \cdot I_{STRING_i}$$

where V_{STRING_i} is the voltage across the LEDs in row i , whereas I_{STRING_i} is the current flowing through the row i . To facilitate the measurement, the voltage drop of all the generators is equalized by connecting them together. In this condition, the power provided to the LEDs is simple to calculate:

Equation 3

$$P_{LOAD} = V_{STRING} \cdot I_{STRING}$$

where V_{STRING} is the voltage across the parallelized channels, whereas I_{STRING} is the total current delivered to the load (the sum of the current of the six channels). Since all the

channels are in parallel, a single string of 700 mA-rated LEDs is required as load (Figure 10).

Figure 10. Efficiency measurement setup

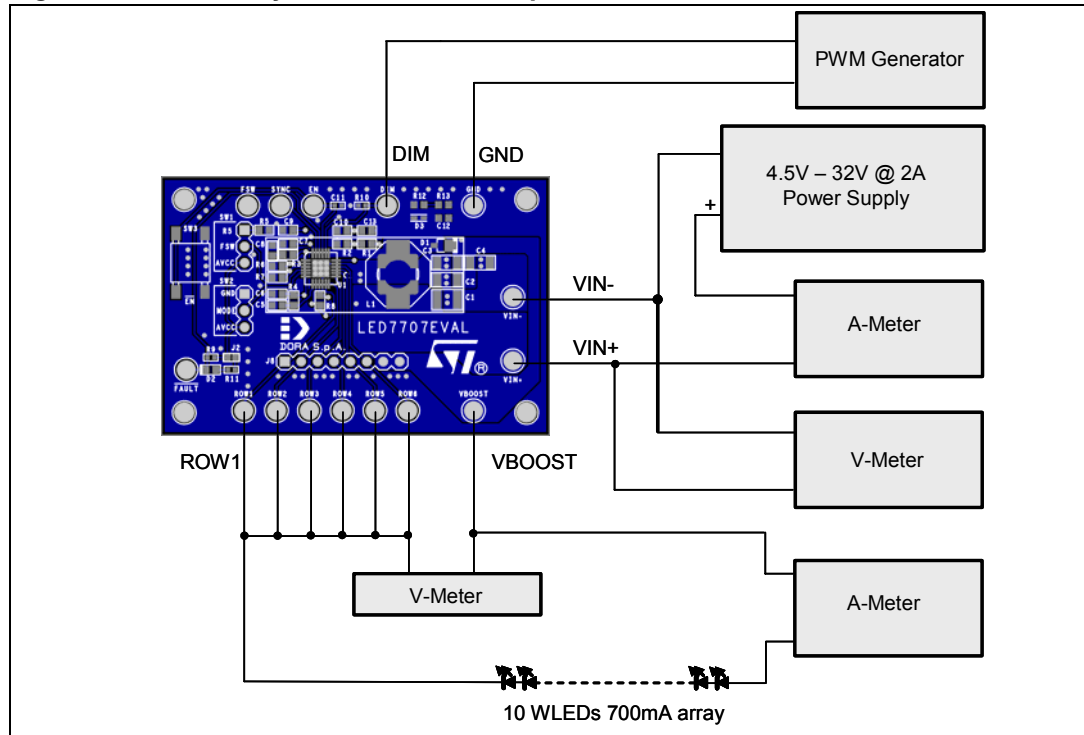
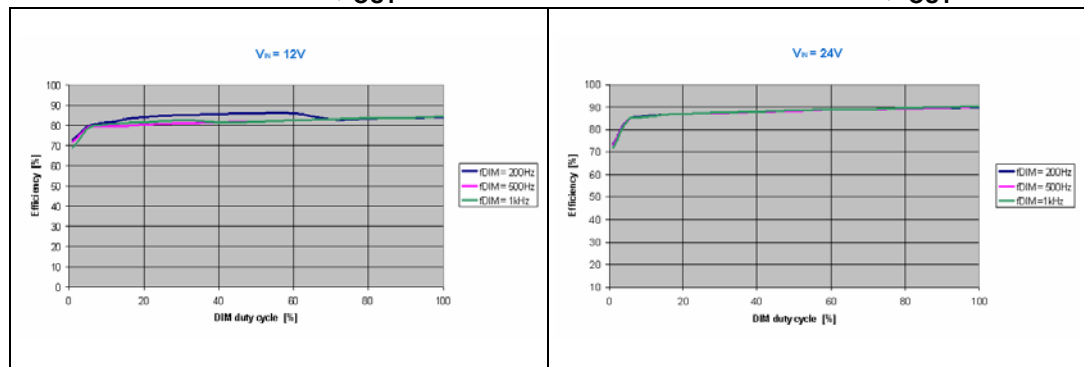


Figure 11 and 12 shows two efficiency measurements versus the duty cycle of the dimming signal at two different input voltages.

Figure 11. Efficiency vs. DIM duty cycle, $V_{IN}=12\text{ V}$, 6 rows, 10 white LEDs in series, $I_{OUT}=360\text{ mA}$ Figure 12. Efficiency vs. DIM duty cycle, $V_{IN}=24\text{ V}$, 6 rows, 10 white LEDs in series, $I_{OUT}=360\text{ mA}$



10 Revision history

Table 5. Document revision history

Date	Revision	Changes
26-May-2009	1	Initial release

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