AN2809
Application note

6-row / 30-mA LED driver with boost converter for the backlight of LCD panels

Introduction

The LED7706 consists of a high-efficiency monolithic boost converter and six controlled current generators (rows) specifically designed to supply the LED arrays used in the backlights of LCD panels. The device can manage an output voltage of up to 36 V (ten white LEDs per row).

The generators can be externally-programmed to sink up to 30 mA and can be dimmed via a PWM signal (a 1% dimming duty-cycle at 20 kHz can be managed). The device detects and manages the open and shorted LED faults and leaves unused rows floating. Basic protections (output over-voltage, internal MOSFET over-current and thermal shutdown) are provided.

Figure 1. LED7706 demonstration board

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1 LED7706 - main features

1.1 Boost section

- 4.5- 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
- 200-kHz to 1-MHz adjustable switching frequency
- External sync for multi-device application
- Pulse-skip power-saving mode at light loads
- Programmable soft-start
- Programmable OVP protection
- Single ceramic output capacitor
- Non-latched thermal shutdown

1.2 Backlight driver section

- Six rows with 30 mA maximum current capability (adjustable)
- Up to 10 white LEDs per row
- Row disabling option
- Less than 500 ns minimum dimming time (1% minimum dimming duty-cycle at 20 kHz dimming frequency)
- ±2.0% current matching between rows
- LED failure (open and short circuit) detection

2 LED7706 demonstration board

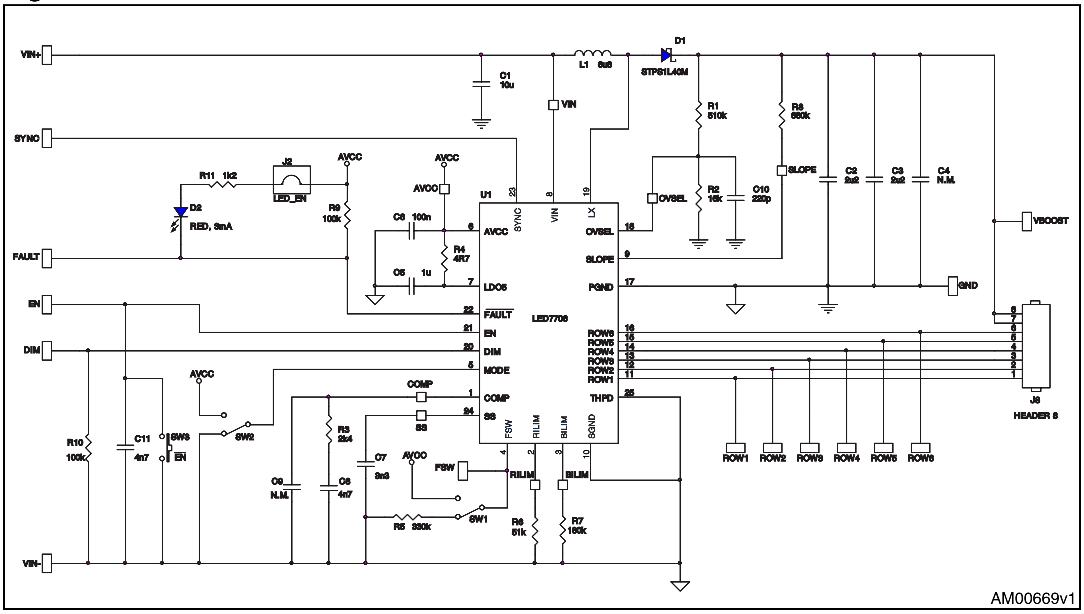
The LED7706 demonstration board has been designed to manage six strings of 8 to 10 white LEDs each.

Table 1 summarizes the board features and *Figure 2* shows the schematic of the LED7706 demonstration board. The input voltage range is limited to 32 V because of the 35 V rated input capacitor. Extended operating input voltage ranges (up to 36 V) can be achieved by using a 50-V rated MLCC.

Table 1. LED7706 performance summary

Parameter	Conditions	Value
Minimum input voltage		4.5 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 = 180 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	500 ns
Output current (each row)	R6=51 kΩ	19.6 mA
Output current accuracy		±2.0%
Efficiency	V_{IN} = 12 V, V_{BOOST} = 34 V, FSW = 660 kHz	91%

Figure 2. LED7706 board schematic



3 Component list

Table 2. LED7706 component list

Qty	Component	Description	Package	Part number	MFR	Value
1	C1	Ceramic, 35V, X5R, 20%	SMD 1210	UMK325BJ106KM-T	Taiyo Yuden	10µF
1	C2	Ceramic, 50V, X7R, 20%	SMD 1206	GRM31CR71H475KA88B	MURATA	4.7µF
2	C3, C4	Ceramic, 50V, X7R, 20%	SMD 1206			N.M.
1	C5	Ceramic, 25V, X5R, 20%	SMD 0603		Standard	1µF
1	C6	Ceramic, 25V, X5R, 20%	SMD 0603		Standard	100nF
1	C7	Ceramic, 25V, X5R, 20%	SMD 0603		Standard	3.3nF
1	C8	Ceramic, 25V, X5R, 20%	SMD 0603		Standard	4.7nF
1	C9	Ceramic, 25V, X5R, 20%	SMD 0603		Standard	N.M.
1	C10	Ceramic, 25V, X5R, 20%	SMD 0402		Standard	220pF
1	C11	Ceramic, 25V, X5R, 20%	SMD 0603		Standard	4.7nF
1	R1	Chip resistor, 0.1W, 1%	SMD 0603		Standard	510kΩ
1	R2	Chip resistor, 0.1W, 1%	SMD 0603		Standard	16kΩ
1	R3	Chip resistor, 0.1W, 1%	SMD 0603		Standard	2.4kΩ
1	R4	Chip resistor, 0.1W, 1%	SMD 0603		Standard	4.7Ω
1	R5	Chip resistor, 0.1W, 1%	SMD 0603		Standard	330kΩ
1	R6	Chip resistor, 0.1W, 1%	SMD 0603		Standard	51kΩ
1	R7	Chip resistor, 0.1W, 1%	SMD 0603		Standard	180kΩ
1	R8	Chip resistor, 0.1W, 1%	SMD 0603		Standard	680kΩ
2	R9, R10	Chip resistor, 0.1W, 1%	SMD 0603		Standard	100kΩ
1	R11	Chip resistor, 0.1W, 1%	SMD 0603		Standard	1.2kΩ
1	L1	6µ8, 75mH, 2.7A	6x6mm	LPS6235-682MLC	Coilcraft	6.8µH
1	D1	Schottky, 40V, 1A	DO216-AA	STPS1L40M	ST	STPS1L40M
1	D2	Red LED, 3mA	SMD 0603		Standard	
1	U1	Integrated circuit	QFN4x4	LED7706	ST	LED7706
1	J2	PCB pad jumper				
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

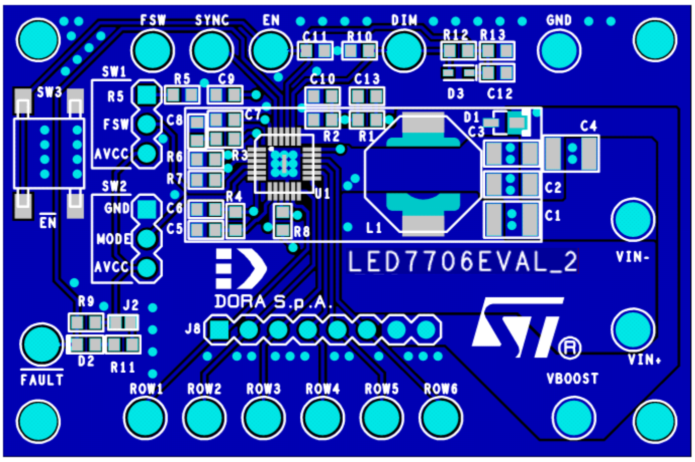
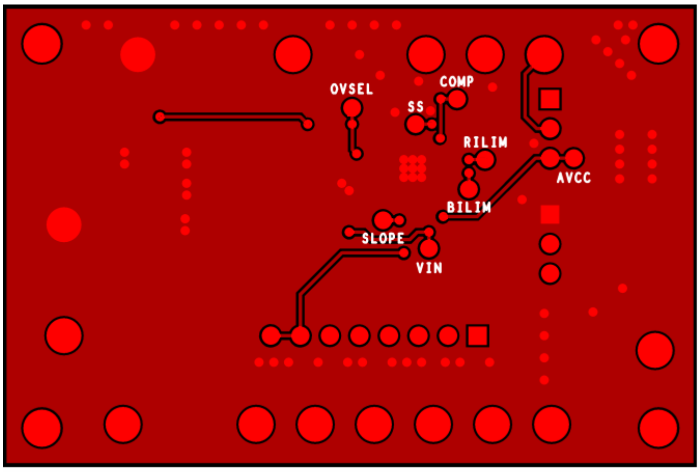


Figure 4. Bottom side test points



5 I/O interface

The LED7706 demonstration board has the following test points.

Table 3. Description of LED7706 demonstration board test points

Test point	Description
VIN+	Input voltage, positive terminal
VIN-	Input voltage, negative terminal
GND	Reference ground
Row1 to row6	Current generators 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

- 4.5–32 V, 2 A capable power supply.
- Digital multimeters.
- 200 MHz oscilloscope.
- Signal generators for PWM dimming and synchronization clock (optional).

7 Configuration

The LED7706 demonstration board allows the user to select the desired mode of operation using the SW1 and SW2 selectors. Refer to the following configuration description. A red LED is connected to the FAULT pin to easily monitor its status; if this option is not desired, the monitor LED can be disconnected by opening the J2 jumper.

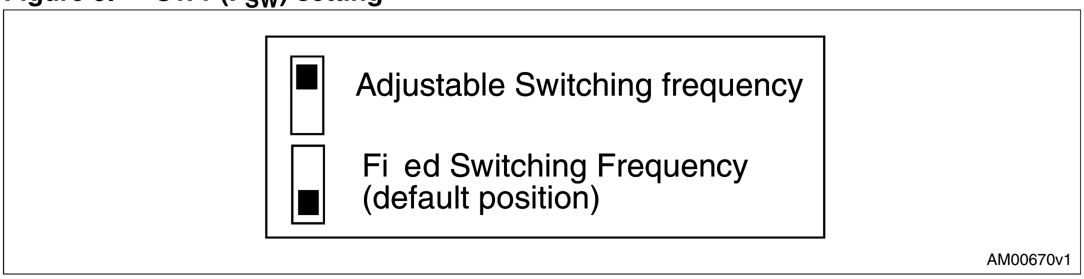
7.1 SW1 fixed or adjustable switching frequency (FSW pin)

The SW1 selector is used to choose between the fixed switching frequency (660 kHz) and a user-defined switching frequency in the range of 200 kHz to 1 MHz. When connected in the lower position, the fixed switching frequency is selected.

If SW1 is in the upper position, the switching frequency is given by:

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

Figure 5. SW1 (F_{SW}) setting



The R5 resistor is set to 330 kΩ (F_{SW} = 825 kHz).

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 lower 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

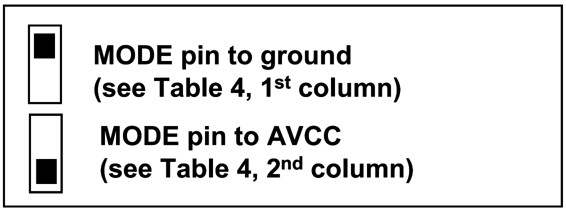


Table 4. Fault management summary

Fault	MODE to GND	MODE to VCC
Internal MOSFET over current	Fault pin HIGH Power MOSFET turned OFF	
Output overvoltage	FAULT pin LOW Device turned OFF, latched condition	
Thermal shutdown	FAULT pin LOW. Device turned OFF. Automatic restart after 30°C temperature drop.	
LED short circuit	Fault pin LOW Device turned OFF at first occurrence, latched condition (V_{th}=3.4V)	Fault pin LOW Faulty row(s) disconnected. Device keeps on working with the remaining row(s) (V_{th}=6V)
Open row(s)	Fault pin LOW Device turned OFF at first occurrence, latched condition	FAULT pin HIGH Faulty row(s) disconnected. Device keeps on working with the remaining row(s)

7.3 SW3 enable function

The terminals of the 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. When the SW3 pin is pressed, the EN pin is connected to ground. When the SW3 is released, the device re-starts (the soft-start is performed). The SW3 switch can be activated whenever a new start-up is required or to escape a latched condition.

8 Test setup

A proper WLED array is required as load to correctly evaluate the LED7706. *Figure 7* shows a possible assembly of LED7706 with a WLEDs test board. This demonstration board includes 60 white LEDs (20 mA), switches, jumpers and test points used to easily perform the functional tests of the LED7706. *Chapter 10* provides a brief description of the test board and its schematic, which can be used as reference for any customized board.

Figure 7. LED7706 demonstration board and white LEDs test board assembly

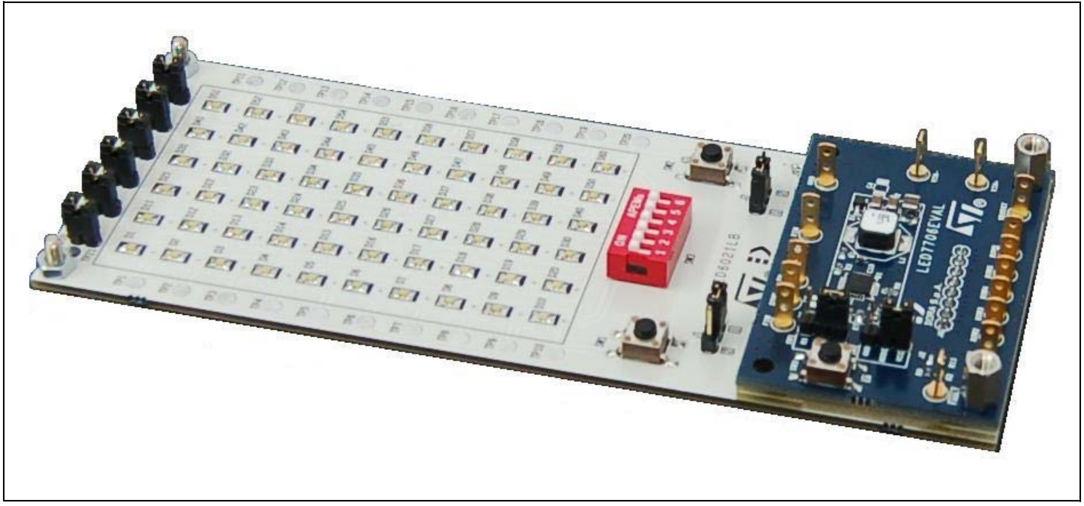
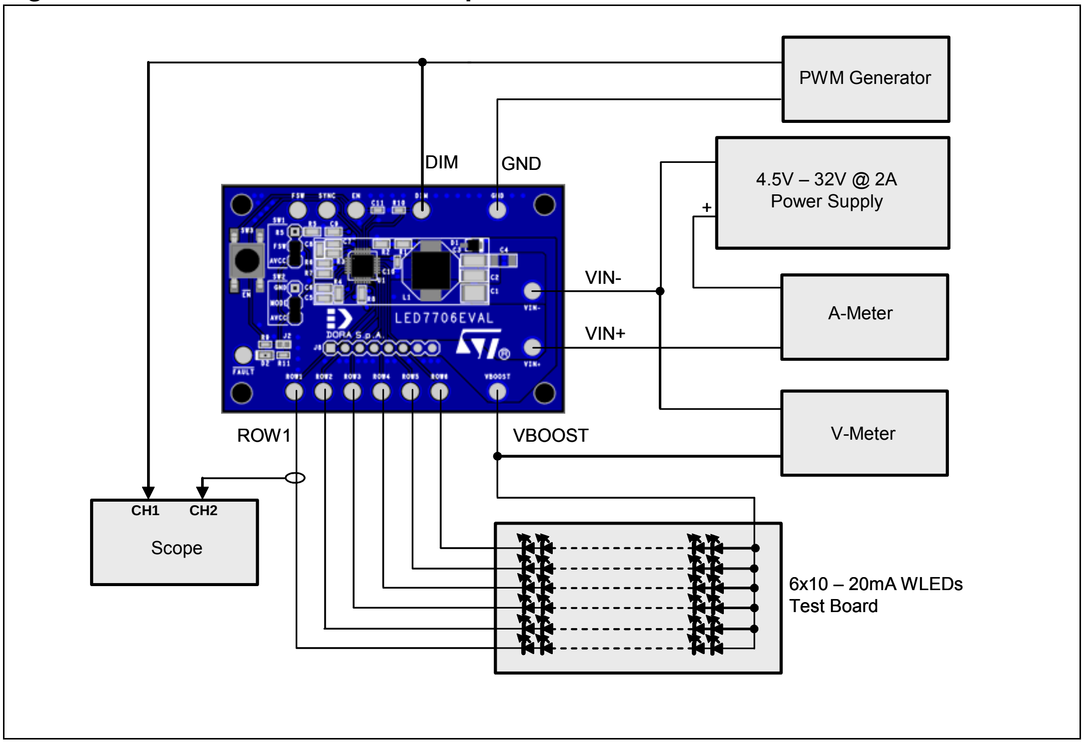


Figure 8 shows the complete test setup.

Figure 8. LED7706 board test setup



9 Getting started

The following step-by-step sequences are provided as a guideline to quickly evaluate the performance of the LED7706 board.

9.1 Quick startup

Note: Working in a ESD-protected environment is highly recommended. First check all wrist straps and mat earth connections before handling the LED7706 board.

1. Connect the power supply to the LED7706 board and insert the A-meter as shown in *Figure 8*. Connect a V-meter between VBOOST and ground to monitor the output voltage.
2. Connect the proper WLEDs array to the J8 connector or to the row1-row6 and VBOOST terminals of the LED7706 board.
3. Set the PWM signal (20 kHz, 5% duty-cycle, 3.3 V CMOS logic levels) on a signal generator and provide it to the DIM input.
4. Set SW1 and SW2 to the lower position (fixed frequency and MODE to AVCC). **Do not change jumper settings when the board is switched on**.
5. Set the input voltage to 12 V.
6. Turn on the PWM generator.
7. Turn on the VIN supply: the device turns on.
8. Vary the input voltage in the range 4.5–32 V.
9. Set the input voltage to 12 V.
10. Vary the dimming duty-cycle from 1 to 100%.
11. Check the shape of the rows' current at a 1% dimming duty-cycle.

Note: When measuring the current of row x, an auto-ranging A-meter can trigger the open-row or shorted-LED fault detection during the automatic scale selection procedure. Disabling the auto-ranging option on the A-meter is recommended.

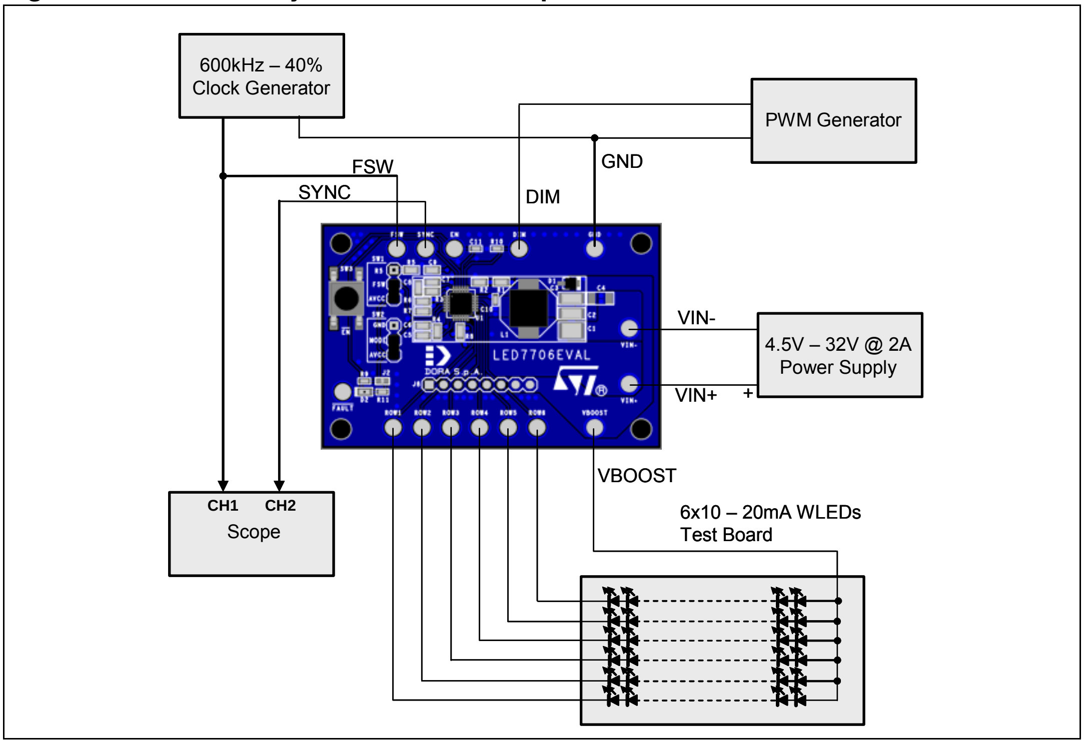
9.2 Open and shorted WLED fault testing

1. Set the input voltage to 12 V.
2. Set the dimming duty-cycle to 20%.
3. Disconnect the rows in sequence and compare the behavior of the LED7706 to *Table 4*.
4. Restore all row connections and force the EN input to ground.
5. Release the EN input.
6. Short one or more WLEDs and compare the behavior of the LED7706 to *Table 4*.
7. Press the SW3 push button of the LED7706 board to reset the device.
8. Turn off the power supply and set the SW2 selector to the upper position (MODE to ground).
9. Turn on the power supply and repeat steps 3 to 7.
10. Remove all shorted WLEDs and leave ROW1 and ROW2 floating.
11. Turn on the power supply: the floating rows are ignored.
12. Turn off the PWM generator.
13. 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 600 kHz clock generator (0 to 1 V logic levels, 40% 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. LED7706 synchronization setup



9.4 Efficiency measurements

Figure 10 shows the set-up used to perform 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 method 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.

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

where V_{STRING_i} is the voltage across the LEDs in row i, whereas I_{STRING_i} is the current flowing through row *i*. In order to ease 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 simply calculated as:

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

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 (120 mA total current), a single string of 150 mA-rated LEDs is required as load (*Figure 10*).

Figure 10. Efficiency measurement setup

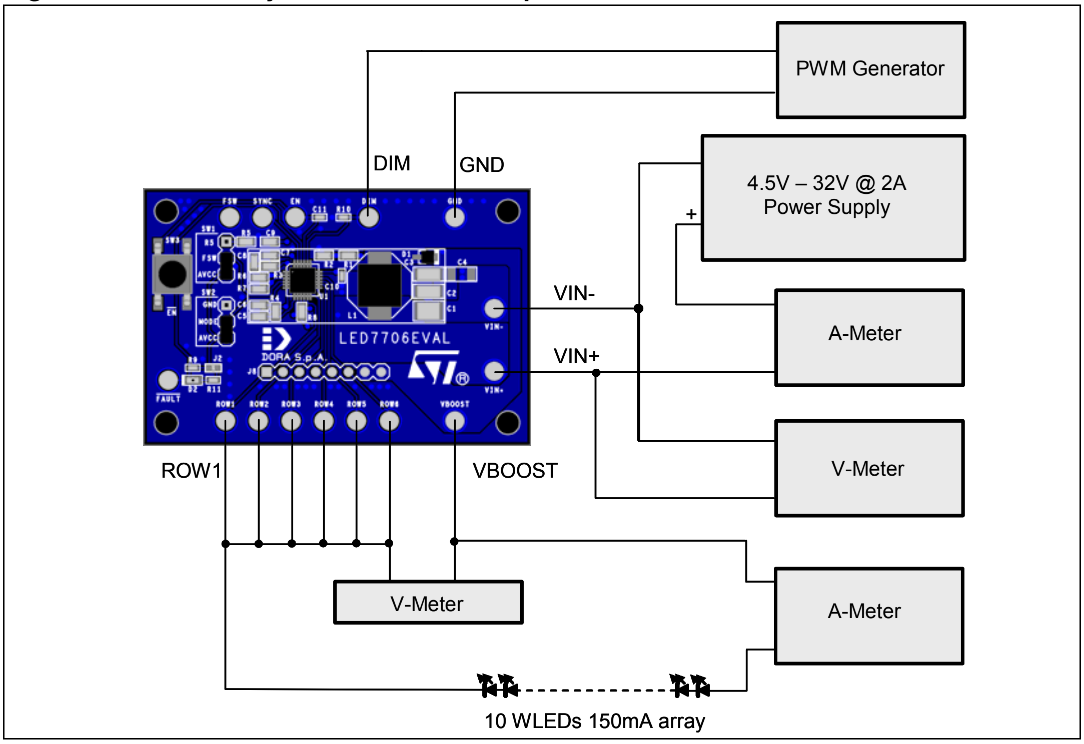


Figure 11 and *Figure 12* show two efficiency measurements against the duty-cycle of the dimming signal at two different input voltages.

Figure 11. Efficiency vs DIM duty-cycle, V_{IN} = 12 V, 10 white LEDs in series, I_{OUT} = 120 mA

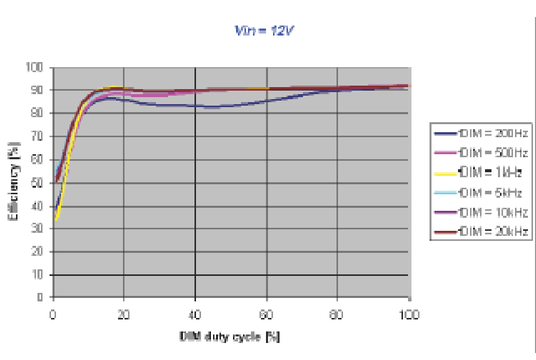
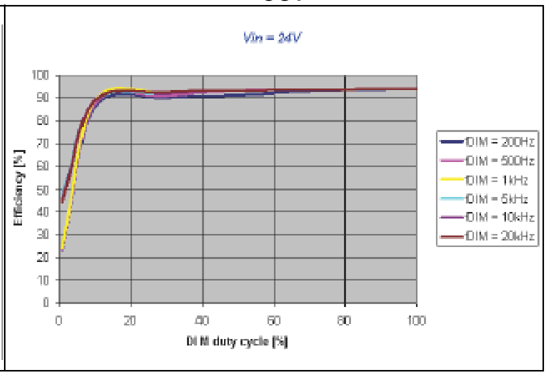


Figure 12. Efficiency vs DIM duty-cycle, V_{IN} = 24 V, 10 white LEDs in series, I_{OUT} = 120 mA



10 WLEDs test board

The WLEDs test board here described mounts sixty vertical white LEDs (size 0603, 20 mA) arranged in a 6 x 10 matrix. *Figure 13* shows an image of the board, whereas *Figure 14* provides the schematic which can be used as reference to realize a customized board. Several jumpers, switches and test points are provided to cover most of the test configurations.

Figure 13. WLEDs test board

Figure 14. WLEDs test board schematic

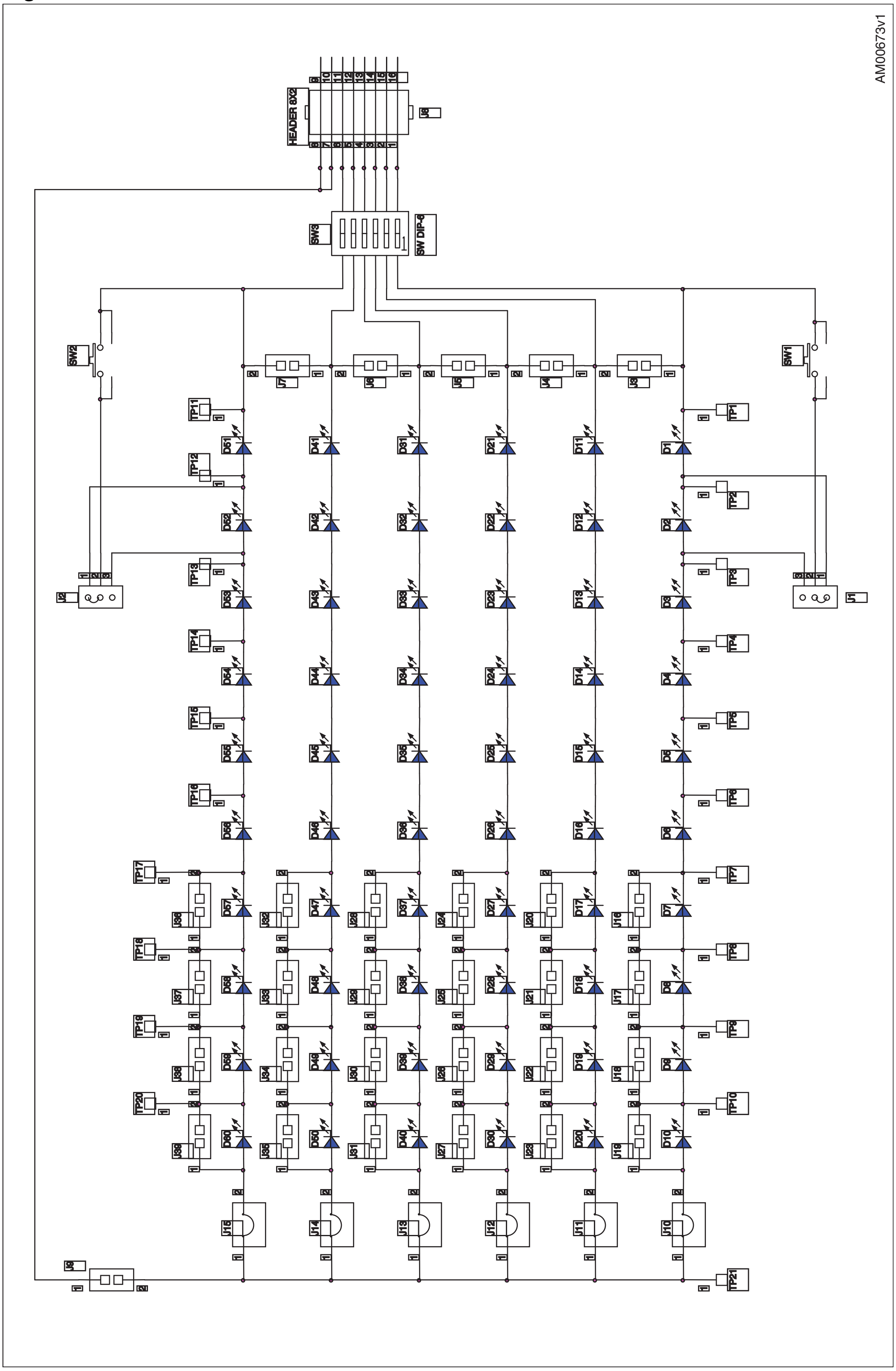


Table 5, *Table 6* and *Table 7* respectively describe the board's jumper functions, switches and test-points.

Table 5. Test board jumper functions

Jumper	Function	Default position
J1	Two-position selector. Used in conjunction with SW1 to simulate a fault on shorted LEDs on row1. When set to position 1, the D10 LED can be shorted by pressing SW1. When set to position 2, both D9 and D10 LEDs can be shorted by pressing SW1.	1
J2	Two-position selector. Same function as J1 but related to row6 (D59 and D60 LEDs).	1
J3 to J7	PCB tin-drop jumpers, bottom-sided. Used to parallelize the desired number of rows.	Open
J8	8-terminal connector. Used to interface the LED7706 demonstration board.	-
J9	PCB tin-drop jumper, bottom-sided. Used to provide the output voltage of the boost section of LED7706 to the low-current (D1-D60), top-sided WLEDs array.	Shorted
J10 to J15	Two-pin jumpers, top-sided. Used to access the LED strings to perform row current monitoring and voltage threshold measurement.	Shorted
J16 to J39	PCB tin-drop jumper, bottom-sided. Used to reduce the number of active LEDs of each row by shorting unused diodes.	Open

Table 6. Test board switch functions

Switch	Function	Default position
SW1	Used in conjunction with J1 to simulate a shorted LED fault condition. See J1 function.	Open (released)
SW2	Used in conjunction with J2 to simulate a shorted LED fault condition. See J2 function.	Open (released)
SW3	DIP switch. Used to individually break ROW1 through row6. Used to simulate open LED fault or unused (floating) rows.	ON

Table 7. Test board test-point functions

Test point	Function
TP1 to TP10	PCB test points, top-sided. Used to easily access each LED of ROW1 (D1-D10).
TP11 to TP20	PCB test points, top-sided. Used to easily access each LED of ROW6 (D51-D60).
TP21	PCB test point, top-sided. Auxiliary access to the output voltage.

11 Revision history

Table 8. Document revision history

Date	Revision	Changes
10-Jan-2009	1	Initial release.
11-Feb-2009	2	Updated *Table 2: LED7706 component list* and *Table 4: Fault management summary*