General Description

The MR16 LED Driver **Module** Evaluation board shows how to use the new AL8812 with integrated MOSFET in one package as a single stage Boost LED driver for an inexpensive PFC front end for a cost effective MR16 LED Driver circuit from which high PFC (~0.9) can be achieved.

Key Features

- Integrated 60V, 3.6A MOSFET
- Non-Dimmable or Triac Dimmable
- Front end Constant On time PFC circuit using the AL8812 Single Stage Boost LED Driver
- PFC for the 12VAC input allowing multiple MR16 units on one transformer
- Compatible with Electronic Transformers

Applications

- MR16 LED Bulb
- Desktop lamps
- Under the counter lamps

AL8812EV2 Specifications

Parameter	Value
Input Voltage	12VAC
LED Current	350mA (Adjustable)
Number of LEDs	26V LED Array @350mA (Under Tested)
XY Dimension	1.06 ” x 0.71”

Evaluation Board

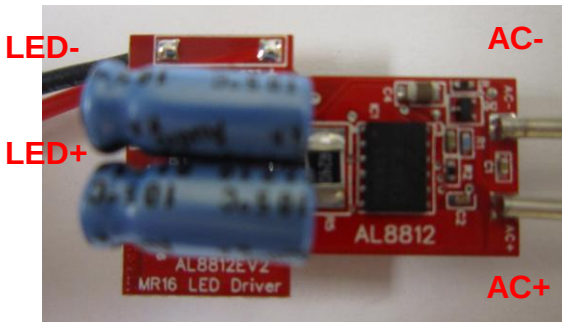


Figure 1: Top View

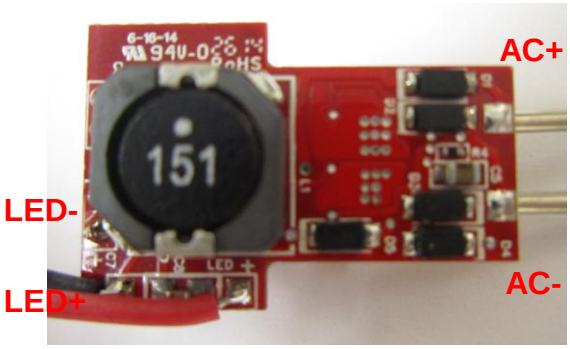


Figure 2: Bottom View

Connection Instructions

Input Voltage: 12VAC (AC+, AC-)
LED Outputs: LED+ (Red), LED- (Black)

Block Diagram:

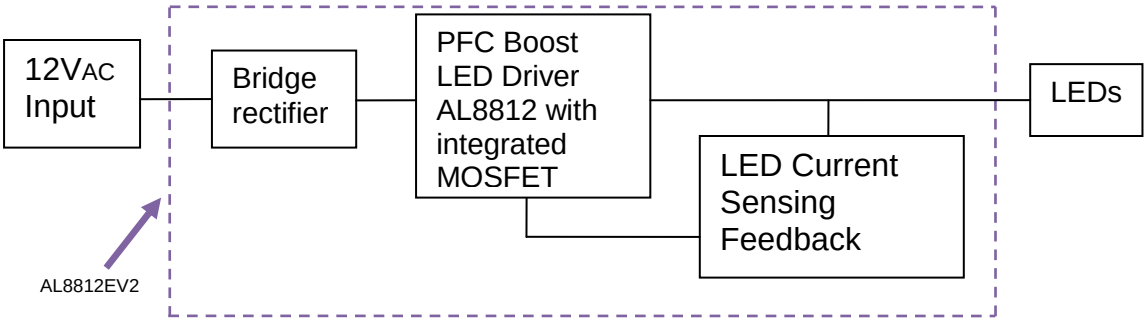


Figure 3: Block Diagram

Evaluation Board Schematic

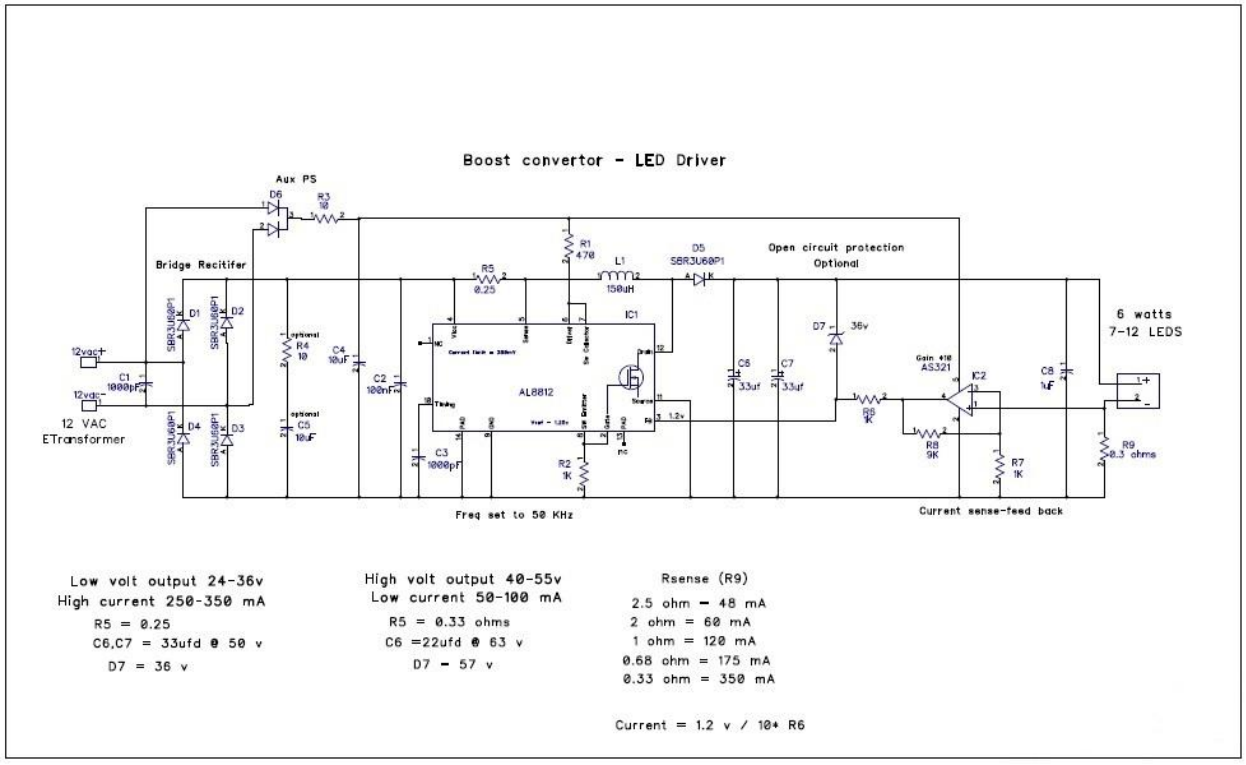


Figure 4: Evaluation Board Schematic

Evaluation Board Layout

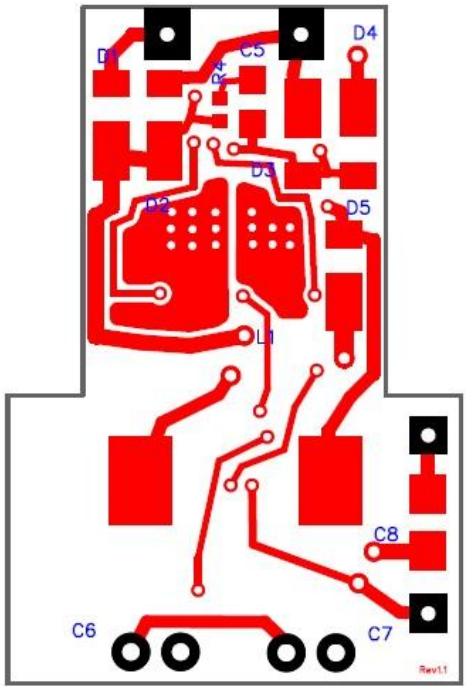


Figure 5: PCB Board Layout Top View

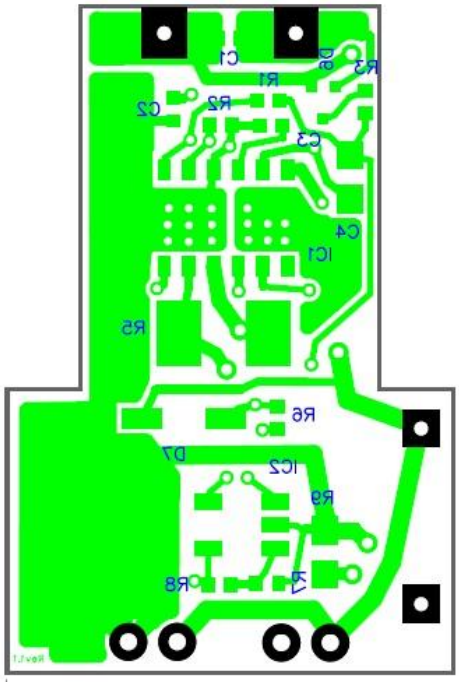


Figure 6: PCB Board Layout Bottom View

Quick Start Guide

1. By default, the evaluation board is preset at 350mA LED Current by R9.
2. Ensure that the AC source is switched OFF or disconnected.
3. Connect the 12VAC AC line wires of power supply to two test points of “12VAC” on the left side of the board.
4. Connect the anode wire of external LED string to LED+ output test point.
5. Connect the cathode wire of external LED string to LED- output test point.
6. Turn on the main switch. LED string should light up.

Bill of Material

#	Name	Quantity	Part number	Manufacturer	Description
1	IC1	1	AL8812	Diodes Inc	Boost IC
2	IC2	1	AS321KTR-G1	Diodes Inc	Opamp
3	D1-D5	5	SBR3U60P1	Diodes Inc	Super Barrier Rectifiers
4	D6	1	BAV70-7-F	Diodes Inc	BAV70 Dual diodes
5	D7	1	DDZ9717S	Diodes Inc	Zener diode – 43 volts
6	L1	1	7447714151	Wurth	150µH, 1.2A Inductor for PFC stage
7	R1	1	ERJ-2RKF4700X	Panasonic	470Ω Resistor 1/10W 1% 0402 SMD
8	R2,R6,R7	3	ERJ-2RKF1001X	Panasonic	1kΩ Resistor 1/10W 1% 0402 SMD
9	R3,R4	1	ERJ-2RKF10R0X	Panasonic	10Ω Resistor 1/10W 1% 0402 SMD
10	R5	1	RCWE1210R240FKEA	Vishay	0.24Ω Resistor 1W 1% 1210 SMD
11	R8	1	ERJ-2RKF9091X	Panasonic	9.09kΩ Resistor 1/10W 1% 0402 SMD
12	R9	1	ERJ-3RQFR33V	Panasonic	0.33Ω Resistor 1/10W 1% 0603 SMD
13	C1,C3	2	C0402C102J5GACTU	Kemet	1000pF Cer Cap 50V 5% 0402 SMD
14	C2	1	C1005X7R1H104K050BB	TDK	100nF Cer Cap 50V 10% X7R 0402
15	C4,C5	2	C2012X5R1E106K125AB	TDK	10µF Cer Cap 25V 10% X5R 0805
16	C6,C7	2	UKA1H330MDD1TD	Nichicon	33µF Aluminum Cap 50V 20% Radial
17	C8	1	CL21B105KBFNNNE	Samsung	1µF Cer Cap 50V 10% X7R 0805

Functional Performance (26V LED array @350mA peak)

AL8812EV2 Module Board Performance (without dimmer and electronic transformer)										
Manuf	Board Type	VIN (V_{RMS})	I_{IN} (I_{RMS}) (mA)	P_{IN} (W)	PF	V_{LED} (V)	I_{LED} (I_{RMS}) (mA)	P_{LED} (W)	I_{LED} Ripple (%)	**Efficiency (%)**
Diodes Inc	AL8812EV2 Module Board	12	777.3	8.29	0.89	25.92	249.4	6.46	8	77.95

Functional Waveforms

For 120VAC dimmable MR16 design bench testing:

The electronic transformer type is Hatch RS12-150 / 150W.
The dimmer type is Lutron SELV-300P.

Following is a block diagram of the bench circuit that indicates voltage and current designations where the scope plots are functionally captured on the bench set-up. The bench set-up is used in the evaluation of the AL8812EV2 module dimmable MR16 design.

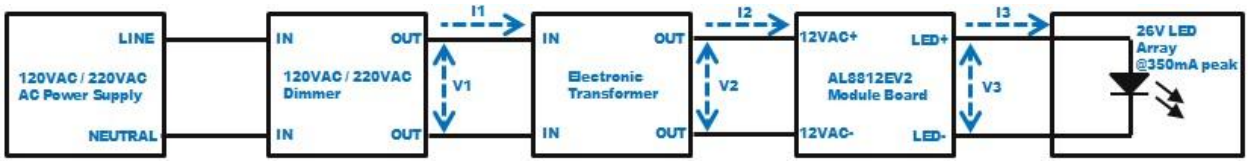
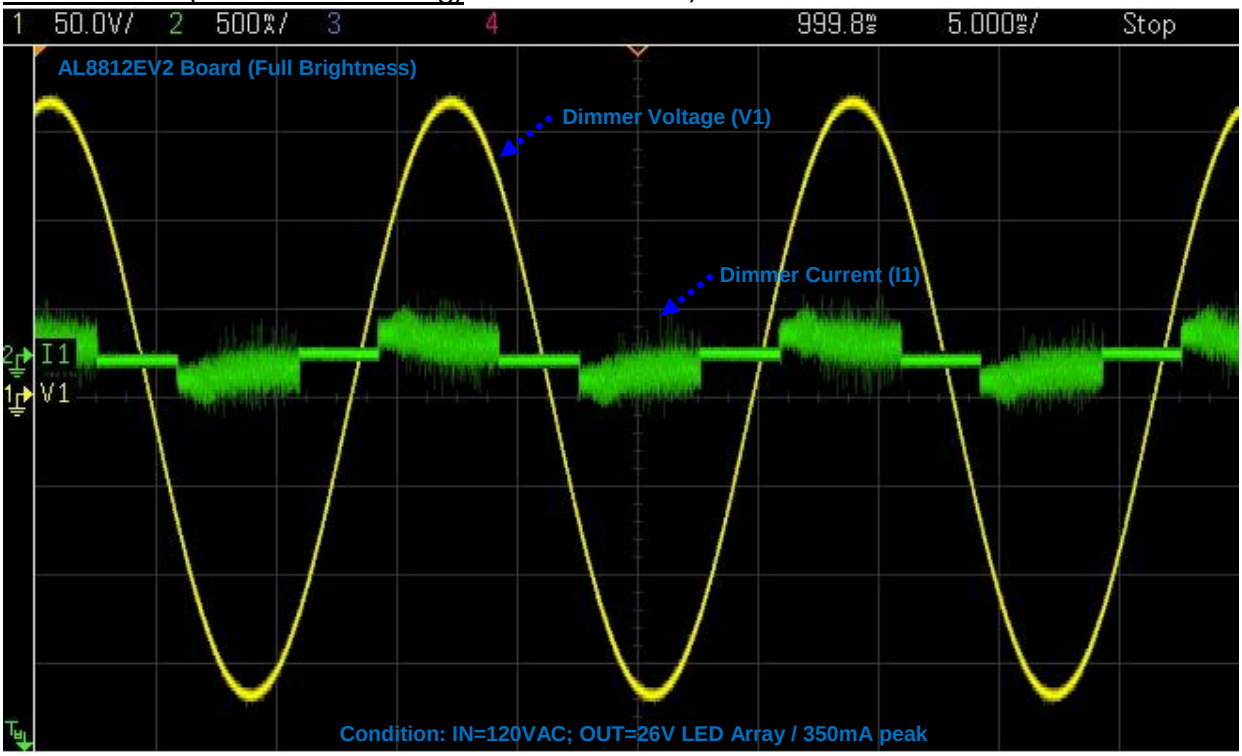
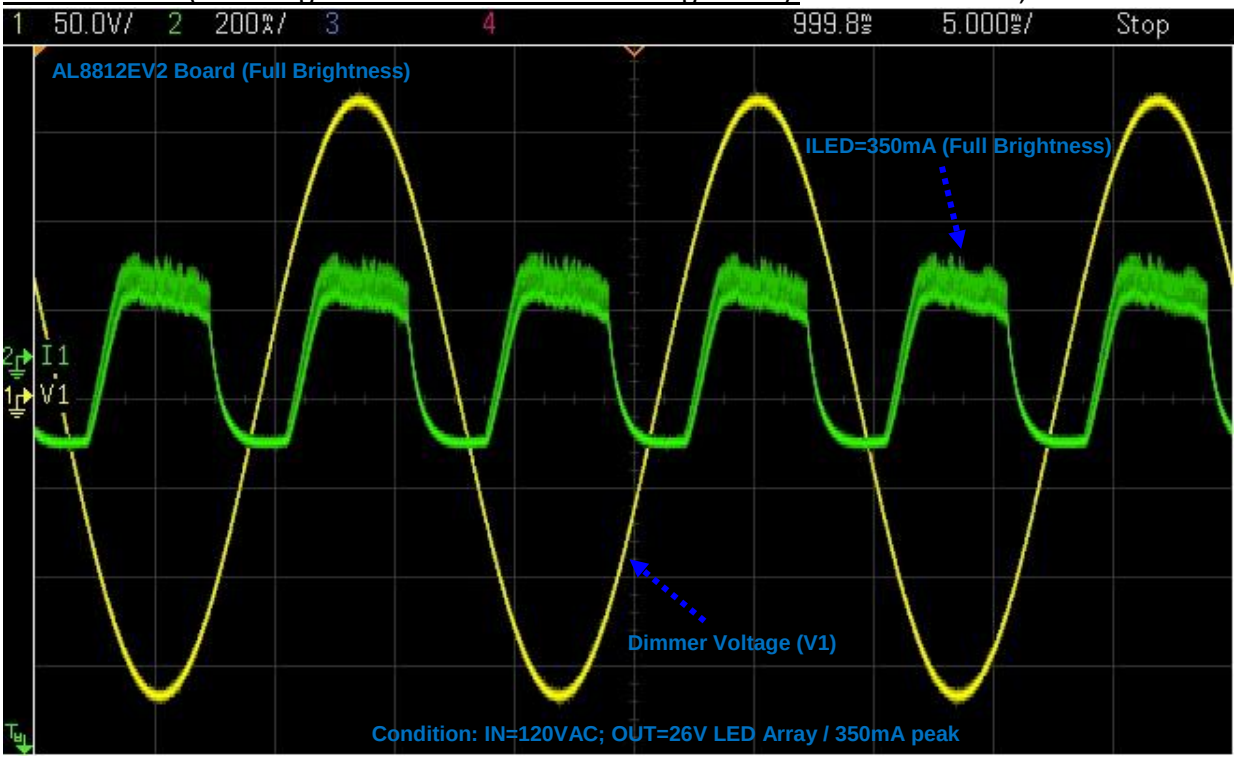


Figure 7: Bench Set-up Circuit

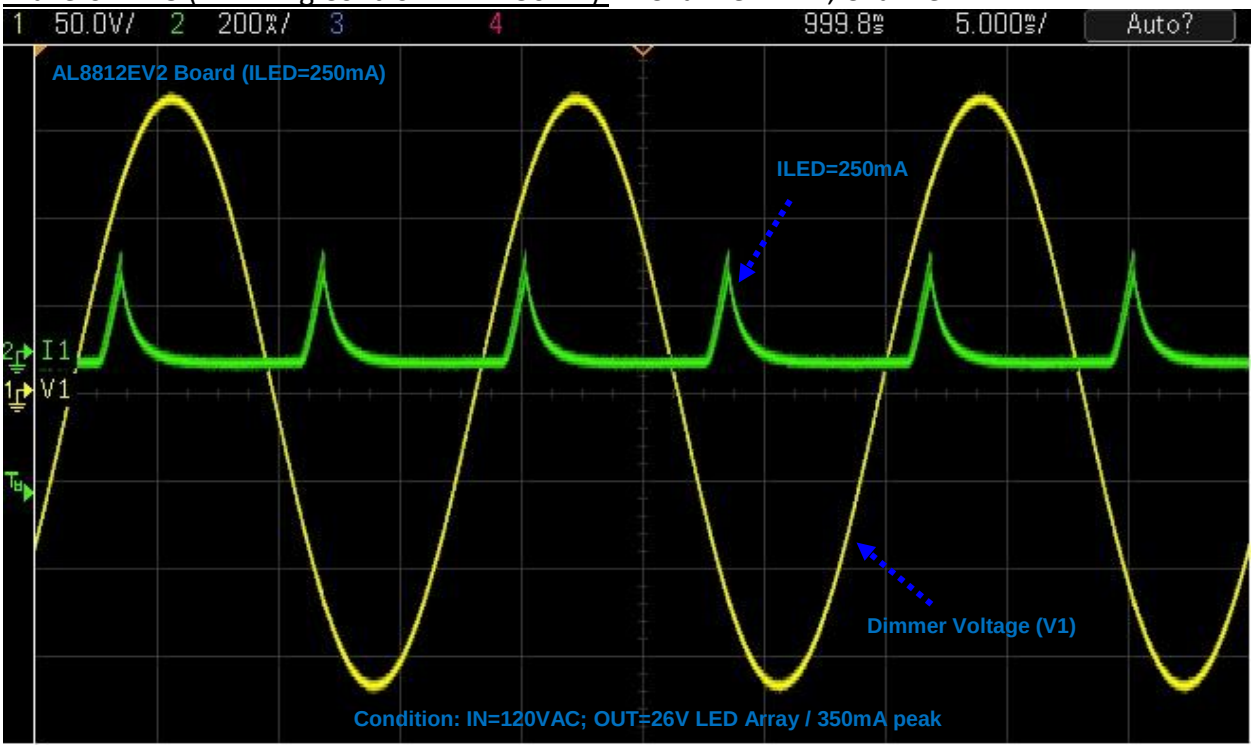
Waveform #1 (Maximum Dimming) => Channel 1: V1; Channel 2: I1



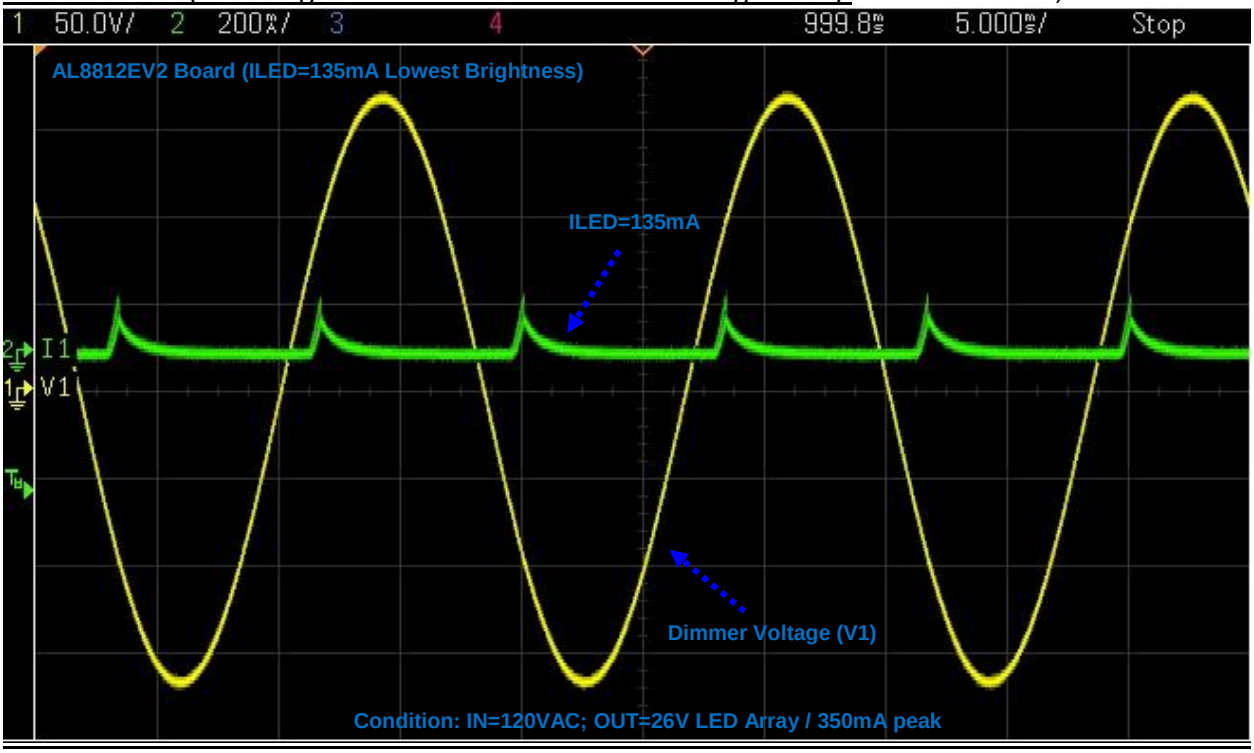
Waveform #2 (Dimming Control ILED=350mA full brightness) => Channel 1: V1; Channel 2: I1



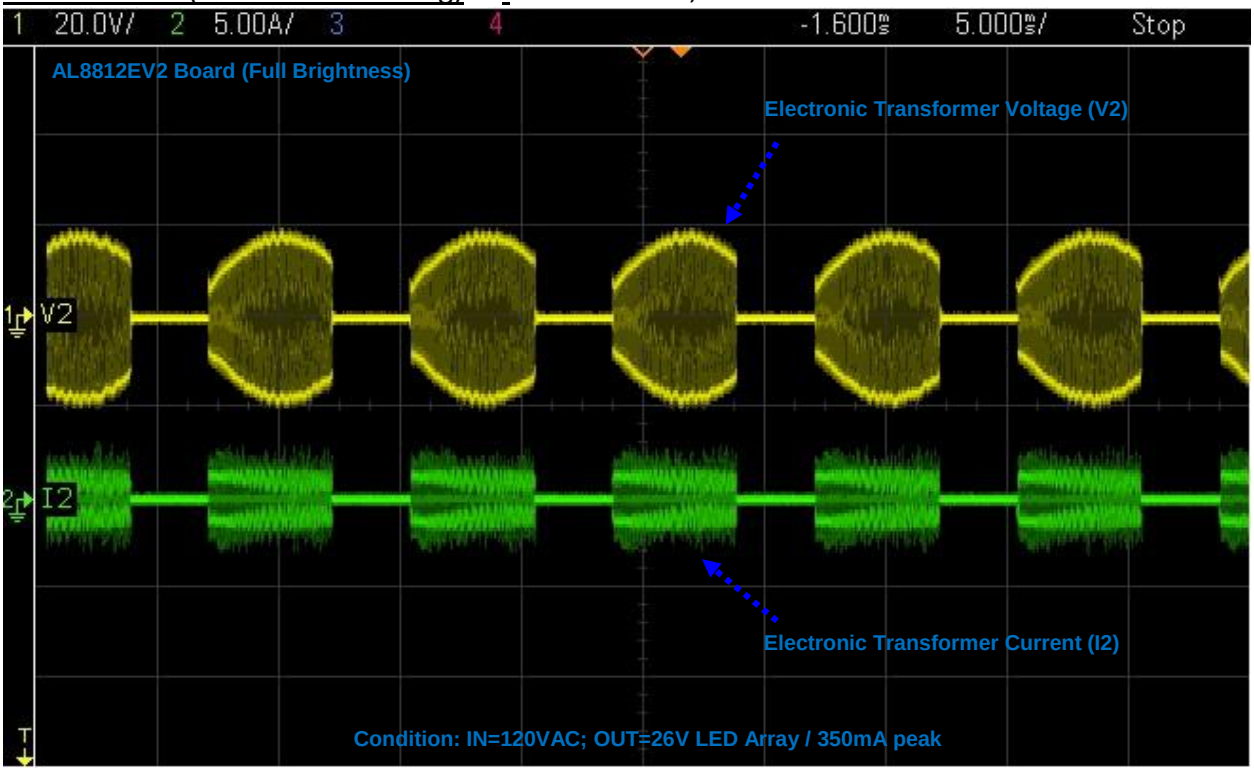
Waveform #3 (Dimming Control ILED=250mA) => Channel 1: V1; Channel 2: I1



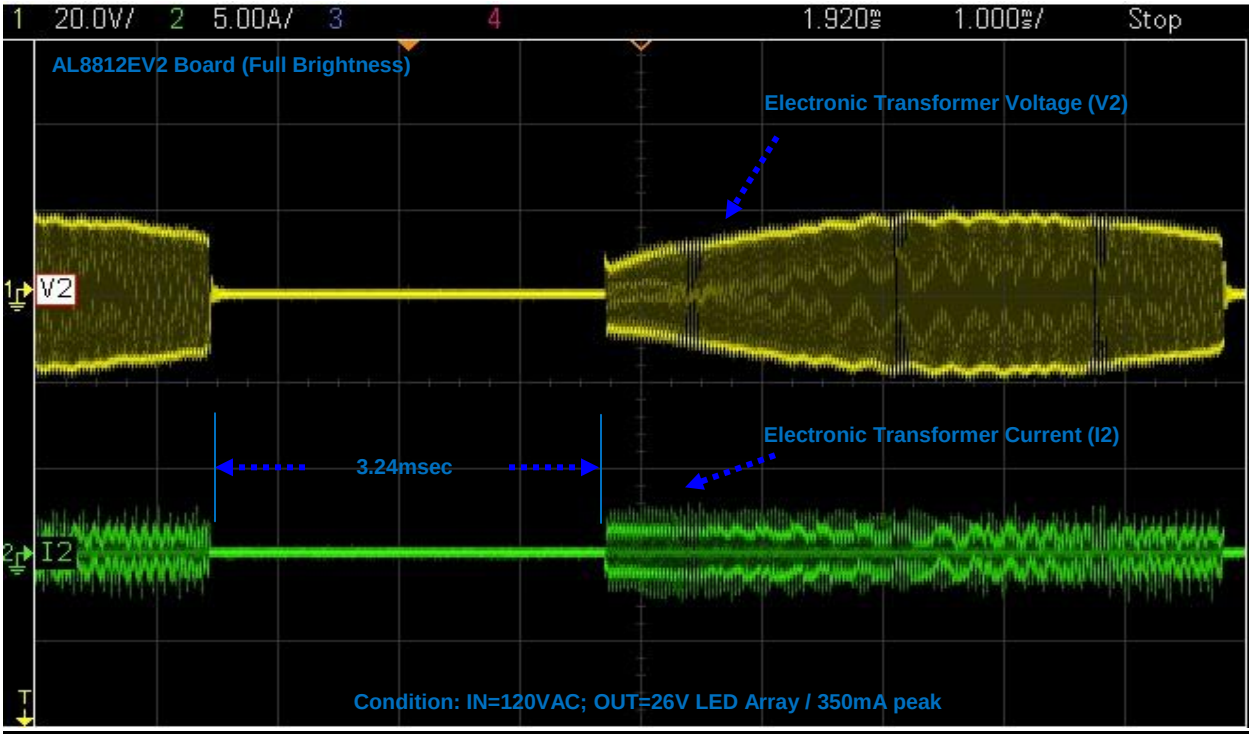
Waveform #4 (Dimming Control ILED=135mA Lowest Brightness) => Channel 1: V1; Channel 2: I1



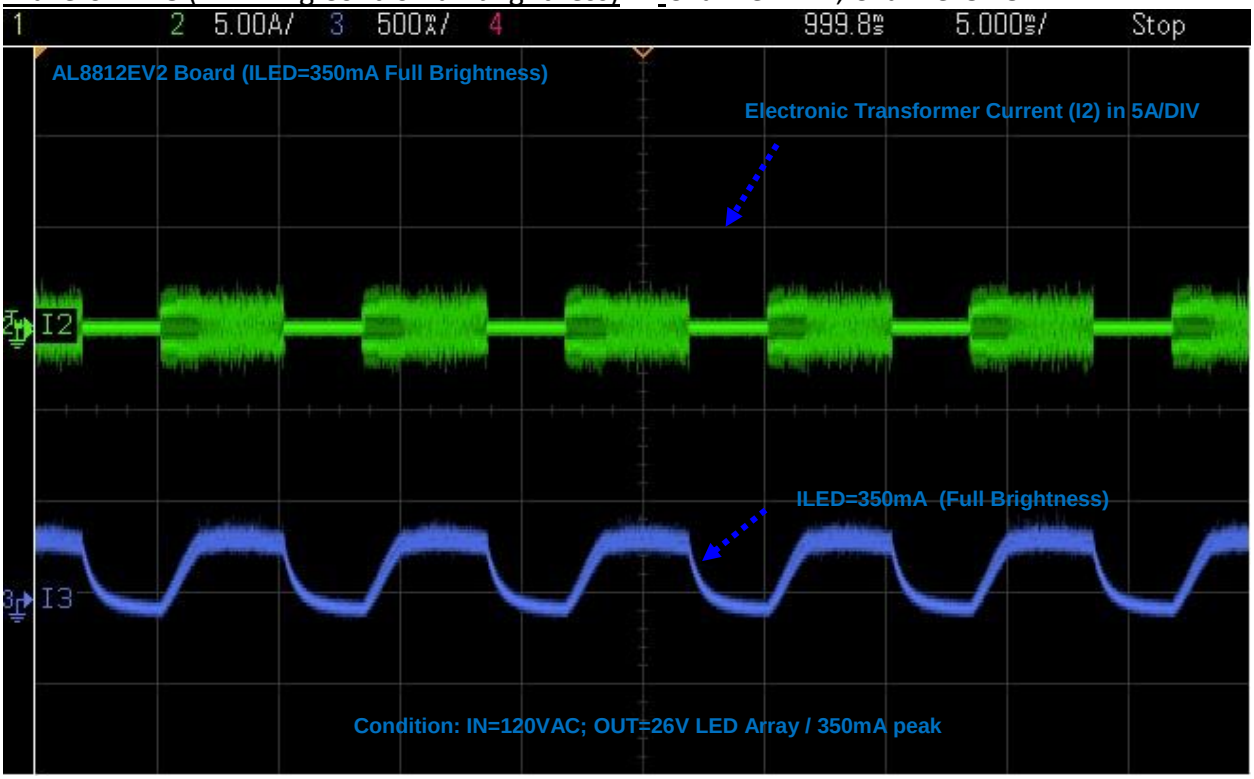
Waveform #5 (Maximum Dimming) => Channel 1: V2; Channel 2: I2



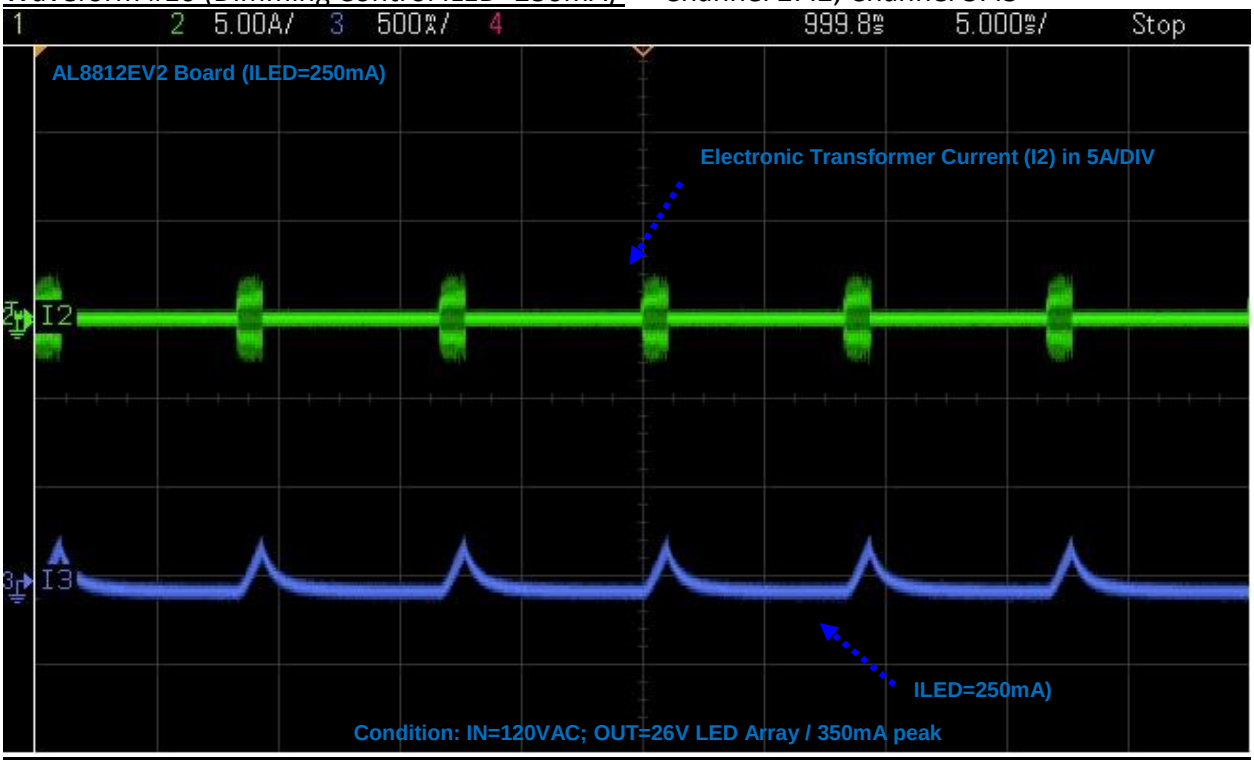
Waveform #6 (Zoom-in for Maximum Dimming) => Channel 1: V2; Channel 2: I2



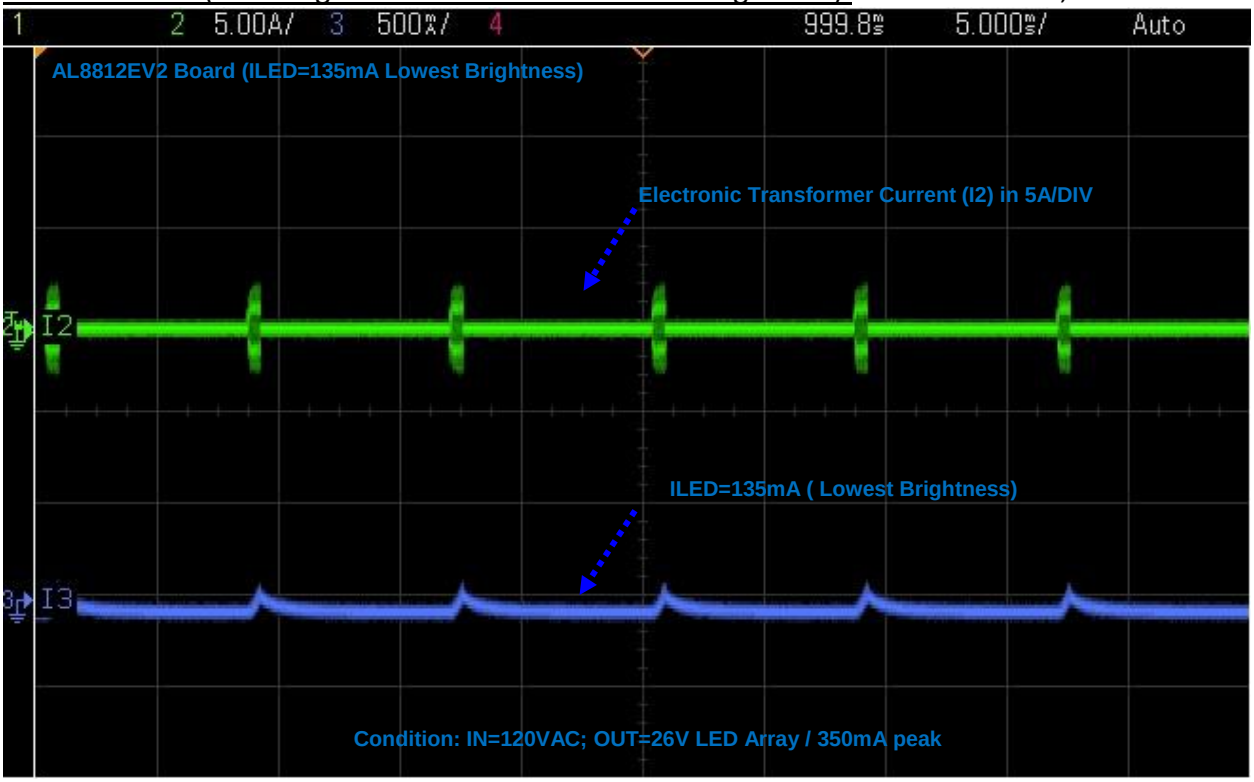
Waveform #8 (Dimming Control full brightness) => Channel 2: I2; Channel 3: I3



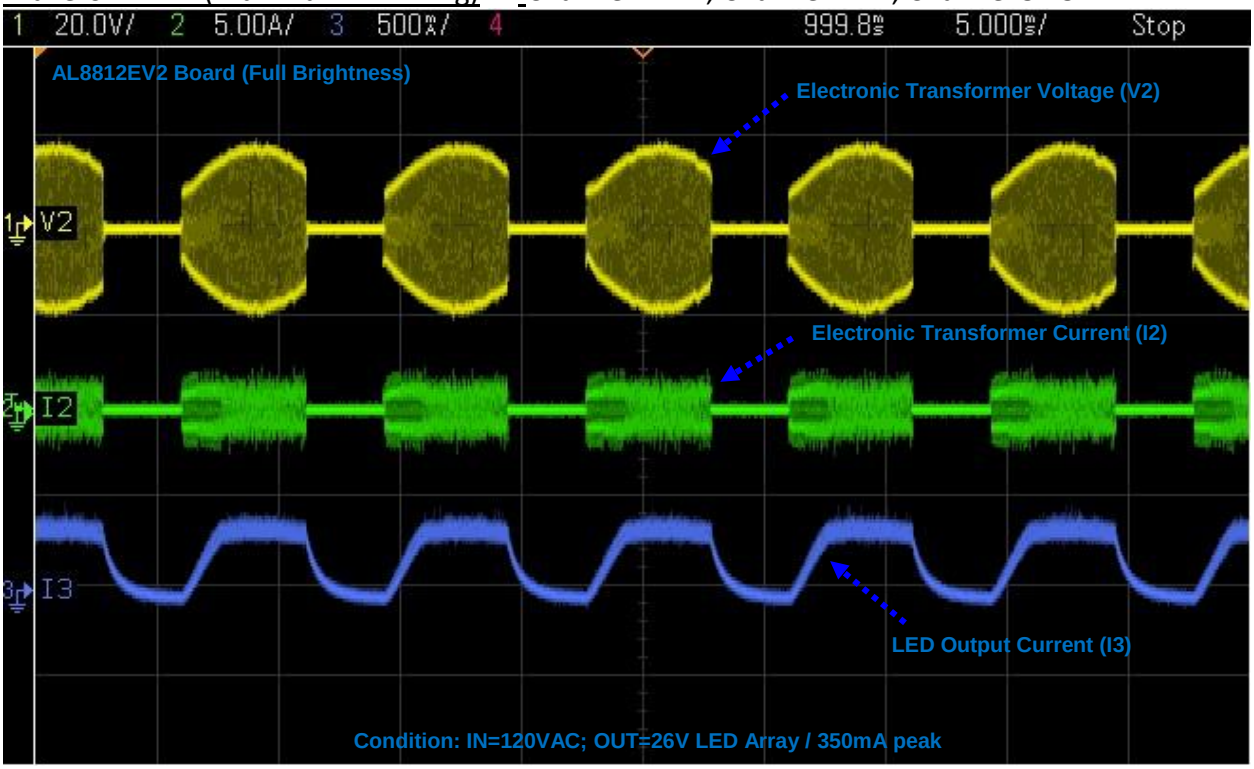
Waveform #10 (Dimming Control ILED=250mA) => Channel 2: I2; Channel 3: I3



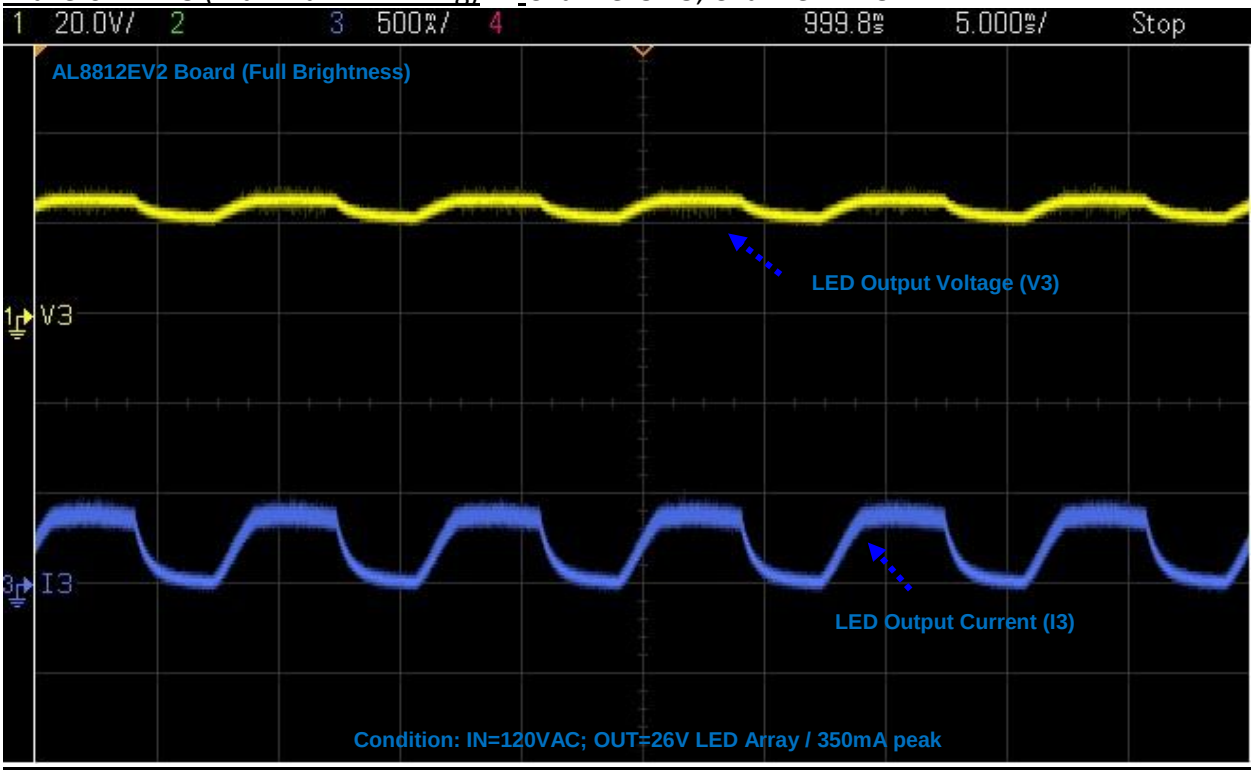
Waveform #11 (Dimming Control ILED=26mA Lowest Brightness) => Channel 2: I2; Channel 3: I3



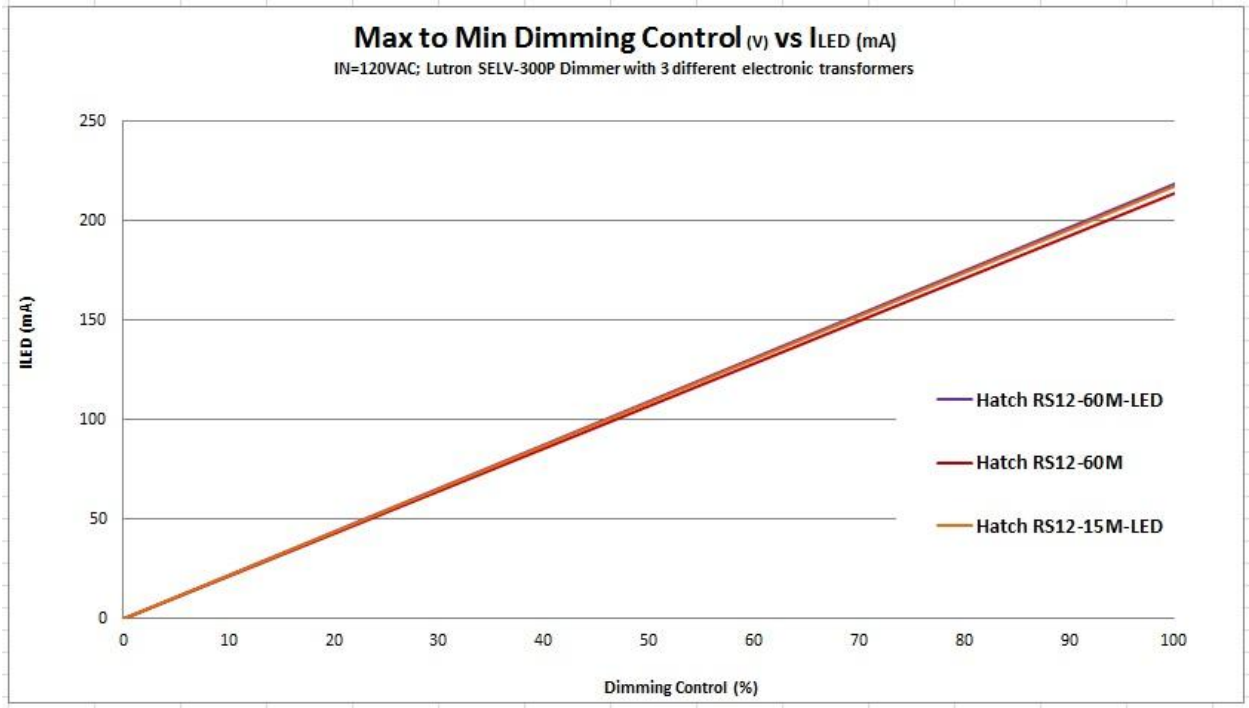
Waveform #12 (Maximum Dimming) => Channel 1: V2; Channel 2: I2; Channel 3: I3



Waveform #13 (Maximum Dimming) => Channel 3: I3; Channel 1: V3



Functional Data Curves



Transformer Compatibility List

1) 120VAC to 12VAC Electronic Transformers without dimmers in 1 (26V) LED array:

Index	Electronic Transformers (120VAC to 12VAC)		Performance Result (No flicker)
	Brand	Model	
1	RSA	RT60A (60W)	√
2	HATCH	RS12-150 (150W)	√
3	HATCH	RS12-60M-LED (60W)	√
4	HATCH	RS12-60M (60W)	√
5	HATCH	RS12-80M (80W)	√
6	HATCH	RS12-105 (105W)	√
7	HATCH	RS12-15M-LED (15W)	√

2) 120VAC to 12VAC Electronic Transformers with dimmers in 1 (26V) LED array:

Index	Electronic Transformers (120VAC to 12VAC)		120VAC Dimmer Type	
	Brand	Model	LUTRON SELV-300P / 300W	LUTRON MAELV-600 / 600W
1	HATCH	RS12-60M-LED (60W)	√	√
2	HATCH	RS12-60M (60W)	√	√
3	HATCH	RS12-15M-LED (15W)	√	√

Note: √ = No Flicker

Application Information

Circuit Description

This design consists of three sections:

1) The input boost circuit converts the 12V_{AC} input voltage to a DC voltage around 26V (AL8812).

2) The open circuit protection circuitry.

3) Finally, the LED current sense circuit generates a voltage to feedback the boost converter.

Boost Circuit

The AL8812 Boost converter is a simple “Constant ON time controller”. By keeping the same ON time throughout the AC cycle, the circuit will draw a current that will closely match the voltage and result in a constant input current. This eliminates the classic peak current problem with a bridge rectifier and a large input filter capacitor.

The boost circuit includes the input bridge rectifier, EMI filter (if needed) and the AL8812 Boost converter. The AC input voltage is rectified by the bridge circuit and filtered by C1, R4, C2, and C5. This first filter removes the high frequency that is generated by the Electronic Transformer in the range of 20-30 KHz. An additional diode rectifier circuit (D6, C4) is used to generate a voltage that is used to power the circuit that will turn on/off the internal MOSFET of the Boost converter and to power the operational amplifier in the LED current sense feedback circuitry.

The AL8812 has a current limit resistor R5 which sets the maximum current allowed through the inductor L1. The output voltage is set to around 26 volts and filtered by the two capacitors C6 and C7. These two capacitors store energy that will be used when the input voltage is low during the AC cycle.

Open Circuit Protection:

This circuit is used to limit the output voltage from going above the voltage limit of the output capacitors (C8) if the LED string is disconnected. In this example, a 35 volt output capacitor would be a good choice so the output maximum voltage would be around 30 volts. The output overvoltage is equal to the zener diode (D7) voltage plus the 1.2 volt threshold of the boost feedback pin. Note be aware that zener diodes have a typical range of +/- 2 volts.

Overvoltage = 30v (zener voltage) + 1.2 v

Overvoltage protection range from 28 volts to 32 volts

LED Current sense circuit:

The current thru the LED is set with the LED sense resistor (R9). This control voltage is applied to the feedback node of the boost converter. When the voltage on the feedback pin is over 1.2 volts, the boost converter will turn off. To keep the power dissipated in this resistor small, the voltage is amplified by an amplifier with a gain of 10 reducing the resistance by 10.

The current in the LED string is:

$$\text{Rsense (R9)} = \frac{1.2\text{ v}}{10 * \text{LED Current (amps)}}$$

For a LED string current of 0.5 amps:

Rsense = 1.2 v / (10 * 0.5) = 0.25 ohms (SMD 0603 resistor)

Setting the Boost Variables (AL8812)

The choice for the size of the boost converter inductor selected in this design is based on a compromise which it is able to support a peak current to around 1.5A since the average input voltage will be around 12-14V.

The boost converter (AL8812) includes a current limit resistor R5 which will limit the current through the inductor and thus the power delivered to the output load. The formula for the resistor is:

$I_{PK(switch)} = 0.25V / R5$

For a current limit of 1A, R5 is 0.25Ω.

In this evaluation design, this value was selected based on having eight LEDs in series drawing about 350mA. It was found that two 33µF capacitors mounted in parallel would just fit into the cavity of the MR16 bulb.

Performance Description

The evaluation board allows the testing of different combinations of circuit component values to match the final design specifications. The main design goal is to have a constant load on the Electronic Transformer so that it will be operating throughout the AC cycle. This is accomplished when the input power is about the same as the output power.

Overall, there are three major components that are essential to the operation of the circuit.

The first component to select is the resistor (R9) in the LED current sense circuit that sets the final current through the LED string. This will set the amount of power the system needs.

The second component is the value of the (R5) which limits the current provided to the output filter capacitors. This should be adjusted so that the boost input circuit by AL8812 LED driver is always running and thus providing a load to the Electronic Transformer. This usually means that the output voltage of the boost circuit will have a large ripple. This will be okay as long as the lowest voltage is higher than the maximum final LED string voltage.

The third component is the output capacitors (C6 and C7) of the boost circuit. These should not be too large that the PFC circuit stops working. If it happens, the resonant circuit of the Electronic Transformer will become erratic and cause the LEDs to flicker.

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