



ON Semiconductor

Simple ENERGY STAR® Compliant LED Driver Retrofit in a T5 Tube using 160mA CCR

Device	Application	Input Voltage	Power	Topology	I/O Isolation
NSI45090JDT4G	T5 23" Fluorescent Replacement LEDs	110V AC $\pm 10\%$	11.2W	Linear	NONE

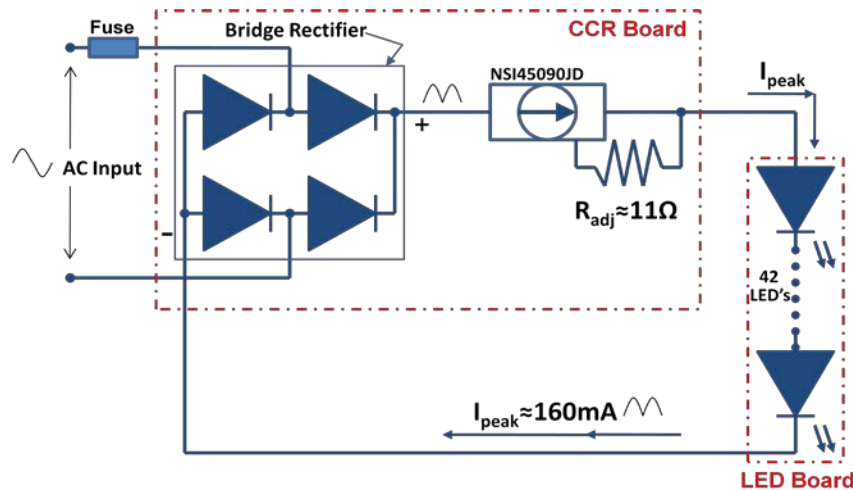


Figure 1 – CCR with 42 LEDs and a Bridge Rectifier Circuit

Overview

The objective is to build a LED retrofit using a T5 fluorescent tube fixture. A constant current regulator, NSI45090JDT4G, is incorporated, and the whole circuit exceeds ENERGY STAR® power factor rating greater than 0.7. The circuit (Figure 1) consists of a bridge rectifier using MURA160T3-D, a constant current regulator (CCR), an adjusting resistor, LEDs (Xlamp ML-E®), and GE® T5 23" fixture (Figure 2). At the input, an overload fuse can be added to protect the circuit from current spikes.

The design consists of two circuit boards, one for the CCR (90mmX18mm) as in Figure 3, and one for the LED's (516mmX18mm) as in Figure 4. The CCR board has 6 parts on it, 4 bridge diodes MURA160T3-D, 1 CCR NSI45090JDT4G, and 1 resistor of 2.5Ω. The LED board has 42 LEDs, 4 resistors of 1Ω, 4 Tyco pins, and a (250mA/125V) fuse.

Key Features

- Simple design
- AC application of LEDs
- No leakage or drive current
- 6 parts on small driver board
- Higher Efficiency than fluorescent
- Current regulation to protect LEDs
- Better lumen output than fluorescent
- Pf exceeds Energy Star Requirements

Circuit Operation

The circuit operates as follows; the bridge rectifier consists of 4 diodes that rectify the input voltage to peak positive voltage at 155.56V @ 120Hz. Following in the circuit is the CCR that uses a 2.5Ω resistor to achieve 160mA of peak current regulation. Now the current flows through the two 1Ω resistors and through the LEDs. The resistors were designed in the LED board in case a voltage reduction is needed to compensate for lower V_f LEDs. They have no purpose in the circuit as is.

Build

Once the fixture was purchased, the bottom side was cut open, and the internal ballast for the fluorescent tube was removed. The CCR board was installed to internally replace the existing board. The LED board was fitted to replace the fluorescent tube, 21" long and 18mm wide, and was designed to be covered by the reflector plastic cover.

Data Analysis

Figure 5 shows data captures from the oscilloscope, and demonstrates the input voltage and current relative to the rectified current through the CCR, and the CCR voltage drop. The LED voltage is simply the result of

subtracting the CCR voltage and the 2 diode forward voltages from the total rectified input voltage. The efficiency is determined using the following equation;

$$\eta = \frac{V_{LED} \times I_{LED}}{V_{in} \times I_{in}} = \frac{(V_{in} - V_{CCR}) \times I_{LED}}{V_{in} \times I_{in}}$$

Conclusions

The design features better luminosity than the fluorescent, i.e. better power per light output, high power factor and low THD. The average LED light output is twice as much as that of the fluorescent while consuming about the same energy.

Images



Figure 2 – T5 21" Fluorescent Tube and LED Tube

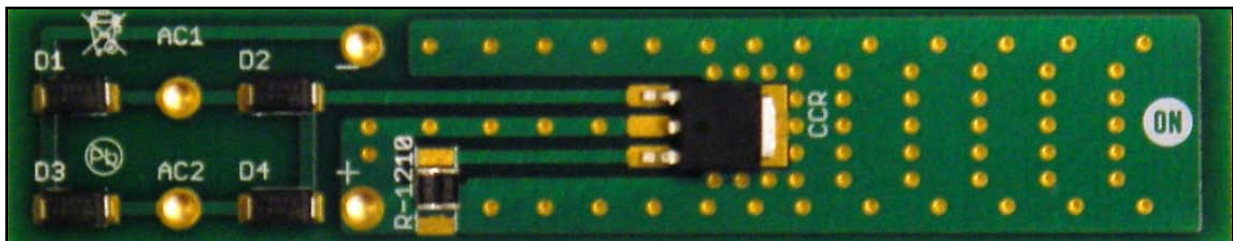


Figure 3 – CCR Board Used in Fixture



Figure 4 – LED Board Replaces Fluorescent Tube

Capture

T5 LED Tube Data Capture

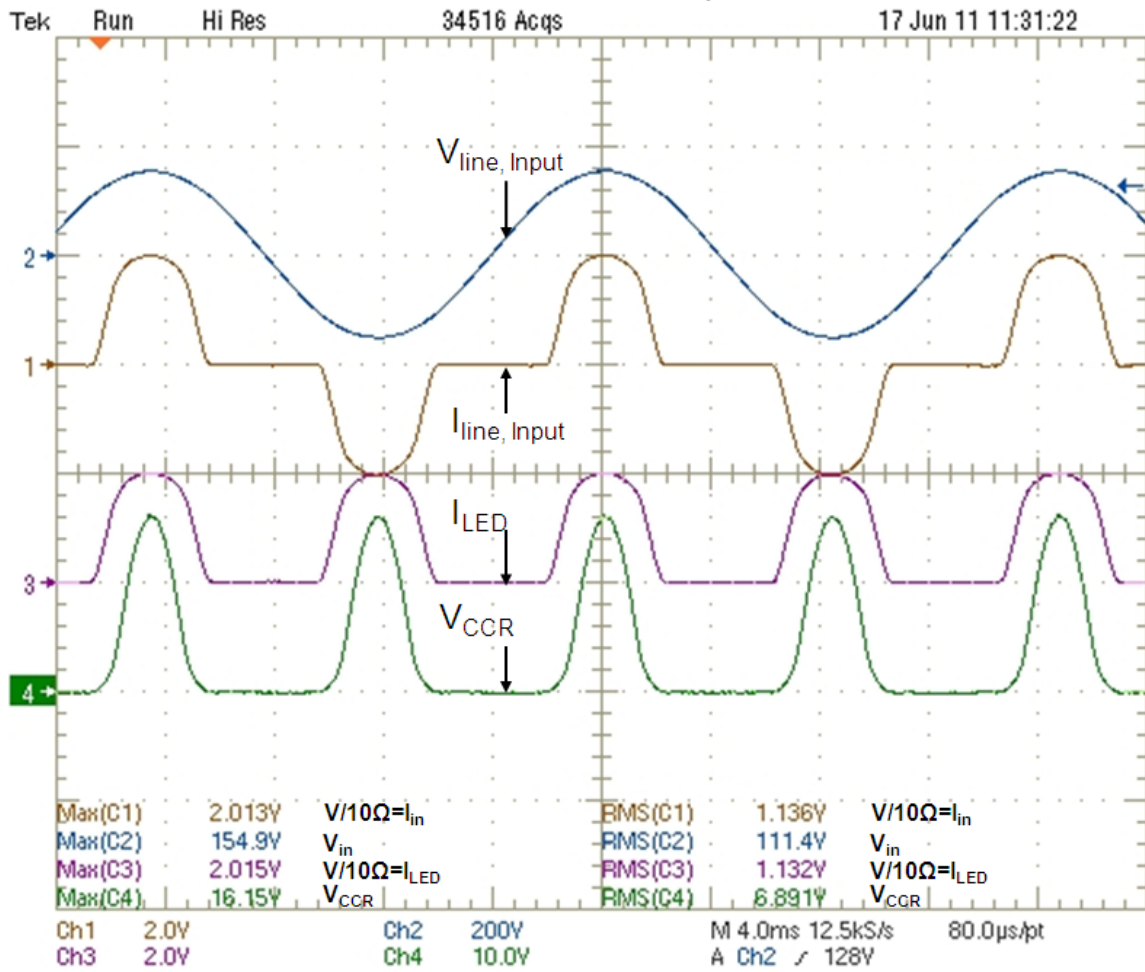


Figure 5 – Oscilloscope Voltages and Currents

Data Summary Table

Fixture Type	V _{in} rms (V) ¹	I _{in} rms (mA) ¹	P (W) ¹	Pf ¹	THD (% _A) ¹	Klux ² Average	CCR Temp (°C) ³	LED Temp (°C) ³
Cree LED Xlamp ML-E	100.1	78.5	6.3	0.79	76	3.4	50	50
	110.2	115.6	11.1	0.87	55	5.2	60	60
	120.1	132.3	14.3	0.90	47	5.9	80	65
Slim Line Fluorescent Tube GE	100.1	182.2	9.7	0.54	111	2.2	N/A	N/A
	110.1	189.8	11.5	0.55	111	2.7	N/A	N/A
	120.2	200.3	13.2	0.55	113	2.9	N/A	N/A

1. Yokogawa WT210 Digital Power Meter was used under equivalent conditions for test acquisition.
2. Extech HD450 was used under equivalent conditions as reference between light sources.
3. Flir InfraCAM was used under equivalent conditions as reference between heat sources.
4. Data may vary depending on NSI45090JDT4G ±10% and Xlamp ML-E.

DN05013/D

Additional Data

PF ENERGY STAR® (Yes/No)	Yes > 0.7
Efficiency	89.66% @ 110V RMS AC
Inrush Limiting / Fuse	Yes
Operating Temperature	-20°C to +45°C
NSI45090JDT4G Ireg SS	153mA @7.5V

Bill of Materials

06/20/2011

Quantity	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number
1	Fuse	250mA/125V	N/A	SMD	N/A	N/A
1	CCR	45V, 90mA	±15%	D-pak	ON Semiconductor	NSI45090JDT4G
4	Diode	600V, 1A	N/A	SMA	ON Semiconductor	MURA160T3-D
1	Resistor	2.5Ω, 1210	1%	1210	N/A	Generic
1	CCR Board	2OZ Cu, 2 layers, FR-4	N/A	PCB	DS Electronics	N/A
42	LED	3.2V, 150mA	N/A	3.50X3.45mm	CREE	Xlamp ML-E
4	Tyco pins	0.062" diam.	N/A	N/A	Tyco Electronics	1-66103-6 type III
4	Resistor	1Ω, 1206	1%	1206	N/A	Generic
1	LED Board	2OZ Cu, 2 layers, FR-4	N/A	PCB	DS Electronics	N/A

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