Design Note – DN06048/D

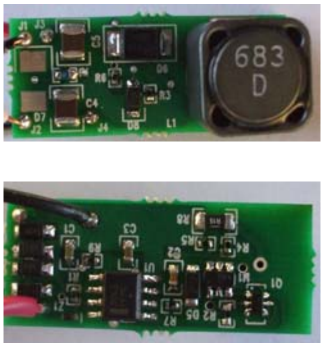
Reference Design for Sharp ZENIGATA LED Module

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP3065	Lighting	12 V_{DC} or 12V_{AC}	3.6 W	Buck-Boost	NONE

Specifications	
AC Input Voltage	12V AC Line transformer (Source Resistance <0.1Ohm), MR16 Solid State AC Ballast
DC Input	6V to 16VDC
Output Voltage	8 – 12 V
Output Current	350 mA / 550mA regulated

Circuit Description

This circuit is proposed for driving the Sharp ZENIGATA LED module in a variety of lighting applications. Configurations like this are found in 12 VAC track lighting applications, automotive applications, and low voltage AC landscaping applications as well as task lighting such as under-cabinet lights and desk lamps that might be powered from standard off-the-shelf 5 and 12 VAC wall adapters. The circuit is based on the NCP3065 operation at ~150 kHz in a non-isolated configuration. Key consideration in this design was achieving flat current regulation across input line variation and output voltage variation with a 12VAC input.



Reference Design
0.457" x 1.148" (11mm x 29mm)

Key Features

- Small size for MR-16 applications
- Buck-Boost operation
- Wide input and output operation voltage
- Regulated output current
- Open LED Protection
- Output Short Circuit Protection

Sharp ZENIGATA LED Module

Schematic

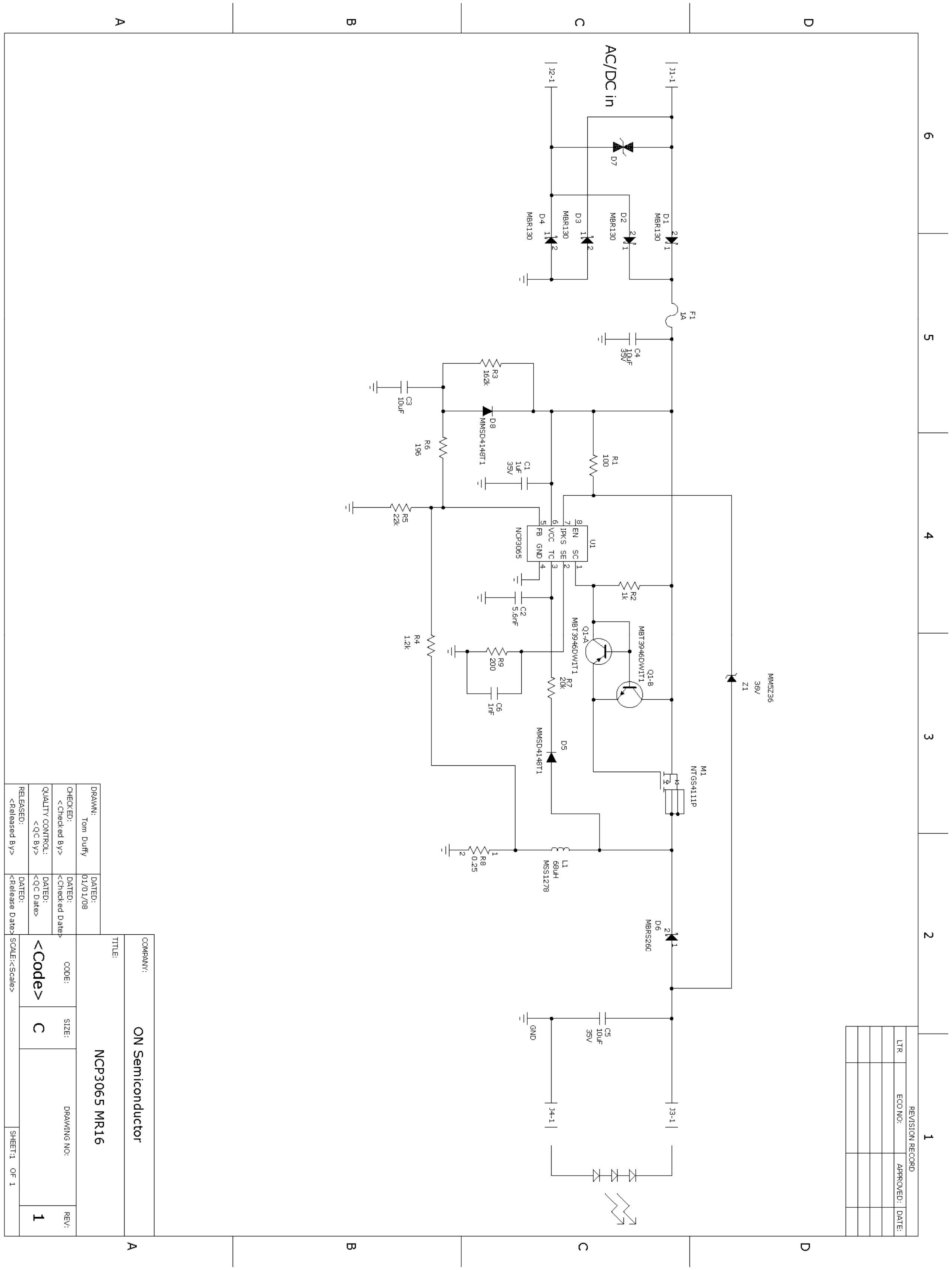


Figure 1 – Buck-Boost converter schematic

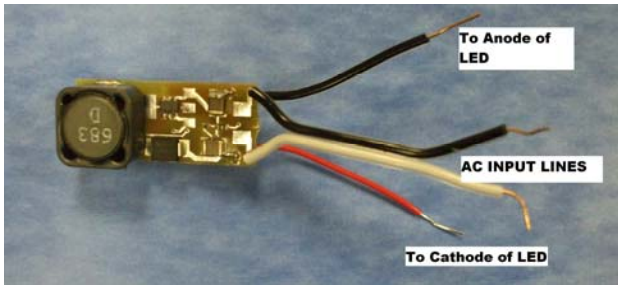
Basic Power Topology

The principle of the Buck-Boost converter is fairly simple (see Figure 2):

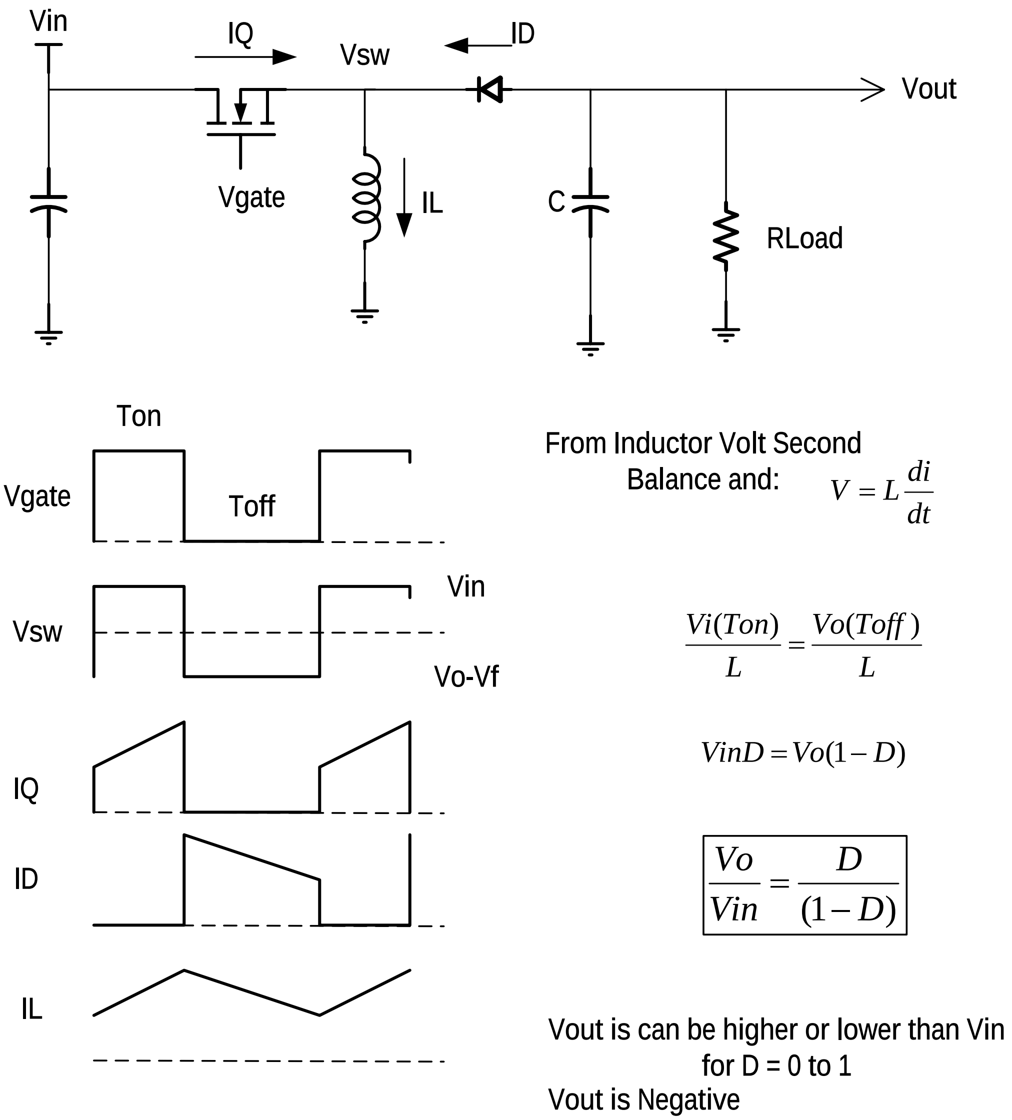
While in the On-state, the input voltage source is directly connected to the inductor (L). This results in accumulating energy in L. In this stage, the capacitor C supplies energy to the output load;

While in the Off-state, the inductor is connected to the output load and capacitor through the Output Diode, so energy is transferred to the load.

Remember this is an inverting output. So the negative output will connect to the anode of the LED, and the positive output will connect to the cathode of the LED.



Also note, when trying to make measurements with a scope probe, that ground is NOT ground. The scope will need to be floating (ground connection removed from the AC wall source) or there will be a ground loop / short circuit that will cause the device to turn off.



From Inductor Volt Second
Balance and: $V = L\frac{di}{dt}$

$$\frac{Vi(Ton)}{L} = \frac{Vo(Toff)}{L}$$

$$VinD = Vo(1-D)$$

$$\boxed{\frac{Vo}{Vin} = \frac{D}{(1-D)}}$$

Vout is can be higher or lower than Vin
for D = 0 to 1
Vout is Negative

Figure 2 – Buck-Boost Operation

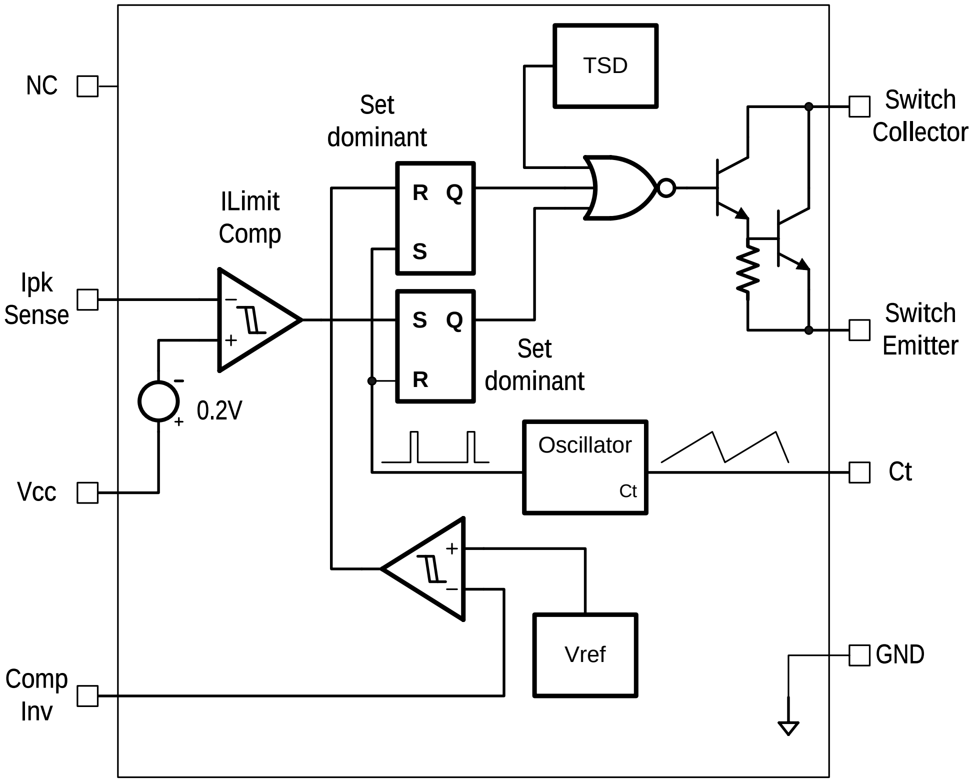


Figure 3 – NCP3065 Burst Mode Controller

Burst Mode Control

The basic control loop consists of a 0.235V internal Reference, a Feedback Comparator, and two Set-Dominant RS Latches. Basically the NCP3065 allows the Power FET for the Buck-Boost stage to switch ON as the Feedback Voltage falls below the reference voltage. The Power FET will be then be forced OFF unconditionally during Ct Ramp down.

R8 is used to sense the inductor current and is fed to the FB pin of the NCP3065.

This application produces OFF time instantaneous (Ivalley) inductor current control (see Figure 4). A cycle of switch ON time is only allowed to start once the OFF time Inductor current crosses the Vref threshold.

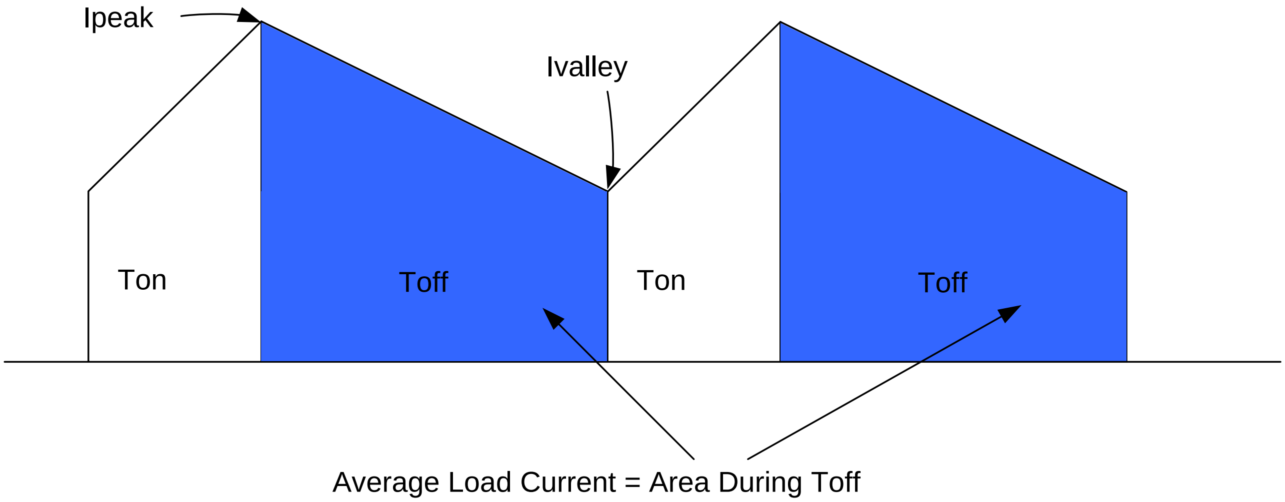


Figure 4 - Buck-Boost Inductor Current

Since the controller does not provide integral PWM control and utilizes only a comparator trip point for feedback, the peak to average load current is not in direct proportion as in a Buck Converter, but rather follows the following formula:

$$Iave = \left(Ivalley + \frac{1}{2}\left(\left(\frac{Vo}{L}\right) \frac{1-\frac{Vo}{Vo+Vin}}{F} \right)\right)\left(1-\frac{Vo}{Vo+Vin}\right)$$

Where, Ivalley is the lowest inductor current point. Plotting Iave vs Vin shows a dramatic curve which would cause a significant change in light output of the LED (see Figure 5).

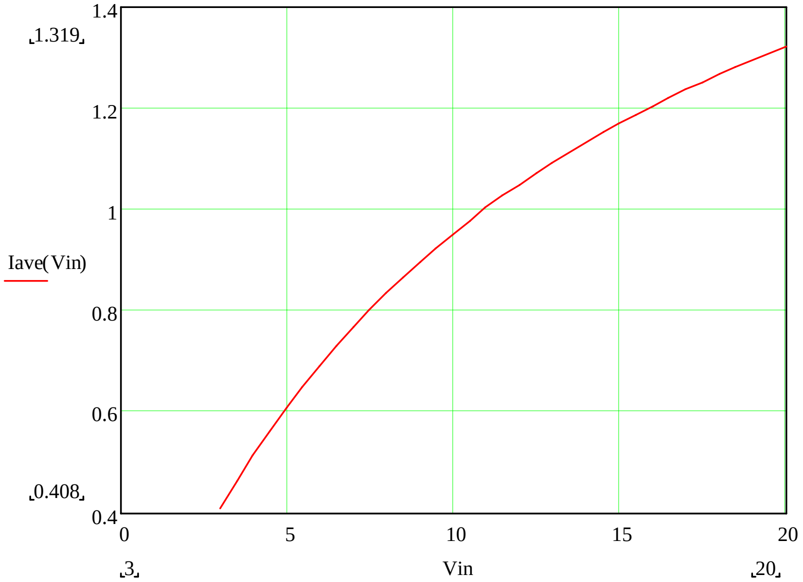


Figure 5 - Average LED Current vs Vin DC (Without Vin Compensation)

Therefore an input voltage feed-forward compensation network is used to reduce the error due to the nonlinear response of the Iout vs Vin curve.

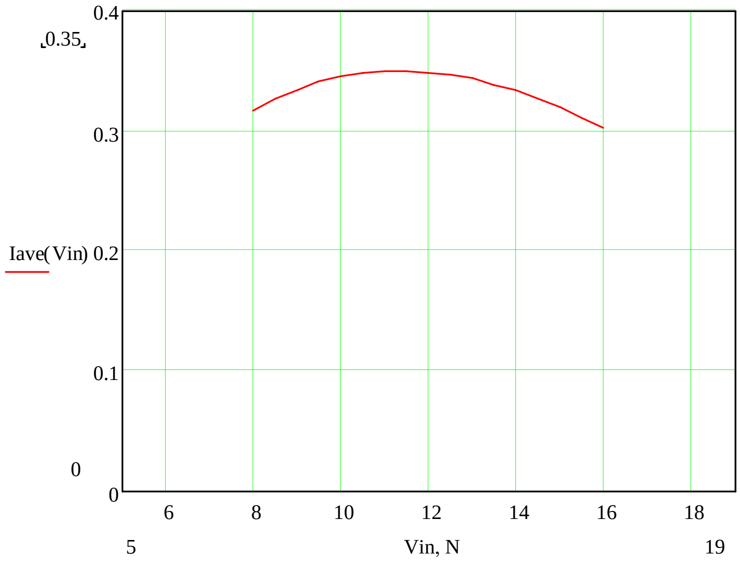


Figure 6 - Average LED Current vs Vin DC (With Vin Compensation)

A resistive divider network consisting of R3, R5 and summing resistor R4 are used to add Vin proportional voltage to the FB pin in order to reduce the load current as Vin is increased. This has the effect of flattening the curve of Figure 5 and reduces the overall current error (see Figure 6). This average line can be DC shifted with R8 and the ends can be aligned by adjusting R5, R3 and R4.

R9 and C6 are used to limit the gate to source voltage on the external switch at high input voltage. The resistor divider network of R9 and R2 are used to program and gate to source maximum.

$$Vgs = Vin - \left(\frac{Vin \times R9}{R9 + R2}\right)$$

Pulsed Feedback Resistor

R7 and D5 are used to reduce the possibility of pulse skipping (see Figure 7). Since burst mode control involves only one feedback voltage, cross-detection per cycle and does not involve the use of a window comparator, it is possible to have skipped pulses which do not effect the DC regulation but could be visible as flicker in an LED application. R7 and D5 add current to the Ct timing capacitor C2. This effectively limits the maximum achievable duty cycle of the NCP3065. When conditions warrant low duty cycle, R7 and D5 make higher than desired duty cycles unavailable. D7 is necessary to block voltage during the OFF time, since this is Buck-Boost Topology. More information on Pulsed Feedback compensation is available in the NCP3065 data sheet.

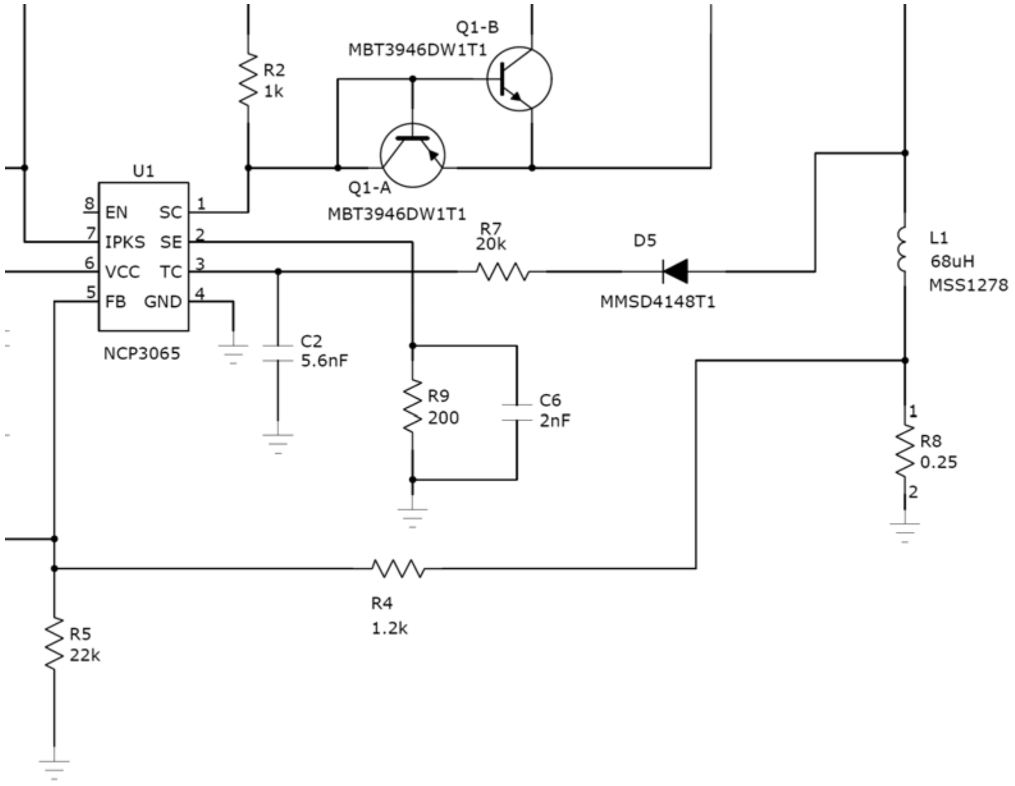


Figure 7 - Pulsed Feedback Resistor

AC Operation vs DC

Since there is a half sine wave input to the Buck-Boost stage, there is a different operating point as compared with pure DC input. Since small size is a goal for this design very little input capacitance is used past the full bridge rectifier. Therefore, the input to the converter is a half wave rectified sine wave. Since the regulator is non-functional below ~4V there are dead spots in the regulation. So we end up with regulation for some finite portion ~80% of the 60Hz line cycle, and then no output for ~20%. This has the effect of reducing the average current by ~20% when operating with AC input.

An additional AC compensation network is added to the Vin Compensation to account for the different operating point (see Figure 8).

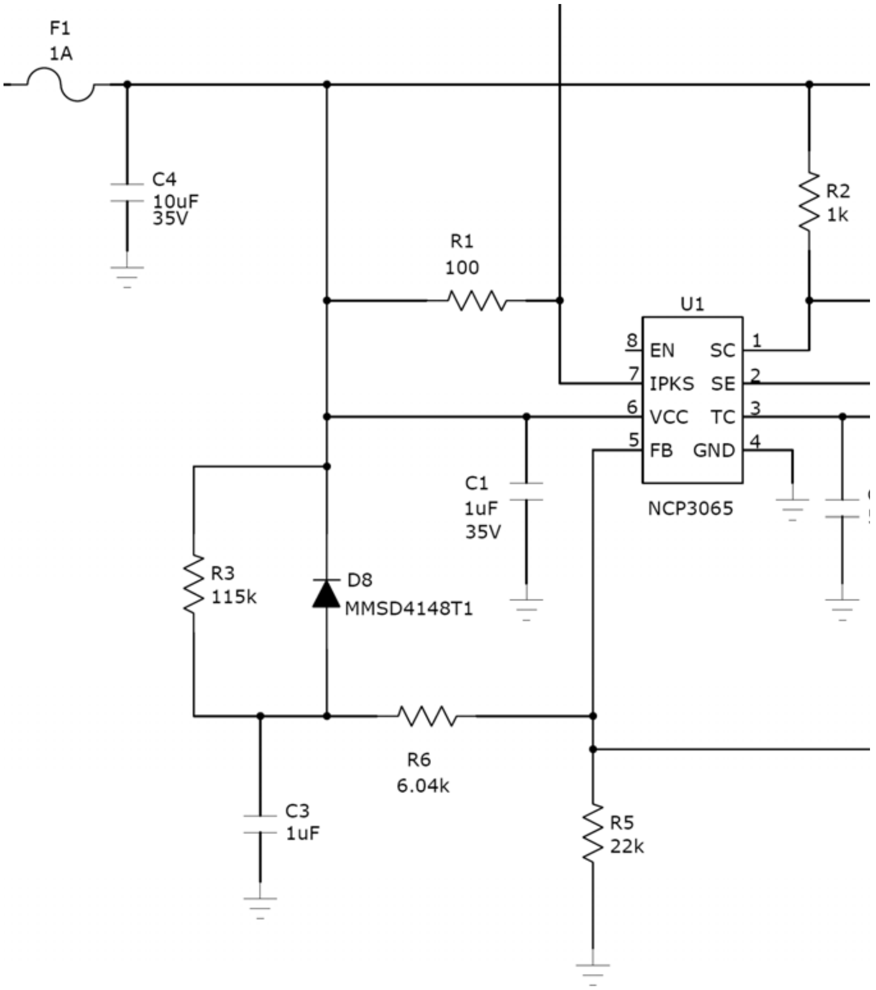


Figure 8 - Pulsed Feedback Resistor

Protection

Z1 and R1, along with the Current limit feature of the NCP3065, are used for open circuit protection. In the event of an open circuit at the load, the loop will try to increase the output voltage in order to satisfy the current demand which feeds back zero current. When (Vin + Vout) exceeds the voltage of Z1, current will flow in R1 which triggers the current limit function of the NCP3065.

Short circuit protection is handled with a fuse, F1, on the input. Surge protection from inductive loads is an important consideration specifically in transformer fed systems that carry significant source inductance. The surge device needs to be selected to a voltage that will never exceed the gate to source voltage of the power FET with reasonable voltage margin. This may require some trial and error to select since the clamp voltage will stretch depending on how much energy needs to be absorbed

Increasing Output Current-

The reference design is configured for 350mA average LED current. Increasing the current regulation point on the reference board is as simple as cutting the current sense resistor R8 in half from 250mOhms to 125mOhms. Also, the input fuse must be increased to accommodate the increased input current draw. Heat sinking may be required depending on the implementation of the Housing and the environmental characteristics when moving to the higher power design.

PC Board

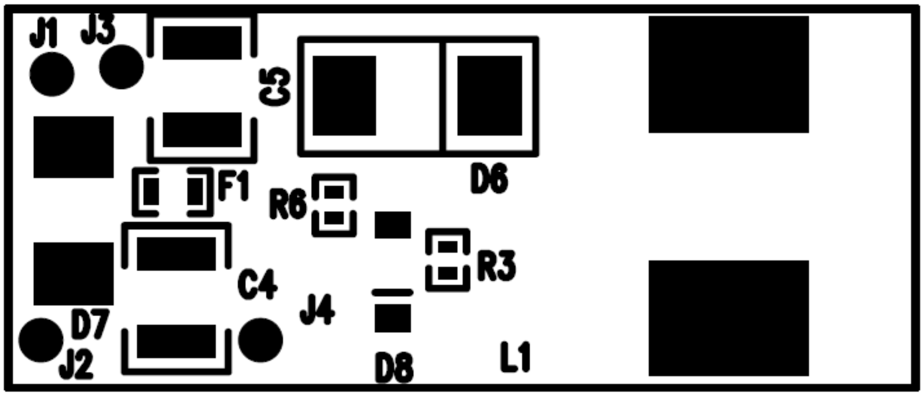


Figure 9 - Component Placement (Top)

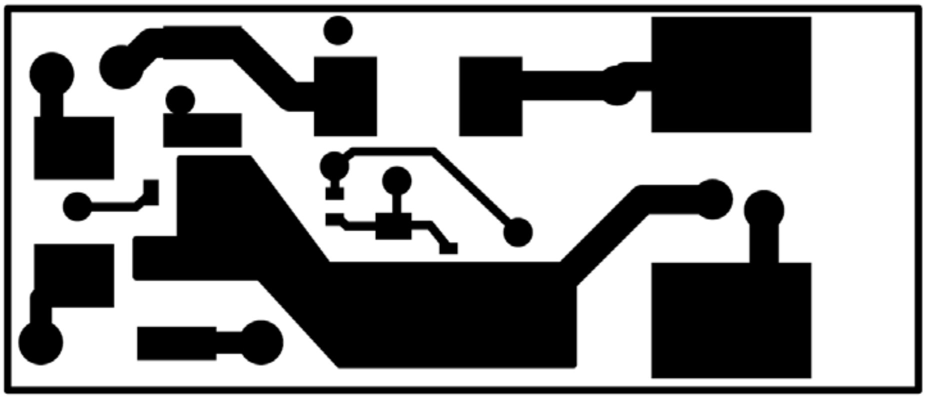


Figure 10 – Traces (Top View)

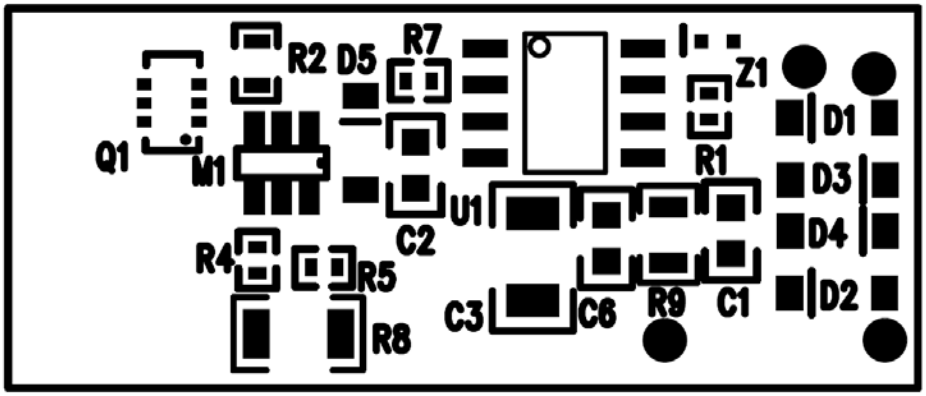


Figure 11 - Component Placement (Bottom)

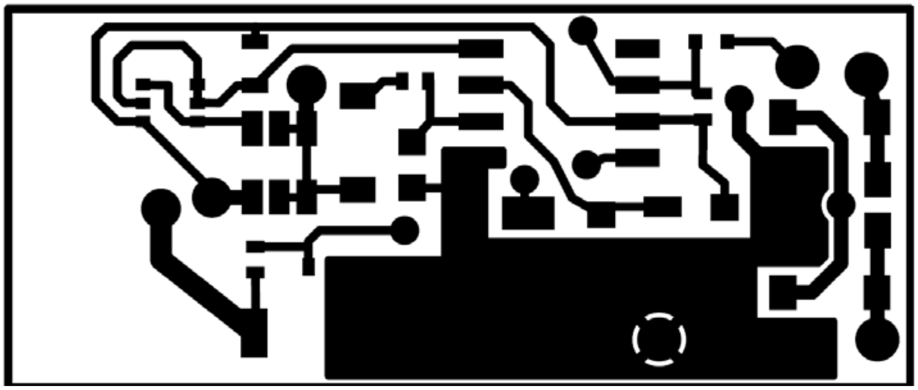
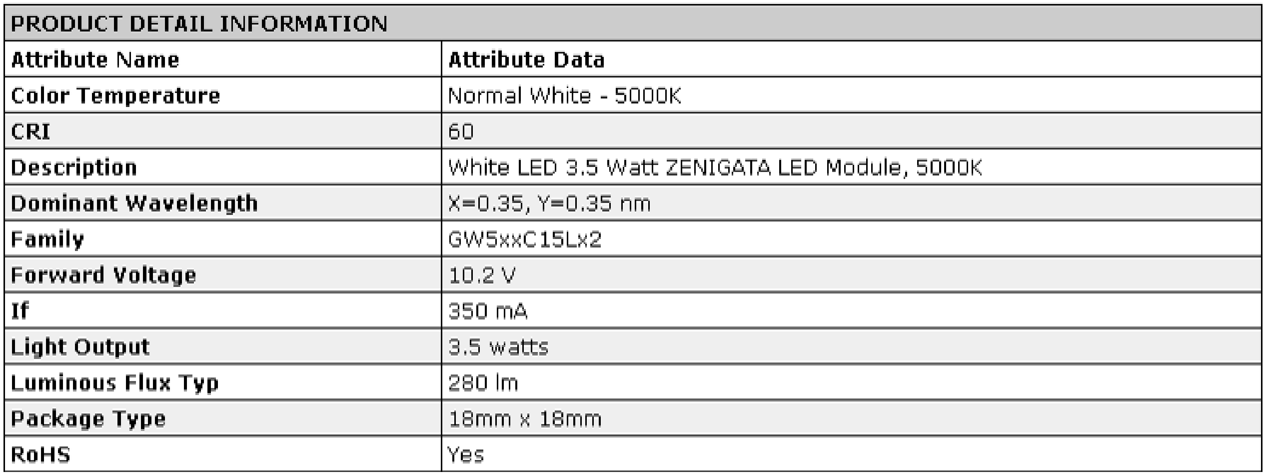


Figure 12 – Traces (Bottom View)

Qty	Ref	Value	Part Number	Description	Manufacturer
1	F1	1A	MFU0603FF01000P100	Fuse	Tyco
1	C3	10uF	GRM21BF51A106ZE15L	Ceramic Chip Capacitor	Murata
1	C6	1nF	GRM188R71H102KA01D	Ceramic Chip Capacitor	Murata
1	C1	1uF	GRM188R61E105KA12D	Ceramic Chip Capacitor	Murata
1	C2	5.6nF	GRM188R71H562KA01D	Ceramic Chip Capacitor	Murata
1	C4	10uF	GRM32NF51E106ZA01L	Ceramic Chip Capacitor	Murata
1	C5	10uF	GRM32NF51E106ZA01L	Ceramic Chip Capacitor	Murata
1	D1	1A, 30V	MBR130T1G	DIODE, SCHOTTKY	ON Semiconductor
1	D2	1A, 30V	MBR130T1G	DIODE, SCHOTTKY	ON Semiconductor
1	D3	1A, 30V	MBR130T1G	DIODE, SCHOTTKY	ON Semiconductor
1	D4	1A, 30V	MBR130T1G	DIODE, SCHOTTKY	ON Semiconductor
1	D6	2A, 60V	MBRS260T3	DIODE, SCHOTTKY	ON Semiconductor
1	Q1	PNP	MBT3946DW1T1	General Purpose NPN Transistor	ON Semiconductor
1	D5	0.2A, 100V	MMSD4148T1	Diode, Small Signal	On Semiconductor
1	D8	0.2A, 100V	MMSD4148T1	Diode, Small Signal	On Semiconductor
1	Z1	36V	MM5Z36VT1	DIODE, ZENER	ON Semiconductor
1	L1	68uH	MSS1278-683MLD	INDUCTOR, SM	Coilcraft
1	U1	40 V 1.5A	NCP3065DR2G	Switching Regulator	ON Semiconductor
1	M1	PFET	NTGS4111PT1G	MOSFET, P	On Semiconductor
1	R4	1.2k	CRCW04021K20FKED	Resistor	Vishay / Dale
1	R1	100	CRCW0402100RFKED	Resistor	Vishay / Dale
1	R3	162k	CRCW0402162KFKED	Resistor	Vishay / Dale
1	R6	196	CRCW0402196RFKED	Resistor	Vishay / Dale
1	R7	22k	CRCW040222K0FKED	Resistor	Vishay / Dale
1	R5	22k	CRCW040222K0FKED	Resistor	Vishay / Dale
1	R2	1k	CRCW04021K00FKED	Resistor	Vishay / Dale
1	R9	200	CRCW0402200RFKED	Resistor	Vishay / Dale
1	R8	0.25	CSR1/20.25FICT-ND	Resistor	Vishay / Dale
1	D7		P6SMB22CAT3	ZENER, BACK TO BACK	ON Semiconductor

Table 1 – Bill of materials

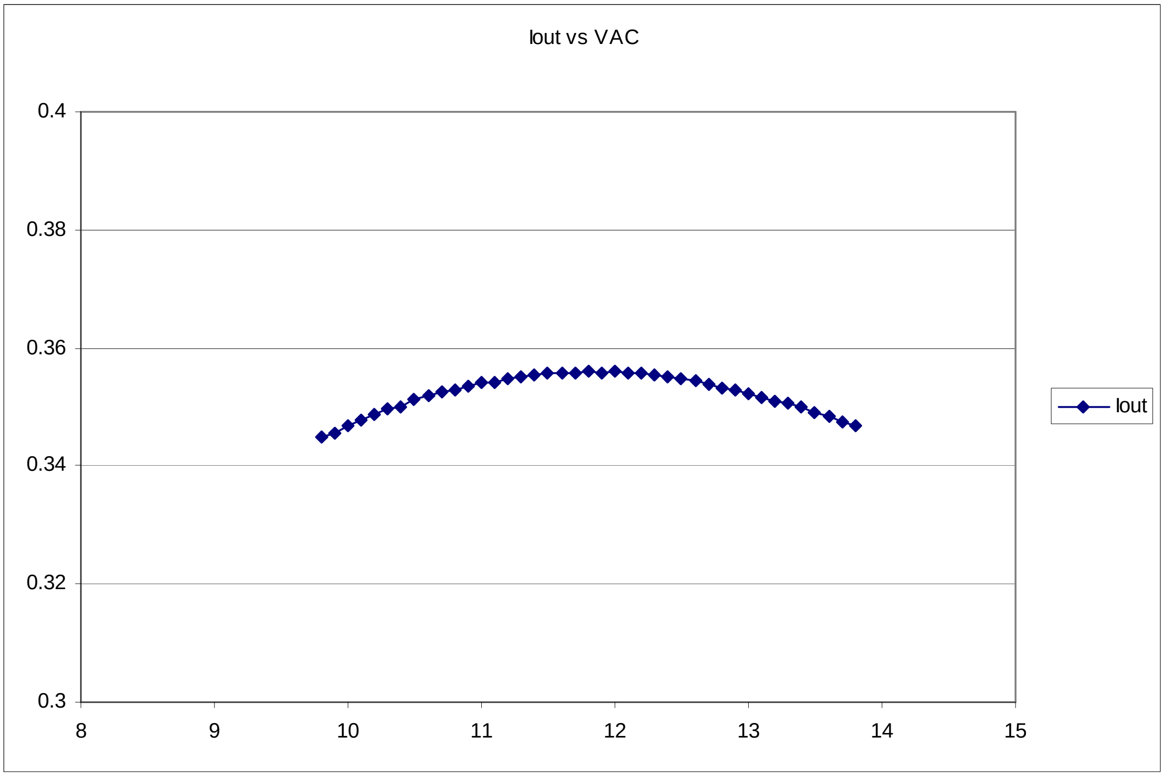


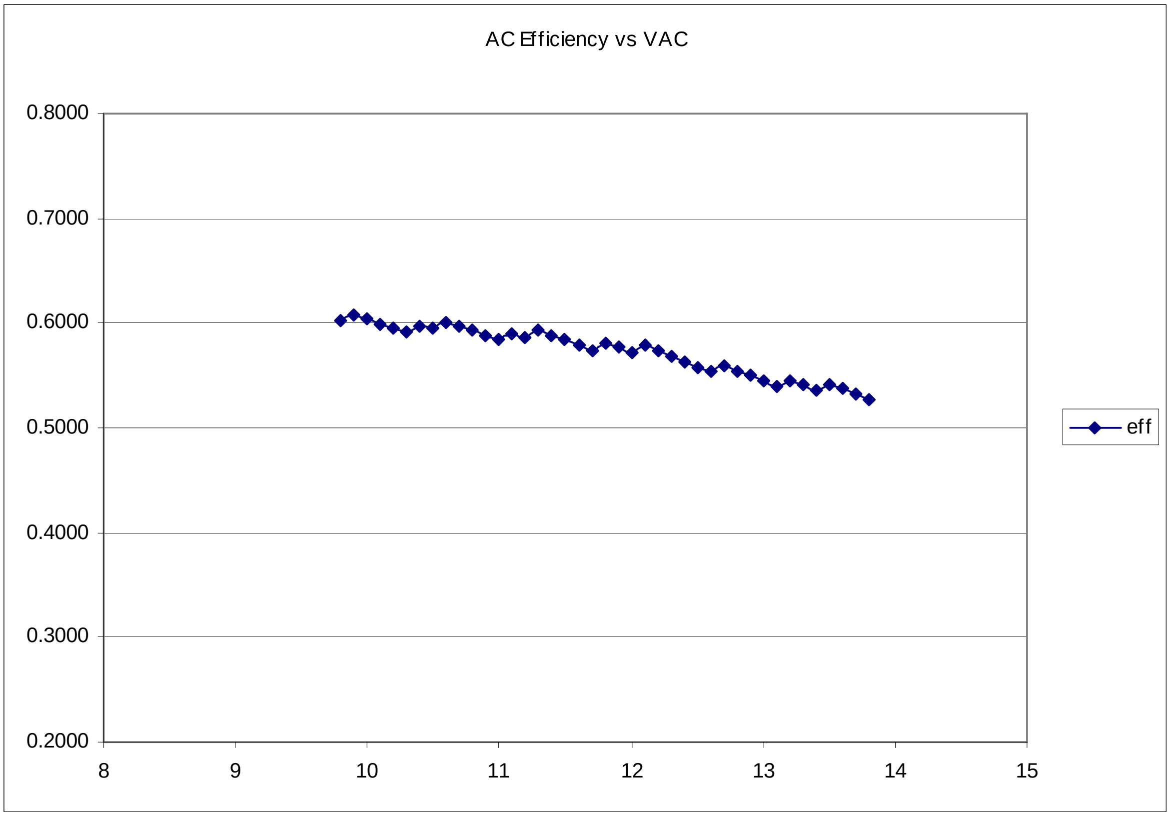
PRODUCT DETAIL INFORMATION	
Attribute Name	**Attribute Data**
Color Temperature	Normal White - 5000K
CRI	60
Description	White LED 3.5 Watt ZENIGATA LED Module, 5000K
Dominant Wavelength	X=0.35, Y=0.35 nm
Family	GW5xxC15Lx2
Forward Voltage	10.2 V
If	350 mA
Light Output	3.5 watts
Luminous Flux Typ	280 lm
Package Type	18mm x 18mm
RoHS	Yes

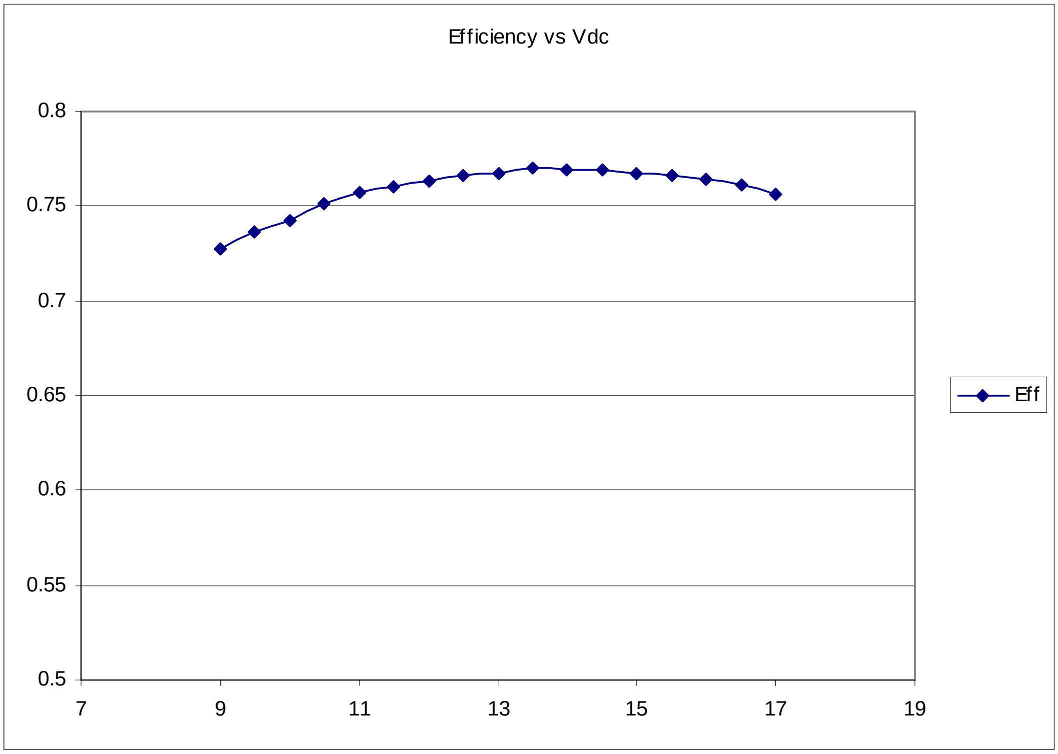
Figure 12 - LED Module Spec (Sharp P/N GW5BWC15L02)

Measurements

12V (ac) Data







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