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Solar Powered LED Street Lighting

Solar Powered LED Street Lighting

Courtesy of BetaLighting

Agenda

- Trends for solar powered LED street lighting
- Regulating voltage out of a solar panel
  - Application overview
  - Maximum Peak Power Tracking (MPPT)
  - Reference design
- Driving High-Brightness LED (HB-LED)
  - Selecting a design approach
  - Reference design

The Application of Solar Powered LED Street Lighting

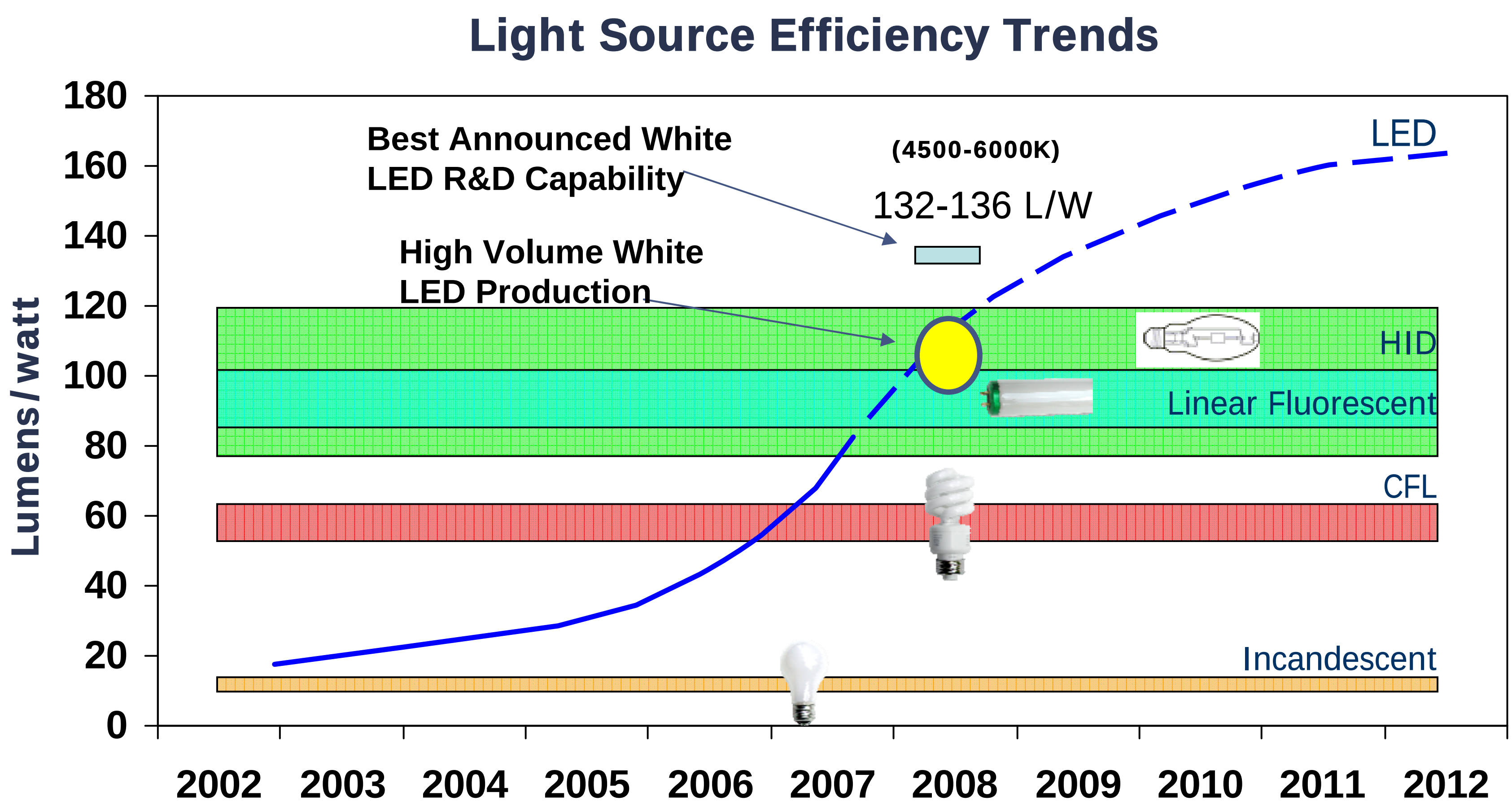



- LED lighting offers high efficiency, long operating life and low voltage operation which ideal for solar

- Solar street lights were initially used in remote locations and disaster prone areas

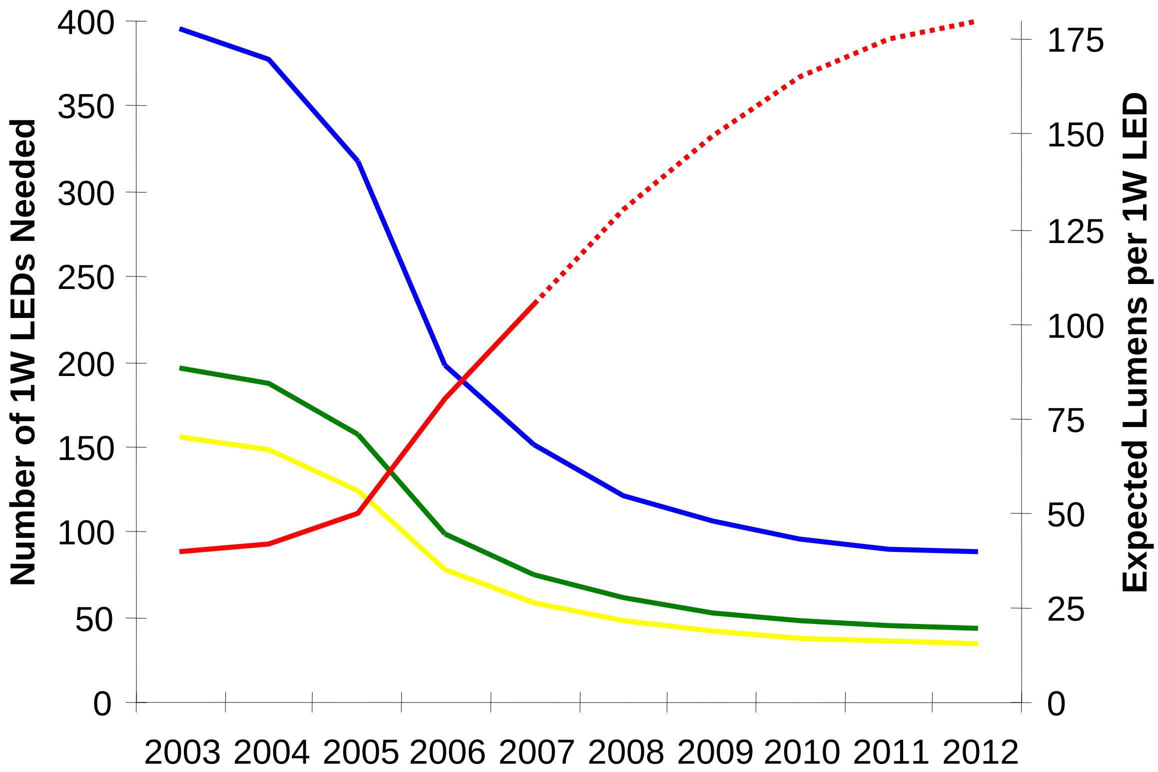
- As LED efficacy and light output have improved, they are becoming mainstream

LED Performance Over Time



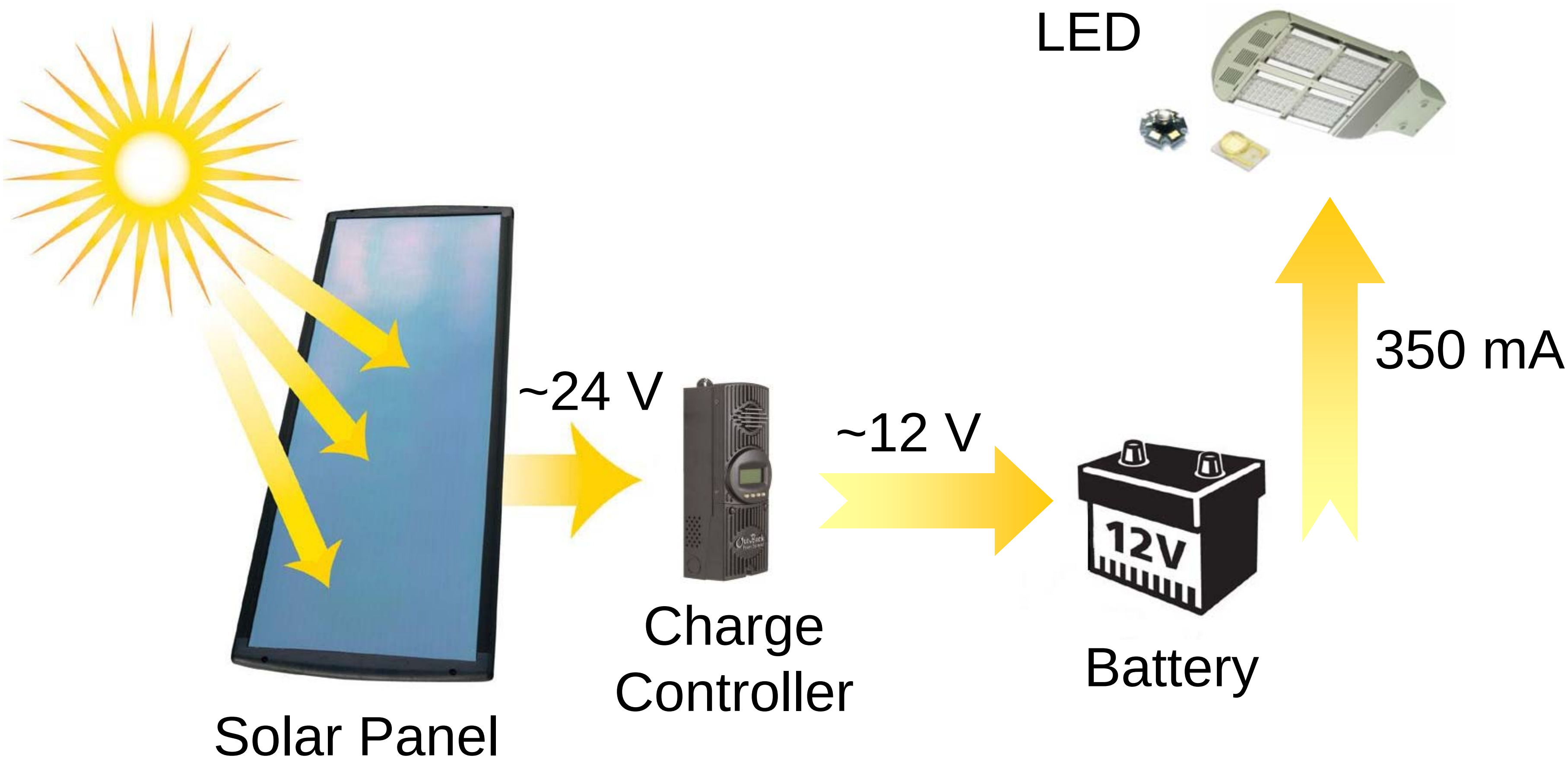
Source: Cree

Tipping Point is Close on All the Major Apps…



Regulating Voltage out of a Solar Panel

Solar Power – Block Diagram



Comparison of Different Types of Charge Controllers

Basic

- Designed to protect the battery from overcharge or undercharge
- Prevents reverse current

PWM

- Controls the amount of current charging the battery
- Trickle charge

MPPT

- Optimize the power output from the cell
- Battery charge to optimal capacity

Maximum Peak Power Tracking (MPPT)

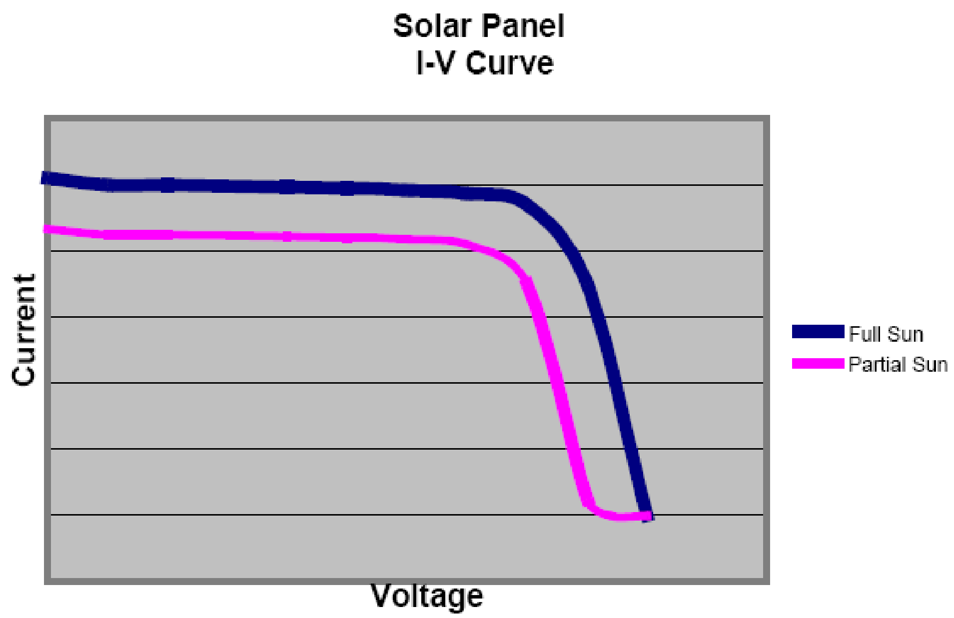
- Solar panels in general are inefficient
  - ~30% efficient
  - Most expensive component in the system

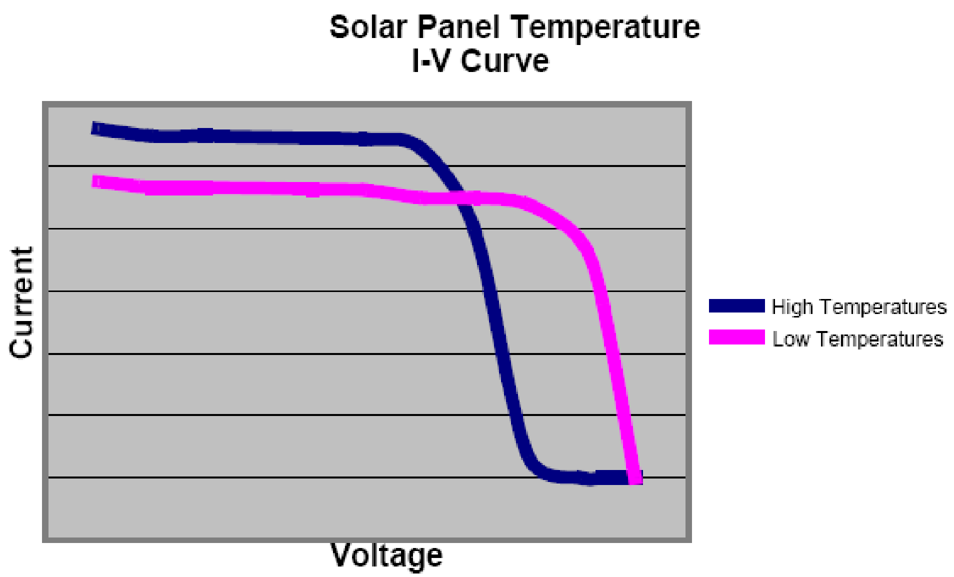
- Charge controllers and other electronics need to be as efficiency as possible to maximize the benefits
  - Typically implemented with a micro-controller

- MPPT compensates for the changing Voltage versus Current characteristic of the solar cell to increase the efficiency

Solar Panel Characteristics

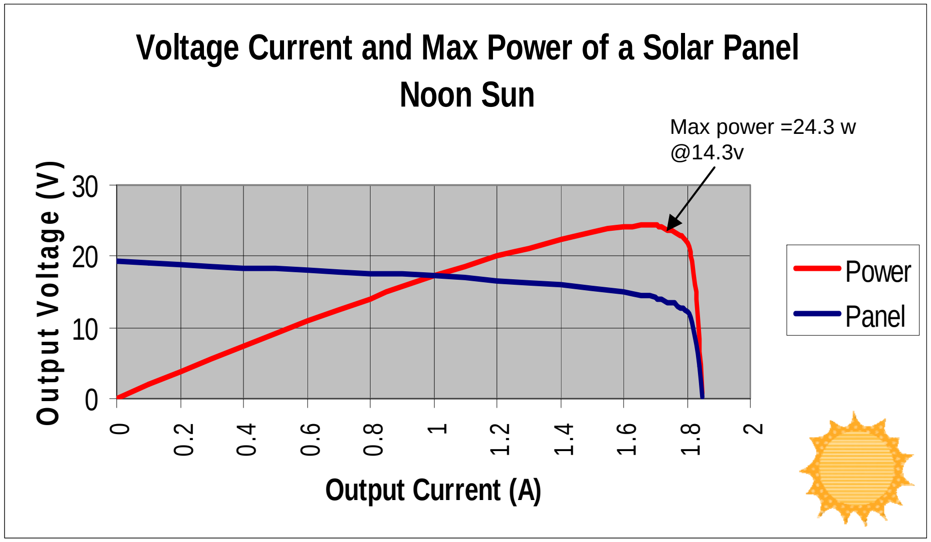
Extracting the maximum amount of power from the solar panel is difficult due to the nonlinearity and variability of the Voltage-Current (V-I) characteristic.

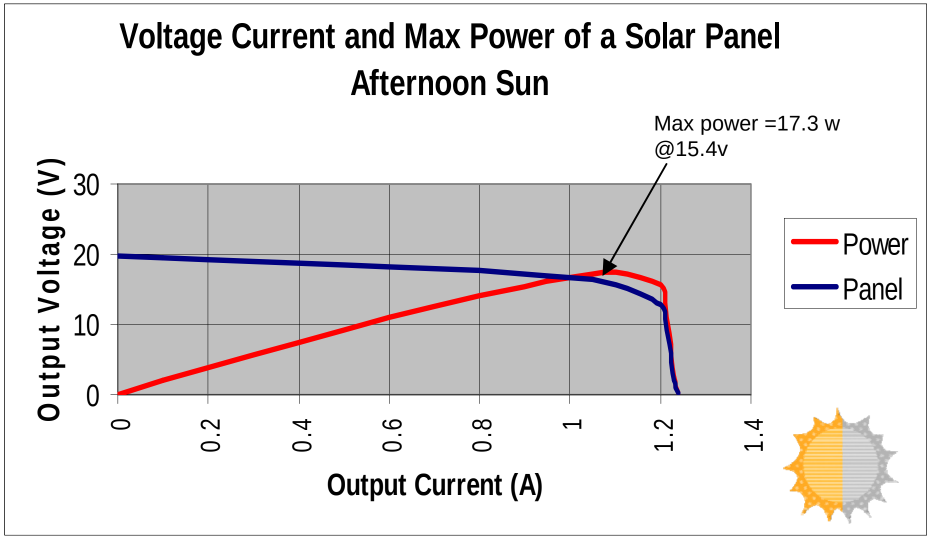


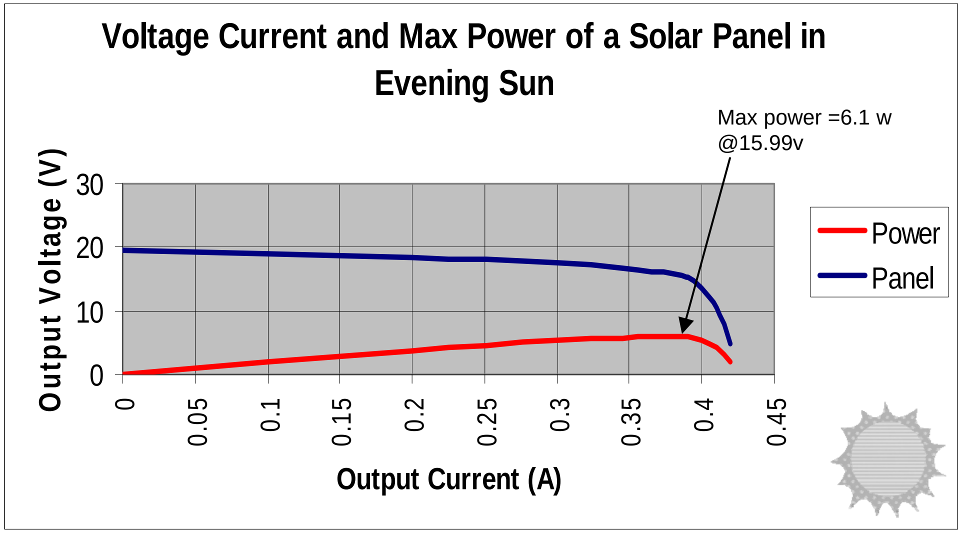


MPPT fools the panels into outputting a different voltage and current allowing more power to go into the battery by making the solar cell think the load is changing when you really are unable to change the load.

Power and Voltage for a Solar Panel







Solar Panel Charge Controller

- **Solution :**
  - **CS51221**
- **Target Application :**
  - **Solar Panel LED Street Lighting**
  - **Solar Panel Battery Charger**
- **Specification :**
  - **Input : 12 V – 24 V**
  - **Output: 12 V @ 2 A**
  - **Protection: Adj Current Limit, Input UVLO, Input OVLO**
  - **Maximum peak power tracking required**
  - **Efficiency: Target >80%**
  - **Isolation Required: YES – Prevent discharging the batteries**

Component/Topology Justification

- The topology was chosen as it can buck down to 12 V from the solar panel in the case of one battery
- The topology can also boost to 24 V in the case of 2 batteries or more and can be easily changed
- Aux rail available for remote transmission and monitoring
- Can accommodate panels as large as 90 W
- Implement maximum peak power tracking to improve efficiency
- Need to meet good efficiency, target costs and easy to implement

- CS51221 offers:
  - Isolated and non-isolated topology
  - Adjustable pulse-by-pulse current limit
  - External voltage reference

CS51221 - Voltage Mode PWM Controller

Value Proposition

The CS51221 fixed frequency feed forward voltage mode PWM controller contains all of the features necessary for basic voltage mode operation. This PWM controller has been optimized for high frequency primary side control operation.

Unique Features

- 1 A sink/source gate drive
- Up to 1MHz Fsw
- External voltage reference

Benefits

- High efficiency operation
- Optimize for size or efficiency
- Reduced component count

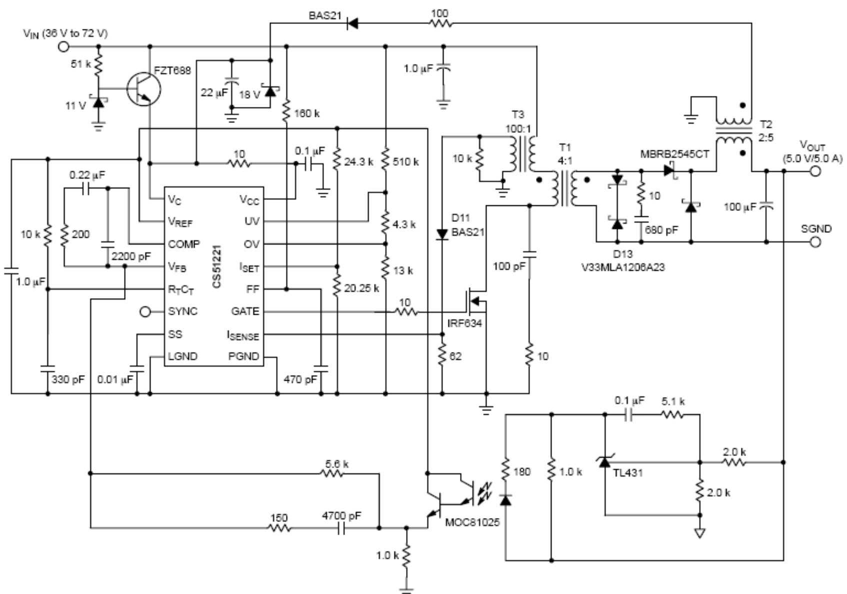
Others Features

- Programmable Max Duty Cycle Limit
- Programmable Pulse−By−Pulse Overcurrent Protection
- Overvoltage Protection with Programmable Hysteresis
- Bidirectional Synchronization

Market & Applications

- Consumer Electronics: PoE PD, …
- Automotive: Body electronics, Navigation, …
- Computing: Power supply, …
- Industrial: Power supplies, Process control, PoE PD, Solar Power Charger…

Application Data

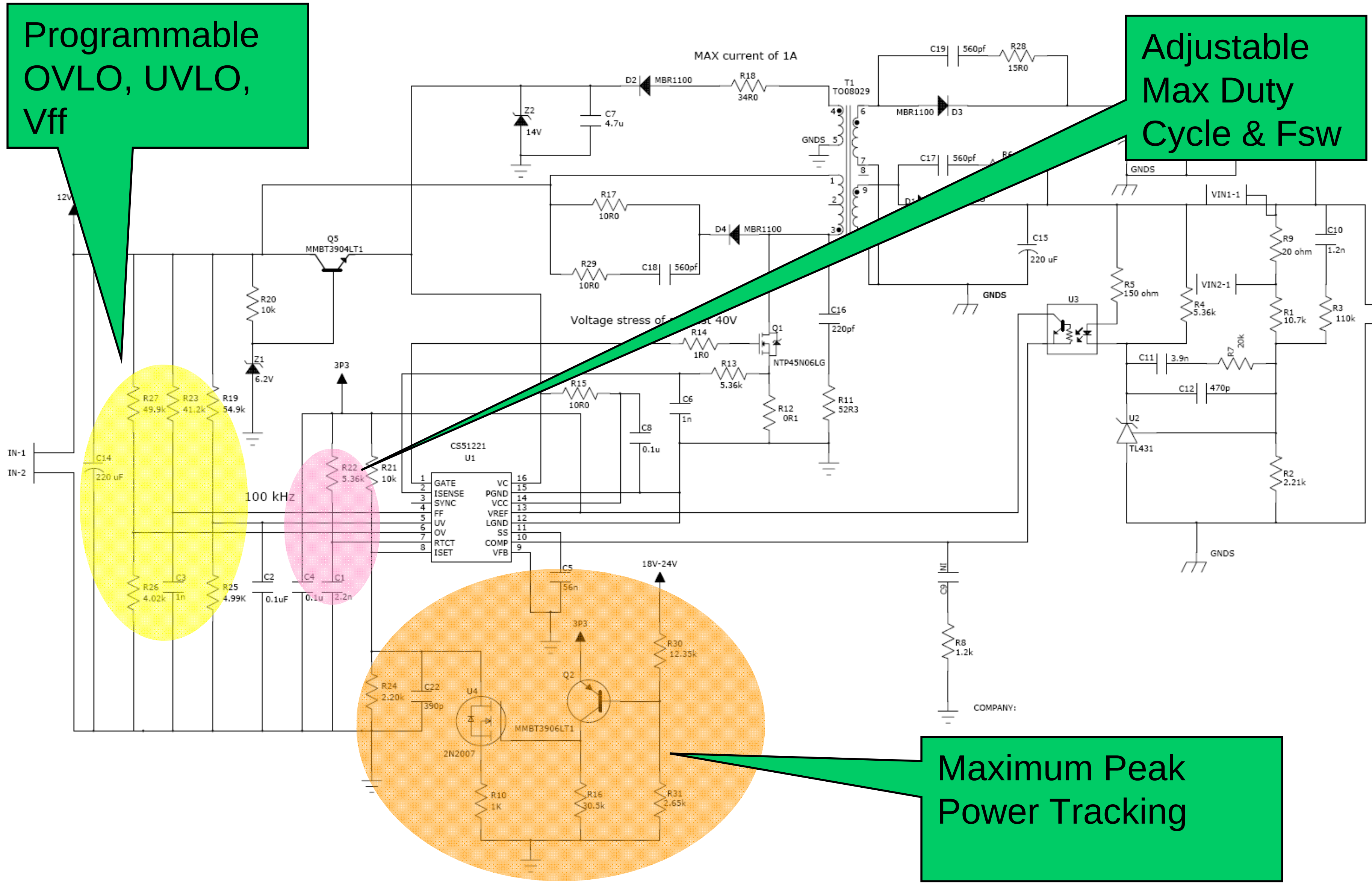


Capable of being configured as Forward, Flyback or Boost

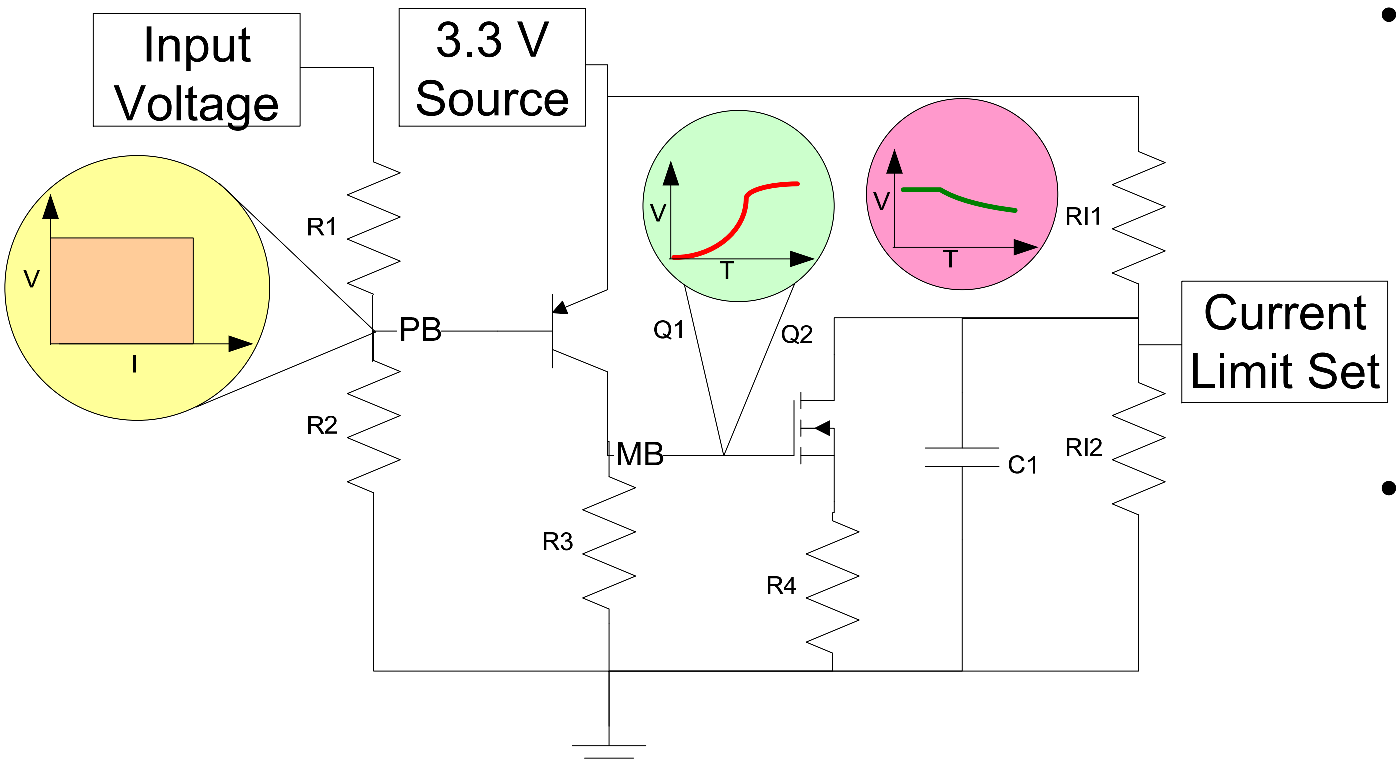
Ordering & Package Information

- SOIC-16
- CS51221: -40 to +125°C Tj

Circuit and Block Diagram



Implementing MPPT With the CS51221

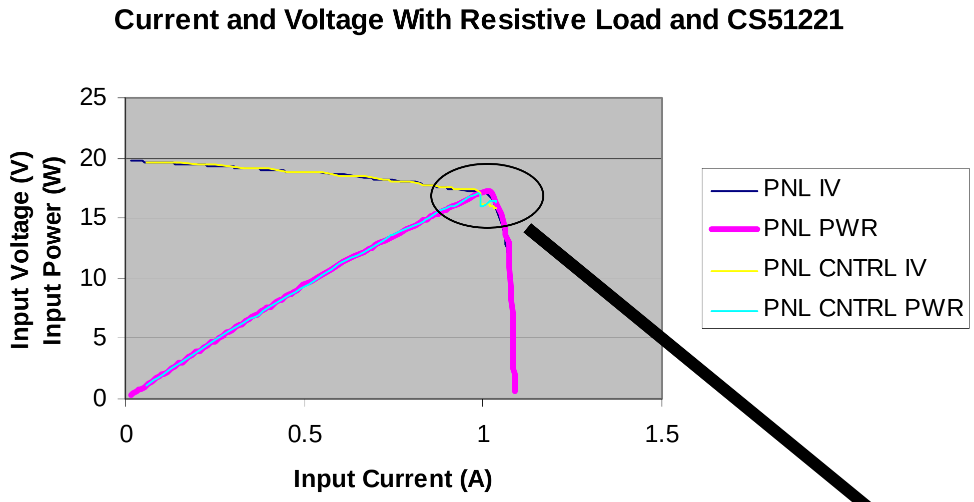


Eliminates the need for an expensive microcontroller

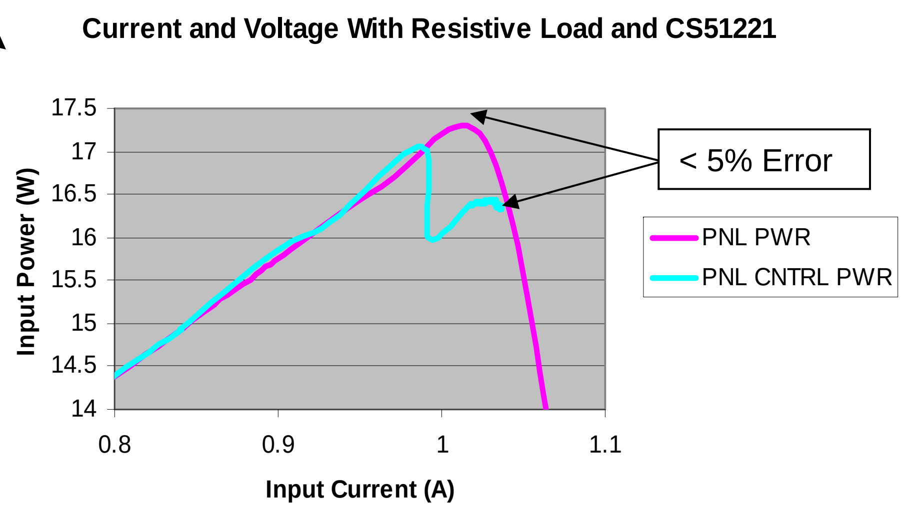
- MPPT is implemented by dynamically adjusting the current limit with the Iset pin

- Once the Input voltage drops the pulse by pulse current limit is lowered until the input voltage returns

Peak Power Tracking



Controller will find the peak power point and adjust dynamically to meet changing source characteristics

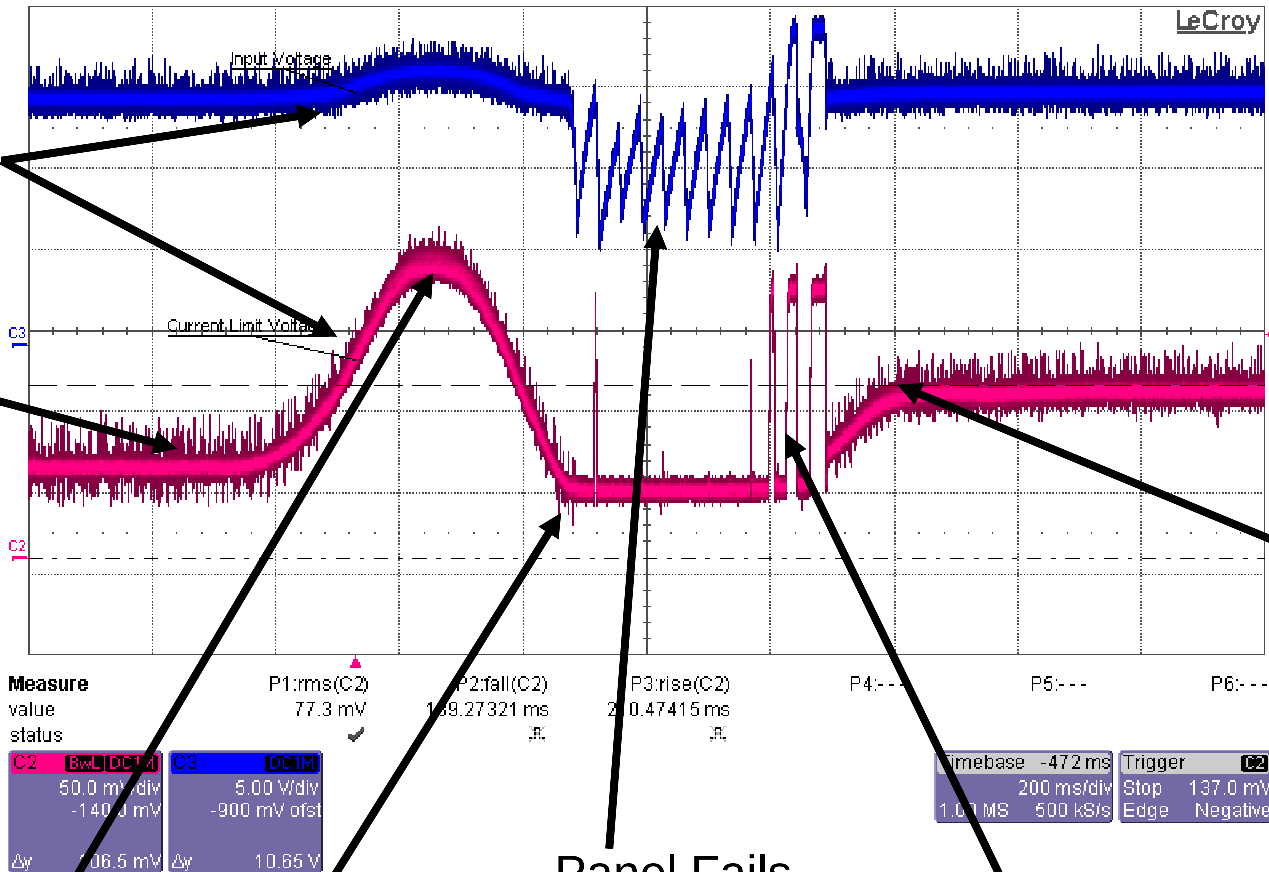


Controller tracks the maximum power the panel can produce within -5% error

MPPT – Dynamic Reaction to Full and Partial Sun

Sun Returns and Current Limit Adjusted

Solar Panel in Partial Shade



Input Voltage

Current Limit Voltage

Panel in 50% Shade

Full Sun

Panel in Full Shade

Panel Fails to Provide Minimum Power

Fast Moving Shade and Full Sun

MPPT Enables Lower System Cost

~30% more charge transferred from the panel to the battery

90 W Panel w/
Basic Charge Controller

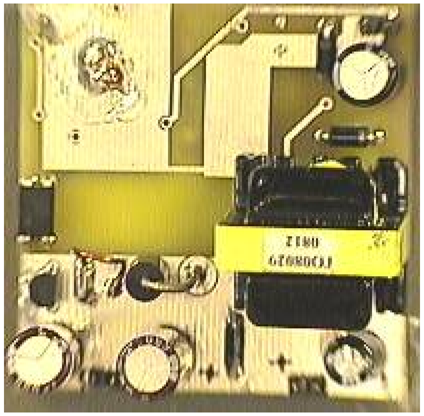
60 W Panel w/
MPPT

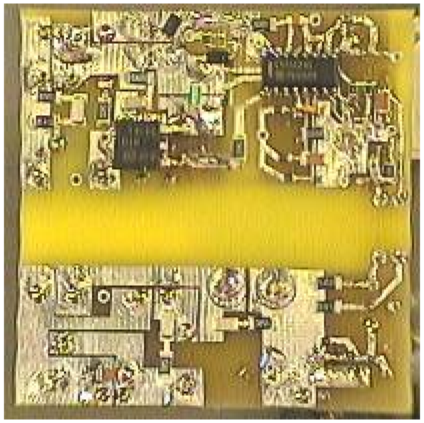
- MPPT enables a smaller size solar panel to be used
- ~$4/W for the panel x 30 W = $120 system savings

Reference Design

Device	Application	Input Voltage	Output Voltage	Output Current	Topology
CS51221	Solar Panel Battery Charger	12 V – 24 V	12 V – 14.4 V	2 A	Flyback

CS51221				
Characteristic	Min	Typ	Max	Unit
Output Voltage		12	14.4	V
Output Current		2		A
Oscillator Frequency		100		kHz

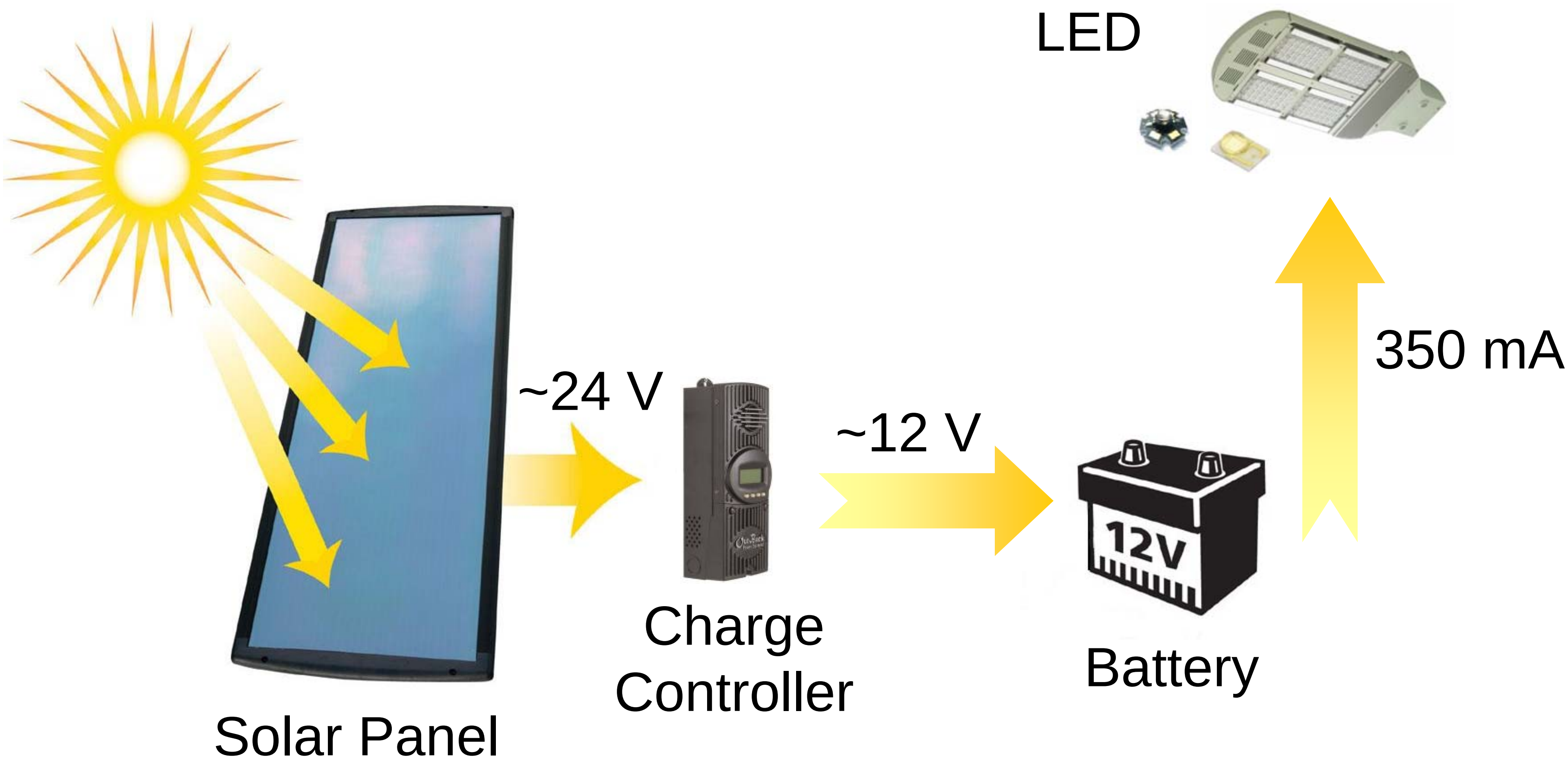




Note: Easily scalable to larger solar panels & multiple batteries

Driving HB-LED for Street Lighting Applications

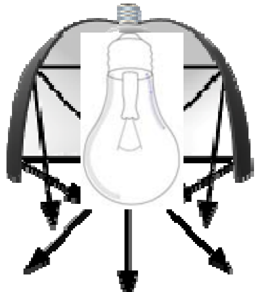
Solar Power – Block Diagram



Metal Halide Source Replacement

Number of LEDs Required

Lamp Type	Average Delivered Lumens*	Number of LEDs Req'd 2007**	Number of LEDs Req'd 2012***
70 W Metal Halide	2,100	18	12
100 W Metal Halide	3,500	30	20
150 W Metal Halide	5,450	46	31
175 W Metal Halide	7,700	66	44
250 W Metal Halide	10,600	90	60
320 W Metal Halide	15,200	130	86
400 W Metal Halide	16,500	141	94



Coefficient of Utilization
60%

* From HID bulb data sheets, includes 60% typical fixture CU

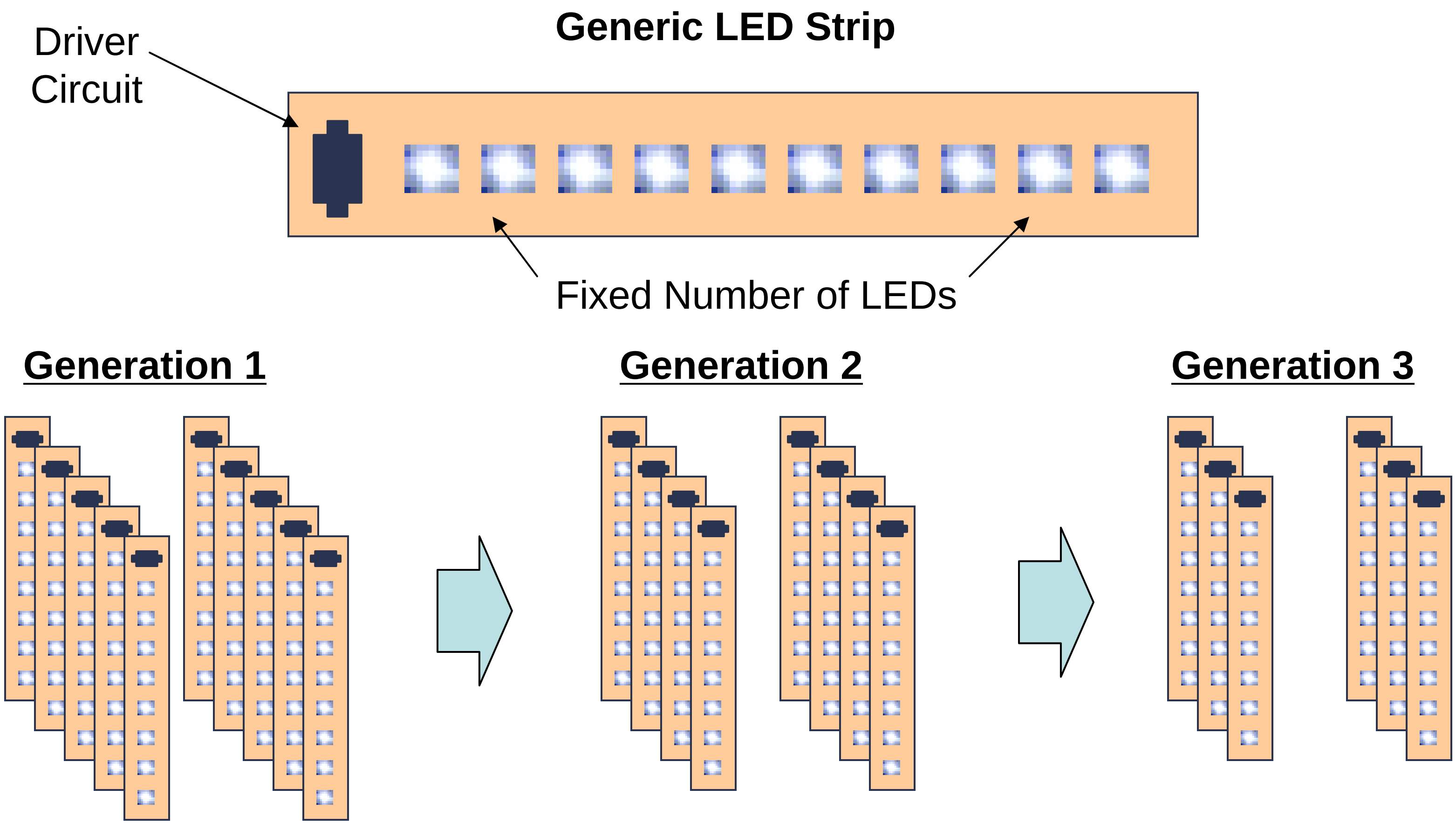
** Current best-in-class LED technology (Cree XLamp Q4 bin @ 6000K, 700 mA), includes 80% typical fixture CU. Assumes thermal equilibrium of LEDs (65°C T_j)

*** Based on DOE projections of LED performance improvement, 80% CU. Assumes thermal equilibrium of LEDs (65°C T_j)

- **LEDs make clear economic sense in lower wattage applications now, all MH applications in the near future**
- **Tradeoff on lifetime versus operating current should be considered based on ambient conditions**

Strategy #1 for Coping with Rapid Change in LED Performance

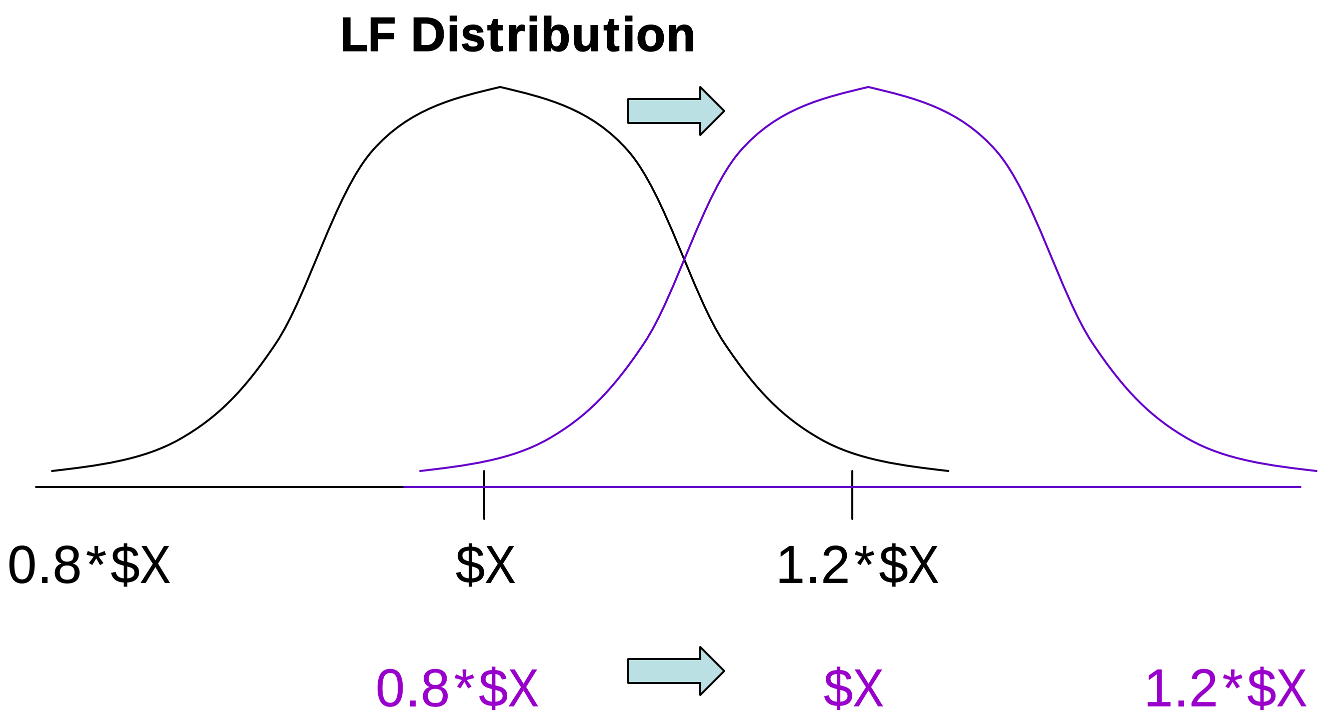
Modular Approach to MH Source Replacement



A modular design approach can yield constant photometric output while facilitating ongoing cost reductions each time LED brightness is improved

Strategy #2 for Coping with Rapid Change in LED Performance

Lifetime Analysis - Aim Ahead of the Duck…

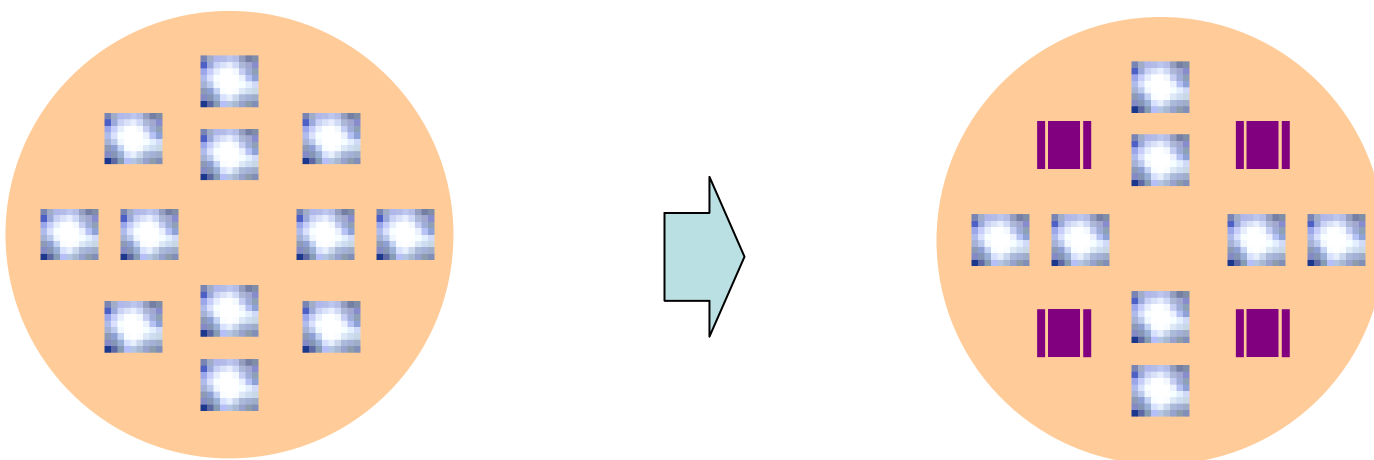


Prototyping with the highest performance LEDs currently available is more expensive, but can yield a more competitive and longer life product over the long term

Strategy #3 for Coping with Rapid Change in LED Performance

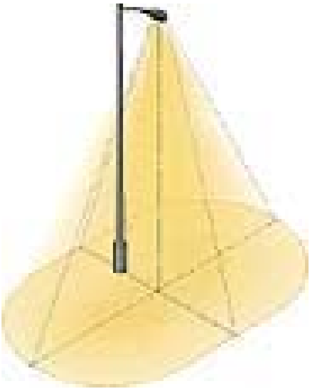
Plan for BOM savings

Generation 1 **Generation 2**



25% brighter LEDs can also mean 25% fewer LEDs. Need to plan flexibility in your driver design to accomplish this

LED Street Light Design



What's important?

- Type III street lighting pattern
- 4200 initial lumens on target
- 12 V Battery Source
- Reasonable optical efficiency; "single layer optics"
- Manage junction temperature for lifetime

What's less important…

- Uniformity (seeing spots is OK…)
- Size

LED Assumptions

1. Output: 100 lm Typical at 350 mA @ Tj = 25 deg C
2. Drive current = 350 mA
3. Optical losses of 12% due to single layer, well coupled optics
4. Max ambient = 40 deg C
5. Driver losses = 10% (90% efficiency target)

Table 1 Major High-Output White LEDs with 80lm (min) on 1W Input

Manufacturer	IDEC Opto Device	Avago Technologies	OSRAM Opto Semiconductor			Citizen Electronics		Sharp	Seoul Semiconductor				Nichia	Matsushita Electric Industrial	Philips Lumileds	
Model	IDEC Sunshine	ASMT-MW20	LE W E2B White	LE W E3B White	LE UW E3B 1000lm	CL-652	CL-102	GW5B series	P1		P4	Acriche	NS6x083A	LUGA	LUXEON K2	LUXEON Rebel
Appearance																
Input power	2.57W	2.8W	10W (max 18W)	15W (max 27W)		1.2W	3.5W	3.6W	2.5W	5W	1W	2W	1.1W	8.5W	2.39W	2.2W
Output color	White/ Incandescent	White	White/ Incandescent (LE CW E2B/E3B)		White	White/ Incandescent	White/ Incandescent	White/ Incandescent/ enhanced color rendering	White/ Incandescent	White/ Incandescent	White	White/ Incandescent	White/ Incandescent/ enhanced color rendering	White/ Incandescent	White 1*2/white 2*3/ Incandescent	
Luminance	White: 180lm Incandescent: 115lm	140lm (at 700mA)	White: 150lm to 520lm Incandescent: 100lm to 450lm	White: 330lm to 820lm Incandescent: 210lm to 610lm	White: 610lm to 1120lm	White: 85lm Incandescent: 57lm	White: 249lm Incandescent: 150lm	White: 260lm Incandescent: 190lm Enhanced: 170lm	White: 103lm Incandescent: 70lm	White: 178lm Incandescent: 120lm	100lm	White: 85lm Incandescent: 68lm (enhanced color rendering model is 60lm)	White: 80lm Incandescent: 70lm Enhanced: 52lm	White: 400lm Incandescent: 280lm	White 1: 100lm White 2: 100lm Incandescent: 75lm	White 1: 180lm White 2: 145lm Incandescent: 110lm
Emission efficiency	70lm/W (white, at 270mA)	65lm/W (at 350mA)	50lm/W (white, at 350mA)		65lm/W [illegible]	70lm/W (white, at 350mA)		78lm/W [illegible]	42lm/W [illegible]	36lm/W [illegible]	88lm/W [illegible]	42lm/W	70lm/W (white, at 300mA)	47lm/W (white, at 800mA)	50.4lm/W (white, at 350mA)	90lm/W (white, at 350mA)
Life	40,000 hours (brightness down to 70%, Tj *1=120°C)	50,000 hours min (brightness down to 30%, Tj=125°C)	50,000 min (brightness down [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30,000 hours (brightness down to 70%, Tj=70°C)	40,000 hours (brightness down to 70%, Tj=90°C)	30,000 hours (brightness down to 70%, Tj=90°C)	50,000 hours (brightness down to 70%, 1000mA)	50,000 hours (brightness down to 70%, 700mA)
Package side	15 x 15 x 1.1mm	10 x 10.85 x 3.3mm	23.1 x 20.2 x 2.9mm (5.6mm [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] x 5.08mm	25 x 25 x 7.15mm	6.5 x 4.85 x 1.35mm	37 x 12 x 2.3mm	11.95 x 7.35 x 5.82mm	4.61 x 3.17 x 2.1mm
Thermal resistance	13K/W	8K/W	4.2K/W	3K/W		26K/W	6K/W	5K/W	6K/W	4K/W	6.5K/W	10K/W	10K/W	1.5K/W	9K/W	10K/W
Remarks	Samples ¥4,000. Only 1.1mm thick. Wide color temperature (2,800K to 6,000K). Developing models with same output power but 30% higher luminance.	Samples ¥750. 5W model to be added in early 2008.	1,000lm samples shipping. Sale planned from fall 2007. E2B series mounts four chips, E3B series mounts six.			Can be wired and mounted on either side	Samples ¥5,000. Plans to ship 280lm model with same output in 2007, and model achieving 500lm at 7W	Samples ¥3,000. Enhanced color rendering models with color temperature of 5,000K and 6,500K	2.5W samples ¥1,000, 5W samples ¥2,000. Also available with substrate. Square models 25 x 25 x 5.75mm, star-shaped 19.9 x 21.13 x 5.75mm		Samples ¥1,000. Handles up to 1A input. Also available with substrate	Runs off 110VAC home power. Samples ¥1,500. Also offers 4W and 8W models in addition to 2W type	Samples ¥200. Enhanced color rendering models also available with color temperatures of 2,400K to 4,200K	Ceramic substrates. Devices mounted as flip-chips	Implemented as single devices. Samples US$3.40 max. Also available as star-shaped products measuring 20.2 x 19.9 x 7.5mm	Implemented as single devices. Samples US$4.40 max. Input currents of 350mA to 1000mA

*1 Tj: Junction temperature *2 White 1: Color temperature 4,500K to 10,000K *3 White 2: Color temperature 3,500K to 4,500K

Many LED Options Available

Sizing the # of LEDs for the Application

First order estimate:

- Number of emitters
- Total wattage

Emitter output = 100 lm @ Tj 25.

Derate for elevated Tj; assume Tj = 90 deg C.

At 90 deg C, emitter output is down 20% = 80 lumens per emitter.

Optical losses – 12% → 71 Lumens per emitter.

4200 lumens required/71 lm per emitter = 60 emitters

Vf= 3.6 volts * .350 A = 1.26 W (60 emitters x 1.26 W = 76 W)

Worst Case driver losses: = 15% => *Total fixture wattage is ~89 W*

LED Street Light

- **Solution :**
  - **NCP3066**
  - **Configured as a Boost Controller**

- **Target Application :**
  - **Solar Panel LED Street Lighting**
  - **LED Light Bar**

- **Specification :**
  - **Input : 12 V battery**
  - **Output : 350 mA**
  - **Protection: Current Limit, Under Voltage Lockout (UVLO)**
  - **Efficiency: Target >90%**
  - **Isolation Required: NO**

Component/Topology Justification

- Supports modular Constant current architecture
- Configurable output LED current from 350 mA to 1 A
- Able to drive 5-10 LEDs in series
- Cost effective system approach
- Easy to implement

- NCP3066 offers:
  - Dedicated ENABLE pin for low standby power
  - Average current sense (current accuracy independent of LED Vf)
  - 0.2 V reference for small / low cost sense resistor
  - User adjustable peak current limit to maximize battery lifetime
  - No loop compensation required

NCP3066 – Constant Current Multi-mode Regulator

Value Proposition

The NCP3066 is a switching regulator designed to deliver constant current to high power LEDs. The device has a very low feedback voltage of 235 mV (nominal) which is used to regulate the average current of the LED string.

Unique Features

- F_{sw} from 52 to 250 kHz
- Wide V_{in} from 3 to 40 V
- Multi-topology
- ENABLE pin

Benefits

- Optimize component size and efficiency
- Allows use in many versatile applications
- <100 uA standby

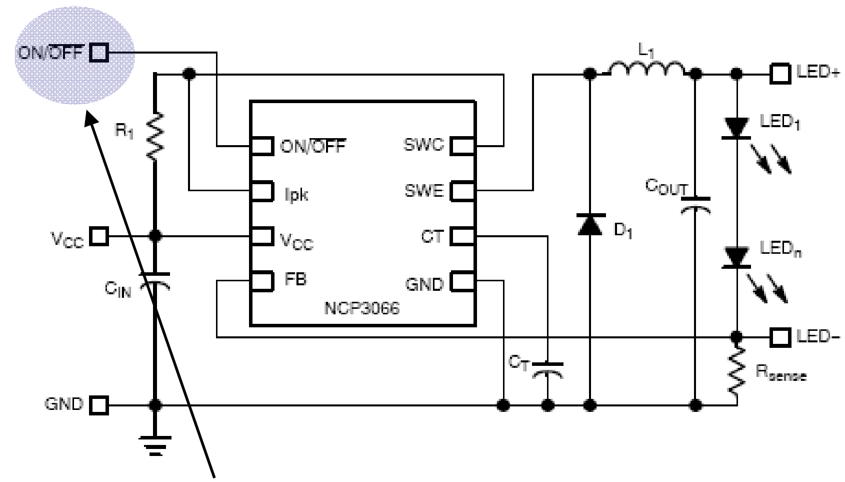
Others Features

- 1.5 A peak current
- Ability to add external transistor to increase output current in buck mode or increase voltage in boost mode
- 2% accurate internal reference over temperature

Market & Applications

- **Consumer Electronics:** CRT, LCD TVs, STB, DVD, …
- **Automotive:** Airbag, Body electronics, Brake systems, Infotainment, Navigation, …
- **Computing**: Power supply, Peripherals (Printer, Scanner, Graphic card, …)
- **Industrial:** Power supplies, Process control, Home energy and control, Security systems, …

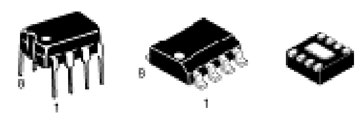
Typical Application diagram & Package info



ENABLE Pin
- **PWM dimming**
- **Low power standby**

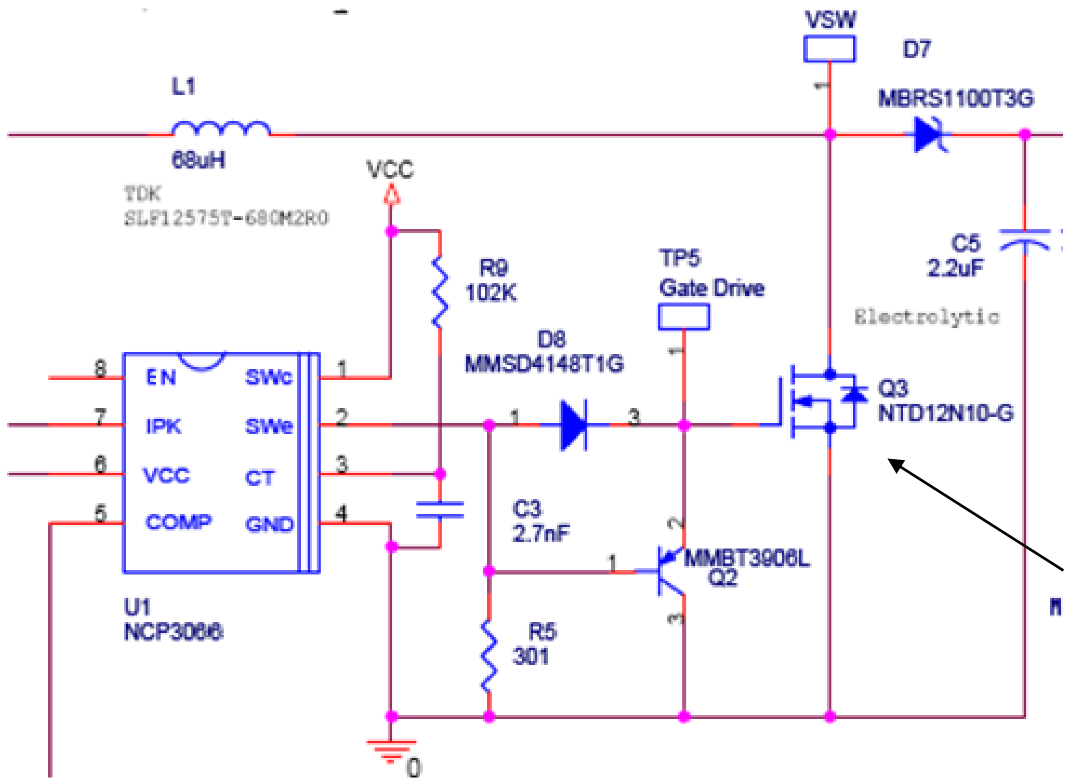
Ordering info & Support

PDIP-8, SOIC-8, DFN-8
NCP3066: -40 to +125°C Tj



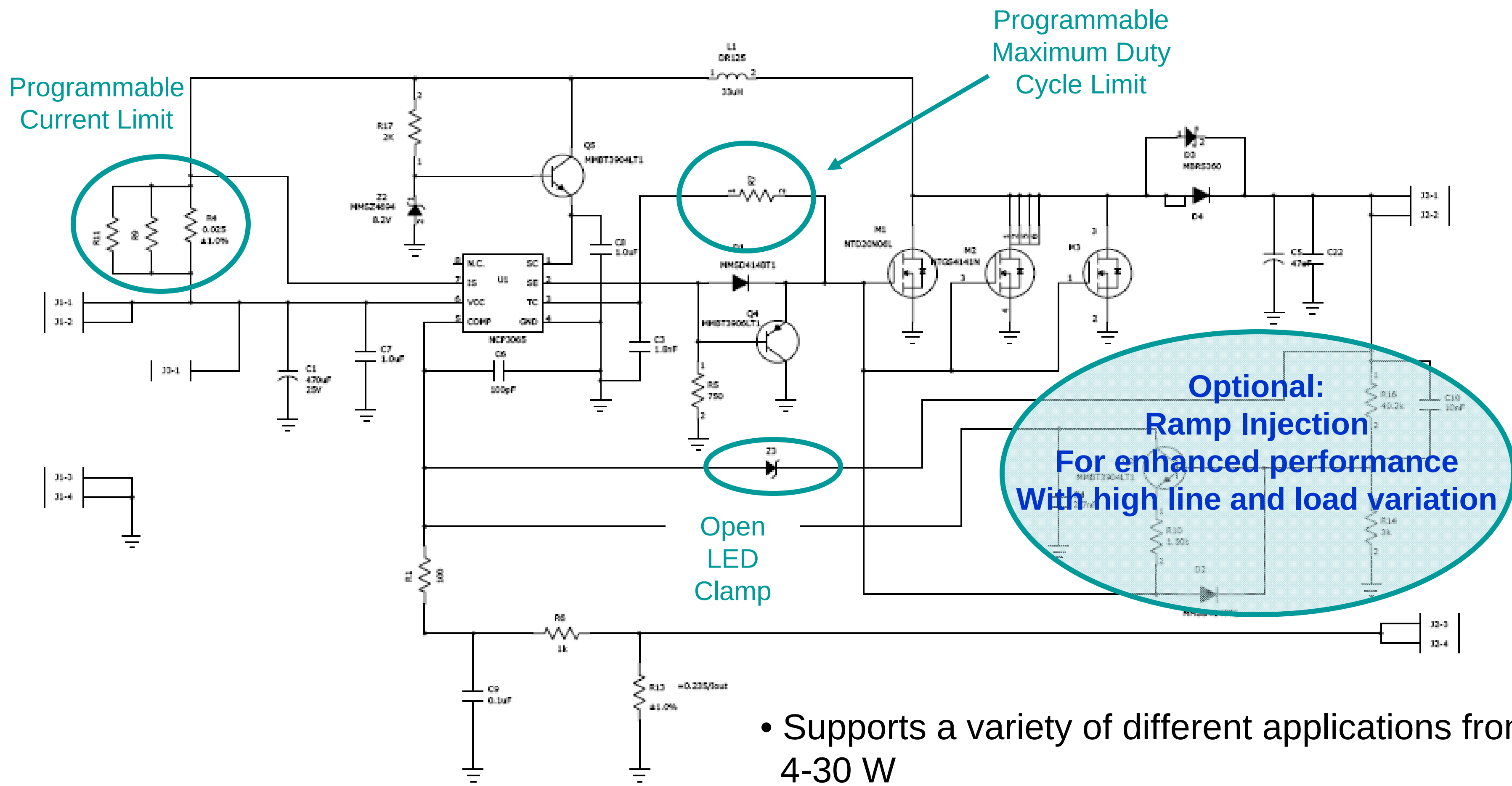
NCP3066 as a Controller

- Boost: Higher output voltage and/or current is desired
- Buck and SEPIC topologies also supported
- Controller efficiency can be optimized for highest performance
- Simple drive circuit to support external MOSFET or Bipolar



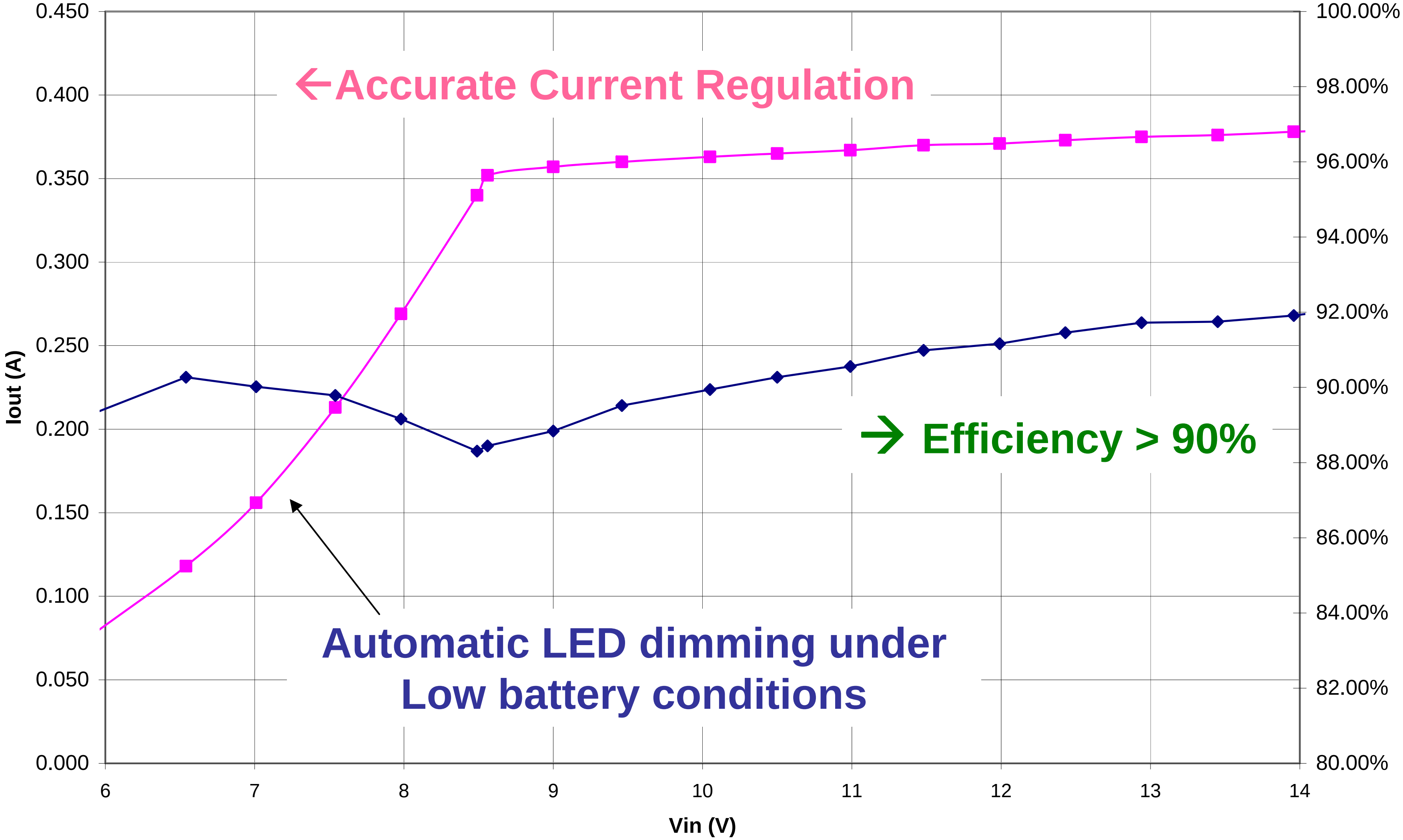
Boost example with 100 V External N-FET From a 24 V Source

Boost Controller Schematic



- Supports a variety of different applications from 4-30 W
- Options for different MOSFETS (Gate Clamp)

Iout vs. Vin of NCP3066 Boost Driving 8 CREE XRE



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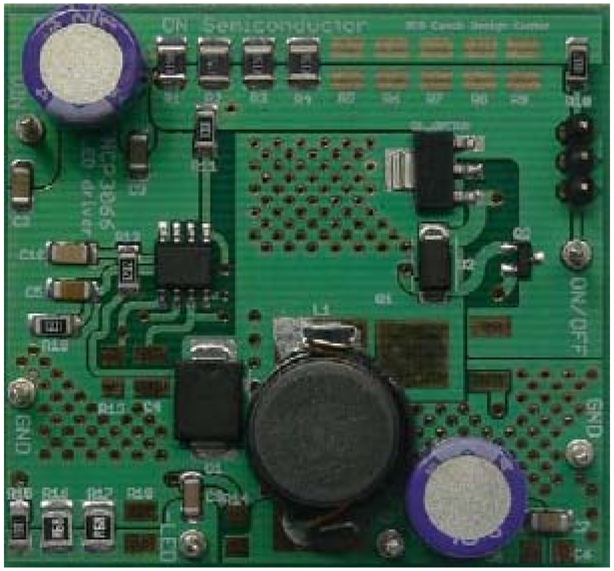
Reference Design LED Street Light

Device	Application	Input Voltage	Output Voltage	Output Current	Topology
NCP3066	LED Street Light	+12 V Battery	~25 V	350 mA	Boost

NCP3066				
Characteristic	Min	Typ	Max	Unit
Output Voltage		25		V
Output Current		350		mA
Oscillator Frequency		250		kHz
Output Voltage Ripple		8		%



Conclusion

- Highly efficient solutions like the CS51221 with MPPT are needed to maximize the efficiency from solar panels

- The NCP3066 provides a flexible/expandable solution for driving LEDs from a battery source

- Expectations are increasing for solar-powered LED lighting to become the environmentally friendly outdoor lighting solution for the 21st century

Backup

Guangzhou, China

Courtesy of Multi-Cell Semiconductor Lighting Technology Co., Ltd.

Hybrid Solar / Grid Powered Street Lamps

Split, Croatia

Courtesy of Schréder

Warm White Street Lamps

For More Information

- View the extensive portfolio of power management products from ON Semiconductor at www.onsemi.com
- View reference designs, design notes, and other material supporting the design of highly efficient power supplies at www.onsemi.com/powersupplies