



# Digital Power Technology Enables the Low-Cost Quality-Light SSL Lamps

## A Simple Reliable and Flexible Digital LED Driver

**iWatt Inc,  
Los Gatos, CA  
09.2011**

**2011 电源网LED专题论坛**

# How to Afford High-quality LED Lamps in Home? **iWatt**

Intelligent AC-DC and LED Power™



**So Low  
Cost <\$**

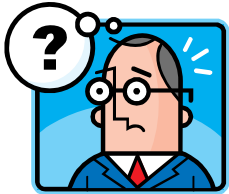


**Cost \$\$**

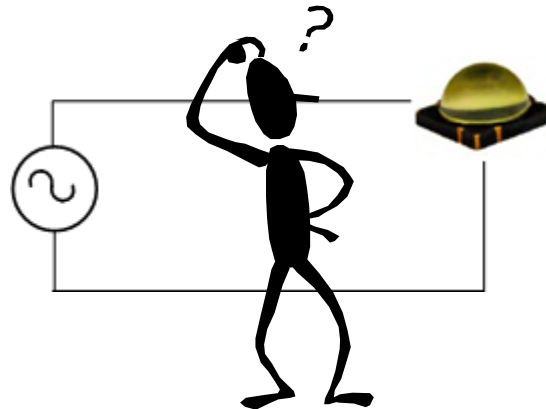
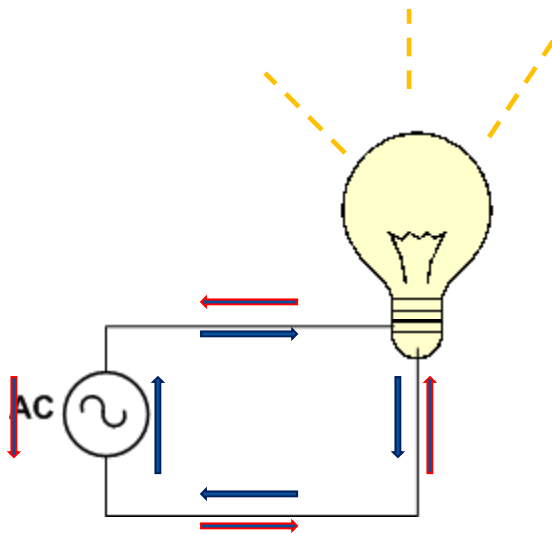
**Light Quality**

**Dimmer Compatibility**

# Can LED Produce Light without Driver?



Can LED produce light without driver?

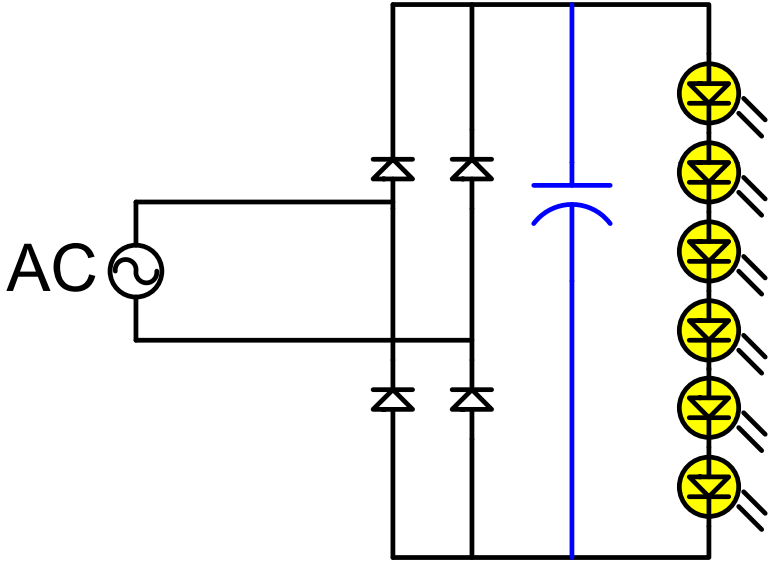
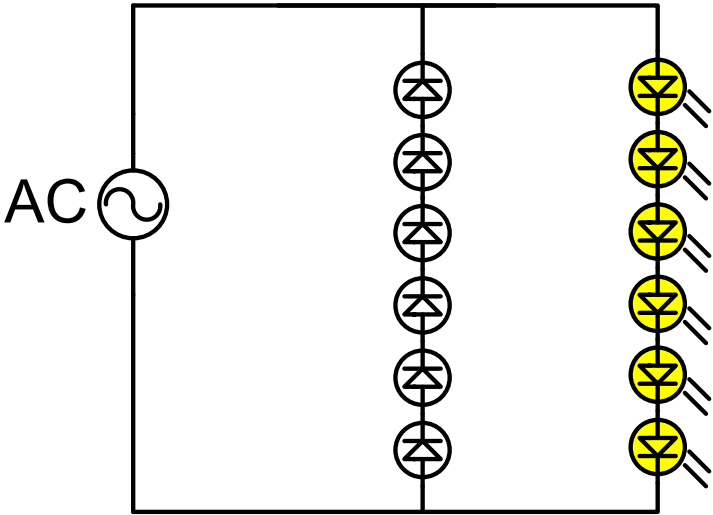


**It is a DC current, flows one-direction only to generate white light**

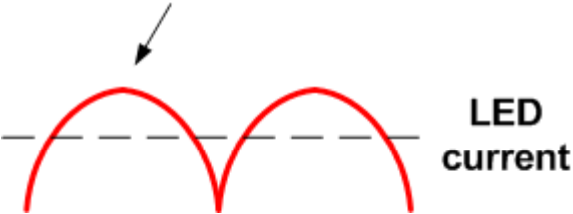
# A Simple Switch without Driver



Does it work very well?



Peak LED current



- ✓ Cheap
- ✓ Simple
- ✓ Small

# Important Factor: Light Quality



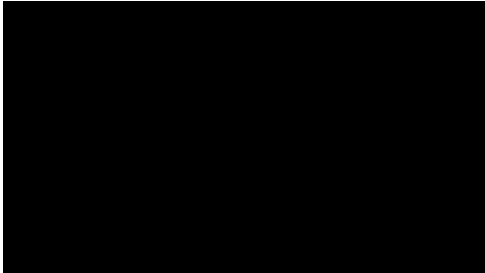
## Light Quality and User Experience

Driver  
Related

Flickering  
Blinking  
Acoustic Noise

Dimmer Compatibility

# Let's Watch a Short Clip Video



## Biological Effects and Health Hazards From Flicker, Including Flicker That Is Too Rapid To See

2/15,  
IEEE Stand:  
<http://grouper.ieee.org/groups/standards/IEEE1789/>

**Purpose of Report:** The goal of this report is to perform an objective scientific summary of the effects on human health for both visible and invisible flicker with attention drawn to implications for the design of LED lighting. Specifically, contributions of this report include making the reader aware of

1. Risks of seizures due to flicker in frequencies within the range  $\sim 3$ - $\sim 70$ Hz;
2. Health concerns due to invisible (not perceivable) flicker at frequencies below  $\sim 165$ Hz including, but not limited to, headaches, migraines, impaired ocular motor control, and impaired visual performance;
3. The differences between "visible" flicker and "invisible" flicker and any relation to health risks;
4. A few, typical driving approaches in LED lighting that may produce flicker.

Health concerns due to invisible (not perceivable) flicker below  $\sim 165$ Hz including, but not limited to, headaches

# Requirement for the Driver Module(JEL 801)

## 9.2 制御装置の出力電流波形 (Output current waveform for the driver)

制御装置は試験用 L 形口金付直管形 LED ランプを使用し、定格入力電圧で動作させる。試験用 L 形口金付直管形 LED ランプが安定した後、全光時のランプ電流波形は、ランプのちらつき（フリッカ）抑制のため、次の条件に適合しなければならない。（調光時については検討中）

- a) 出力電流の半サイクルごと出力電流ピーク値の差は、4%以内でなければならない。

この要求事項の目的は、入力電圧の半サイクルごとの出力電流波形の不一致を防止するための規定である。

- b) ランプ電流波形のリップル率は 1.3 を超えてはならない。波形の周期は 100 Hz 以上であること。  
（高周波成分については検討中）

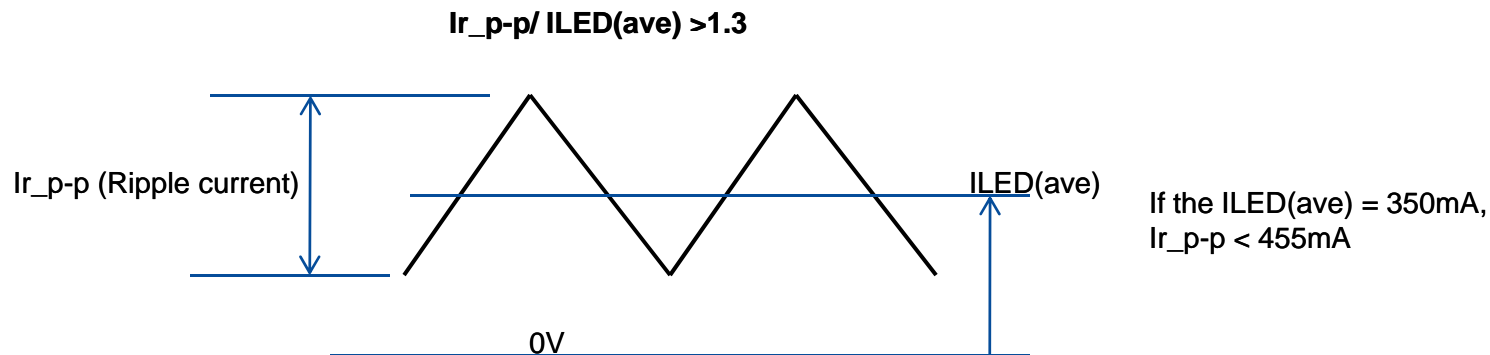


**In order to avoid flicker,**

**a) difference of the peak output current for each half cycle(AC) should be less than 4%**

**b) Ripple ratio of the lamp current should be less than “1.3”**

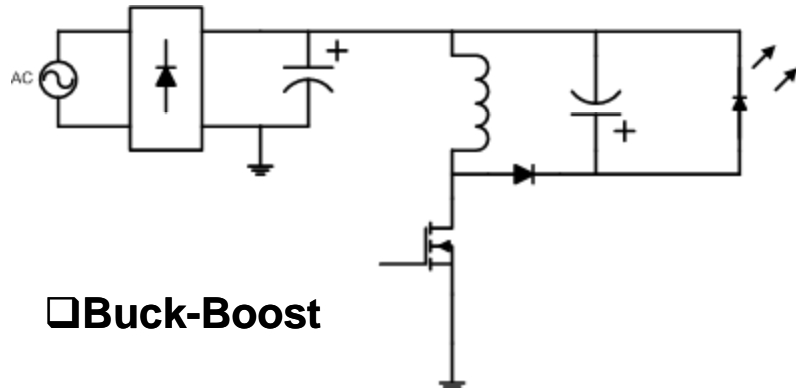
**ripple frequency should be > 100Hz**



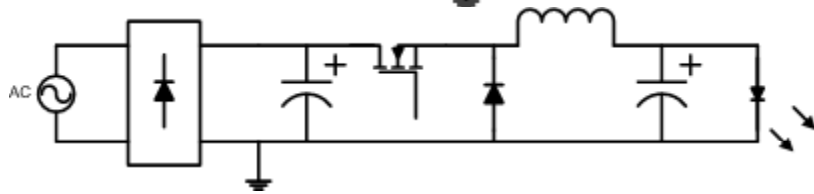


# Offline LED Lamp Driver Topologies

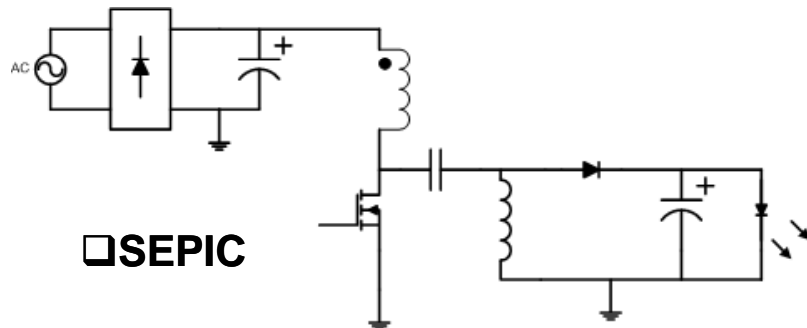
## Non-isolated



□ Buck-Boost

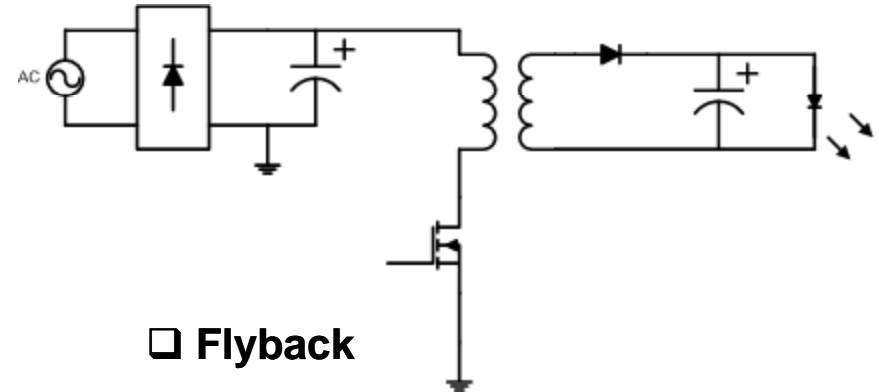


□ buck



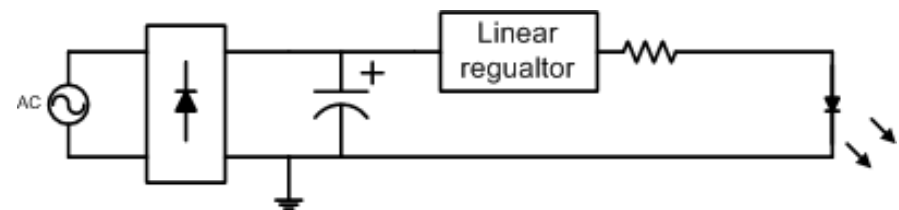
□ SEPIC

## Isolated



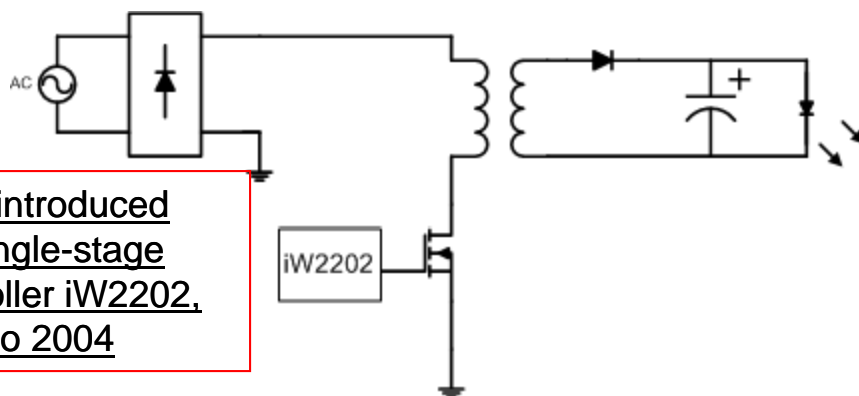
□ Flyback

## Linear



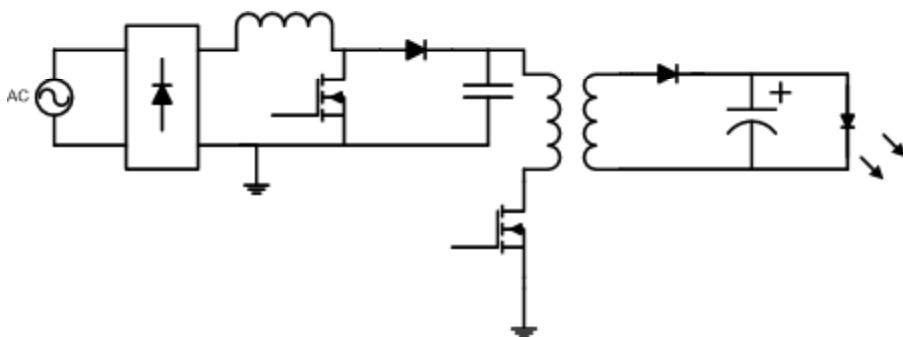
# Single-stage Vs 2-stage Solution

## Basic Flyback: Single-stage Solution



iWatt introduced the single-stage controller iW2202, back to 2004

## Boost + Flyback: Two-stage solutions



### Advantage

- Simple
- No High-voltage bulk e-cap

### Disadvantage

- Concerns of invisible flicker < 150Hz
- Line frequency ripple current
- Lightning Surge
- Hot-swap
- Large Output Capacitor
- Hard to start-up

### Advantage

- Easy for impedance balance between dimmer and LED current regulation

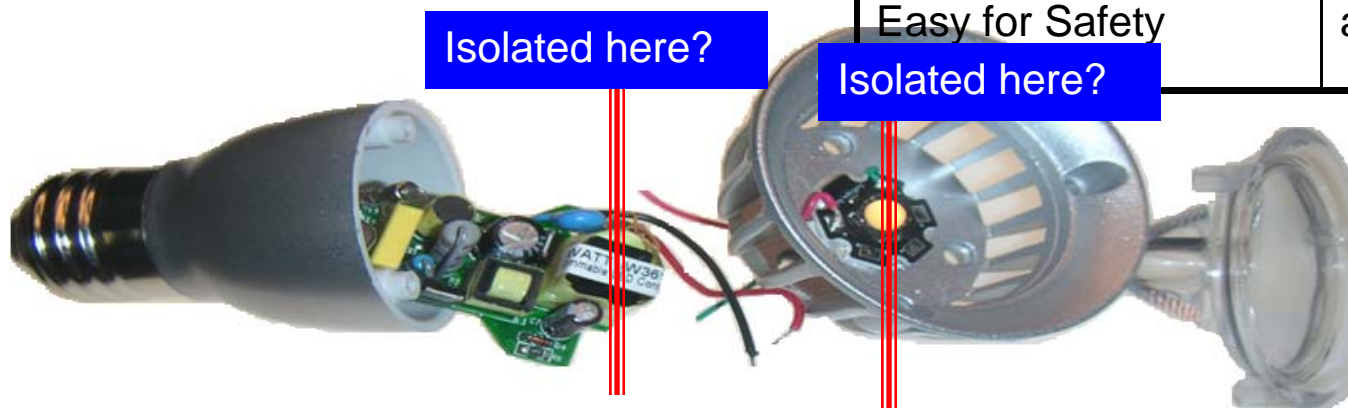
### Disadvantage

- More components

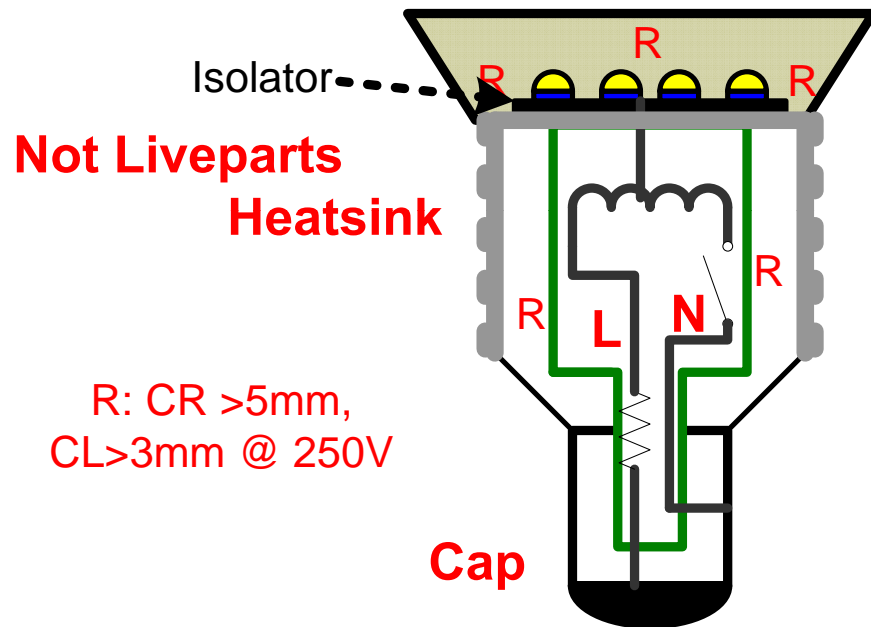
# Driver should be Isolated or Non-isolated?

- Isolation between AC socket and the exposed surface is required
- Isolation can be done in the driver board by transformer
- Or isolation can be done between the emitter and heat sink
- Or the whole lamp is isolated

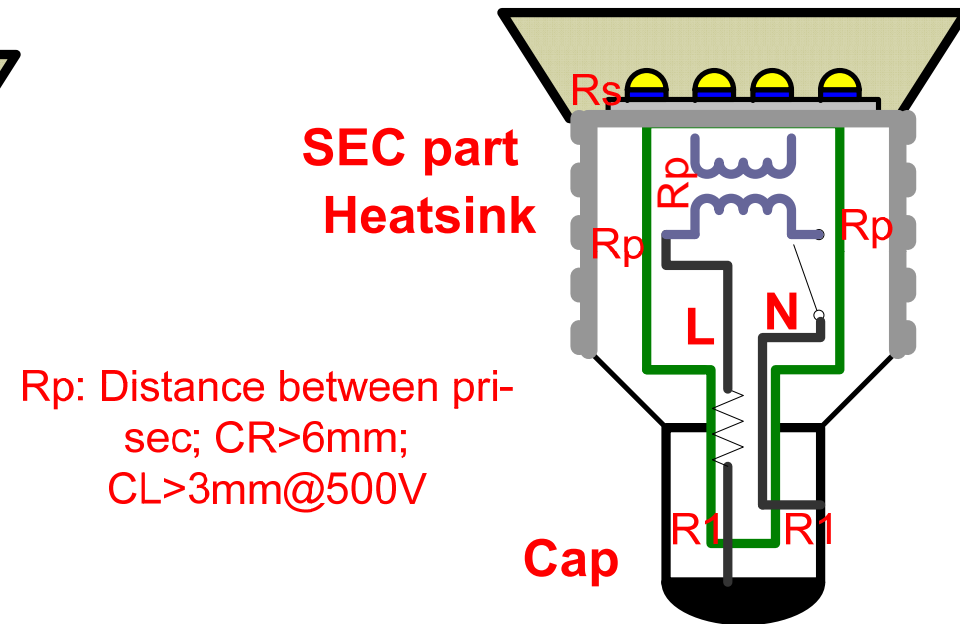
Isolated drivers	Non-isolated drivers
Suitable for high-power high-current low-voltage	Suitable for low-power high-voltage low-current
More components, less power efficiency	Simple, low cost
Easy for mechanical design and thermal management	Easy for electric driver board design
Easy for EMI design, Easy for Safety	Challenges for EMI and safety



# LED Lamp Safety Regulation



▪ Non-isolated Driver



▪ Isolated Class 2 driver

Note: For information only, please refer to UL1993/EN60598/UL8750

# Ownership Cost with Safety Structure

- Driver Electrical BOM Cost may not reflect the total ownership cost
- Non-isolated driver has the lower BOM cost, but may significantly cost more
- Total ownership cost need to be evaluated when you select the topology:

- Isolated or non-isolated
- Lamp structure
- # of LEDs
- Output lumens

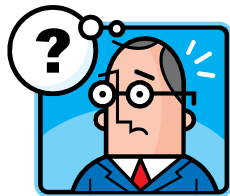
- Caution: LED array/chip structure may make difference as well. Some LED chip may be achievable for non-isolated, some may not.



# Dimming LEDs with Existing Wall Dimmer

- CFL is known with the poor dimming performance with standard wall-dimmer. What about LEDs?
- The retrofit dimmable LEDs with the standard wall-dimmers are more energy efficient and have better light control.

**More Challenges, Dimming with no-flicker, a basic requirement**



How many different dimmers have to work with?  
Maybe hundreds?



# Challenges on the Dimmable LED driver Design **iWatt**

Intelligent AC-DC and LED Power™

- The #1 challenge is to replace the socket of A-lamps with LED lamp, while maintaining compatibility with existing dimmers.

- Existing wall dimmers are designed to drive purely resistive A-lamp loads. When it drives a capacitive load or current source, the dimmer may not work properly.

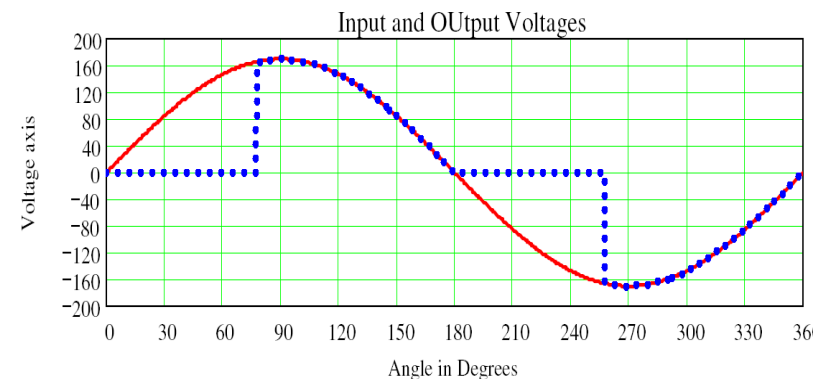
- Different dimmer types:

- Leading-edge dimmers, Trailing-edge dimmers, Smart Dimmers
- In case the LED lamp can not work properly with certain dimmers, the LED lamps should provide certain safety protections to prevent from fire, leakage current etc.

- No flicker

- AC-cycle inrush current

- Audible Noise



# A Low-cost Quality-light Solutions:

One platform configures all you need

PF>0.9, Low THD, All-dim

PF>0.7, High  $\eta$ , All-dim

Low PF, Simple, Low-cost

Non-isolated,

DC dimming

High quality light control, >150Hz Dimming Frequency

High Dimmer Compatibility: Smooth, seamless, wide range

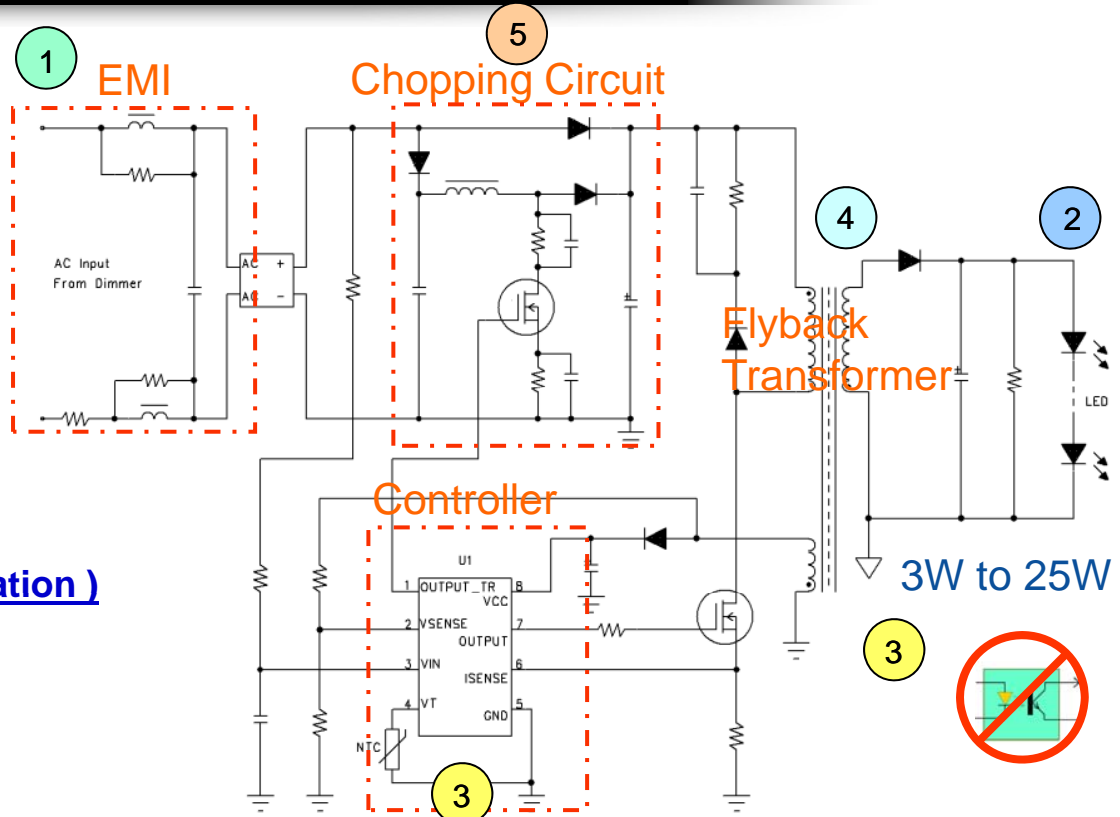
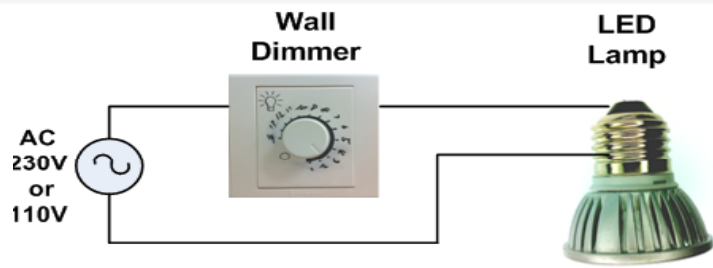
Parallel with more lamps per dimmer

Hot-swap driver module and Emitter

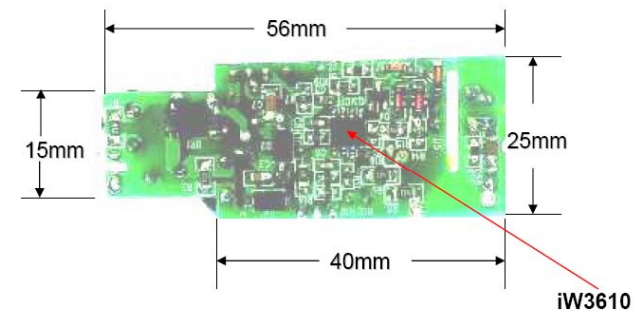
Tolerate more line distortion and surge with tight LED Current



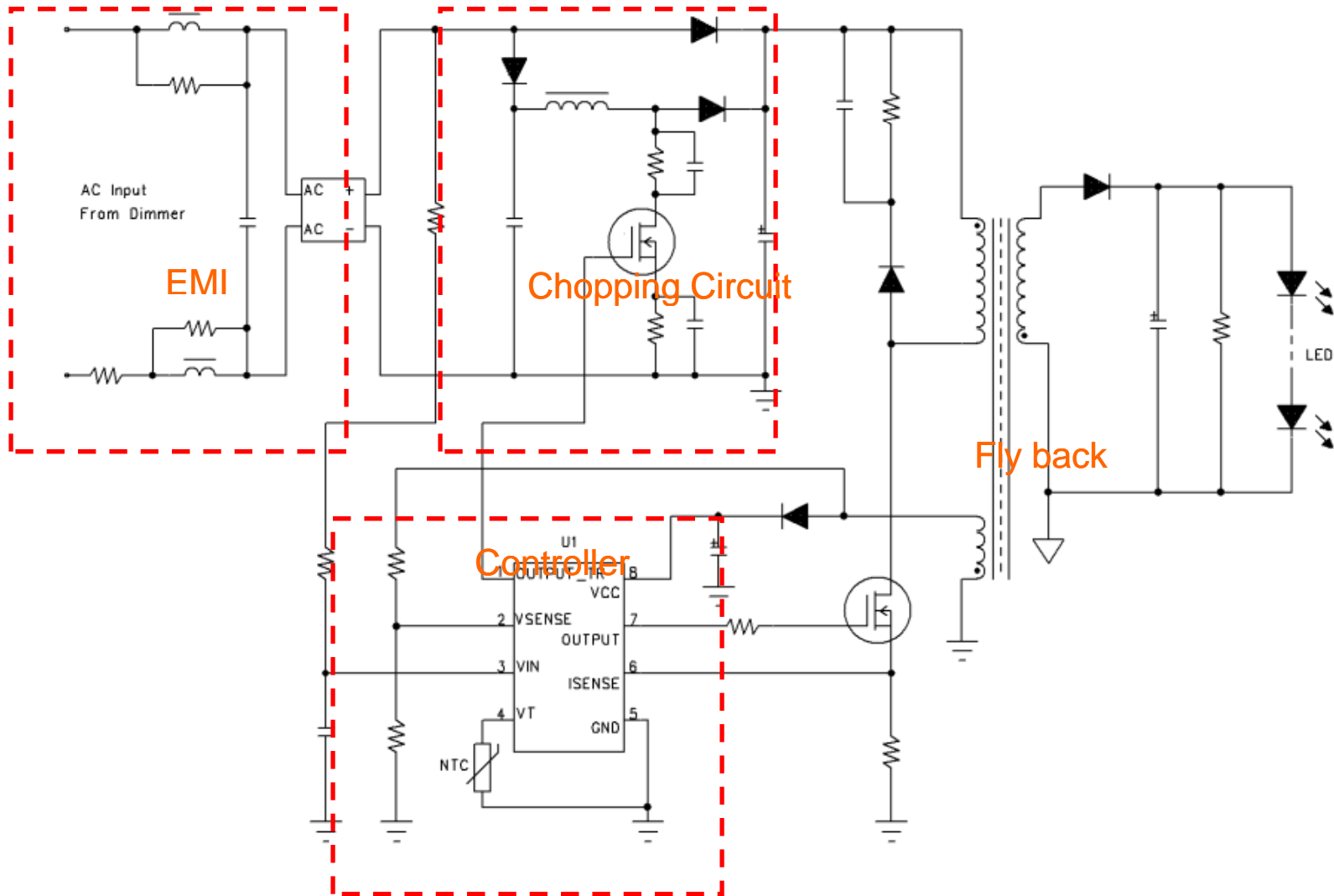
# iW361X Dimmable LED Driver Offers Customers Competitive Advantage



- 1** Low EMI Design  
Saves space and cost  
Meets EMI standards with margin
- 2** High Performance (5% Current Regulation)  
Constant brightness / no flicker
- 3** High Reliability / MTBF  
Eliminates opto-coupler  
Robust fault protection
- 4** Small Size ( max 200kHz operation )
- 5** Automatic Dimmer Detection ( all dimmer types )  
2% to 100% dimming range

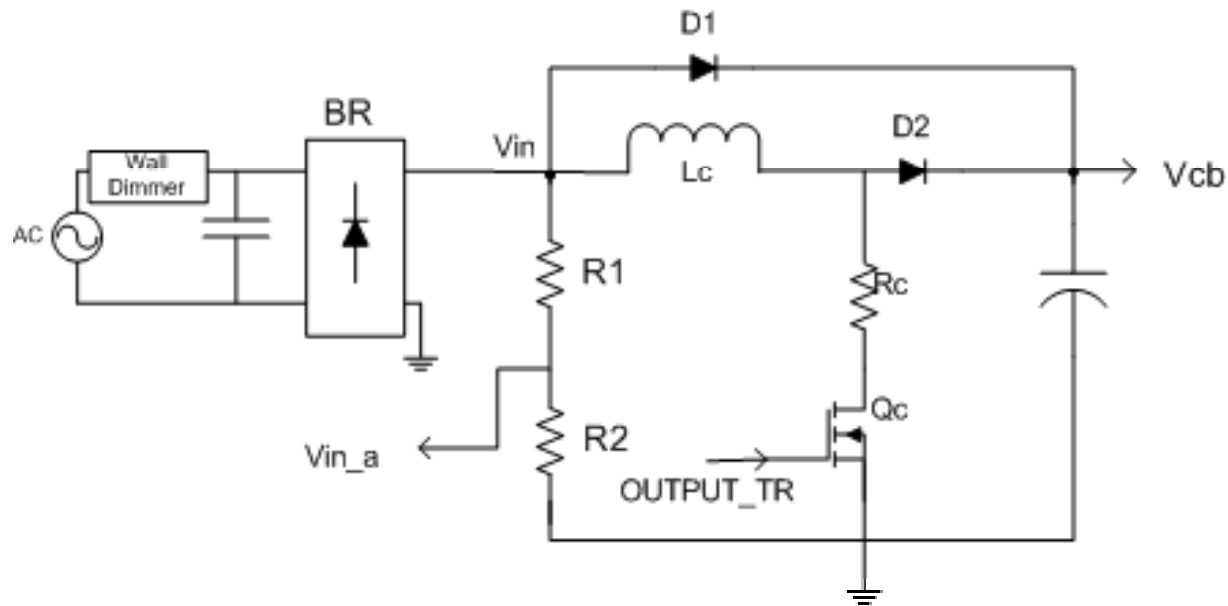


# Overview iW3614 Simplified Schematic

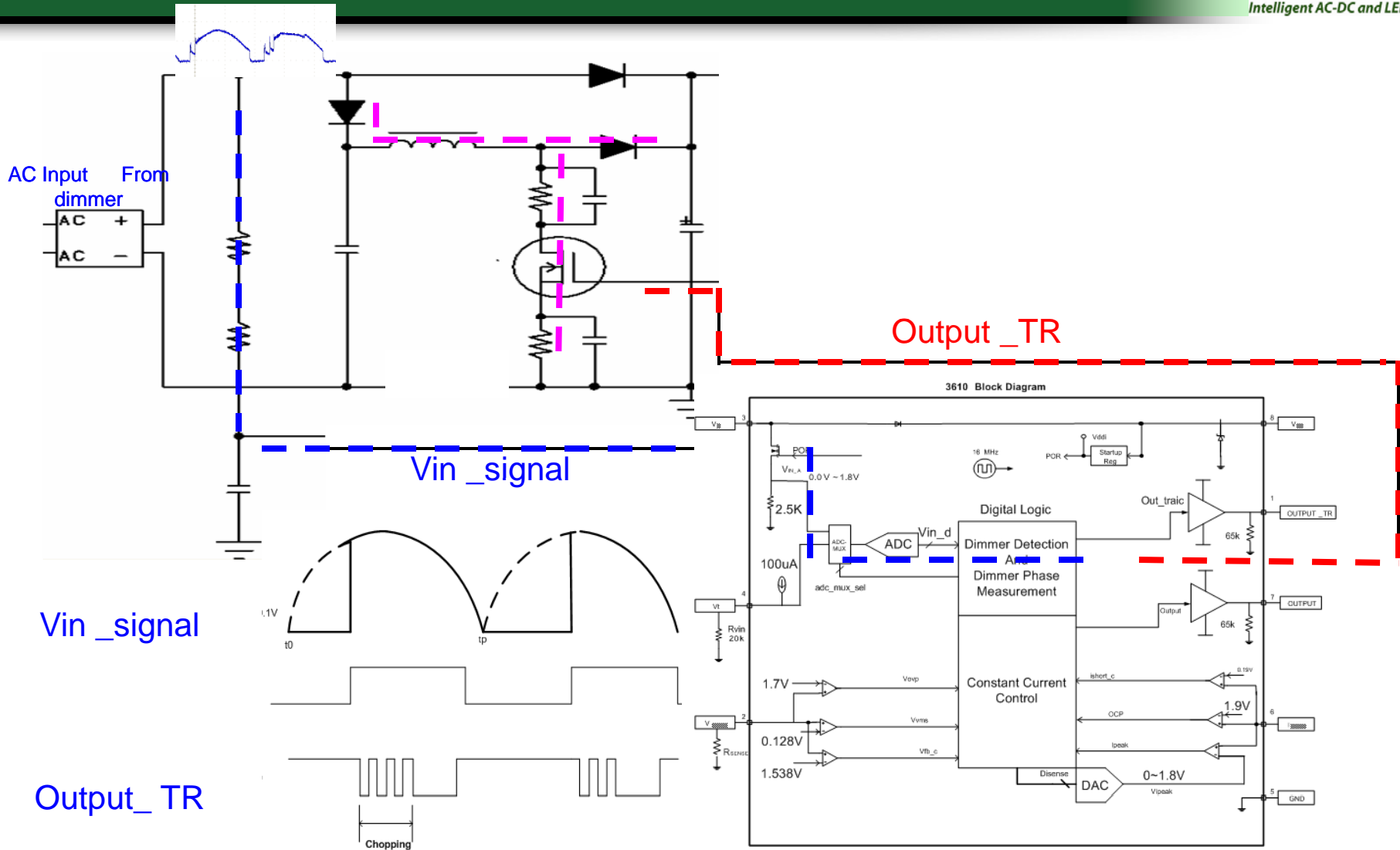


# A Simple Configuration to Combine the Dimmer Detection and PFC

- Unique Method to Configure the Dimmer Type
- Provide the Pure resistive impedance to Wall Dimmer
- Line current shape to improve power factor
- Reduce AC-cycle Inrush current

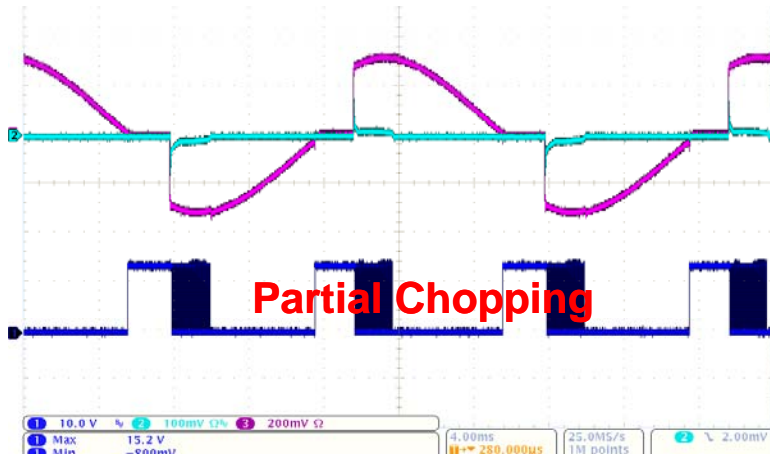


# Chopping Control Scheme



# Chopping Status

## Leading-edge dimmers



## Trailing-edge dimmers

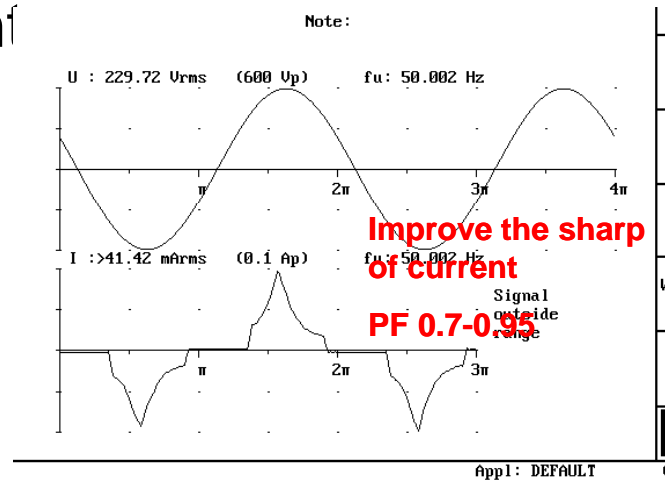
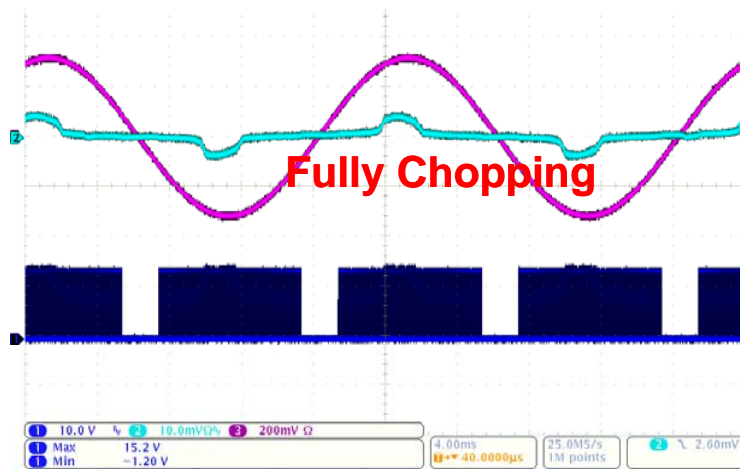


## No dimmers present

Input voltage

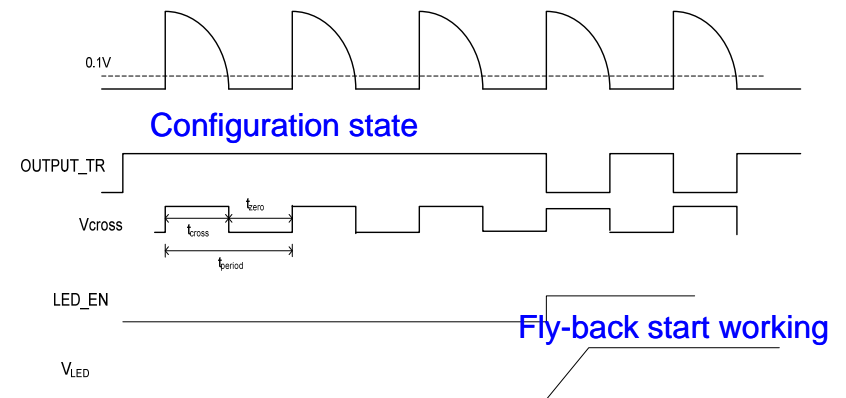
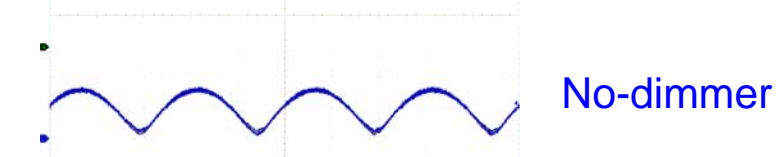
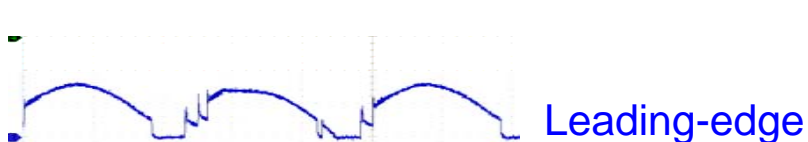
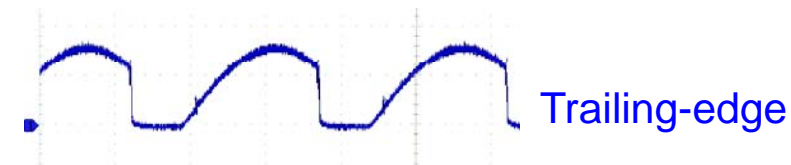
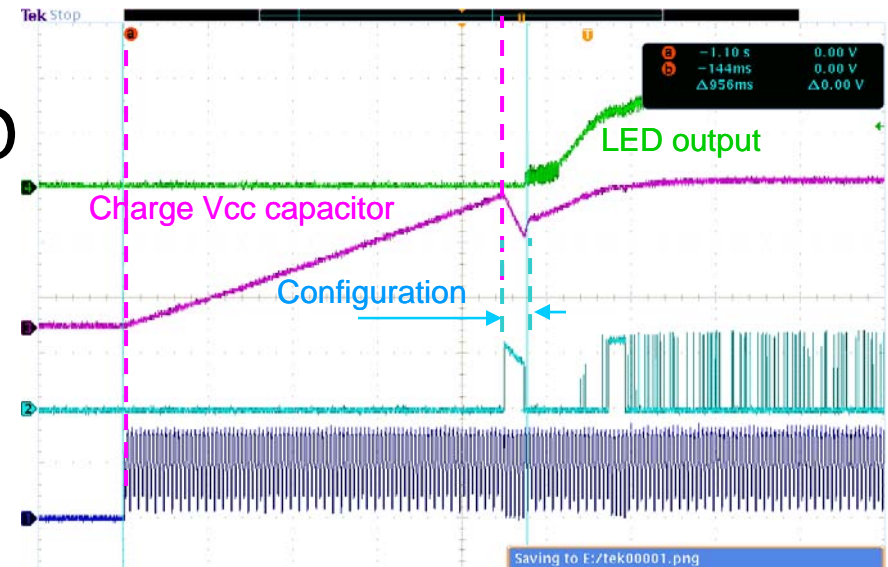
Input current

Chopping control



# Dimmer Detection

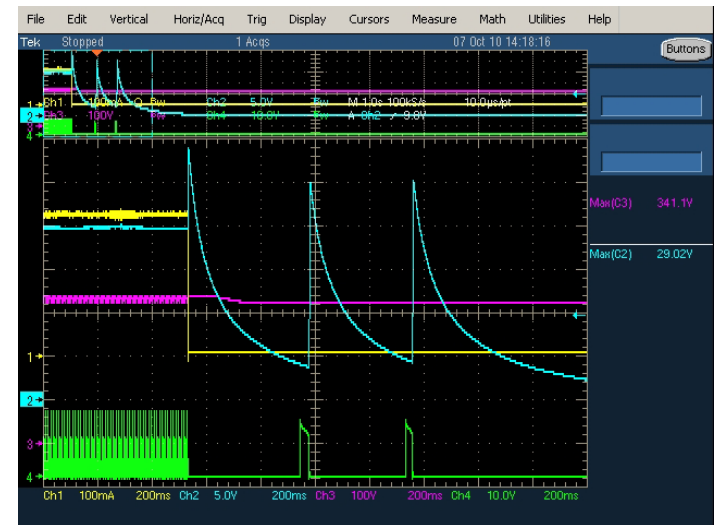
- Smart Dimmer Detection
  - At configuration state, D
    - Leading-edge
    - Trailing-edge
    - No-dimmer



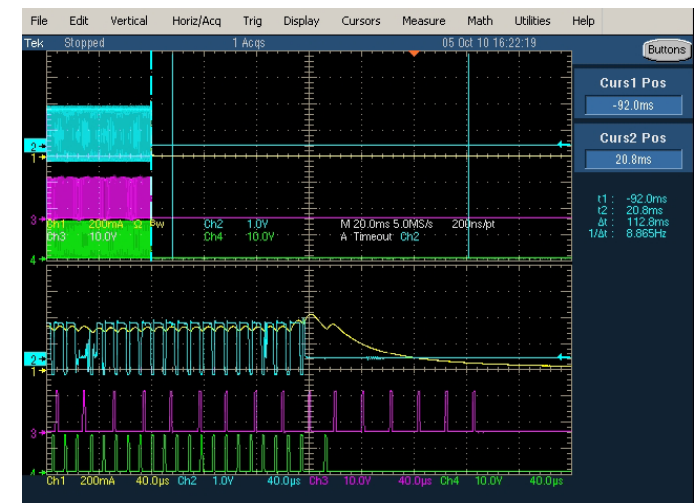
# Fail-safe: Fault Detect & Protection

- **Fail-safe Mode**
  - **Un-support Dimmer Detection**
  - **When the Dimmer can not be detected as “leading, trailing, no dimmer or uncertain” the LED dims at 10%**
- **Single-point fault protection**
  - **LEDs short operation**
  - **Real short circuit protection, OVP**
  - **Current over shoot control, soft start-up**
  - **Current sense resistor short protection**
- **OTP**
- **Watch-dog to protect chopping resistor**

## LED Open Protection



## Isense Short Protection



## ⊕ Design for Reliability

- ✓ No Opto-coupler required, utilize the Patented Primary-feedback technology
- ✓ External NTC application for OTP / Temperature Drifting with threshold
- ✓ Low AC Peak current in Leading edge dimmer mode

## ⊕ Single-point fault protections

- ✓ Single point fault protection, any component short, open floating
- ✓ OVP latch
- ✓ Current sense resistor short protection
- ✓ LED Open circuit protection
- ✓ Output short circuit protection
- ✓ OTP, OCP



## ⊕ Smart Dimmer Detections

- ✓ Different dimmer type has the different operation mode
- ✓ Leading-edge, trailing-edge, smart dimmers

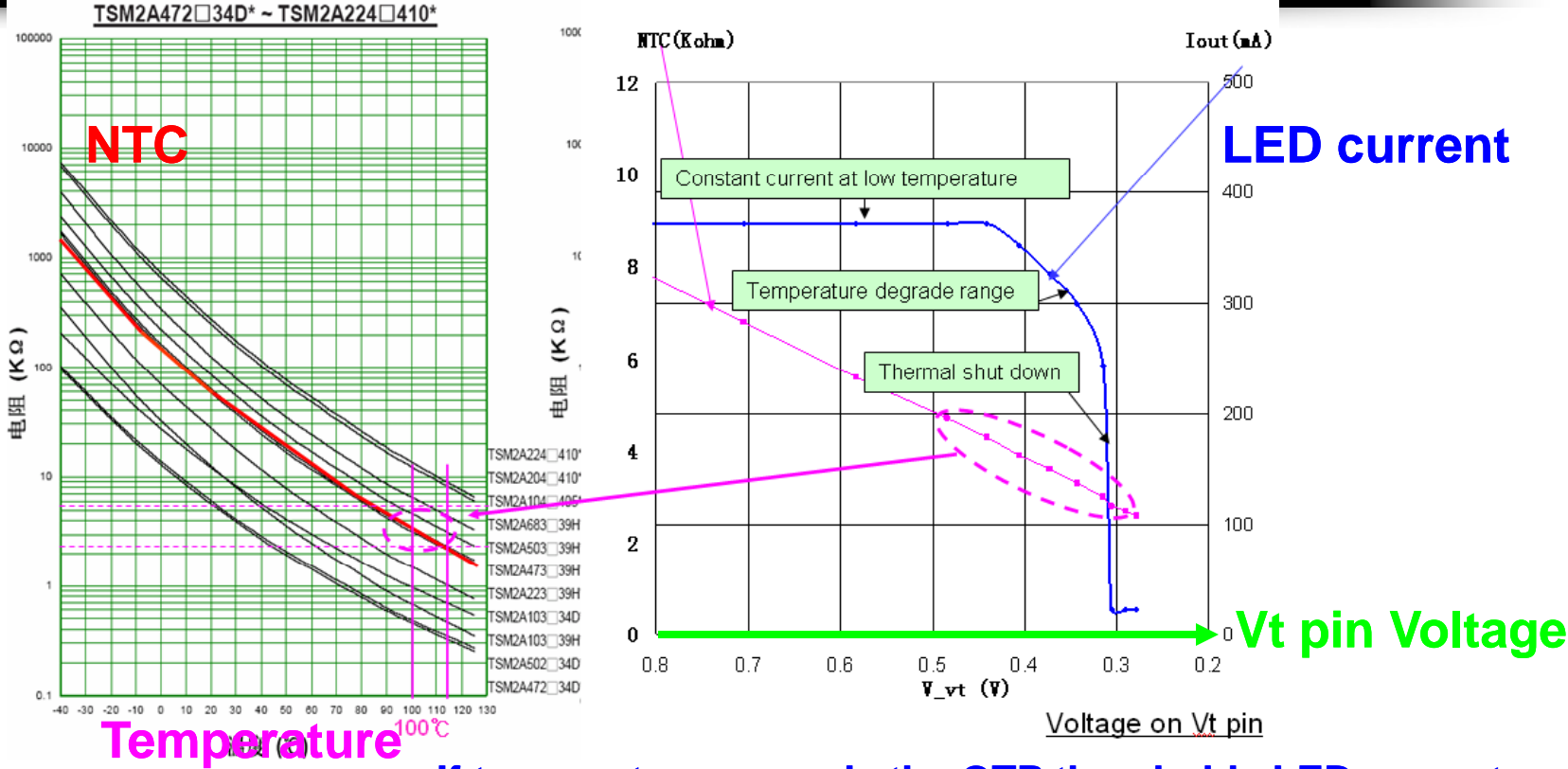
## ⊕ Advanced Dimmer Protections

- ✓ A special dimmer mode for “un-support dimmer detection”. It will be safe for un-support dimmers
- ✓ Advanced thermal protection against any failure
- ✓ AC-cycle inrush current controllable ( <1A)

## ⊕ Adaptive dimming control

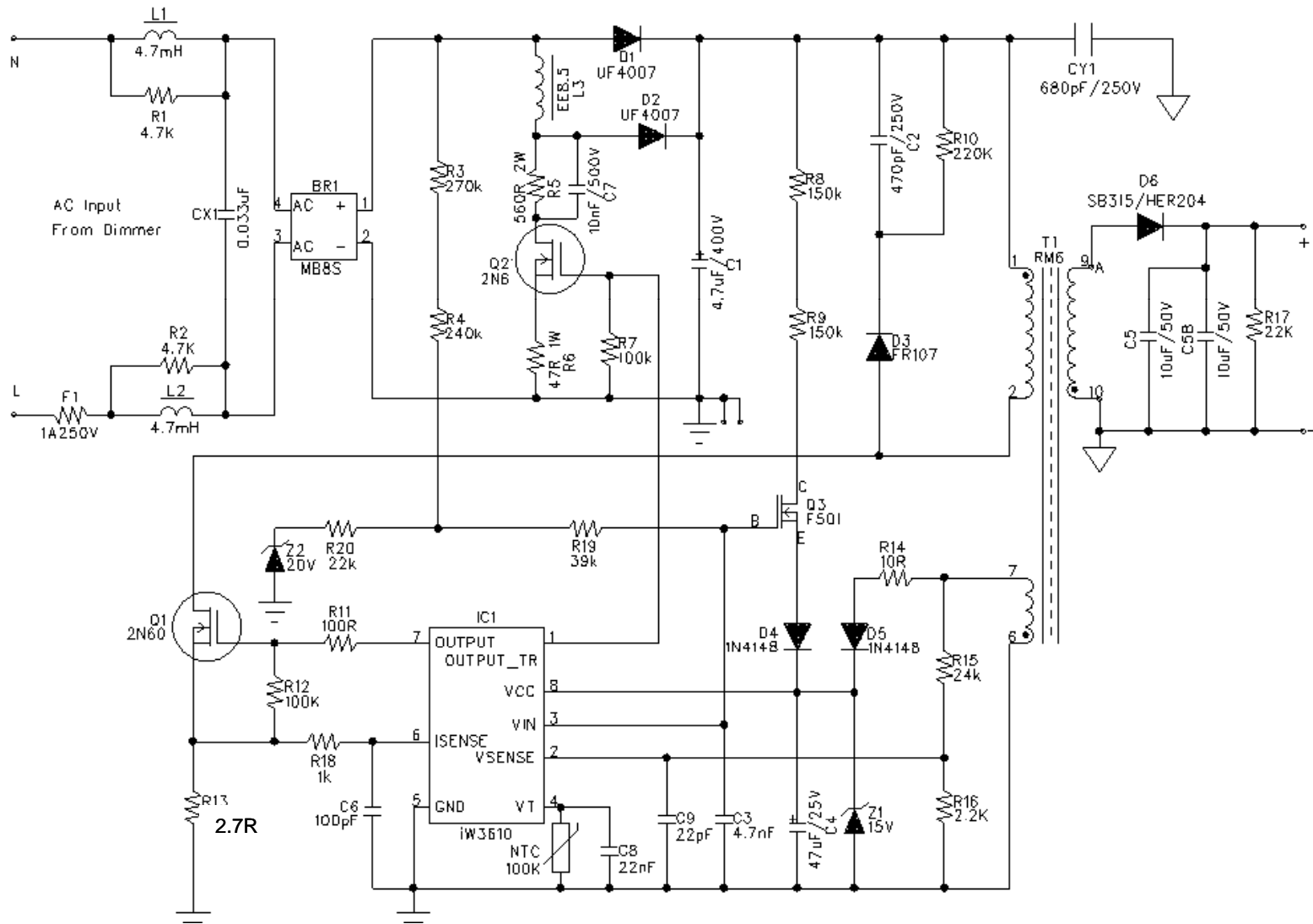
- ✓ Wide dimming range 1% to 100%
- ✓ Advanced mapping technology smoothly dimming control

# Temperature drifting and Protection



- If temperature exceeds the OTP threshold, LED current will decrease via linear function
- If temperature is higher and close to thermal shunt down threshold, LED current will go down to 30%
- Choose NTC to set OTP point

# A Design Case: 24V310mA 230Vac

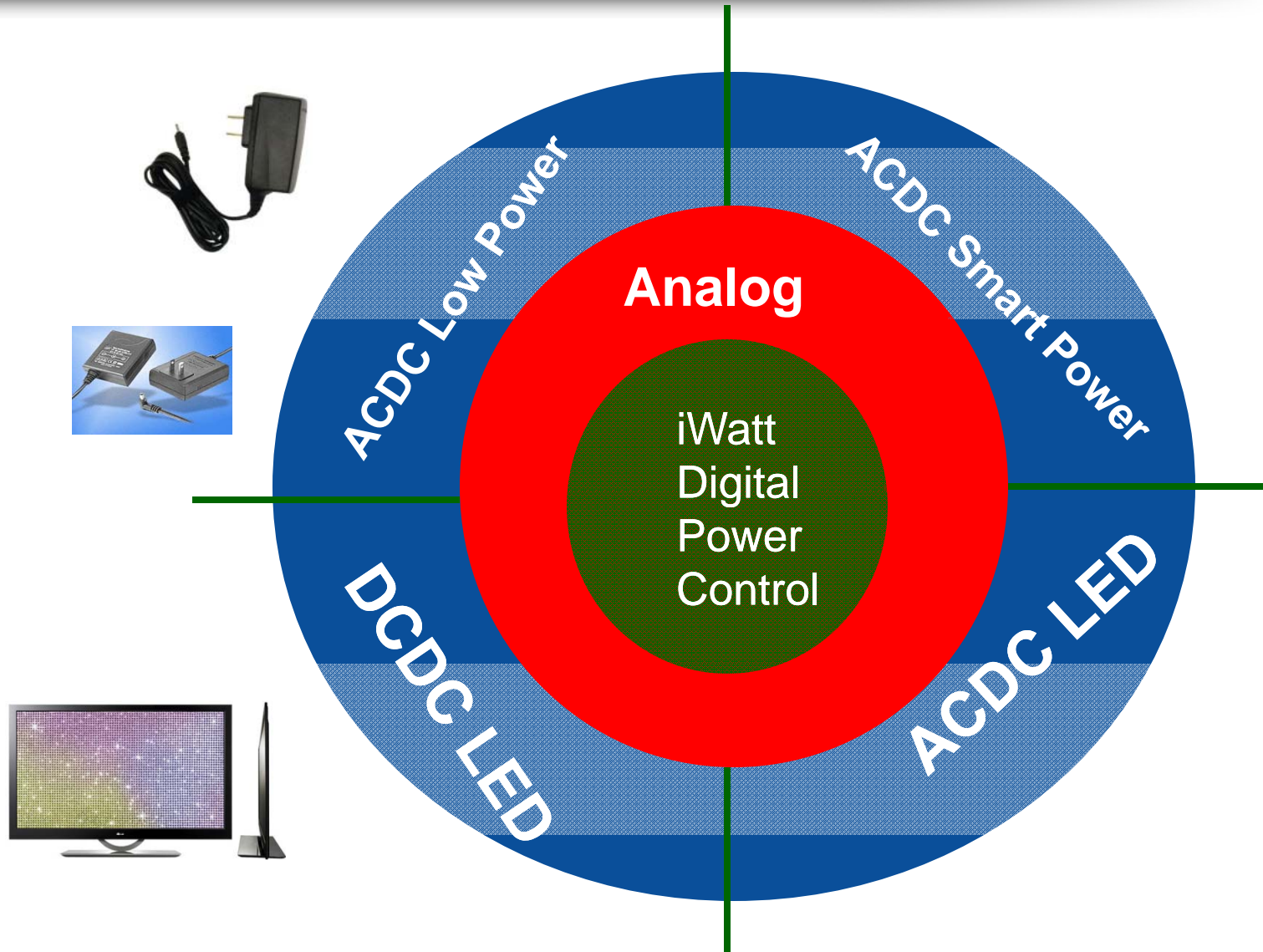


## Constant Current and Efficiency \_\_No Dimmer

(AC input 180~264Vac, Output 7 LEDs)

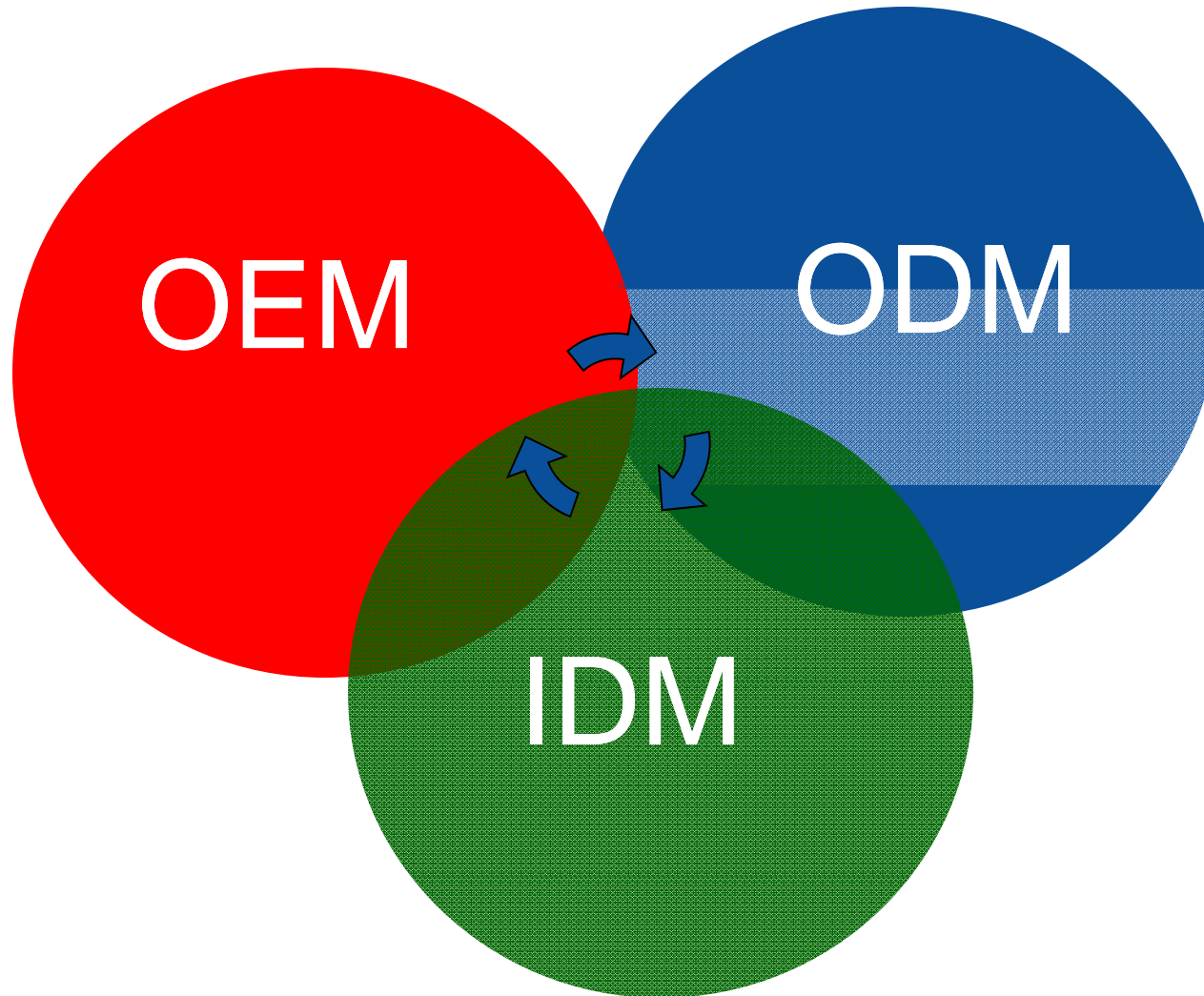
#of LEDs	Vin	Pin	Vout	Iout	Ripple	efficiency	PF
	(V)	(W)	(V)	(A)	(mA)		
7LEDs	180	9.060	23.28	0.323	132	83.00%	0.933
	190	8.930	23.01	0.323	128	83.23%	0.938
	200	8.890	22.83	0.323	128	82.95%	0.936
	210	8.880	22.77	0.323	120	82.82%	0.935
	220	8.870	22.73	0.323	124	82.77%	0.937
	230	8.870	22.7	0.323	120	82.66%	0.938
	240	8.880	22.64	0.323	120	82.35%	0.939
	250	8.900	22.63	0.323	116	82.13%	0.940
	264	8.930	22.61	0.324	112	82.03%	0.940

# Green Power Solutions Providers

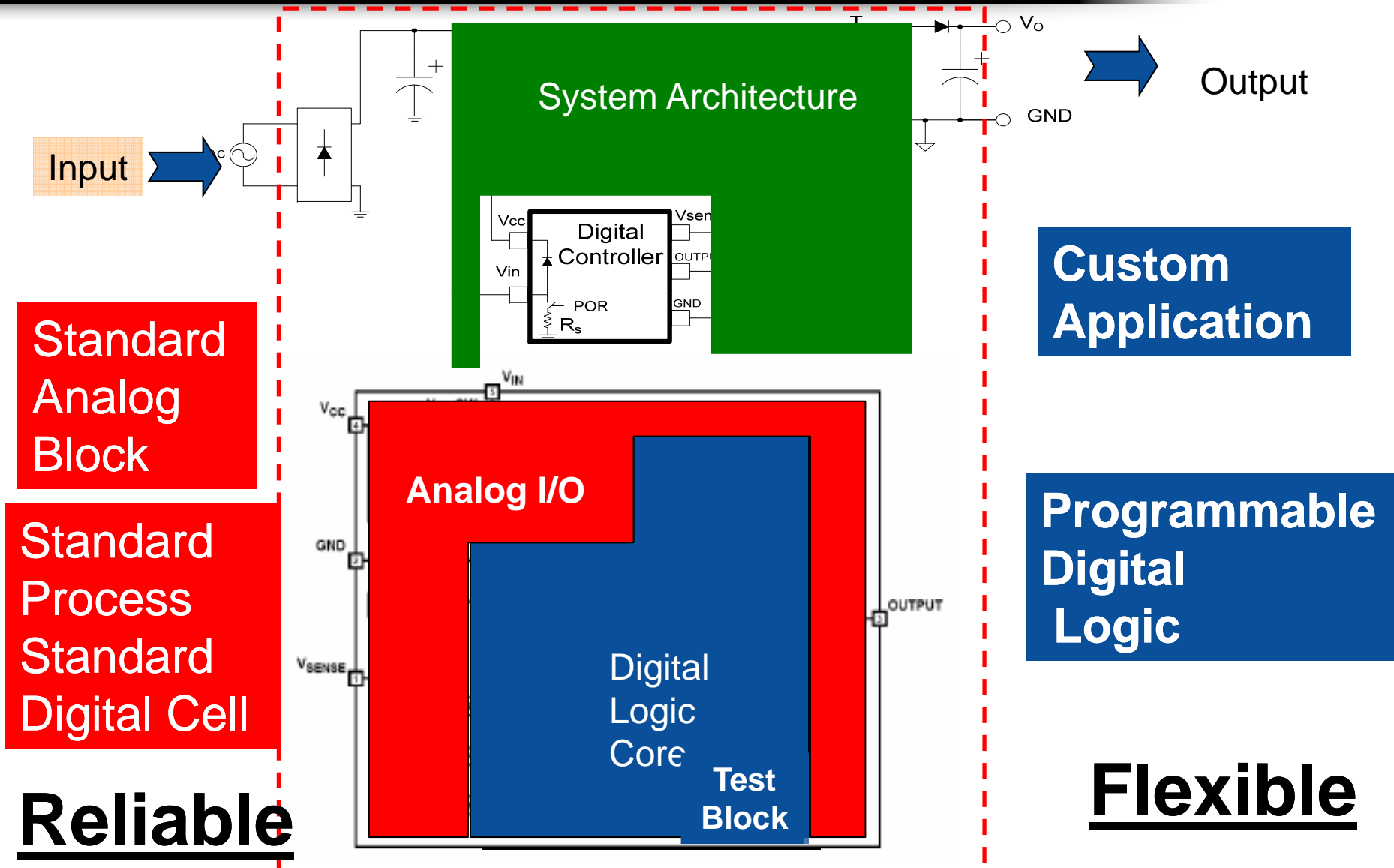


## Fact of iWatt

- A US-based technology company, located in Silicon Valley
- A fabless company to provides intelligent digital power management IC
- Found at 2000. A first company to introduce the digital power technology
- Shipped over 600M unit of IC worldwide, Serves directly to Tier-1 customer
- Issued patent: 42, Pending 23, PCT 25



# Intelligent Digital Power Control Platform





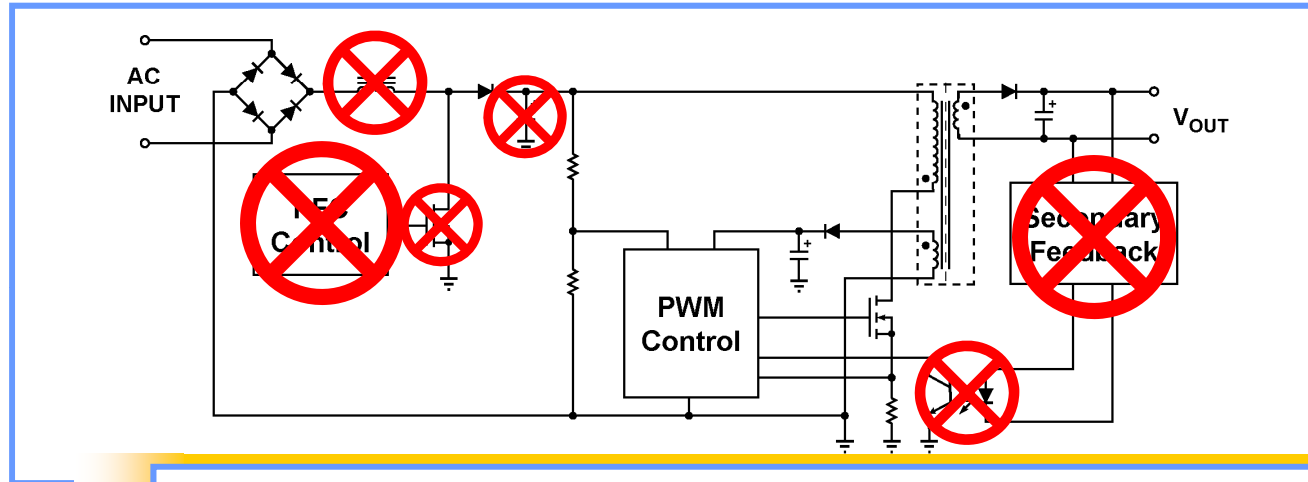
# Proven Digital Power Control Technology



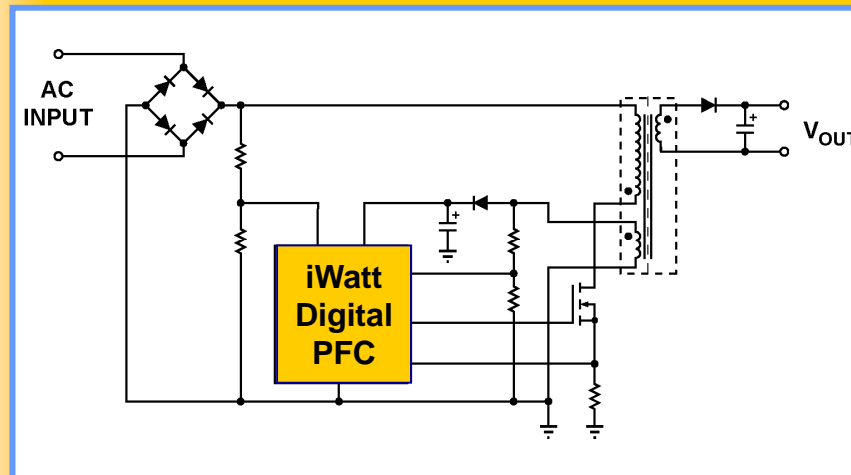
- **The first company to release Digital Power Control IC's for ac/dc offline**
  - *iW1689, iW1692, iW1690, iW1696, iW1698, iW1691 & iW1710.*
  - *LED offline drivers iW3620, iW3610, iW3612, iW3614*
  
- Provides Total System Solutions for low-power adapters and chargers with low cost and high performance
  - **Patented digital primary-feedback control technology with Tight CV regulation**
  - **Patented Constant Current (CC) regulation with primary-feedback**
  - **Advanced multi-layer fault protection technology**

# The Value of Digital Power Controller

Before



**iWatt**



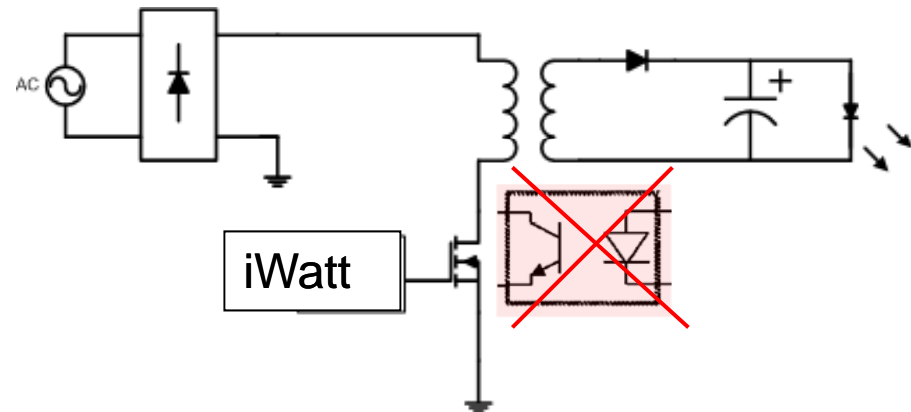
- Fewer Components
- Higher Efficiency
- Reduced Size
- Lower Cost

# Key Technology: Isolated LED Driver without Opto-coupler

## Benefits on Primary-side control

- Line Isolation
  - Easier for heat sink design
  - Easier for heat spreading
  - Easier to meet safety regulation
- More reliable and longer life time
  - No opto-coupler
  - No Y-cap
- High Efficiency design
  - Isolated current transformer is easy for optimize efficiency

**Isolation Needed? Yes**  
**Opto-coupler? No**



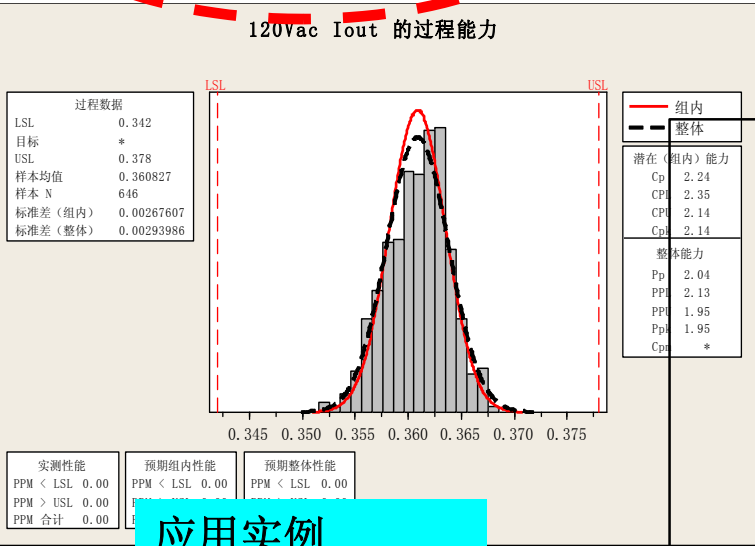
- +/- 5% Overall constant current Cross-regulation
- Eliminate the impact of Lm, Vin and leakage inductance
- LED open circuit protection
- Single fault protections
- Current overshoot control

# Tight CC Regulation

$$I_o = \frac{I_{pri\_pk} N_{ps} T_{rst}}{2 T_s}$$

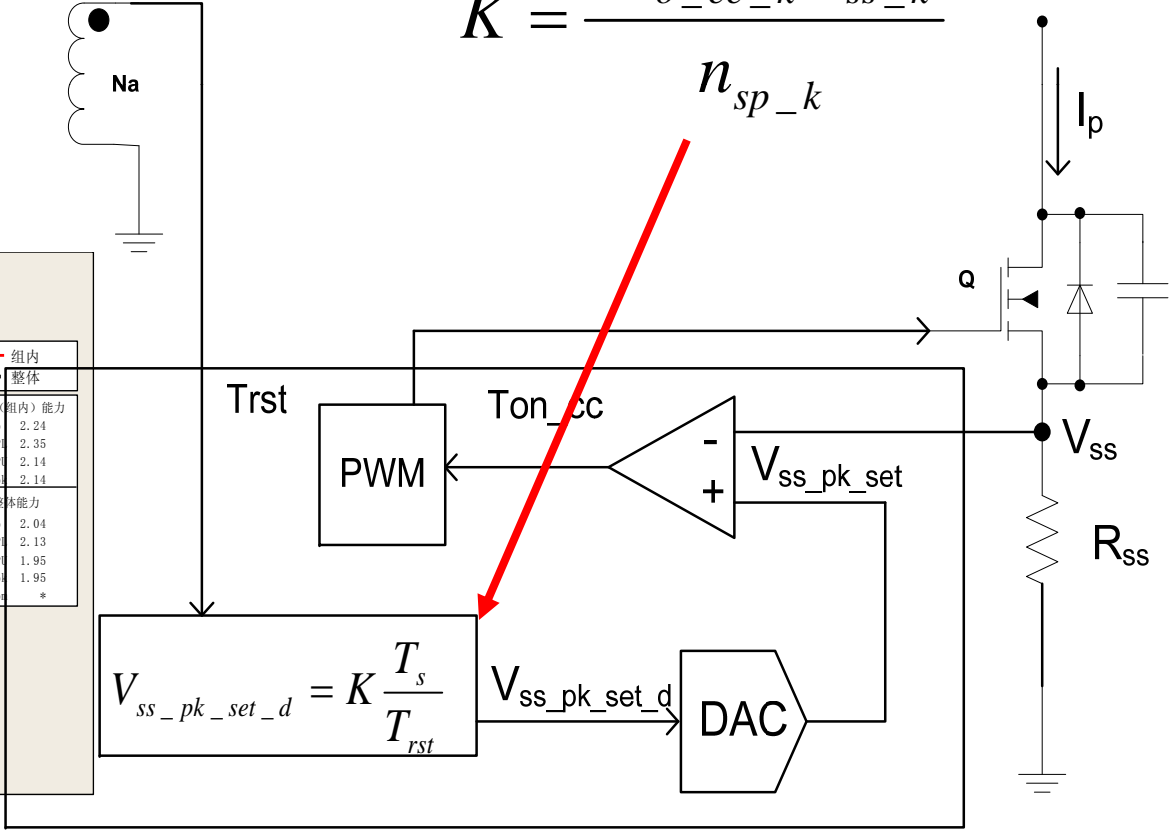
Directly use primary current information.

$$I_{pri\_pk} = \frac{2I_o T_s}{N_{ps} T_{rst}}$$

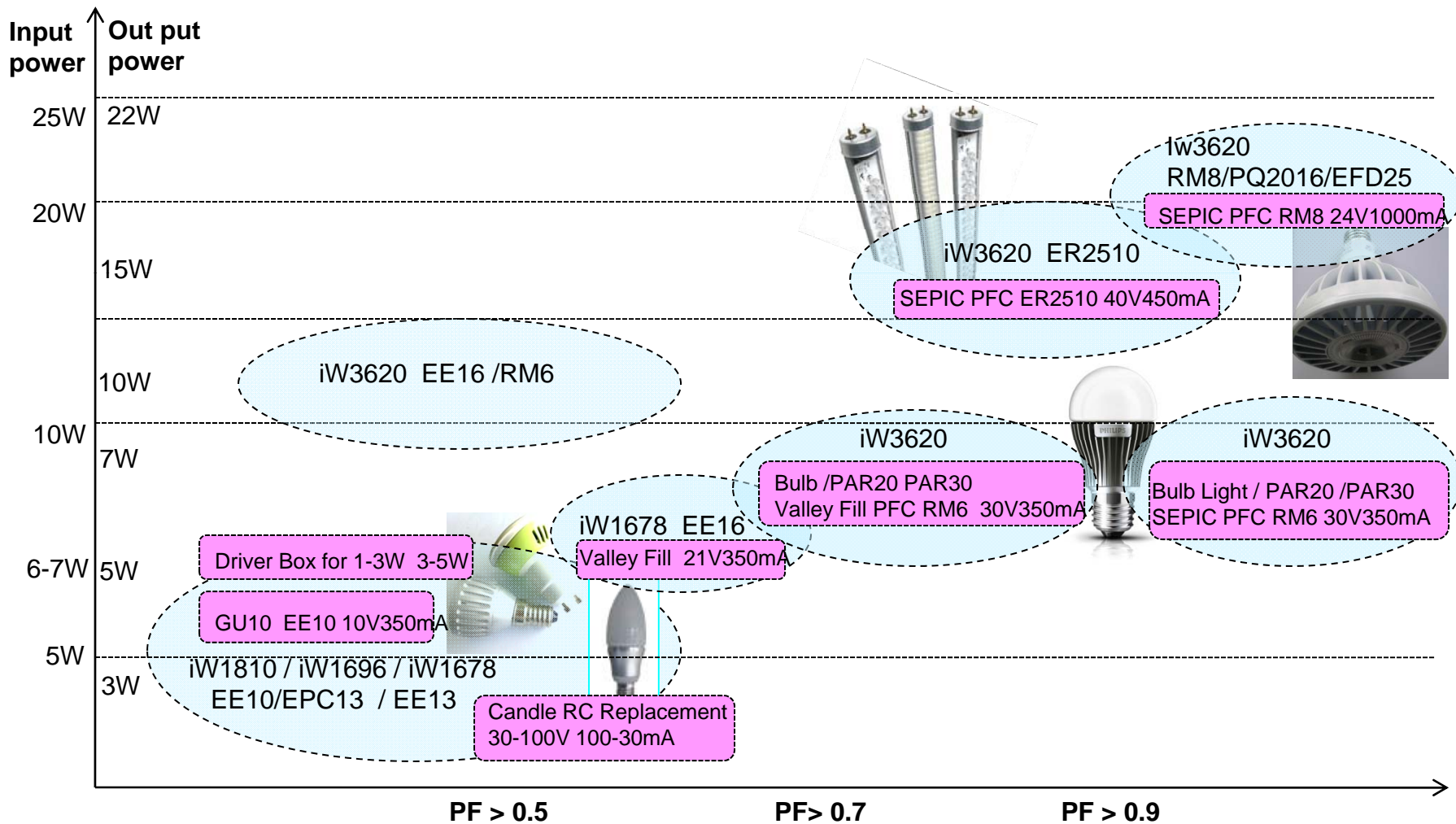


应用实例

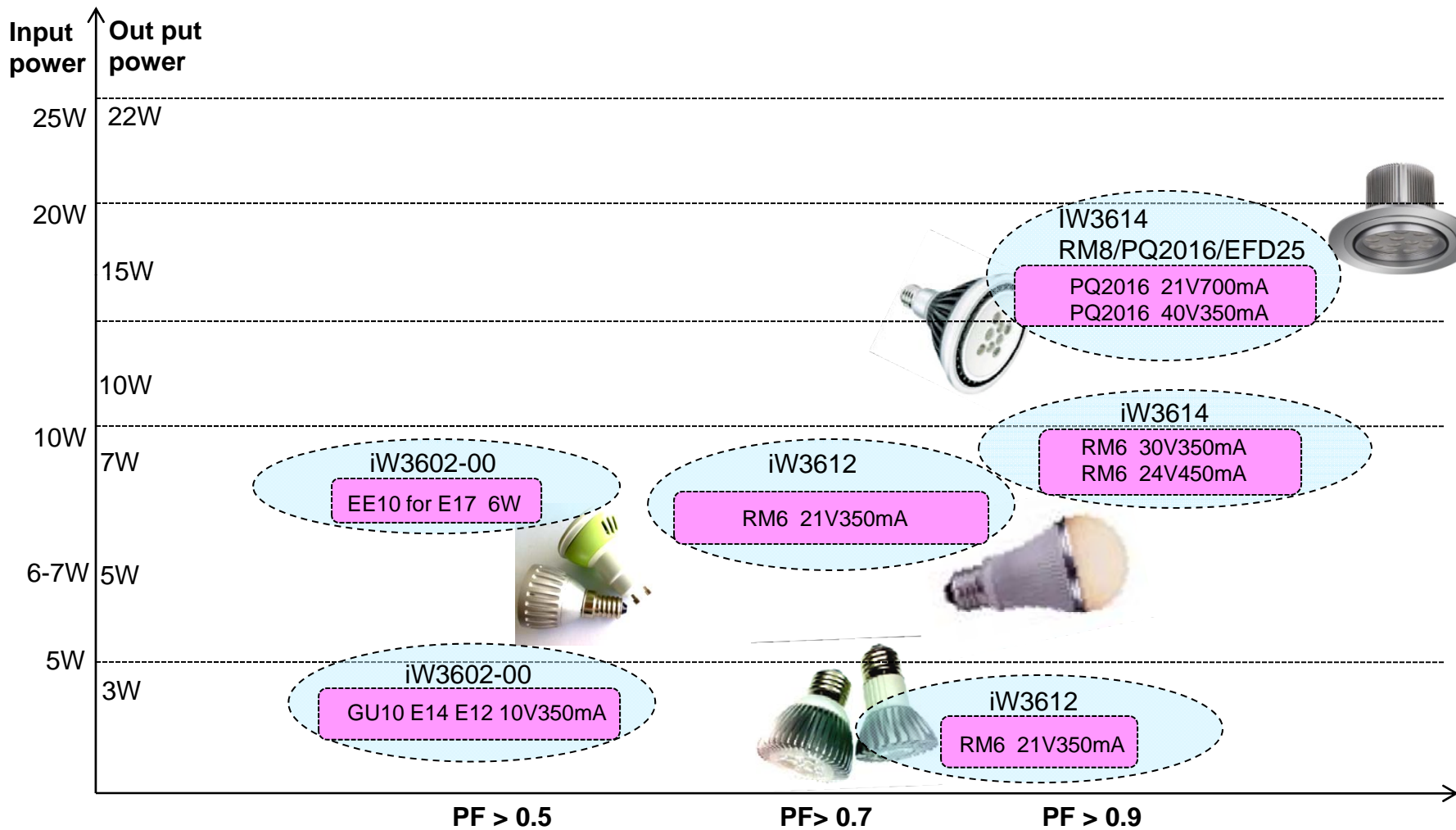
$$K = \frac{2I_{o\_cc\_k} R_{ss\_k}}{n_{sp\_k}}$$



# iWatt LED Driver Solution\_\_ Non-dimmable



# iWatt LED Driver Solution \_\_\_ Dimmable



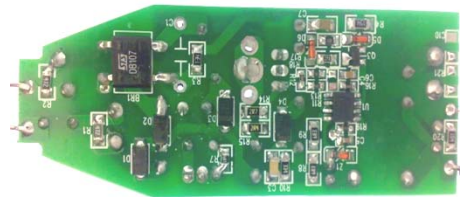
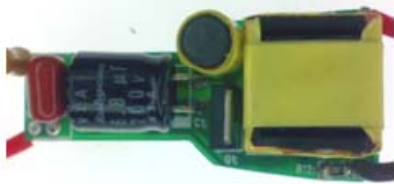
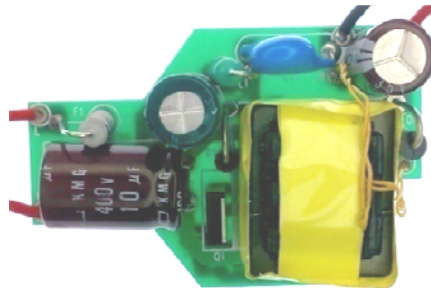
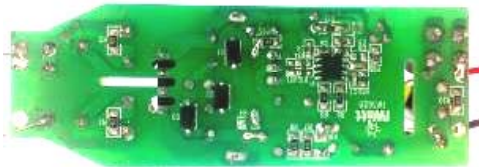
# A complete Solutions from iWatt

**1W-30W**

**Dimmable and Non-dimmable**  
**Isolated and Non-isolated**  
**General PF and High PF**



**Down Light**



**LED Tube lighting**

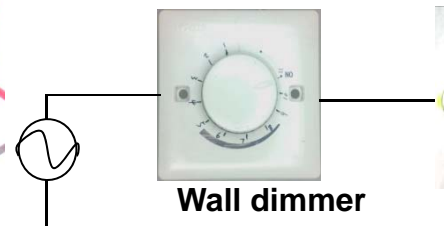
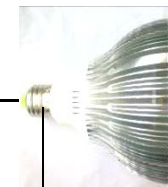


**GU10**



**GU10**

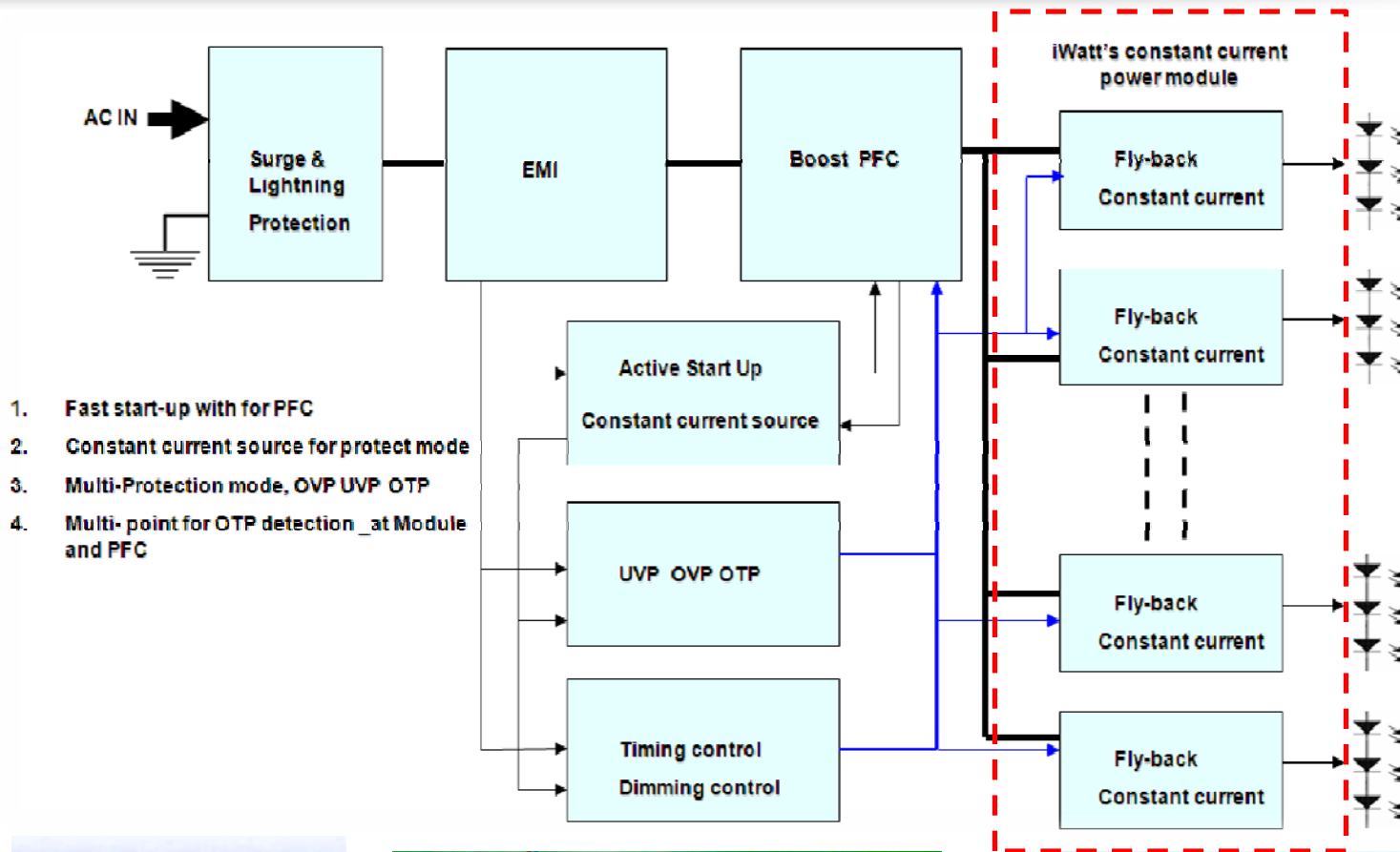
**E14**



**Wall dimmer**

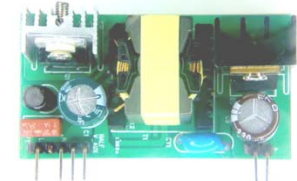


# A Reliable High-power Outdoor/Street-light driver Solution



1. Fast start-up with for PFC
2. Constant current source for protect mode
3. Multi-Protection mode, OVP UVP OTP
4. Multi-point for OTP detection\_at Module and PFC

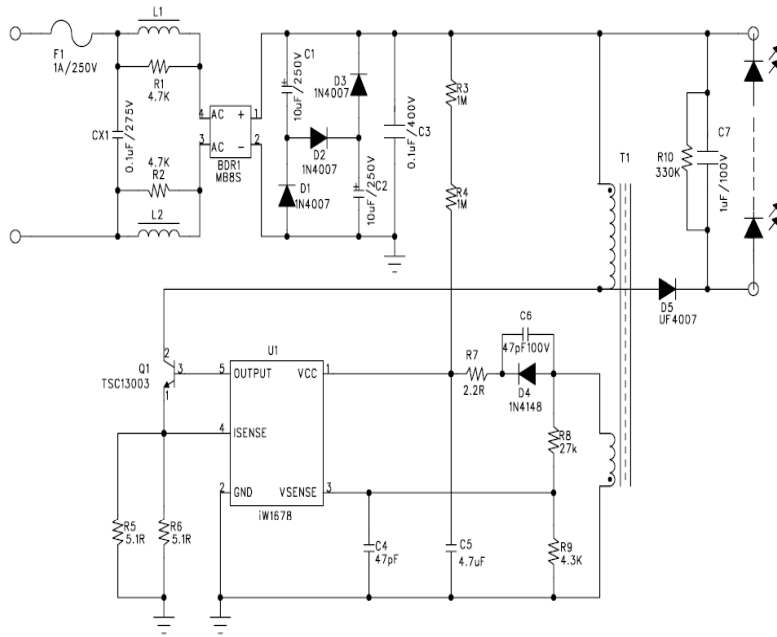
Iw3620  
恒流模块





# iWatt PSR solution for Non-isolated Bulb Lamp **iWatt**

Intelligent AC-DC and LED Power™



This product is covered by the following patents:

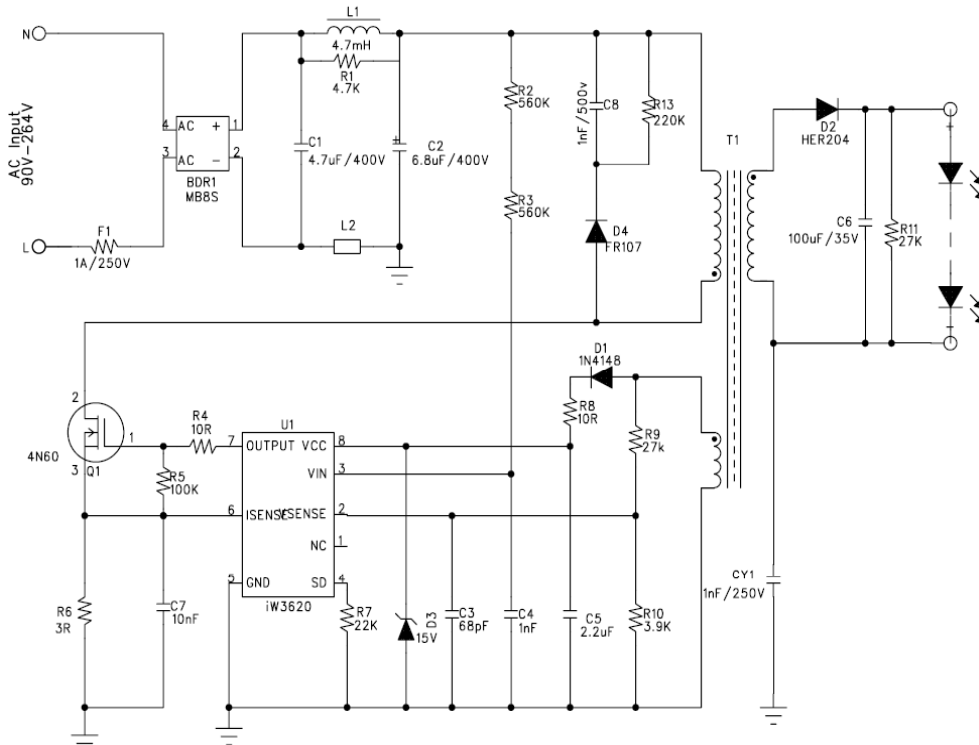
- 1) To detect / sense the output voltage indirectly through the auxiliary winding:  
**6,956,750; 6,990,000; 6,882,552; 6,900,995; 6,370,039; 6,385,059;**
- 2) To detect / sense the output load current indirectly and control the output load current at constant; and maintain the tight constant-current regulation across wide line-load;  
**6,944,034; 6,972,969; 7,443,700; 7,876,582; 7,974,107; 7,589,983**



- Input: 230Vac
- Output: 70V  
86mA
- PF>0.85
- Efficiency >90%
- Non-Isolated

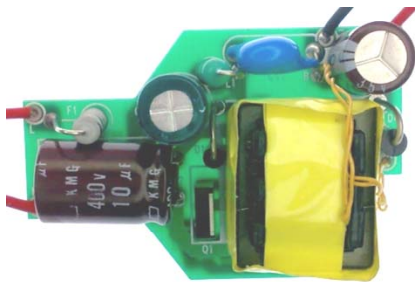


# iWatt PSR solution for isolated PAR Lamp



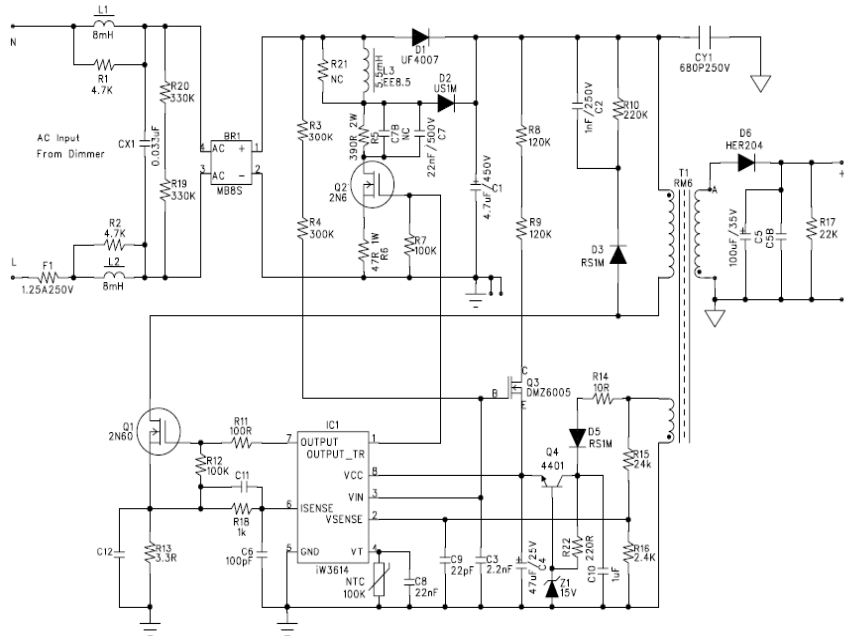
This product is covered by the following patents:

- 1) To detect / sense the output voltage indirectly through the auxiliary winding:  
**6,956,750; 6,990,000; 6,882,552; 6,900,995; 6,370,039;; 6,385,059;**
- 2) To detect / sense the output load current indirectly and control the output load current at constant; and maintain the tight constant-current regulation across wide line-load;  
**6,944,034; 6,972,969; 7,443,700; 7,876,582; 7,974,107; 7,880,447; 7,589,983;**

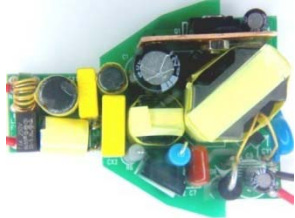


- Input: 90-264Vac
- Output: 25V 350mA
- Efficiency >85%

# iWatt Dimmable Solution for PAR Lamp



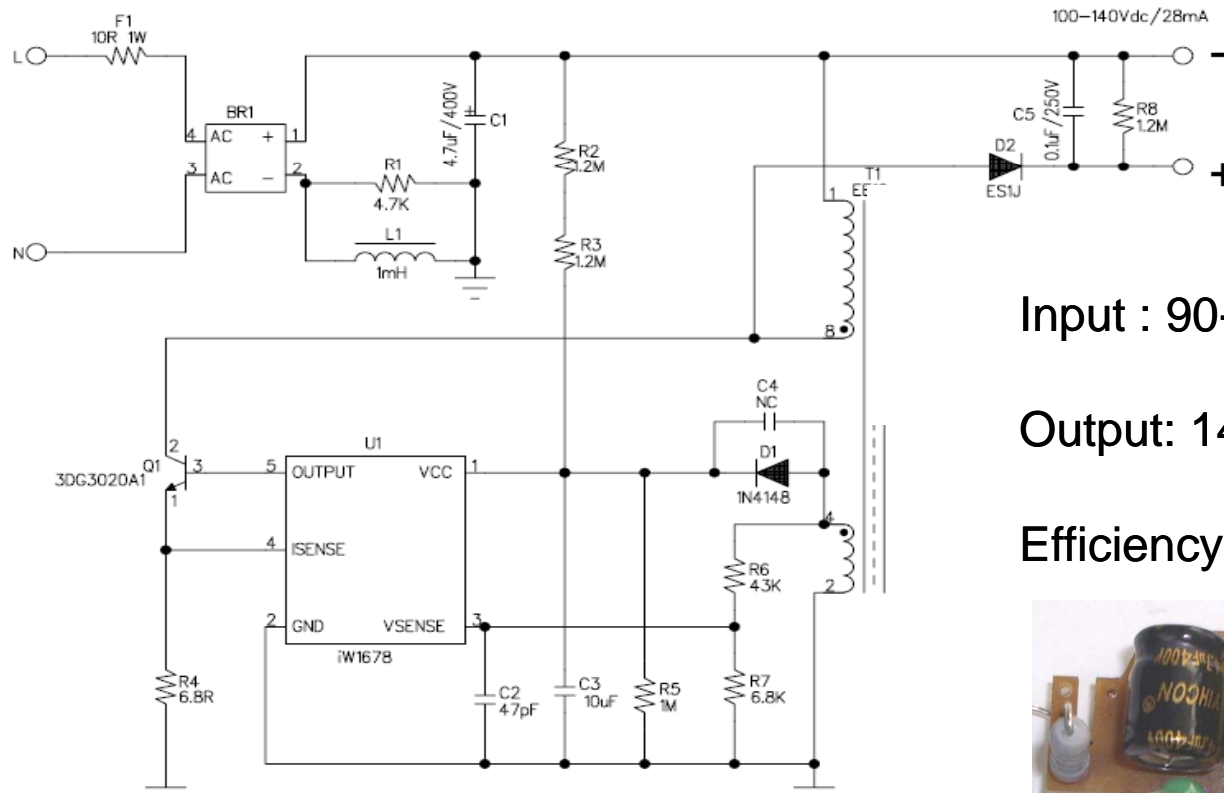
- Input: 100-120v or 220-240Vac
- Output: 25V 400mA
- Efficiency >82%
- PF >0.9 @ No-dimmer mode
- THD meet IEC61000-3-2
- Dimming compatibility RC R RL



This product is covered by the following patents:

- 1) To detect / sense the output voltage indirectly through the auxiliary winding:  
**6,956,750; 6,990,000; 6,882,552; 6,900,995; 6,370,039;; 6,385,059;**
- 2) To detect / sense the output load current indirectly and control the output load current at constant; and maintain the tight constant-current regulation across wide line-load;  
**6,944,034; 6,972,969; 7,443,700; 7,876,582; 7,974,107; 7,880,447; 7,589,983;**
- 3) To dim the output current and correct power factor: **7,433,211; 7,936,132;**

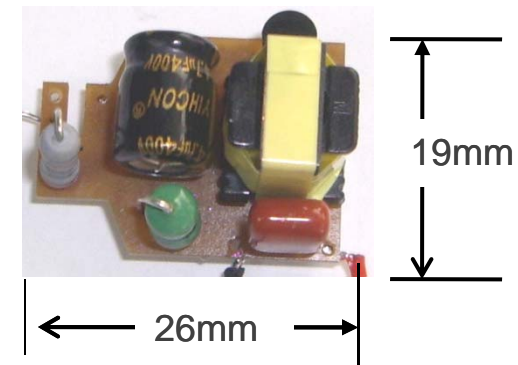
# iW1678 Used for Non-isolated 4W LED Driver Design



Input : 90-264Vac;

Output: 140V30mA

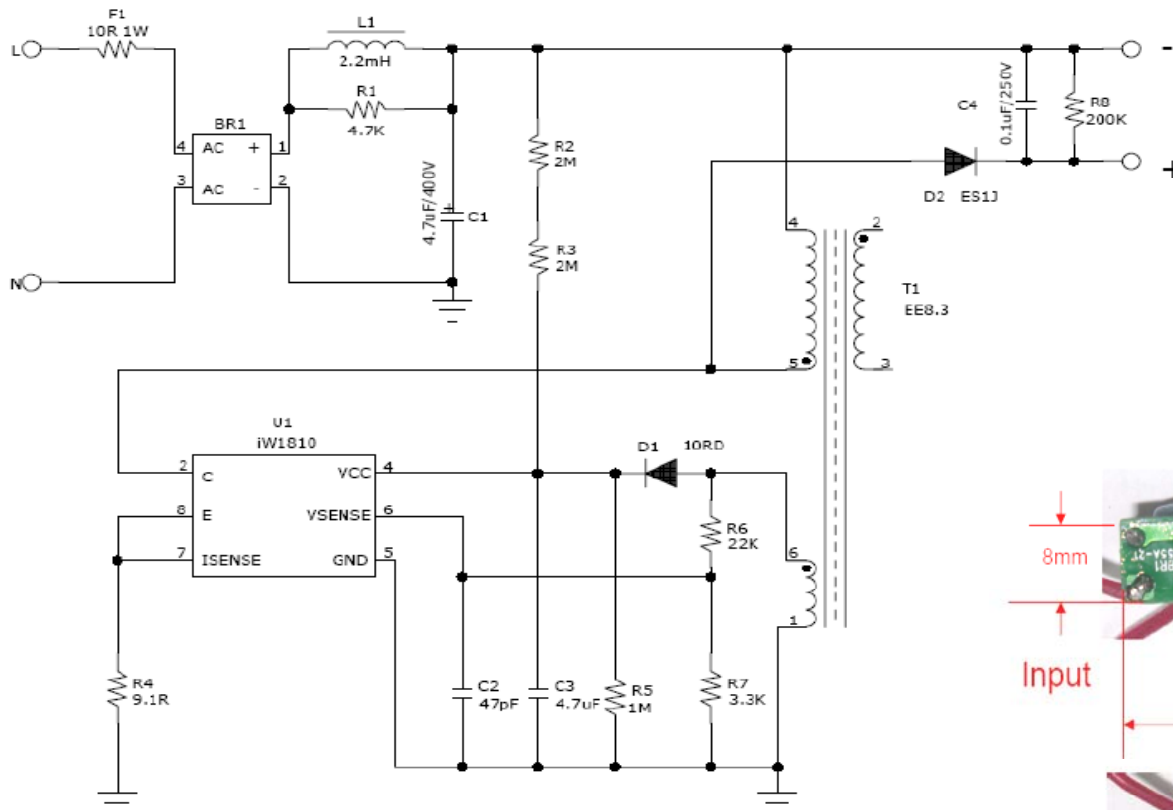
Efficiency: >90%



- iW1678 switching frequency 64KHz, drive BJT
- Good for wide AC input, 2-5W design
- High efficiency, small size, low cost, comparable to RCC
- CC accuracy reaches 3%

Refers to iWatt demo for details

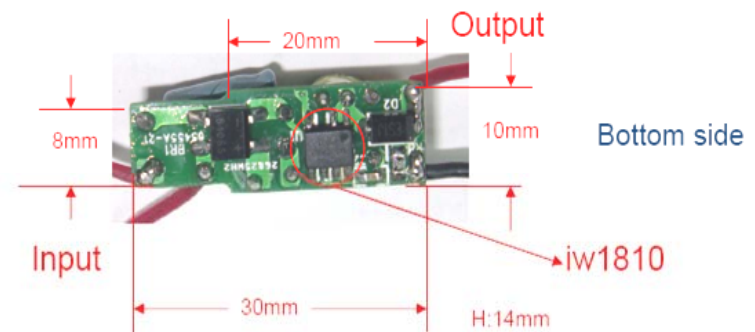
# iW1810 for Non-Isolated 2-4W LED Design



Input : 90-264V;

Output: 100V20mA

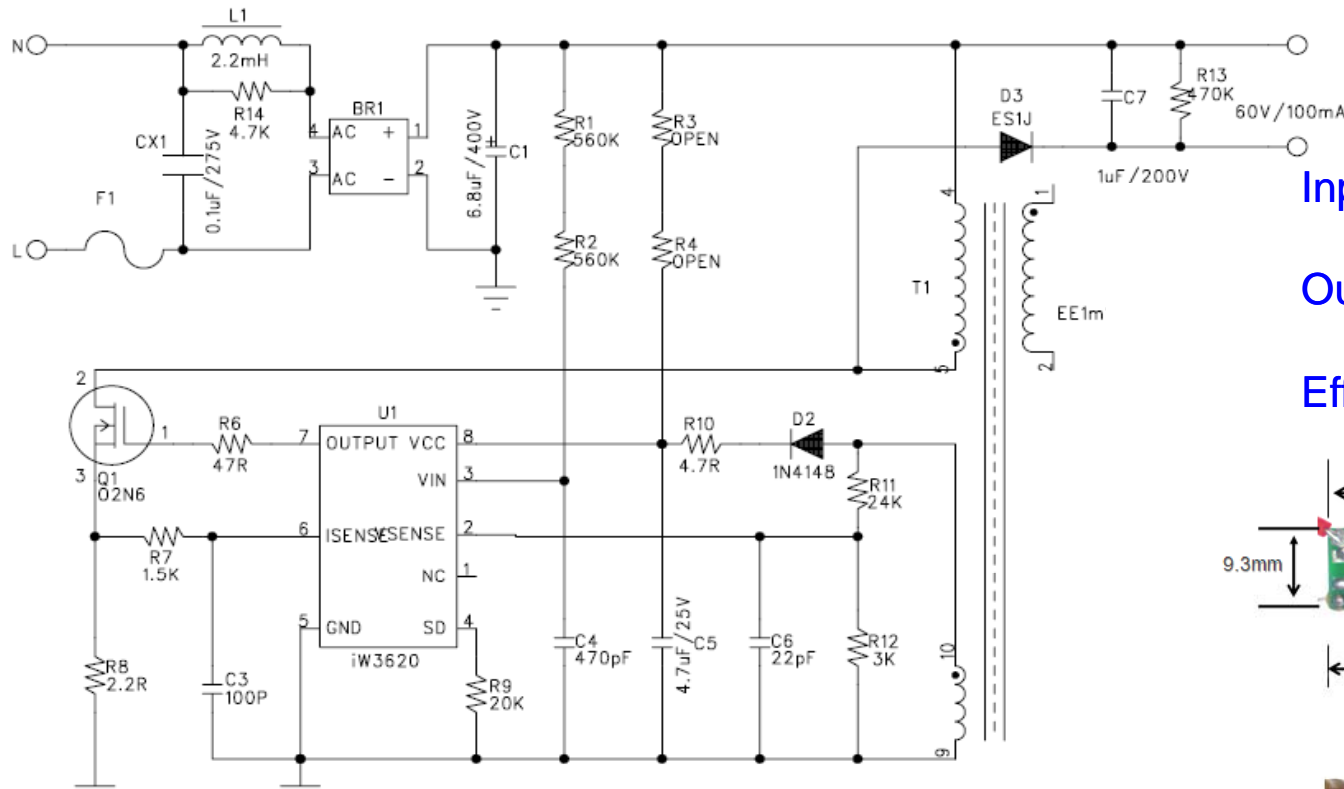
Efficiency: >81%



Refers to iWatt demo for details

- iW1810 switching frequency 64KHz, Integrated BJT
- Good for wide AC input, 2-5W design
- High efficiency, small size, low cost, comparable to RCC
- CC accuracy reaches 3%

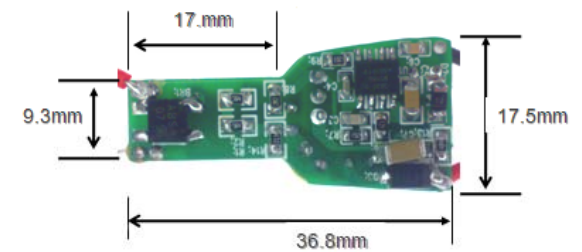
# iW3620 for Non-Isolated -6W LED Design



Input : 90-264V;

Output: 60V100mA

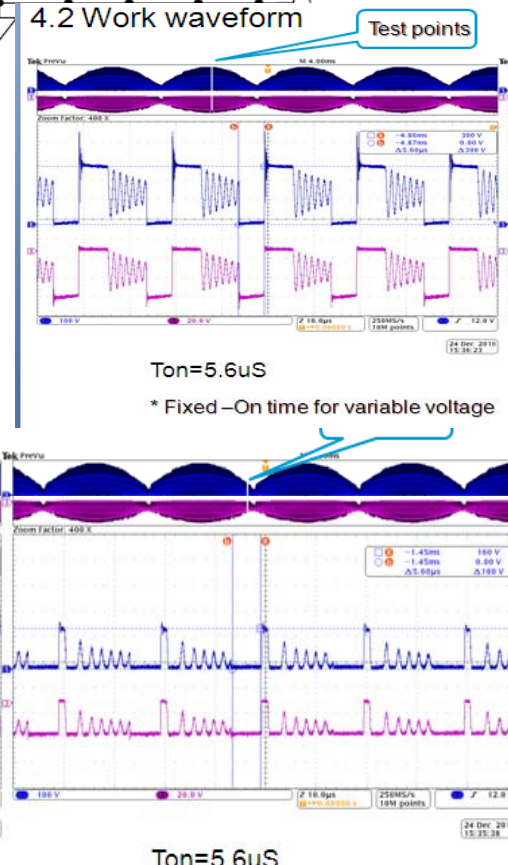
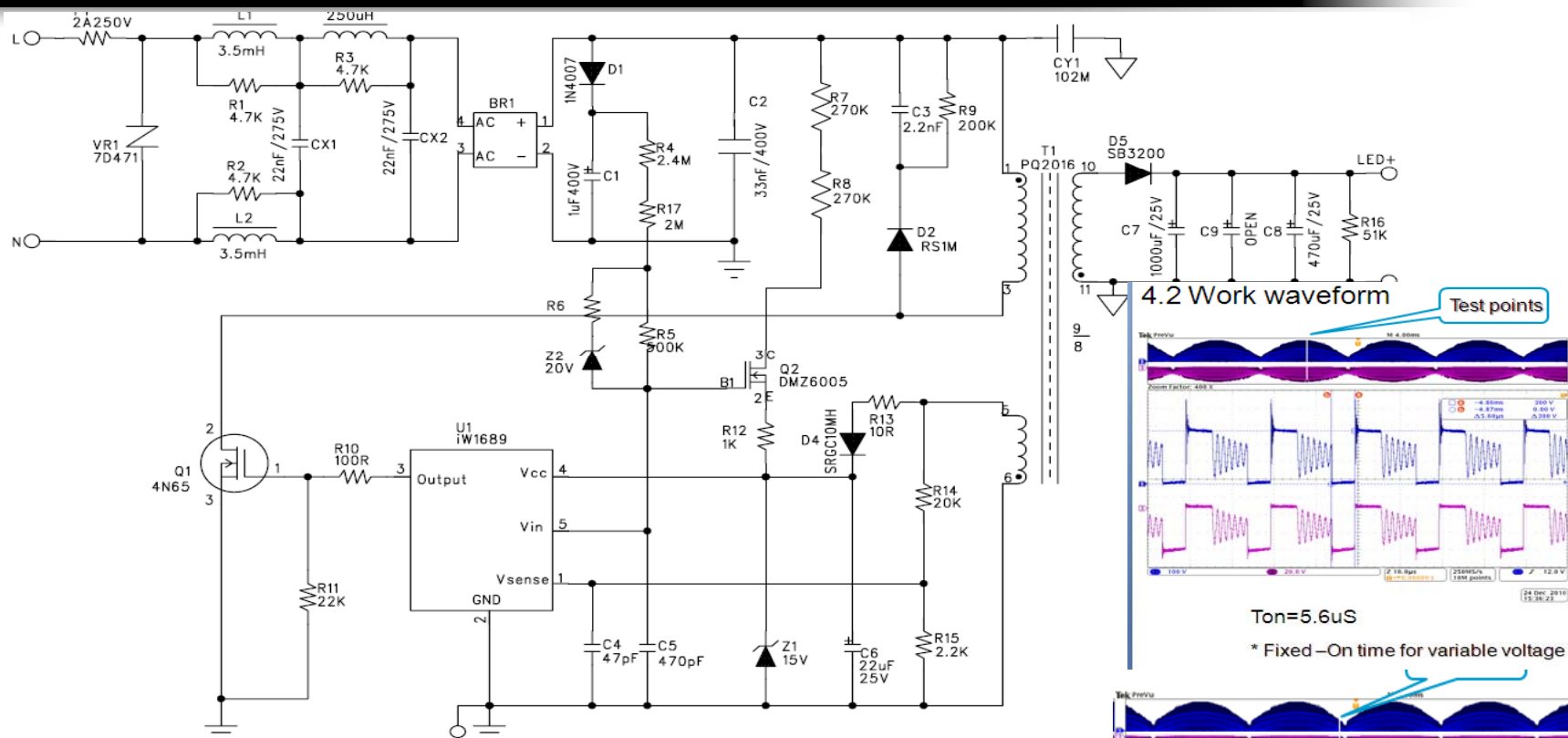
Efficiency: >88%



- iW3620 operating frequency up to 130KHz, MOSFET drive
- Good for wide AC input, 4-20W designs
- High efficiency, small size, low cost
- CC accuracy reaches 3%

Refers to iWatt demo for details

# Low Cost iW1689 Single Stage Design



- **Lowest cost**
- **Wide range input, PSR CC/CV mode**
- **Minimum components counts , Small PCB size**
- **No-poto-coupler,**

# Thanks

iWatt, your partner to deliver green power

**Jerry Zheng**  
VP, Technical Marketing

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Los Gatos, CA  
jjzheng@iWatt.com