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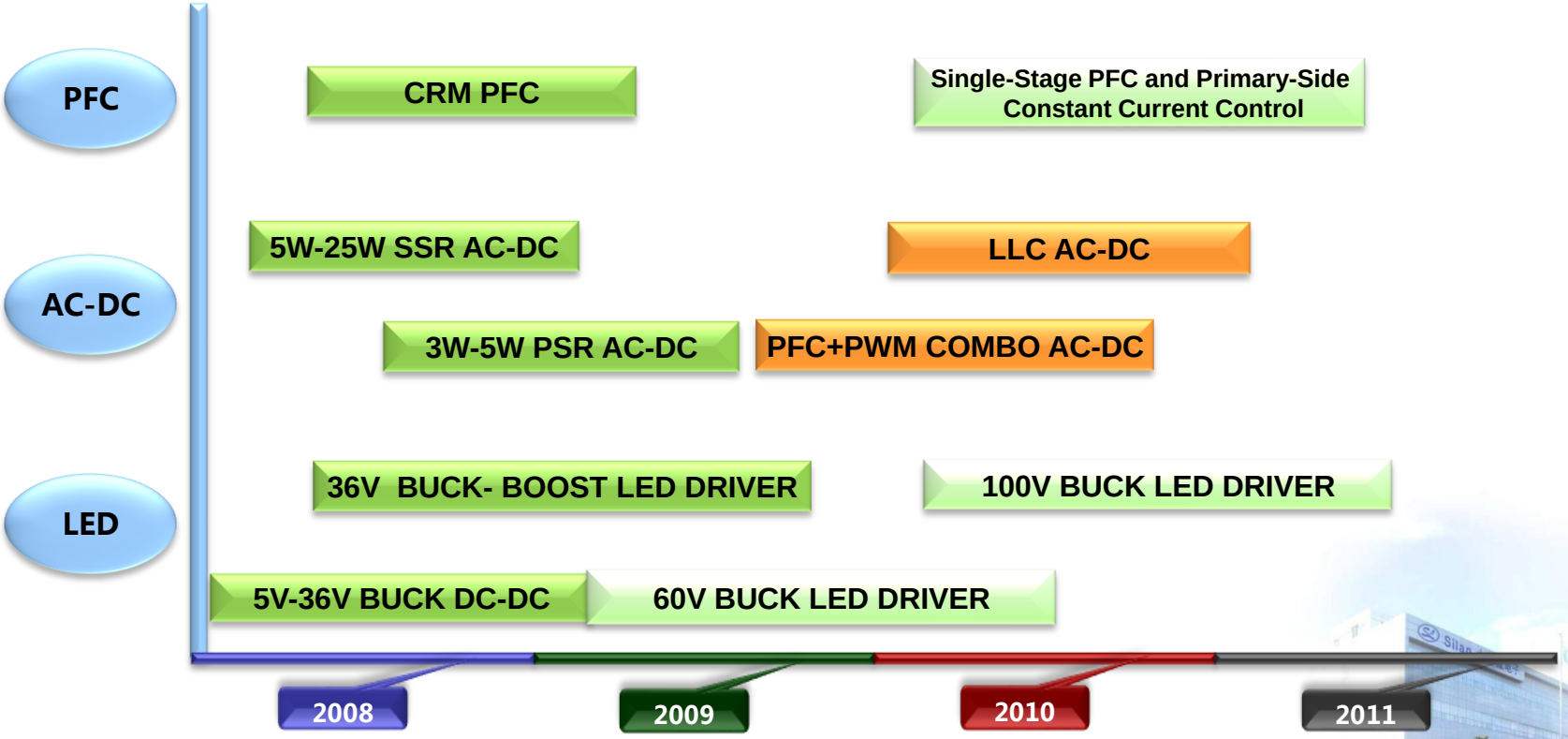
LED Illumination Solutions (2010)

- LED Driver Solution with Low Voltage Input (MR16, etc.)
- Intelligent Solar Lawn Lamp Solution
- High Voltage Spotlight/Bulb Lamp/PAR Light Solution
- Fluorescent Lamp Solution

2010-10-22

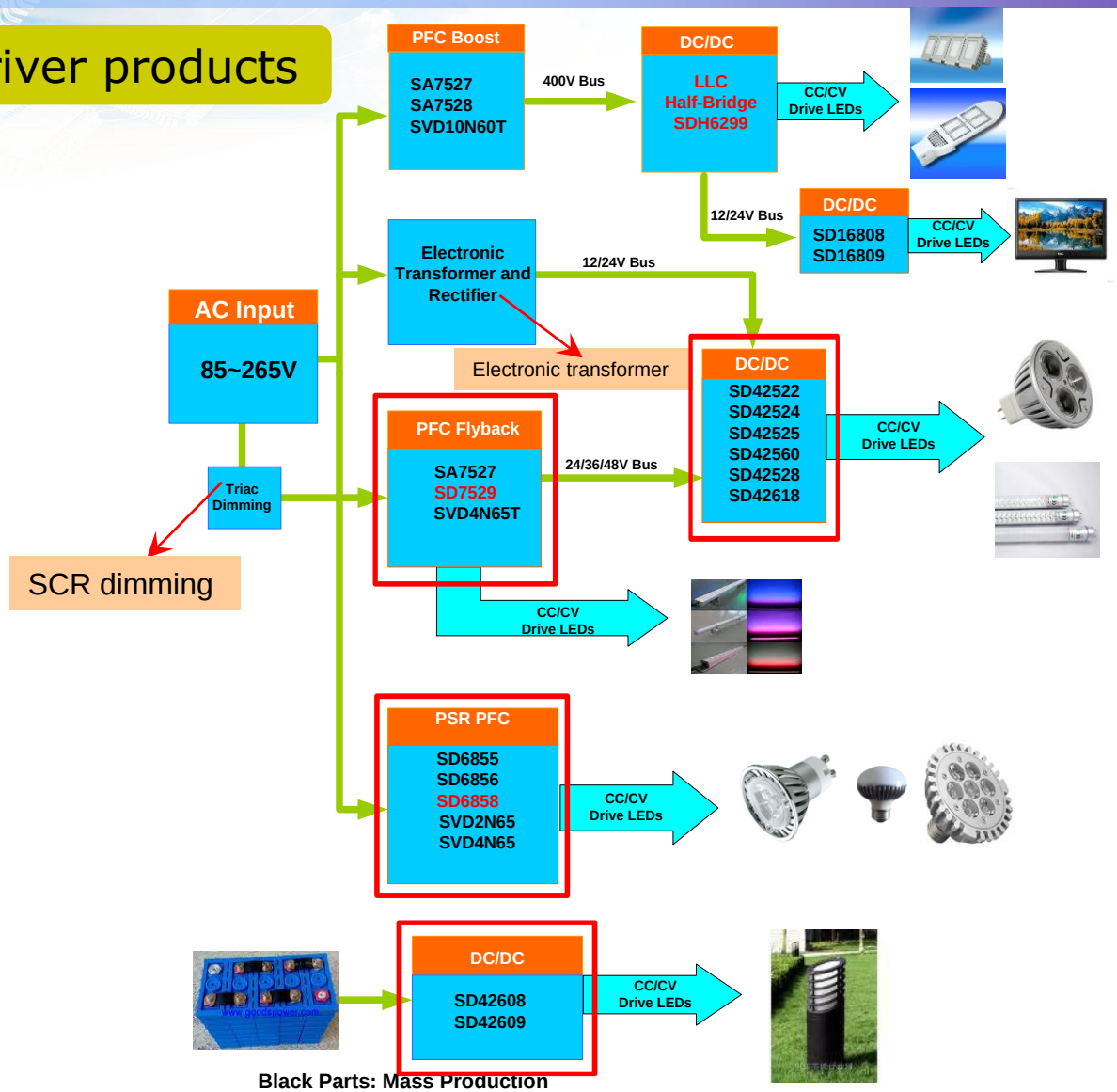
LED product topology

- DC-DC technology platform, including topology of BUCK, BOOST, BUCK-BOOST
- AC-DC technology platform, including topology of flyback (SSR/PSR), forward, LLC etc.
- PFC technology platform, including PSR+PFC



LED Product Line

LED driver products



Black Parts: Mass Production

Red Parts: Under design

DC-DC LED Driver

Power supply	Application	Max. output power	Input voltage	Output voltage	Max. output current	CC Accuracy	LED Qty. in series	Efficiency	Power factor	Part No.	Features
AC 12V/24V DC 12V~60V Electronic transformer	MR16 spotlight secondary constant current	24W	6-36V	Vin*0.95	1000mA	±1.5%	10	max.96%	-	SD42522	*
		24W	6-36V	Vin*0.95	1000mA	±1.5%	10	max.96%	-	SD42524	Linear dimming PWM dimming
		18W	6-36V	Vin*0.95	1000mA	±3%	10	max.96%	-	SD42525	hysteresis loop linear dimming PWM dimming
		28W	6-36V	Vin*0.95	1200mA	±1.5%	10	max.96%	-	SD42560	PWM dimming
		24W	6-36V	Boost	1000mA	±1.5%	10	Max.95%	-		
		6W	Note 1	Buck-Boost	400mA	±2%	10	max.82%	-		
		-	6-36V	Boost	Note 2	±2%	-	Max.95%	-	SD42618	external MOSFET PWM dimming
		36W	6-60V	Vin*0.95	1000mA	±2%	15	max.96%	-	SD42528	wide voltage input
2.4V-5.0V	lawn lamp	0.5W	2.4-5.0V	Buck-Boost	150mA	±1%	1	Max.85%	-	SD42608	asynchronous charge/discharge control current reduced on
		0.6W	2.4-5.0V	Boost	100mA	±1%	2	Max.90%	-		
2.4V-5.0V	lawn lamp	0.6W	2.4-5.0V	Boost+CC	200mA	±1%	1	Max.90%	-	SD42609	synchronous current reduced on schedule
DC12V/24V	Backlight	8W	4.5-28V	40V	30mA	±3%	8*10	Max.90%	-	SD16808	linear dimming PWM dimming
DC12V/24V	Backlight	23W	8.0-28V	60V	60mA	±3%	12*10	Max.90%	-	SD16809	linear dimming PWM dimming

Note 1: input voltage +output voltage <36V;

Note 2: output current is externally defined;

AC-DC LED Driver

Power supply	Application	Max. output power	Input voltage	Max. output current	CC accuracy	Efficiency	Power factor	Part No.	Features
85V-265V	High-voltage spotlight	5W	85V-265V	1000mA	±5%	75%(3*1W)	-	SD6855	PSR Driver TR
	Bulb lamp	7W	85V-265V	1000mA	±5%	77%(3*1W)	-	SD6856	PSR Driver MOSFET
	PAR lamp	12W	85V-265V	1000mA	±5%	-	-	SD6858	PSR PFC dimming
85V-265V	Fluorescent lamp	36W	85V-265V	-	-	87%	>0.96	SA7527	PFC
	Fluorescent lamp	36W	85V-265V	-	-	87%	>0.96	SD7529	PFC
85V-265V	Street lamp	100W	85V-265V	-	-		-	SDH6128	PFC+PWM
		150W	85V-265V	-	-		-	SD7528	PFC
		150W	85V-265V	-	-		-	SDH6299	LLC

Silan's **LED driver solution**

1 LED driver solution with low-voltage input (MR 16 etc.)

2 Intelligent solar lawn lamp driver solution

3 High-voltage spotlight, bulb lamp, PAR lamp driver solution

4 Fluorescent lamp driver solution

1. Low-voltage input LED driver solution

36V 1A BUCK structure
48V/60V MOSFET
3 strings MR16/stage lamp/secondary CC

36V 1A BUCK hysteresis loop
48V MOSFET
3 strings MR16, landscape lighting

36V BOOST structure
external power MOSFET
electronic transformer lighting
secondary CC

BCD1536
BIC0809
BCD1560

Applications	Power Supply	2009 Q1	2009 Q2	2009 Q3	2009 Q4	2010 Q1	2010 Q2	2010 Q3	2010 Q4	2011 Q1	2011 Q2	2011 Q3	2011 Q4
LED Spotlight Landscape Lighting LED streed Lamp	6V-75V	SD42522/4					SD42618						
				SD42525				SD42528					
					SD42560								

36V BUCK-BOOST structure
48V MOSFET
electronic transformer lighting/5 strings MR16
Solar LED lamp

60V 1A BUCK structure
75V MOSFET
T8-T10, street lamp

The whole product series, including topology of BUCK, BOOST and BUSK-BOOET.

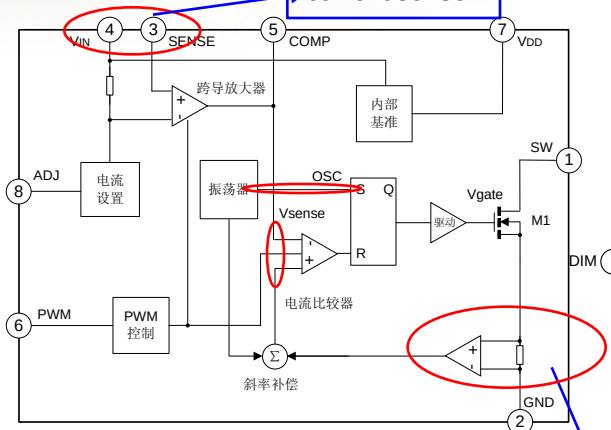
Typ. maximum operating voltage: 36V, max. operating voltage: 60V,product with 100V is under design.

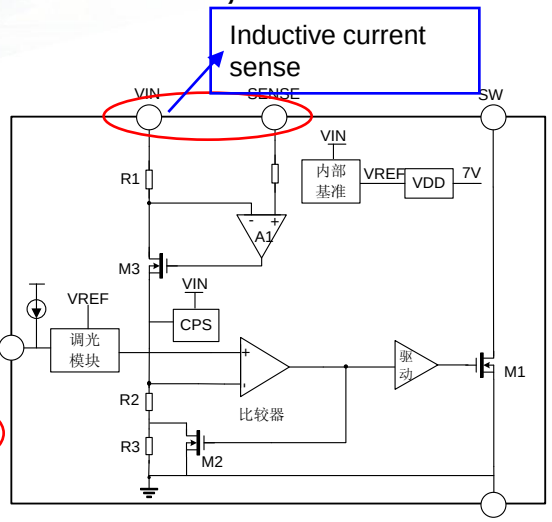
the voltage withdraw of MOSFET are 48V/60V/75V except that used in SD42618

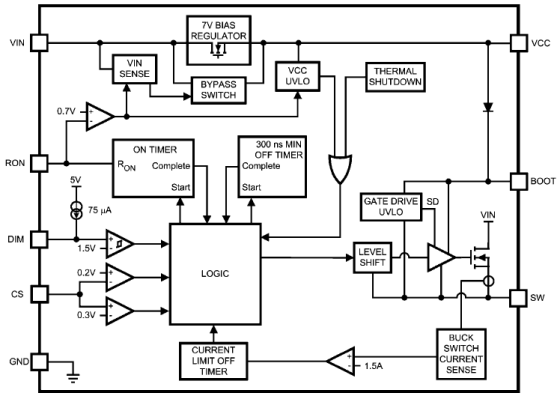
Part No.	Topology	Operating voltage	Output current	VIN-VOUT	MOSFET	CC accuracy	PWM dimming	Linear dimming	Package
SD42522/4	BUCK, average	6V~36V	1A(Max)	0.5V@350mA	0.35@48V	±1.5%	no/yes	no/yes	SOP8
SD42522/4EH	BUCK, average	6V~36V	1A(Max)	0.5V@350mA	0.6@60V	±1.5%	no/yes	no/yes	ESOP 8
SD42525	BUCK, hysteresus loop	6V~36V	1A(Max)	0.8V@350mA	0.5@48V	±3%	no	no	SOT89
SD42560	Buck-Boost average	6V~36V	1.5A(Max)	*	0.25@48V	±1.5%	yes	yes	ESOP 8
SD42618	BOOST, average	6V~36V	Externally defined	*	Externally defined	±1.5%	yes	yes	SOP16
SD42528	BUCK, average	6V~60V	1A(Max)	0.5V@350mA	0.6@75V	±1.5%	yes	yes	ESOP 8

1.0 Average current mode, hysteretic mode, constant-on mode

- Block diagram







Average current

Switching current sense

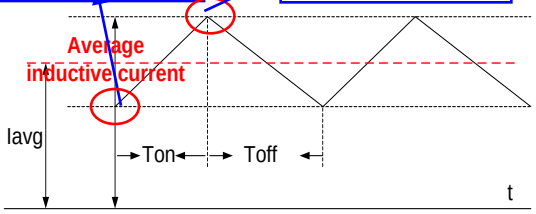
Hysteretic mode

Constant ON

- Inductive current

Fixed frequency ON

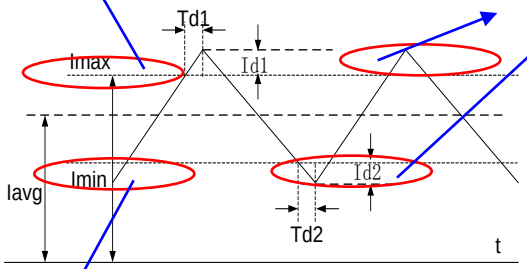
Turn off if the peak value is up to threshold value



Average current

Turn off when higher then the upper threshold value

CC characteristics are OK with three structures in ideal status.

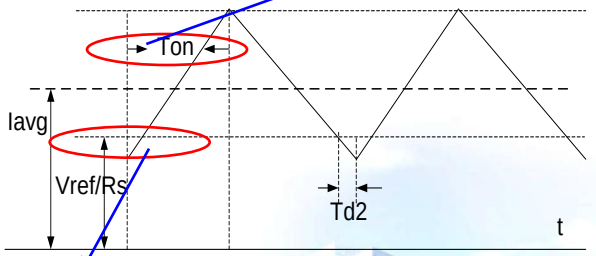


Turn on when lower than threshold value

Hysteretic mode

Rising slopes of inductive current are different with different power supplies and different loads, and Idl is different, as the same, Id2 is different in different conditions.

Turn off after ON period



Turn on when lower than threshold value

Constant ON

1.0 Comparison of average current mode, hysteretic mode and constant-on mode

- Characteristics

	Average current mode	Hysteretic mode	Constant on mode
Load regulation	Load has little effect on open-loop gain, and output current has small change	$\Delta I = -\frac{\Delta Vout}{2*L}*(Td1+Td2)$	$\Delta I = -(\frac{Td2}{L}+\frac{K}{2*L*Vin})*\Delta Vout$
Line regulation	Supplier voltage little effect on open-loop gain, and output current has small change	$\Delta I = \frac{\Delta Vin}{2*L}*Td1$	$\Delta I = \frac{Vo*K}{2L*Vin^2}*\Delta Vin$
Current ripple	$\frac{Vout}{L}*Toff$	$\frac{\Delta V}{Rs}$	$\frac{Vin-Vout}{L}*\frac{K}{Vin}$
current vs. external inductor	In continuous mode, the effect on current caused by inductor can be ignored	$\Delta I = -\frac{Vin*Td1-Vout*(Td1+Td2)}{2*L^2}*\Delta L$	$\Delta I = (\frac{Vout}{L^2}*Td2-\frac{K}{2*L^2}+\frac{K*Vout}{2*L^2*Vin})*\Delta L$

ΔI: current change
ΔVout: output voltage change
Td1: off-delay
Td2: on-delay
L: inductance
ΔL: inductance change
ΔV: hysteresis voltage
Rs: sense resistance
Vout: output voltage
Toff: off time
Ton: on time
K: time coefficient for fixed on

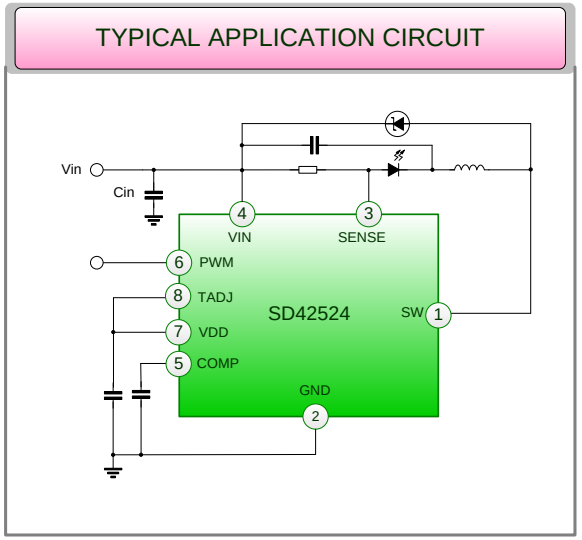
- **Conclusion**

	Average current mode	Hysteretic mode	Constant on mode
Line regulation	Good	Bad	Bad
Load regulation	Good	Bad	Bad
Current ripple	Small	Large	Affected by Ton
current vs. external inductor	can be ignored	great influence	great influence
Frequency	Fixed frequency	inverted frequency	inverted frequency
dimming response	common	Fast	Fast
loop	complex	simple	simple

1.1 Buck LED driver– SD42522/4

- Features

1. 6V~36V input voltage range
2. Buck average current mode
3. Maximum 1A output current
4. Efficiency up to 96%
5. Excellent constant current accuracy ±1.5%
6. Built-in temperature shutdown and over current protection
7. Frequency jitter
8. Linear/PWM dimming, and the ratio is 500:1
9. Temperature balance

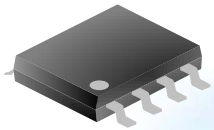


- **Application**

MR16 (1*1W,1*3W,3*1W)

LED illumination secondary CC (Max. 24W)

- Package: SOP8/ESOP8



1.1 Buck LED driver– SD42522/4 (continued)

- Line regulation/load regulation

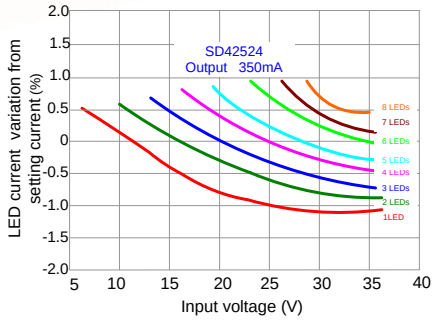


Figure 1: the CC accuracy is controlled within ±1.0% with different input voltages and different loads

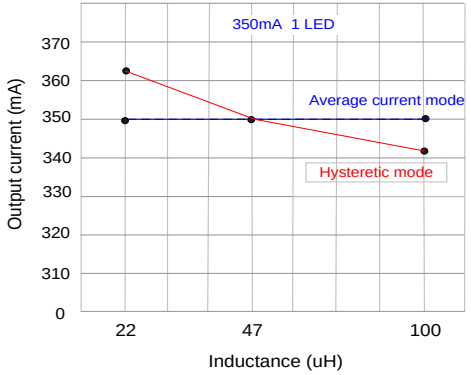
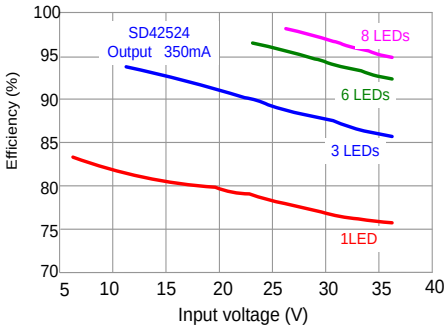


Figure 2: inductance vs. constant current (hysteretic mode is marked in red)

- Conversion efficiency



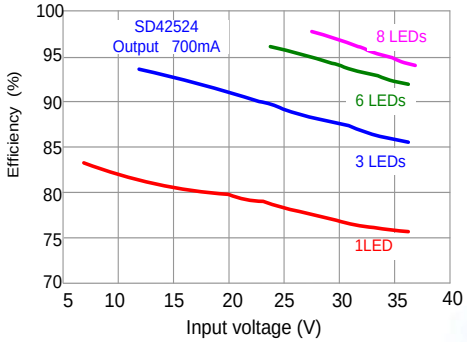


Figure 3: efficiency is up to 96%

- Temperature balance

$$V_{ADJ} > 1.22V \quad Iout = \frac{0.088}{Rs}$$

$$V_{ADJ} < 1.22V \quad Iout = \frac{0.088}{Rs} \times \frac{V_{ADJ}}{1.22}$$

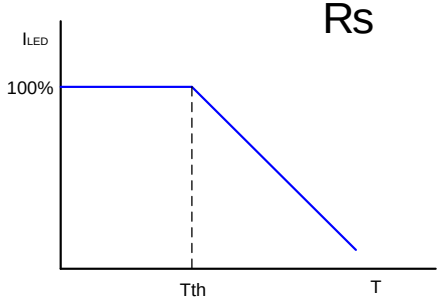
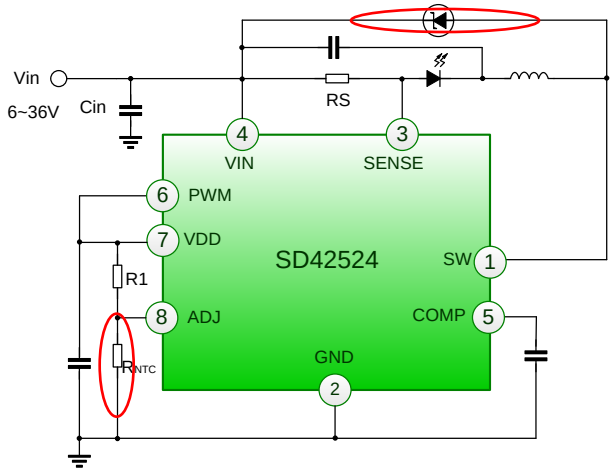


Figure 4: LED temperature can be reflected on thermal resistor. Temperature balance is available through selecting proper R1/NTC.



- Low-voltage current characteristics

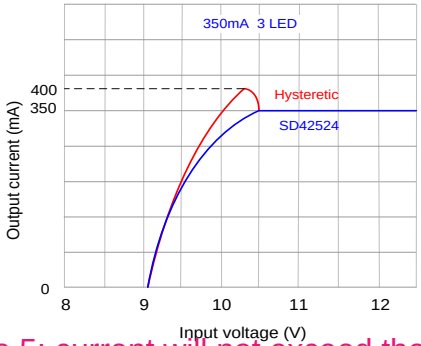


Figure 5: current will not exceed the preset value with low dropout.

- Frequency jitter

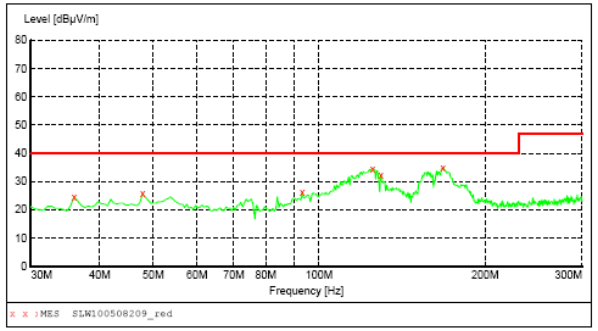
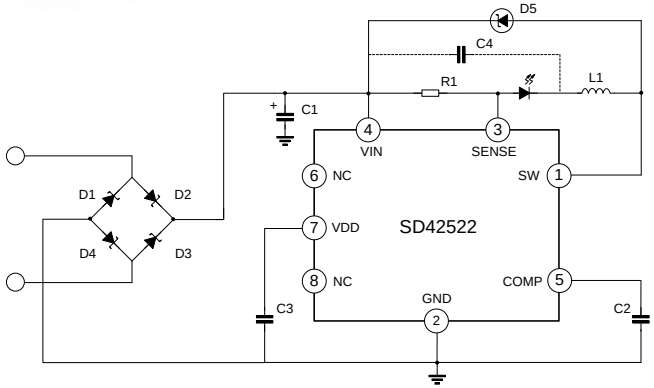
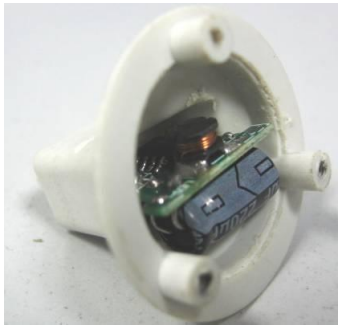


Figure 6: frequency jitter for low EMI. Generally, magnetic beads are needed for flywheel diode, then the peak value will be increased. MOSFET: 48V/60V

1.1 Buck LED driver– SD42522/4 (continued)

- MR16(3*1W)





- 2*18W External fluorescent lamp

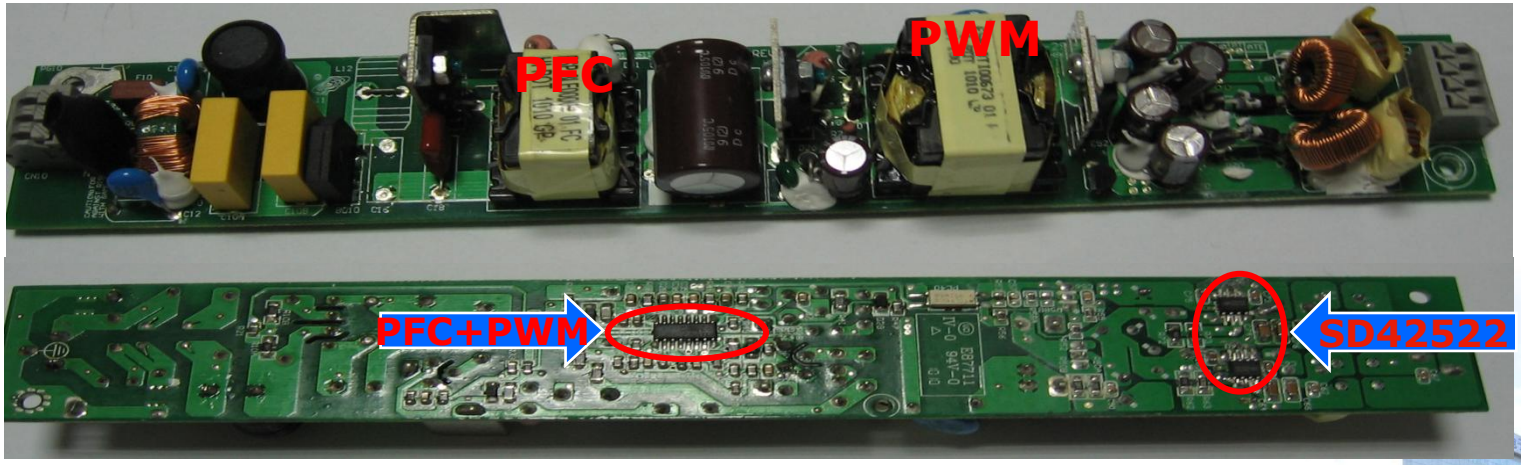
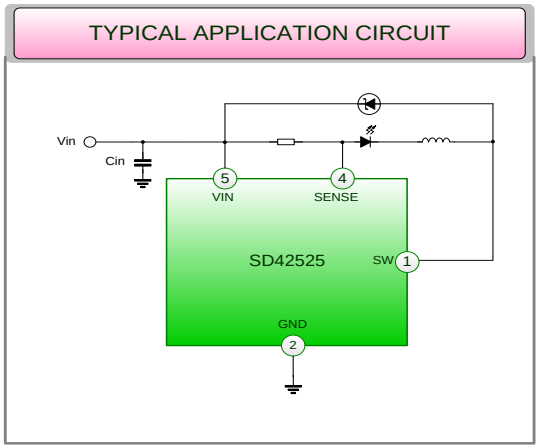


Figure 7: PWM+PFC+SD42522

1.2 Buck (hysteretic mode) LED driver– SD42525

Features

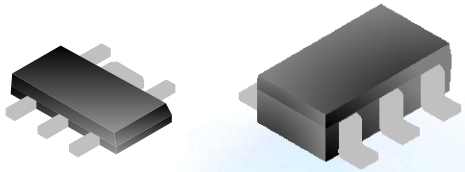
1. 5V~36V input voltage range
2. Buck hysteretic mode
3. Maximum 1A output current
4. Efficiency up to 96%
5. Excellent constant current accuracy ±3%
6. Built-in temperature shutdown and over current protection
7. Linear /PWM dimming, the ratio is 1000:1
8. Built-in line voltage compensation **(patent),** improving the line regulation
9. Low dropout overshoot current compensation **(patent)**



Application

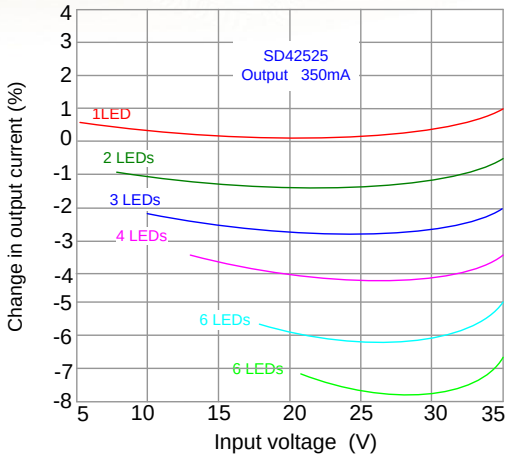
MR11/16 (1*1W,1*3W,3*1W)

Package: SOT89/SOT23

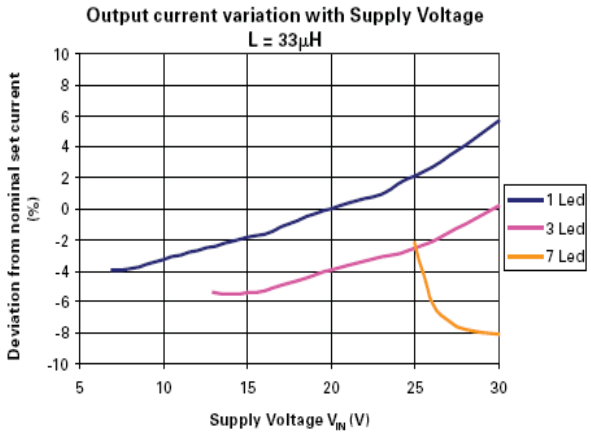


1.2 Buck (hysteretic mode) LED driver– SD42525 (continued)

- Line regulation and load regulation

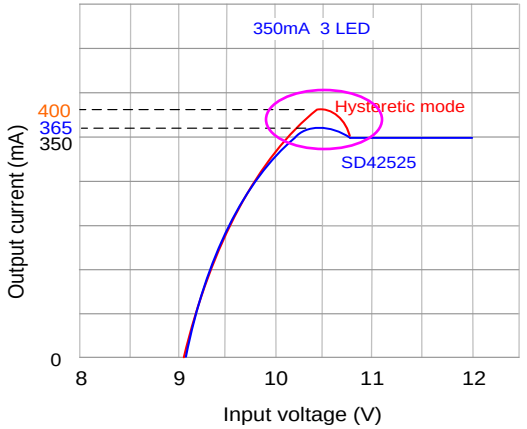


SD42525 voltage regulation (line voltage compensation)



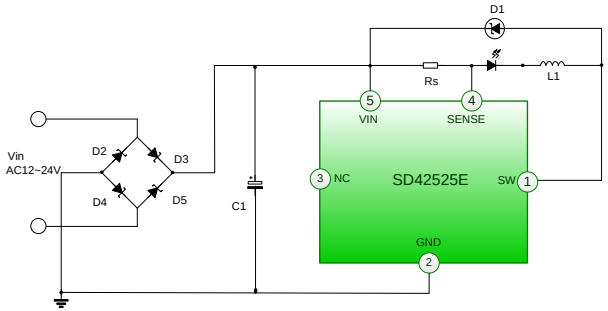
Voltage regulation in common hysteretic mode

- Low dropout overshoot current



Current before/after compensation

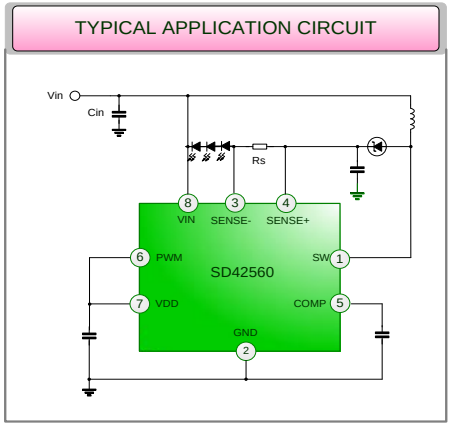
- MR11/16(3*1W)



1.3 Buck-boost LED driver-SD42560

Features

1. 5V~36V input voltage range
2. Buck-boost average current mode
3. Maximum 1.2A output current (Buck mode)
4. Efficiency up to: Buck 96%/ Boost 95%/Buck-Boost 83%
5. Excellent constant current accuracy ±1.5%
6. Threshold value of over voltage protection: 40V(Boost/Buck-Boost)
7. Built-in temperature shutdown and over current protection
8. PWM dimming and the ratio is 500: 1
9. Frequency jitter



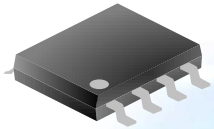
Application

MR16 (4*1W, 5*1W)

Electronic transformer

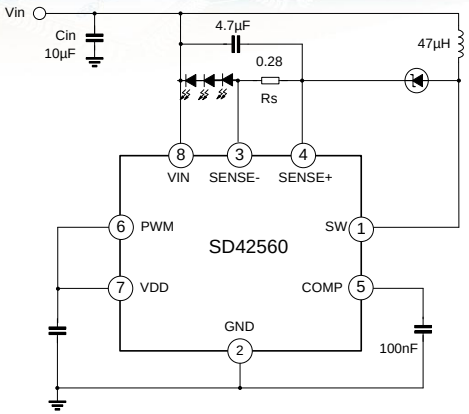
Solar LED illumination

Package: SOP8/ESOP8

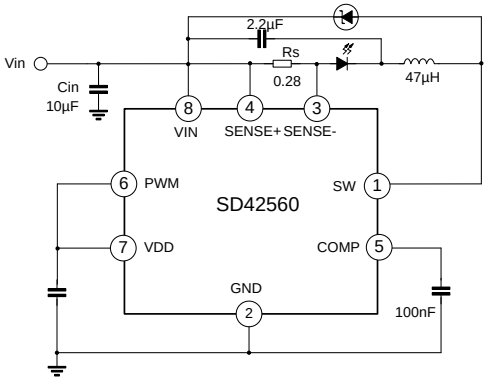


1.3 Buck-boost LED driver-SD42560 (Continued)

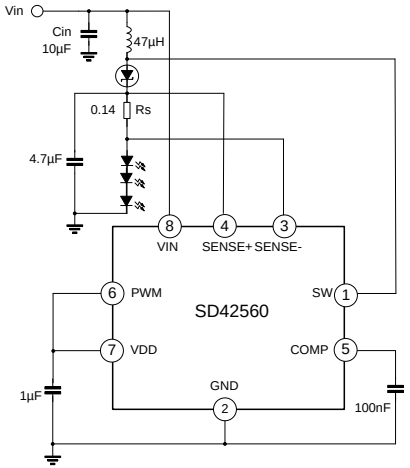
- Boost / Buck / Buck-Boost



Buck-Boost mode

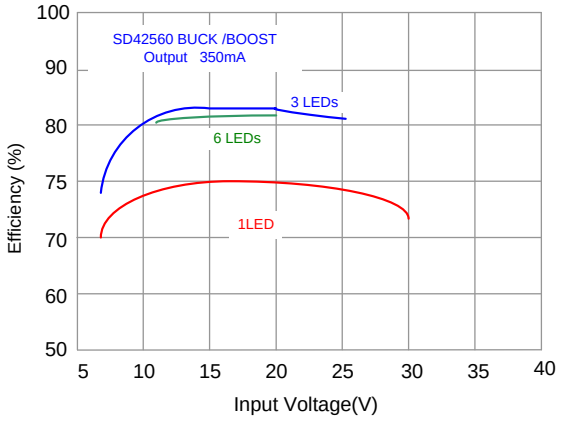


Buck mode



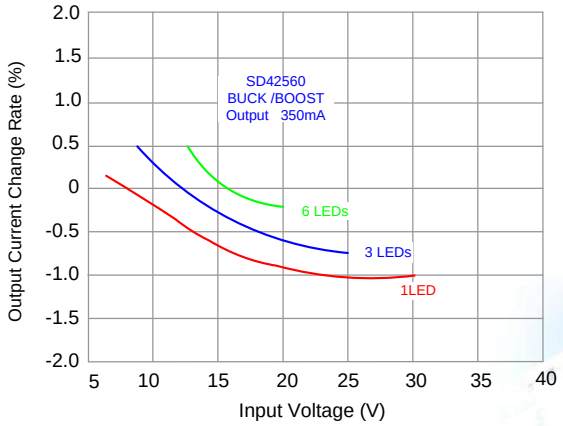
Boost mode

- Conversion efficiency (Buck-Boost)



IOUT=350mA

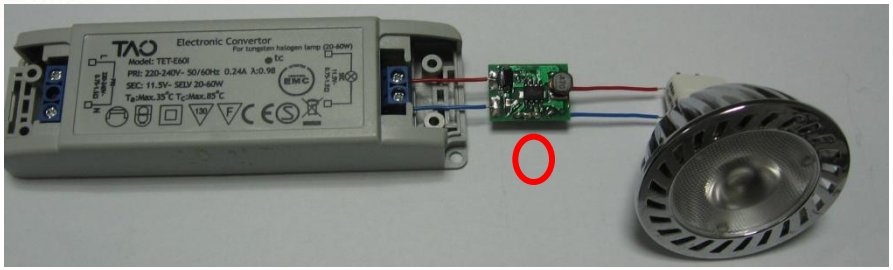
- CC accuracy (Buck-Boost)



IOUT=350mA

1.3 Buck-boost LED driver-SD42560 (Continued)

- Application of electronic transformer

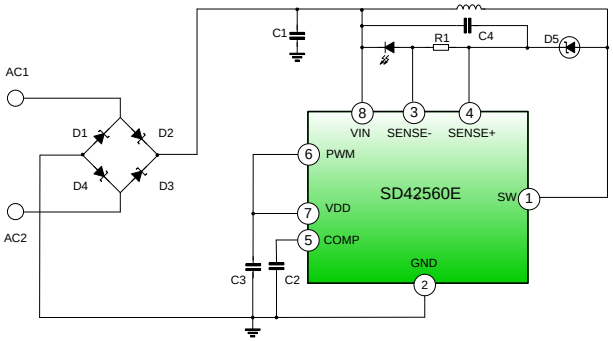


In LED illumination powered by electronic transformer, the frequent questions are failure in power on and power shortage with light load

SD42560 adopts Buck-Boost for enlarging operating voltage range and improving the energy efficiency.

Other patents relating to electronic transformer are under application.

- MR16(AC 12V 5*1W)



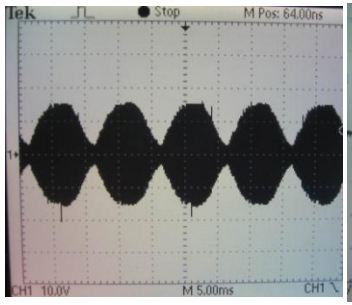


Figure 1. waveform output from electronic transformer

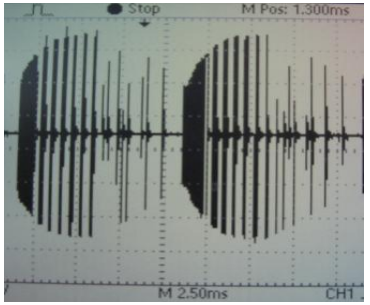
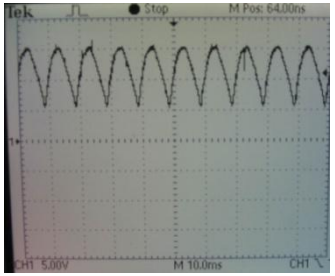
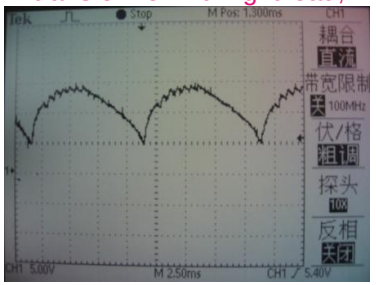


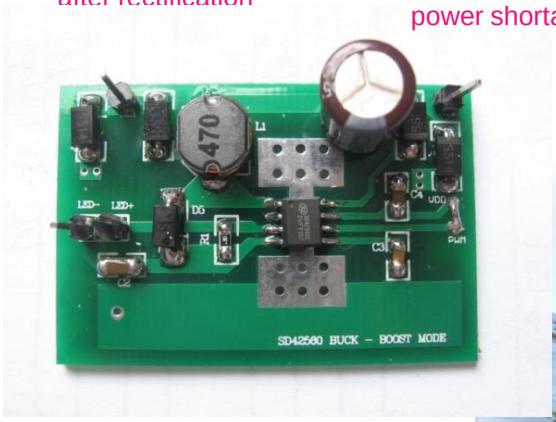
Figure 2. uncontinuous waveform from electronic transformer with light load,



Waveform (6V～14V) after rectification



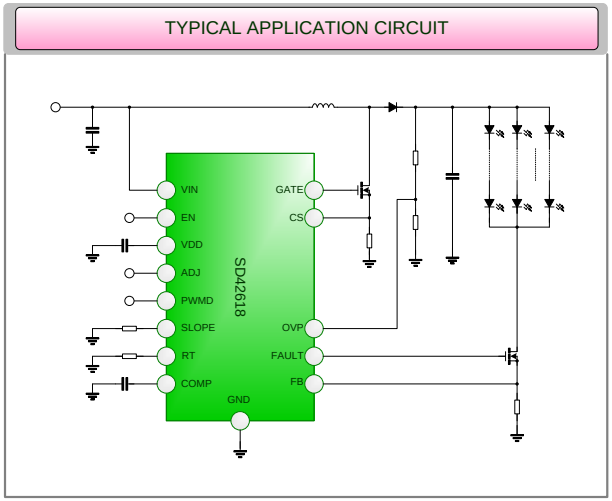
Abnormal waveform after rectification will cause power shortage



1.4 Boost LED driver – SD42618

Features

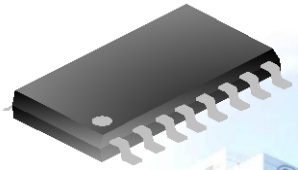
1. 6V~36V input voltage range
2. Boost average current mode
3. External MOSFET, and the current is decided by sense resistor
4. Built-in short-circuit protection
5. Built-in over voltage prtoection (the threshold value is externally defined)
6. Built-in temperature shutdown and over current protection
7. PWM/linear dimming
8. Frequency jitter
9. Thermal balance compensation



Application

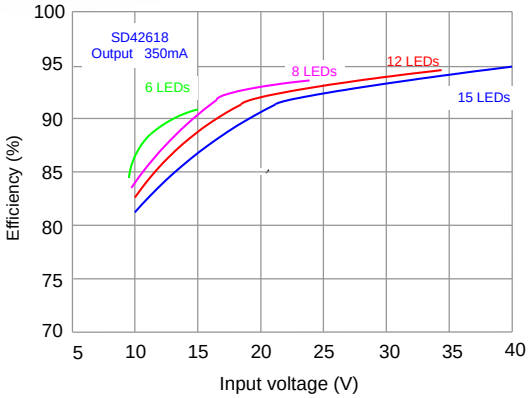
LED illumination secondary constant current (External MOSFET)
Electronic transformer

Package: SOP16



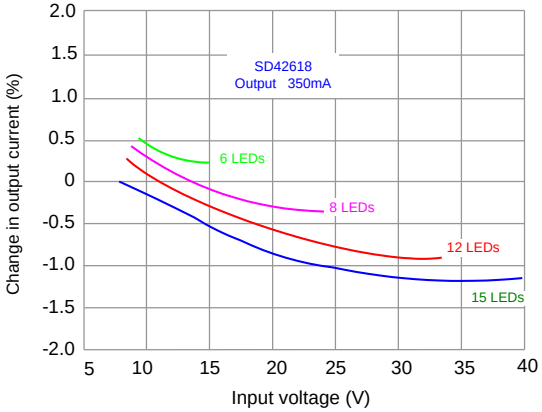
1.4 Boost LED driver – SD42618 (Continued)

- Conversion efficiency



IOUT=350mA

- CC accuracy

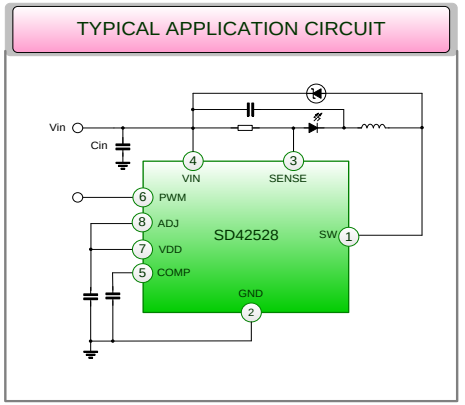


IOUT=350mA

1.5 Buck LED driver – SD42528

Features

1. 6V~60V input voltage range
2. Buck average current mode
3. Maximum 1.0A output current
4. Efficiency up to 96%
5. Excellent constant current accuracy ±2%
6. Built-in temperature shutdown and over current protection
7. PWM dimming and the ratio is 500: 1
8. Frequency jitter
9. Thermal balance compensation



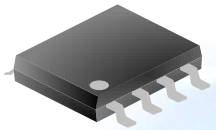
Application

T8-T10 secondary constant current (Max. 36W)

Street lamp

Automobile illumination

Package: ESOP8



HV spotlight, bulb lamp, PAR lamp

3. PSR PFC LED controller

BCD10700
BIC0809

Applications	Output Power	2009 Q1	2009 Q2	2009 Q3	2009 Q4	2010 Q1	2010 Q2	2010 Q3	2010 Q4	2011 Q1	2011 Q2	2011 Q3	2011 Q4
HV spotlight	3W-7W					SD6855							
						SD6856							
PAR lamp	5W-12W							SD6858					

Output power: 5-7W
external driver
MOSFET
HV spotlight, bulb lamp, PAR lamp

Output power: 3-5W
external driver
HV spotlight

Output power: 5-12W
External driver MOSFET
PFC function
Triac dimming
HV spotlight, bulb lamp, PAR lamp

GU10 spotlight

E27 spotlight

Bulb lamp

PAR38

Part No.	Start mode	Control mode	MOSFET	Output power (Max.)	Package
SD6855	Resistor	PFM	External	3W-5W	SOT23-6
SD6856	Resistor	PFM	External	5W-7W	SOT23-6
SD6858	Resistor	PFM	External	5W-12W	SOP8

3.1 PSR LED driver– SD6855(transistor), SD6856 (MOSFET)

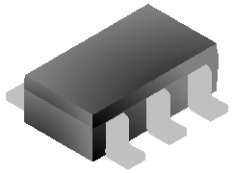
Features

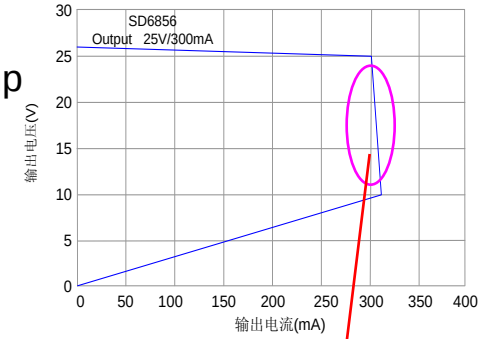
1. Low start current: < 3uA
2. PFM mode
3. Successive current limit
4. CV/CC control mode
5. Over voltage, under voltage, open-circuit and over temperature protections
6. CC accuracy: ±5%
7. Output power: 5W (transistor), 7W (MOSFET)
8. No need of opto-coupler and 431

Application

Spotlight, bulb lamp, PAR lamp

Package: SOT23-6





LED works in CC mode

Resistor start, the low start current is helpful to reduce power dissipation and improve the efficiency. Resistor: 5M-10M

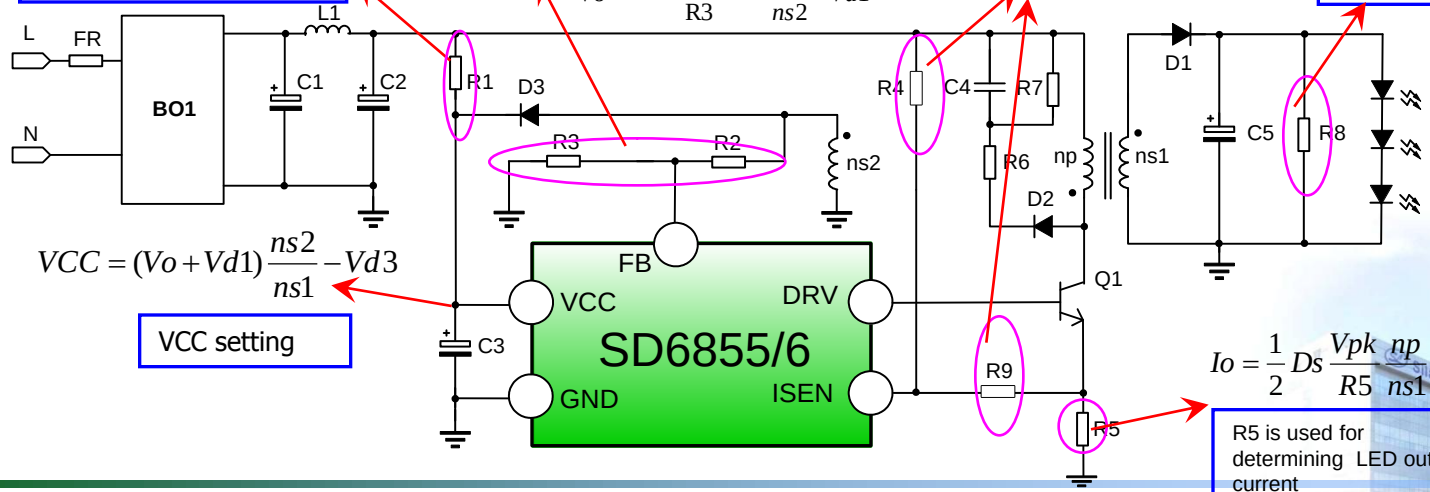
The output voltage should be set considering the LED quantity to ensure VO>LED VF and to make the IC working in CC mode. Also, the no-load voltage should be taken into consideration.

$$Vo = \frac{2.1(R2+R3)}{R3}\frac{ns1}{ns2} - Vd1$$

R4 is used for adjusting current consistency with high/low voltage inputs.

$$\frac{R9}{R4 \cdot R5} = \frac{Tdel}{Lm}$$

R8 is used for controlling no-load voltage



$$VCC = (Vo + Vd1)\frac{ns2}{ns1} - Vd3$$

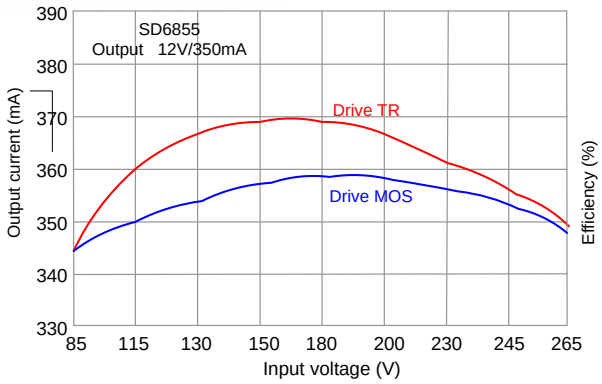
VCC setting

$$Io = \frac{1}{2} Ds \frac{Vpk}{R5} \frac{np}{ns1}$$

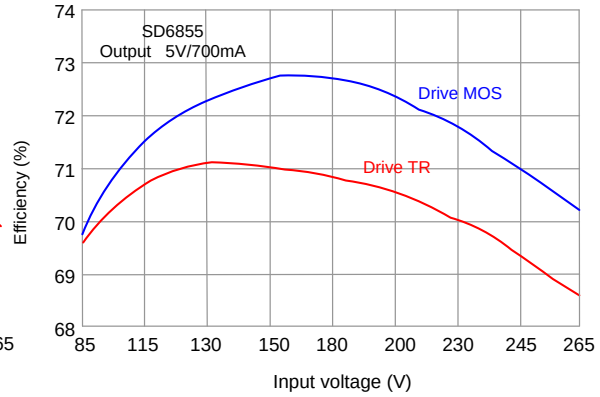
R5 is used for determining LED output current

3.2 PSR LED driver– SD6855(transistor), SD6856 (MOSFET)(Continued)

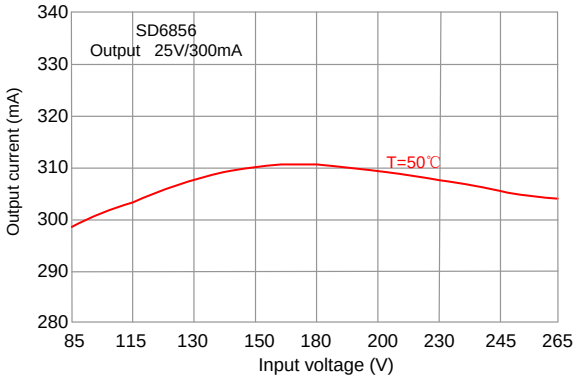
- 3×1W current accuracy



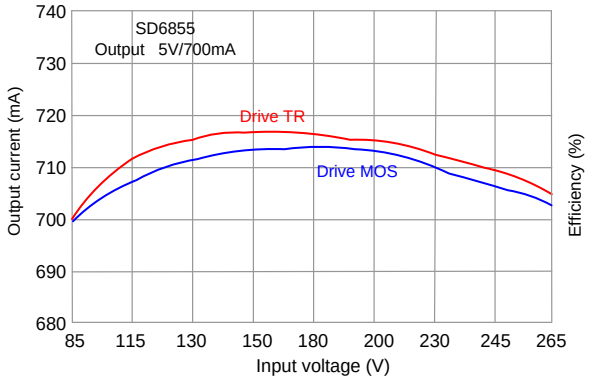
- 1×3W current accuracy



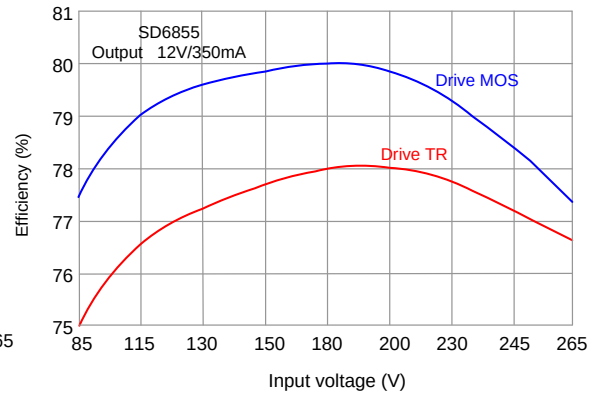
- 7×1W current accuracy



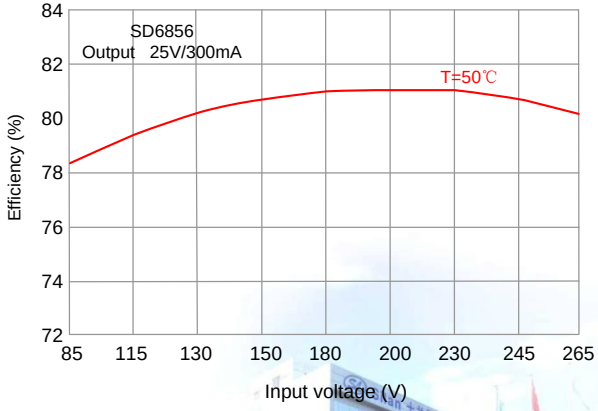
- 3×1W current accuracy



- 1×3W Efficiency



- 7×1W Efficiency

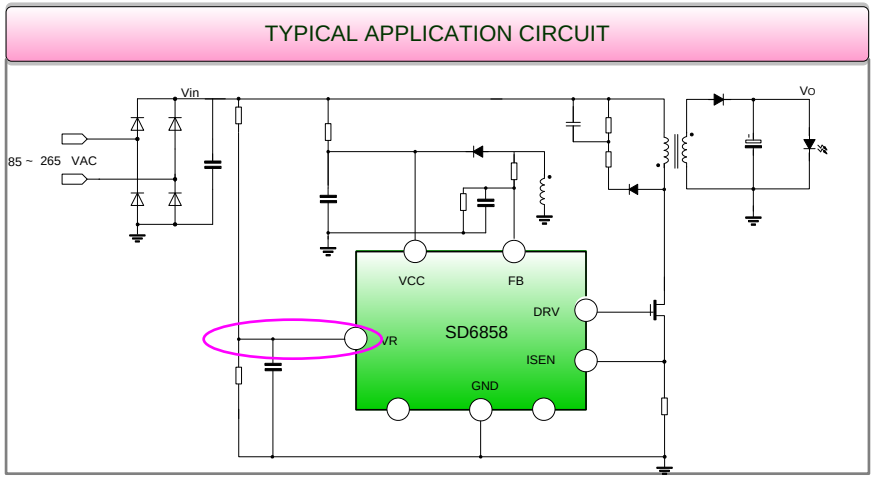


Driver MOSFET features high efficiency, suitable for large power needed

3.1 PSR PFC LED driiver– SD6858

- **Features**

1. Integrated PFC function
2. SCR dimming
3. Built-in soft start
4. Built-in VCC under voltage protection
5. Cycle-by-cycle current limit
6. Output short-circuit and over-voltage protections
7. Maximum output power:12W

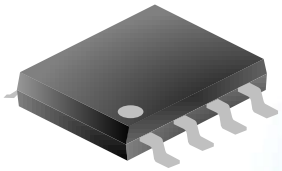


Patent of PSR PFC CC control with dimming is under application

- **Application**

Spotlight, bulb lamp, PAR lamp

- Package: SOP8



Fluorescent light

4. PFC LED controller

BCD1525
BCD10700

Applications	Output Power	2009				2010				2011			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
LED fluorescent lamp	12W-36W	SA7527					SD7529						

TM PFC for LED fluorescent lamp (Flyback application)

To reduce no-load standby power dissipation
To increase OCP to increase source over current protection

Part No.	Description
SA7527	CRM PFC controller
SD7529	No-load standby/OCP/source over current

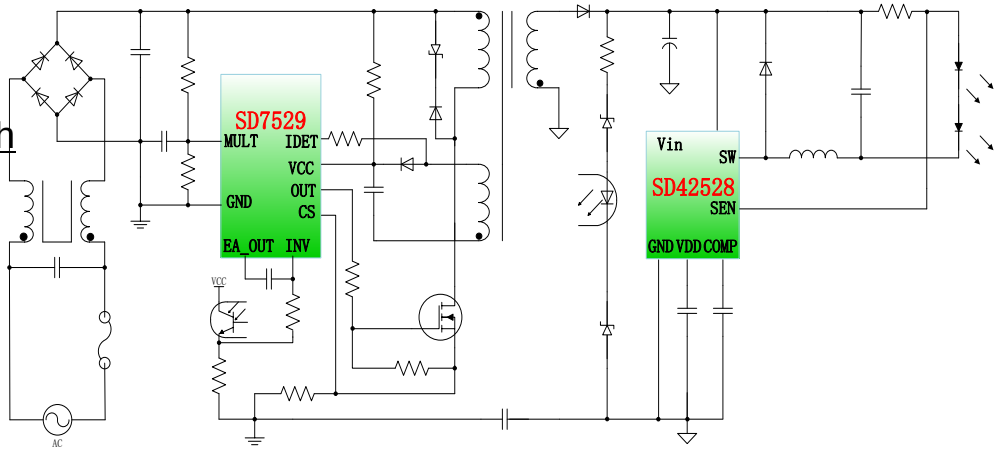
Fluorescent lamp

4.1 PFC LED driver−SD7529

- **Features**

1. Low start current: 30uA
2. High-quality linear multiplier
3. Over voltage adjustment with high accuracy.
4. Built-in soft start
5. Source over current protection
6. Output short-circuit protection (patent is under application)

TYPICAL APPLICATION CIRCUIT

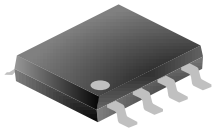


- **Application**

Built-in 18W fluorescent lamp

Built-in 18W*2 fluorescent lamp

- Package: SOP8



4.2 15W-18W isolated single-stage PFC driver solution

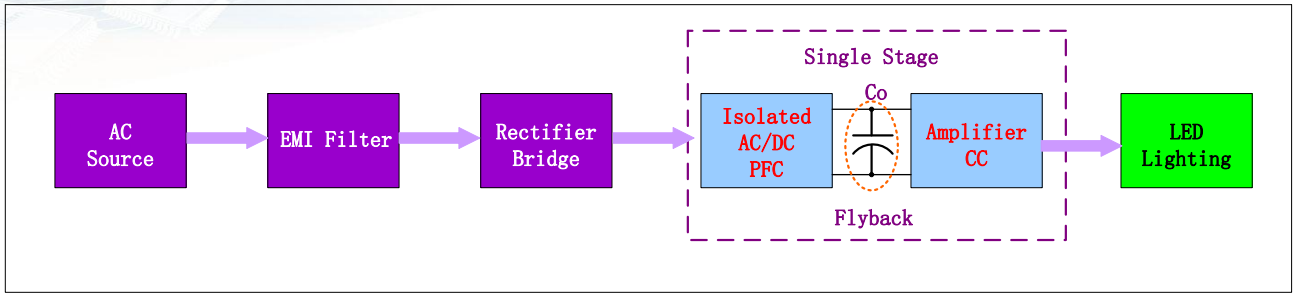


Figure 1 Block diagram

PFC output ripple is large and it is needed to reduce ripple by large output capacitor Co

Features(10 strings 550mA)

- 85～265V input voltage range
- PF>0.96
- Change in output current is less than ±3% with full-range input
- Efficiency: >86%
- Standby power dissipation< 0.5W
- Output voltage ripple< 1.35V
- Output current ripple< 175mA
- Co=330uF*3
- H=12mm,W=18mm,L=260mm

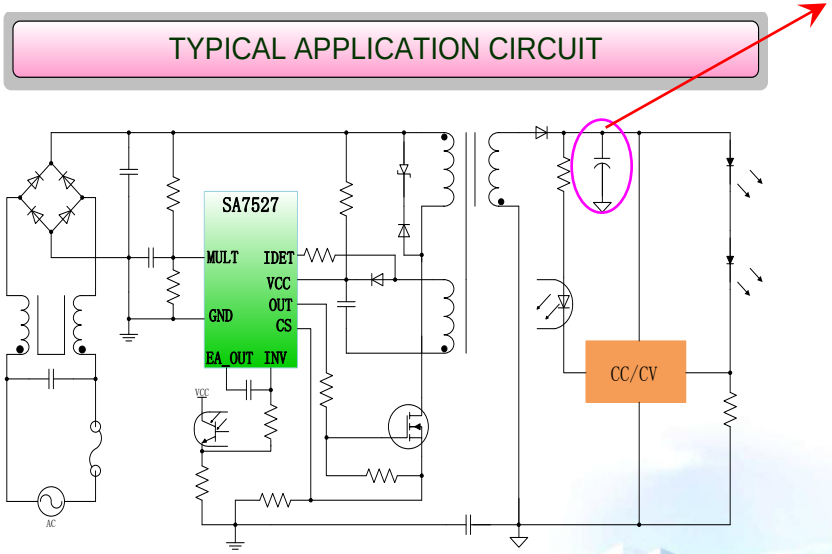


Figure 2 Schematic diagram of single-stage LED fluorescent lamp driver

Single-stage DEMO test results (25 ℃)

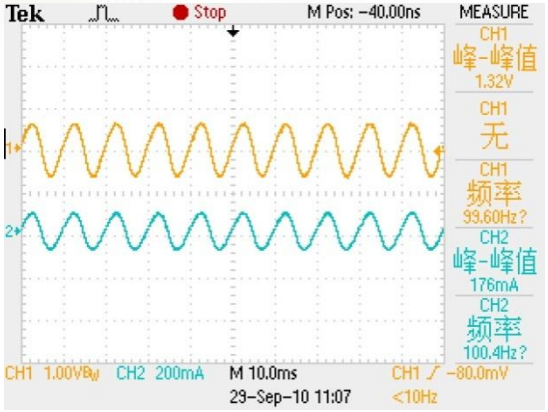


Figure 3 Output voltage ripple and current ripple

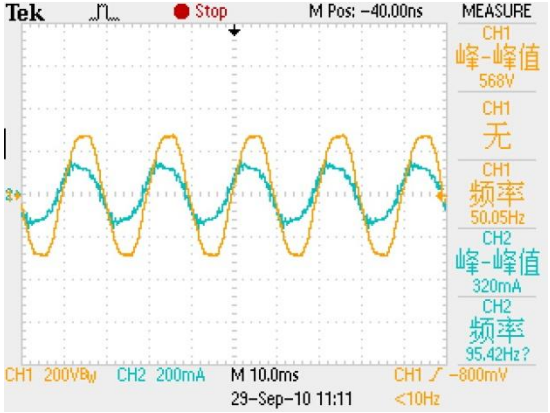


Figure 4 Input voltage ripple and current ripple

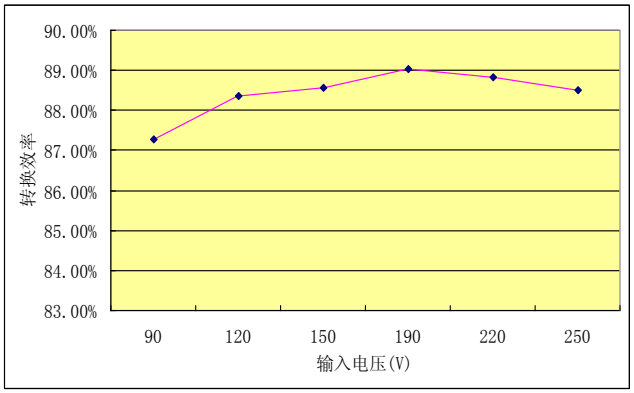
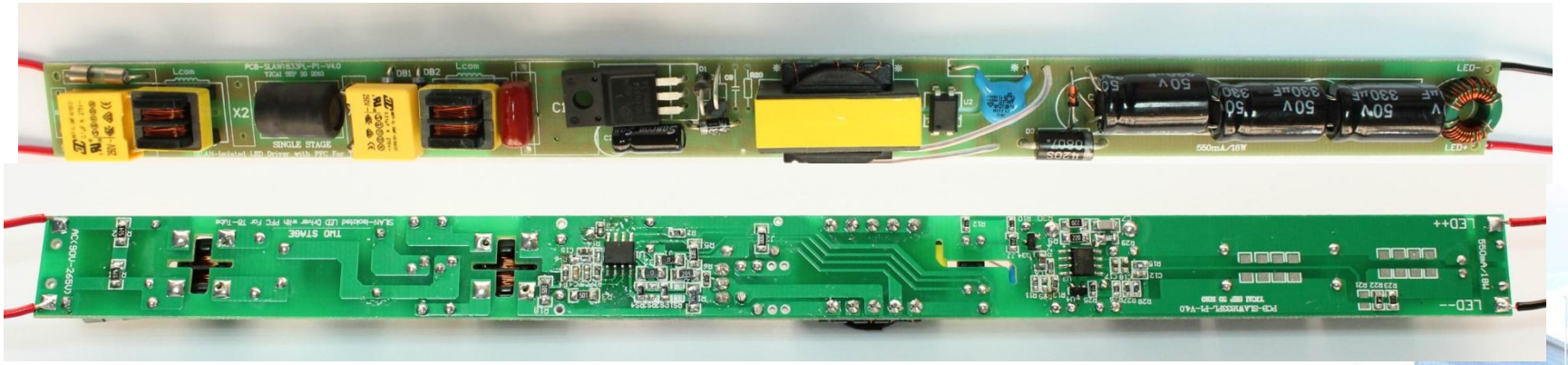


Figure 5 Efficiency

DEMO appearance



4.3 15W-18W isolated two-stage PFC driver solution

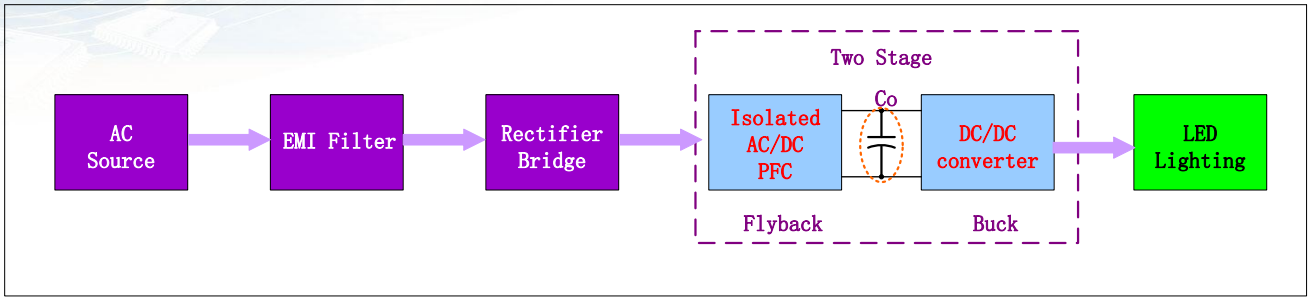


Figure 1 Block diagram for two stage solution

BUCK structure is used for decreasing ripple and reducing PFC output capacitance

Features (10 strings 550mA)

- 85～265V input voltage range
- PF>0.96
- Output current is less than ±1.5% with full-range input
- Efficiency: >85%
- Standby power dissipation< 0.5W->0.3W
- Output voltage ripple < 200mV
- Output current ripple< 20mA
- Co=330uF*1
- H=12mm,W=18mm,L=260mm

Patent of two-stage solution without opto-coupler/431 is under application

SCR dimming patent is under application

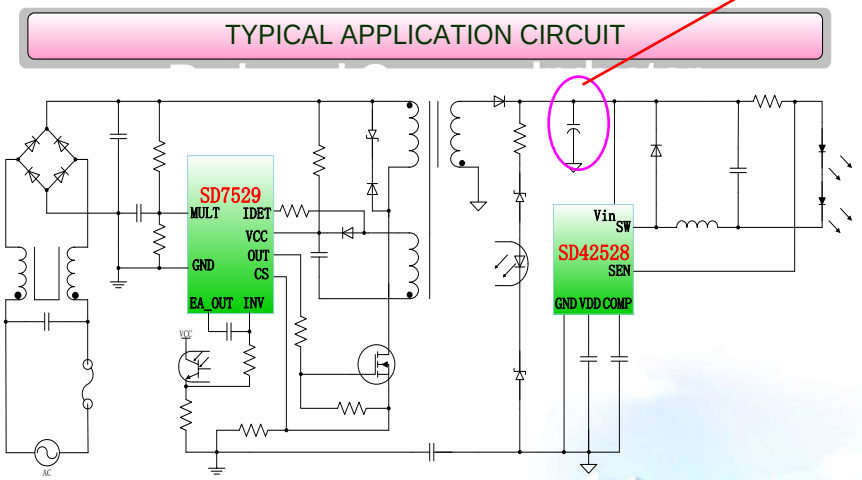


Figure 2 Schematic diagram of two-stage LED fluorescent lamp driver

Two-stage DEMO test results (25 ℃)

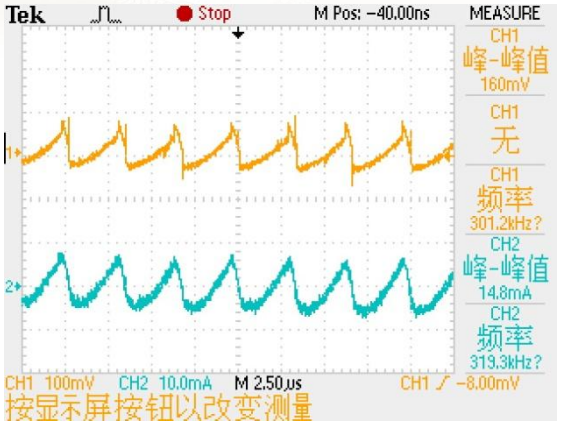


Figure 3 Output voltage ripple and current ripple

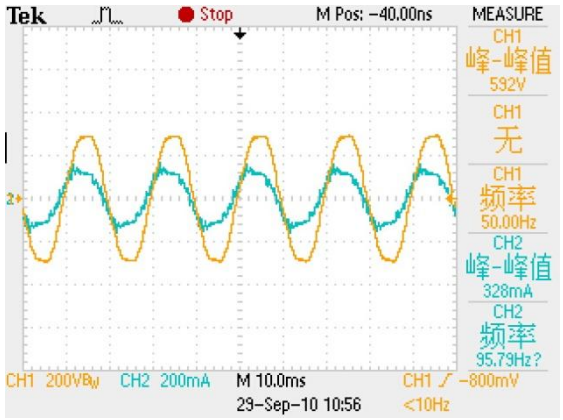


Figure 4 Input voltage ripple and current ripple

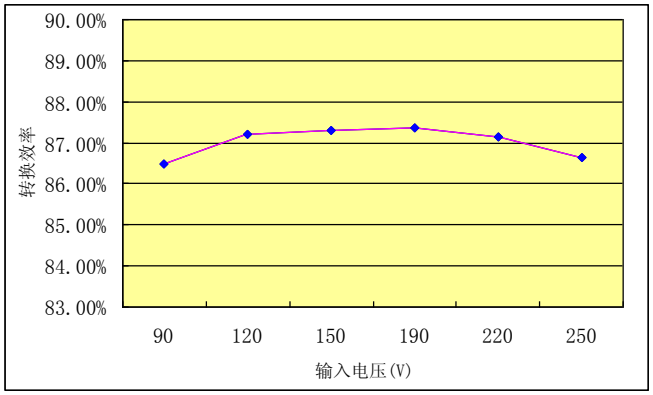
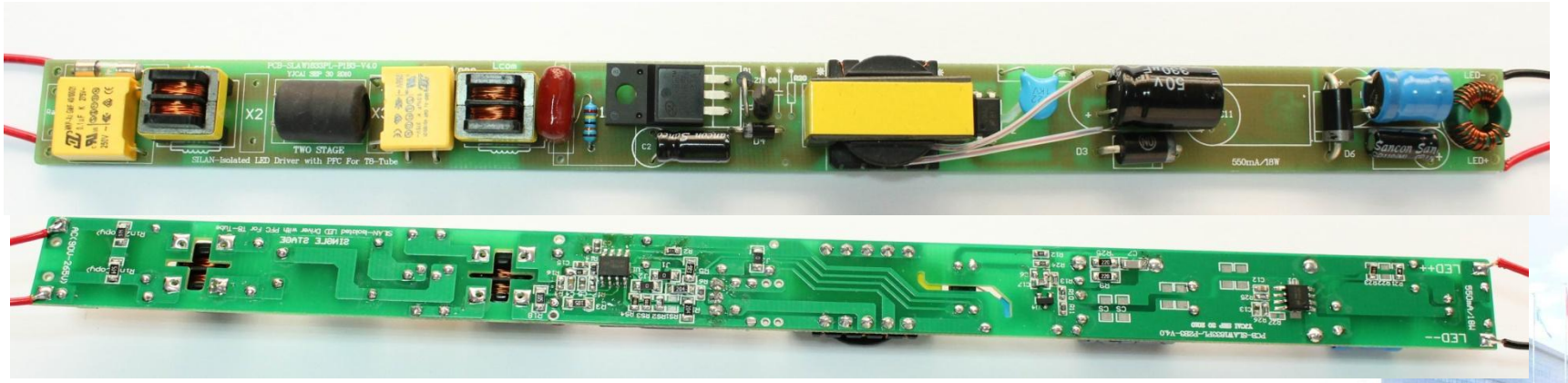


Figure 5 Efficiency

DEMO appearance



Thank you !