

GENERAL DESCRIPTION

The PT4211 is a continuous conduction mode inductive step-down converter, designed for driving single or multiple series connected LEDs from a voltage source higher than the LED voltage. The device operates from an input supply between 5V and 30V and provides an externally adjustable output current of up to 350mA.

The PT4211 includes the output switch and a high-side output current sensing circuit, which uses an external resistor to set the nominal average output current, and a dedicated DIM input accepts a wide range of pulsed dimming. Applying a voltage of 0.4V or lower to the DIM pin turns the output off and switches the device into a low current standby state. Built-in Soft Over Temperature Protection protects the device from over temperature damage.

The PT4211 is available in SOT23-5 package.

FEATURES

- Simple low parts count
- Wide input voltage range: 5V to 30V
- Up to 350mA output current
- PWM dimming
- 3% output current accuracy.
- Up to 1MHz switching frequency
- Typical 3% output current accuracy
- Inherent open-circuit LED protection
- High efficiency (up to 93%)
- Adjustable Constant LED Current
- High-Side Current Sense
- Hysteretic Control: No Compensation
- Soft Over Temperature Protection

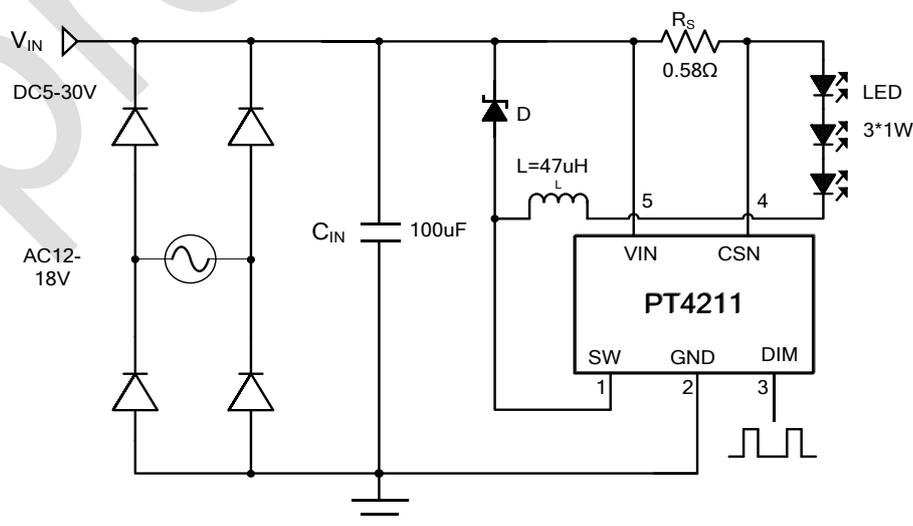
APPLICATION

- Low voltage halogen replacement LEDs
- Automotive lighting
- LED back-up lighting
- Illuminated signs

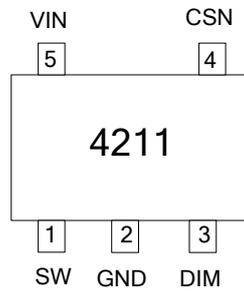
ORDERING INFORMATION

PACKAGE	TEMPERATURE RANGE	ORDERING PART NUMBER	TRANSPORT MEDIA	MARKING
SOT23-5	-40 °C 到 85 °C	PT4211E23E	Tape and Reel 3000 units	4211
SOT23-5	-40 °C 到 85 °C	PT4211F23E	Tape and Reel 3000 units	4211

TYPICAL APPLICATION CIRCUIT



PIN ASSIGNMENT



PIN DESCRIPTIONS

PIN No.	PIN NAMES	DESCRIPTION
1	SW	Switch Output. SW is the drain of the internal N-Ch MOSFET switch.
2	GND	Signal and power ground. Connect directly to ground plane.
3	DIM	Logic level dimming input. Drive DIM low to turn off the current regulator. Drive DIM high to enable the current regulator.
4	CSN	Current sense input
5	VIN	Input Supply Pin. Must be locally bypassed.

ABSOLUTE MAXIMUM RATINGS (note1)

SYMBOL	ITEMS	VALUE	UNIT
V _{IN}	Supply Voltage	-0.3~40	V
SW	Drain of the internal power switch	-0.3~40	V
CSN	Current sense input (Respect to VIN)	+0.3~(-6.0)	V
DIM	Logic level dimming input	-0.3~5.5	V
P _{DMAX}	Power Dissipation (Note 2)	260	mW
P _{TR}	Thermal Resistance, SOT23-5 θ _{JA}	250	°C /W
T _J	Operation Junction Temperature Range	-40 to 150	°C
T _{STG}	Storage Temperature	-55 to 150	°C
HBM	ESD Susceptibility (Note 3)	2	kV

RECOMMENDED OPERATING RANGE

SYMBOL	ITEMS	VALUE	UNIT
V _{IN}	V _{DD} Supply Voltage	0 ~ 30	V
T _{OPT}	Operating Temperature	-40 to +85	°C

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Recommended Operating Range indicates conditions for which the device is functional, but do not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Range. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

Note 2: The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{JMAX}, θ_{JA}, and the ambient temperature T_A. The maximum allowable power dissipation is P_{DMAX} = (T_{JMAX} - T_A) / θ_{JA} or the number given in Absolute Maximum Ratings, whichever is lower.

Note 3: Human body model, 100pF discharged through a 1.5kΩ resistor.

ELECTRICAL CHARACTERISTICS (Note 4, 5)

The following specifications apply for $V_{IN}=12V$, $T_A=25^\circ C$, unless specified otherwise.

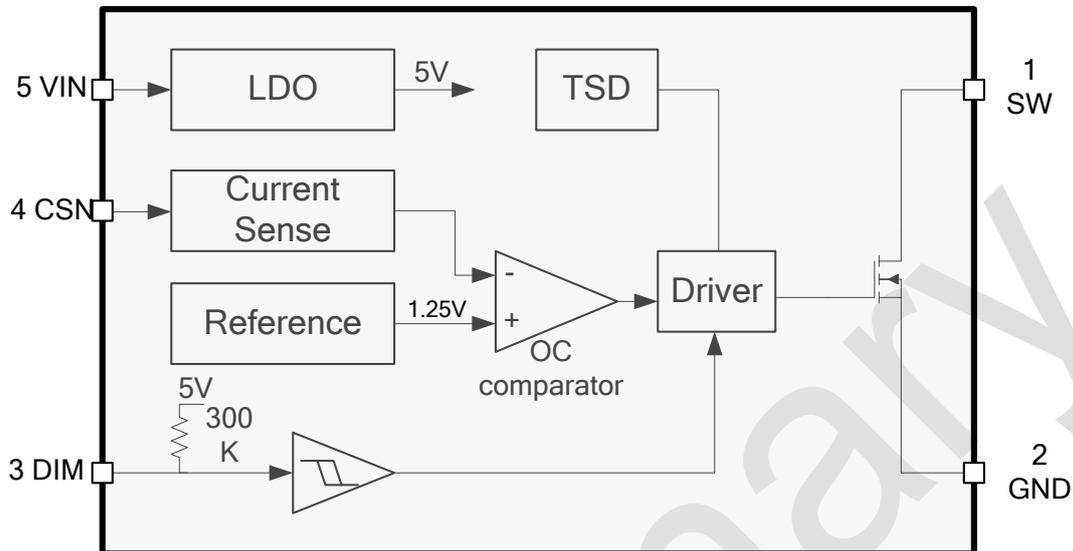
Symbol	Parameter	Test condition	Min	Typ	Max	Unit
V_{IN}	VIN supply voltage		5		30	V
F_{SW}	Maximum operating frequency				1	MHz
V_{CSN}	Current sense Reference voltage	$V_{IN} - V_{CSN}$	194	200	206	mV
V_{CSN_hys}	Current sense Hysteretic voltage			± 15		%
I_{CSN}	CSN pin bias current	$V_{IN} - V_{CSN} = 50mV$		8		μA
I_{OFF}	Off state operating current	$V_{DIM} < 0.4V$		95		μA
V_{DIM}	DIM pin floating voltage	DIM floating		5		V
V_{DIM_H}	DIM input logic high		1.7			V
V_{DIM_L}	DIM input logic low				0.4	V
f_{DIM} (note 6)	Maximum dimming frequency	$f_{OSC} = 500kHz$			50	kHz
R_{DIM}	DIM pin internal pull up resistance			300		K Ω
I_{DIM_L}	DIM pin short to GND current	$V_{DIM} = 0$		15		μA
R_{SW}	SW on stage resistance	$V_{IN} = 24V$ $V_{IN} = 12V$		0.8 1.0		Ω
I_{SW_mean}	SW maximum current				500	mA
I_{LEAK}	SW leakage current	$V_{sw} = 33V$, SW off		0.5	2	μA
T_{CT}	Constant temperature operating range			135~150		$^\circ C$
T_{SD}	Thermal shut down threshold			150		$^\circ C$
T_{SD-hys}	Thermal shut down hysteretic			15		$^\circ C$

Note 4: Typical parameters are measured at $25^\circ C$ and represent the parametric norm.

Note 5: Datasheet min/max specification limits are guaranteed by design, test, or statistical analysis.

Note6: The maximum dimming frequency is limited by operating frequency, because operating frequency varies with supply voltage, output voltage and inductor selection, to achieve the best dimming linearity, the dimming frequency is recommended to limited less than 1% of operating frequency.

SIMPLIFIED BLOCK DIAGRAM



OPERATION DESCRIPTION

The device, in conjunction with the coil (L) and current sense resistor (RS), forms a self oscillating continuous-mode buck converter.

When input voltage VIN is first applied, the initial current in L and RS is zero and there is no output from the current sense circuit. Under this condition, the output of CS comparator is high. This turns on the internal switch and switches the SW pin low, causing current to flow from VIN to ground, via RS, L and the LED(s). The current rises at a rate determined by VIN and L to produce a voltage ramp (VCSN) across RS. When (VIN - VCSN) > 230mV, the output of CS comparator switches low and the switch turns off. The current flowing on the RS decreases at another rate. When (VIN - VCSN) < 170mV, the switch turns on again and the mean current on the LED is determined by

$$I_{OUT} = \frac{0.17 + 0.23}{2 \times R_s} = 0.2 / R_s .$$

The high-side current-sensing scheme and on-board current-setting circuitry minimize the number of

external components while delivering LED current with $\pm 3\%$ accuracy, using a 1% sense resistor.

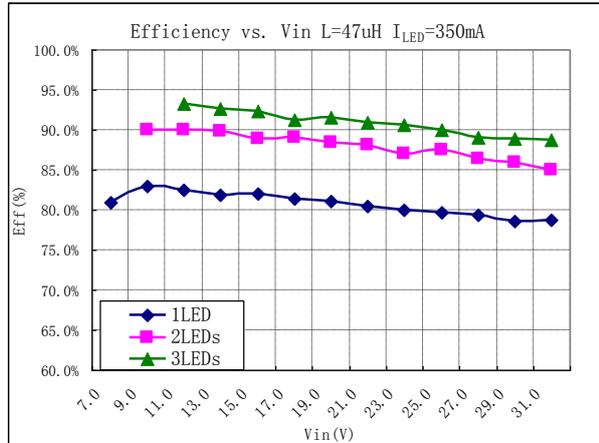
The PT4211 allows dimming with a PWM signal at the DIM input. A logic level below 0.4V at DIM forces PT4211 to turn off and the logic level at DIM higher than 1.7V to turn the device on. The frequency of PWM dimming ranges from 100Hz to more than 20 kHz.

The DIM pin is pulled up to the internal 5V by a resistor when it is floating. When a voltage applied to DIM falls below the threshold (0.4V nom.), the switch is turned off. The internal regulator and voltage reference remain powered during shutdown to provide the reference for the shutdown circuit. Quiescent supply current during shutdown is nominally 95uA and switch leakage is below 5uA.

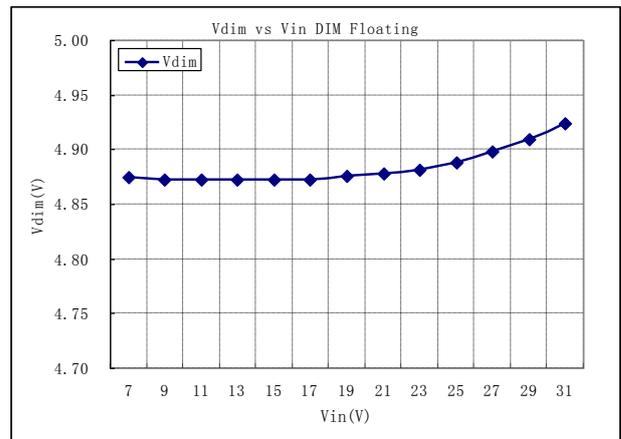
Additionally, to ensure the reliability, the PT4211 is built with a thermal shutdown (TSD) protection. The TSD protects the IC from over temperature, when junction temperature more than 135°C the output current begins to decrease until to zero at 150°C.

TYPICAL PERFORMANCE CHARACTERISTICS

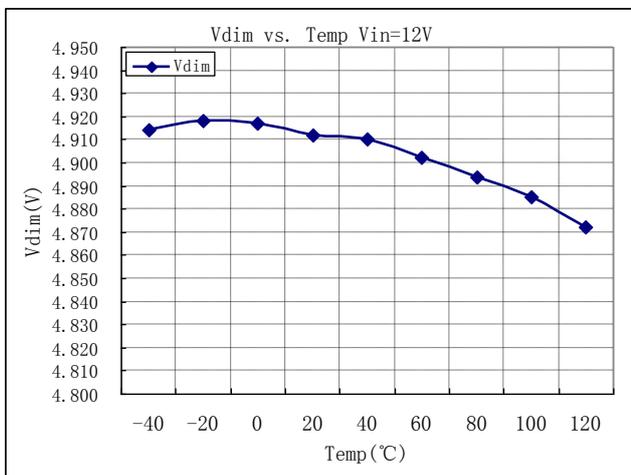
Efficiency vs. input voltage L=47uH, I_{LED}=350mA



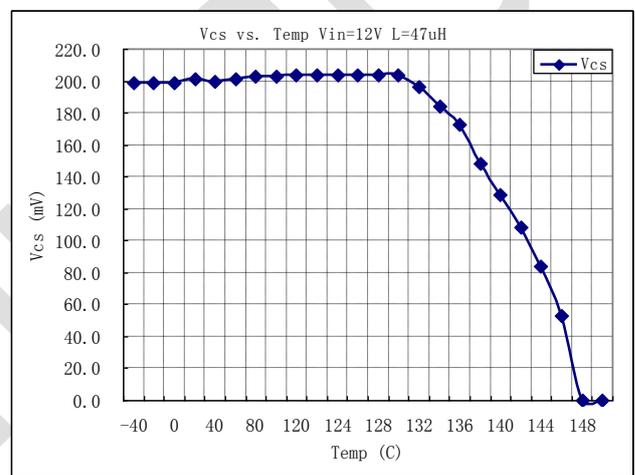
DIM pin voltage vs. VIN DIM floating



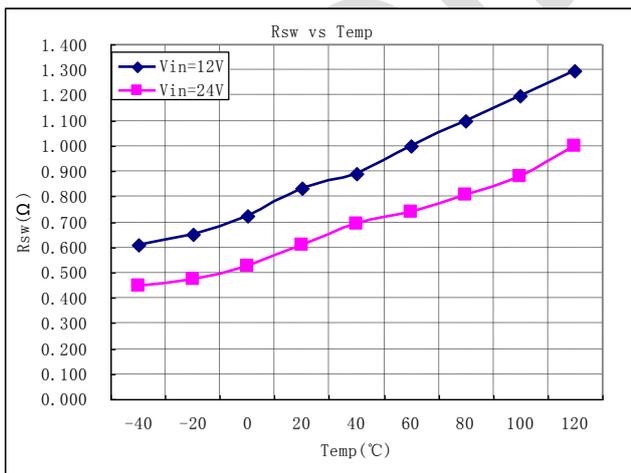
DIM pin voltage vs. temperature Vin=12V



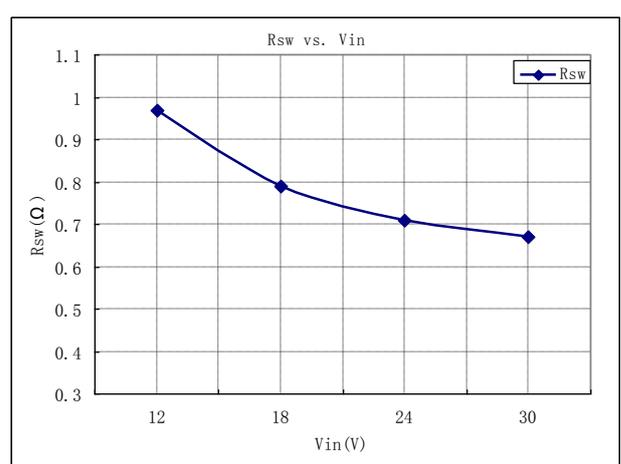
VCS vs. Temperature Vin=12V, L=47uH



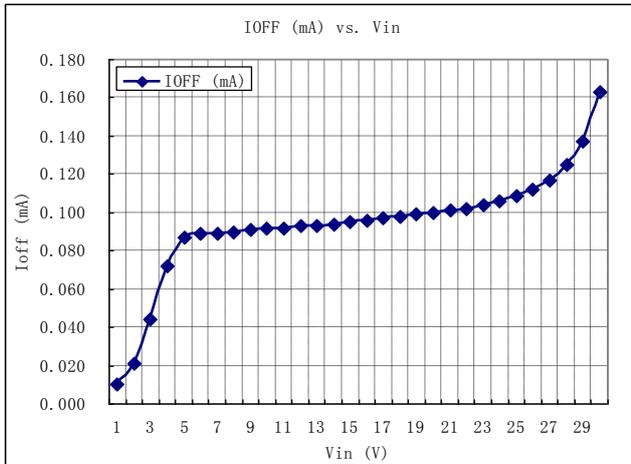
Rsw vs. temperature Vin=12V/24V



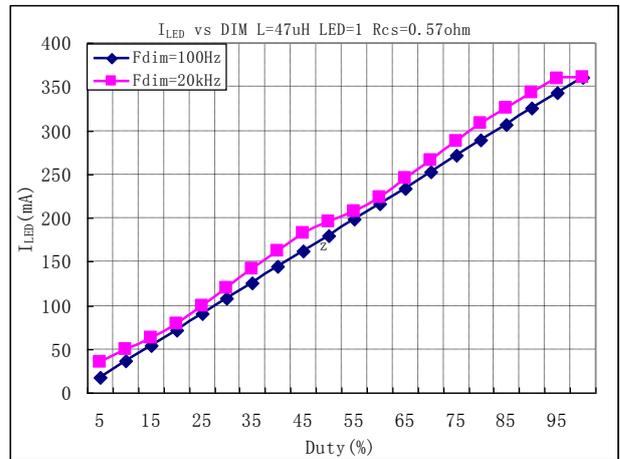
Rsw vs. VIN



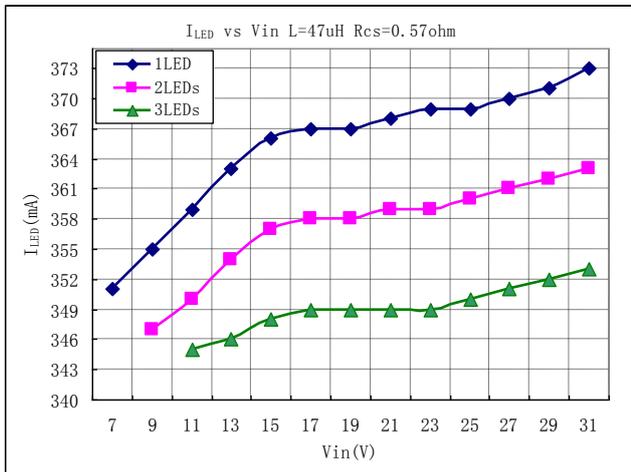
Shut down current vs. VIN. VDIM=0



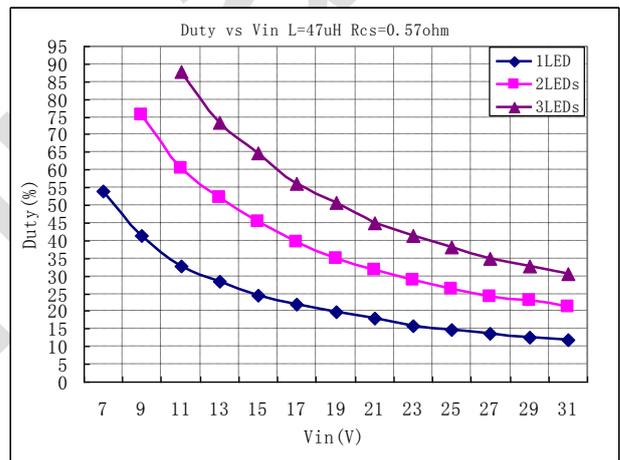
Iout vs. PWM duty cycle. Vin=12V, L=47uH



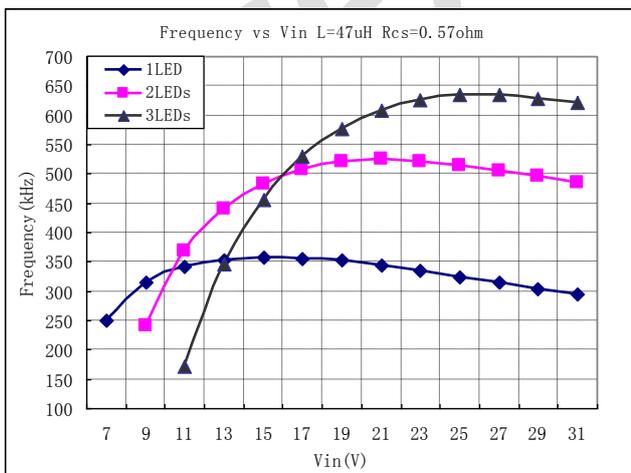
Iout vs. VIN. L=47uH, Rcs=0.57 ohm



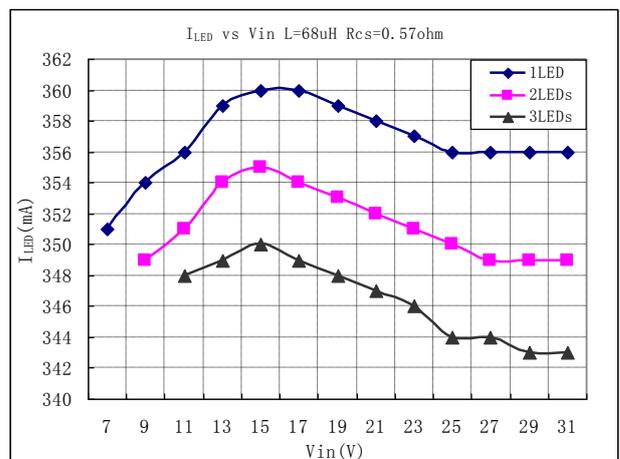
Duty cycle vs. VIN L=47uH, Rcs=0.57 ohm



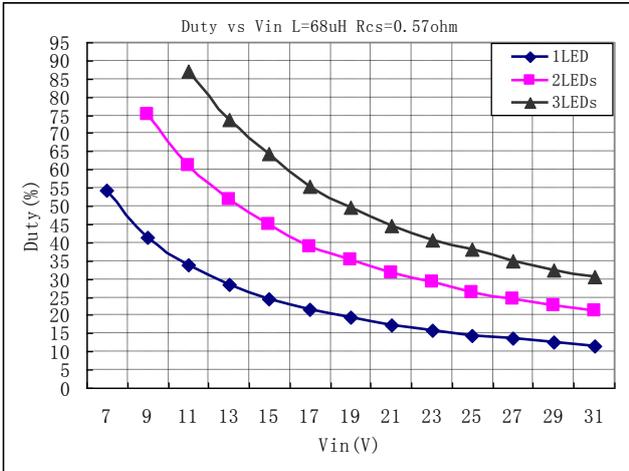
工作频率随 VIN 变化 L=47uH, Rcs=0.57 ohm



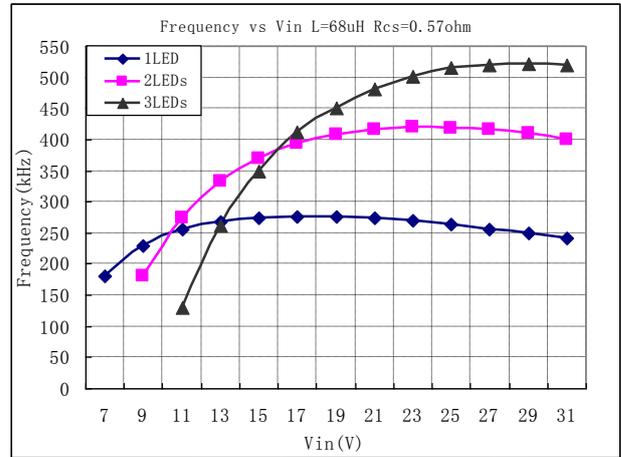
输出电流随 VIN 变化 L=68uH, Rcs=0.57 ohm



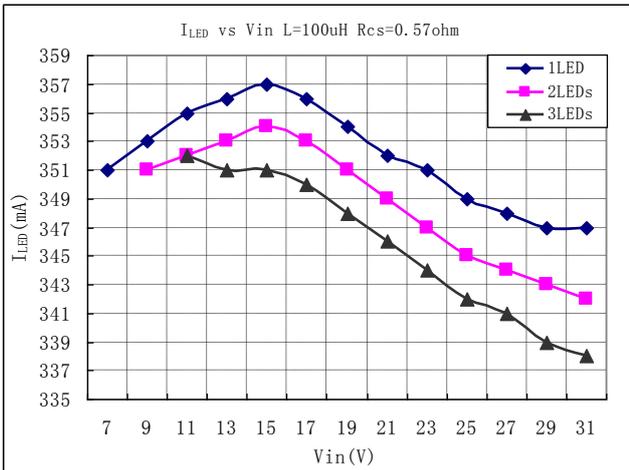
Duty cycle vs. VIN. L=68uH, Rcs=0.57ohm



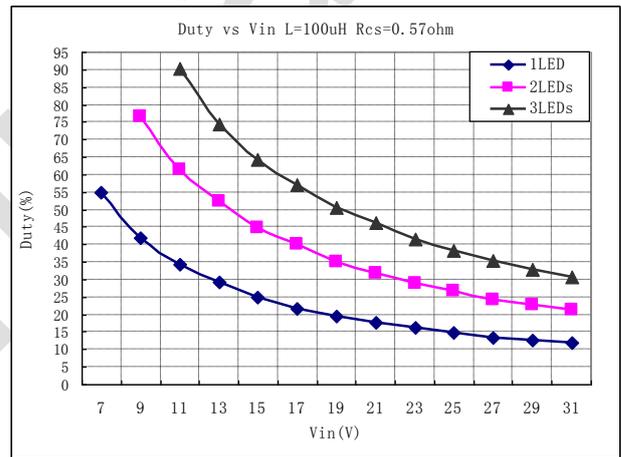
Frequency vs. VIN. L=68uH, Rcs=0.57ohm



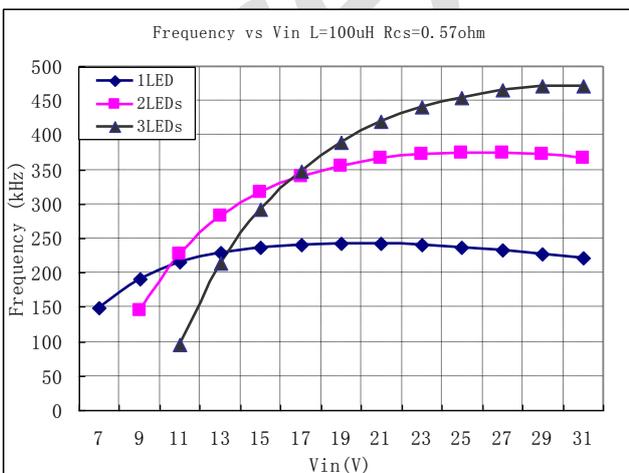
I_{LED} vs. VIN. L=100uH, Rcs=0.57ohm



Duty cycle vs. VIN. L=100uH, Rcs=0.57ohm



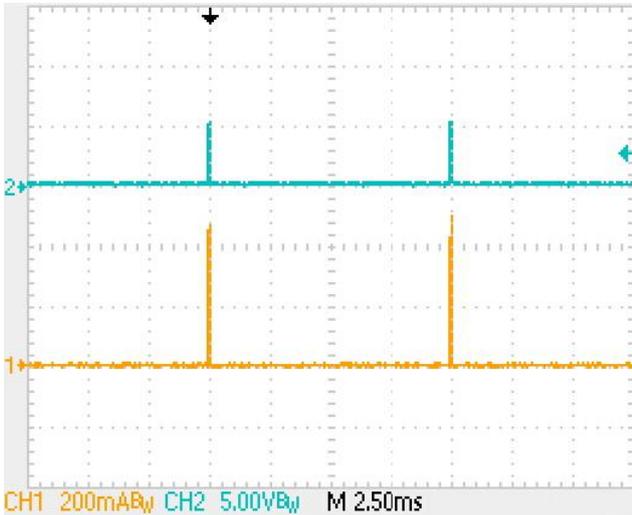
Frequency vs. VIN. L=100uH, Rcs=0.57ohm



Dimming waveform $V_{in}=24V$, $F_{dim}=100Hz$, $Duty=1\%$

$L=47\mu H$, $R_{cs}=0.57\Omega$

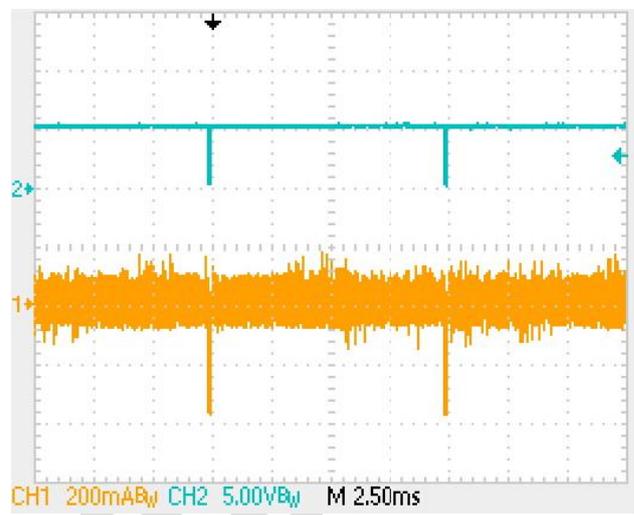
CH1: I_{out} CH2: DIM pin voltage



Dimming waveform $V_{in}=24V$, $F_{dim}=100Hz$, $Duty=99\%$

$L=47\mu H$, $R_{cs}=0.57\Omega$

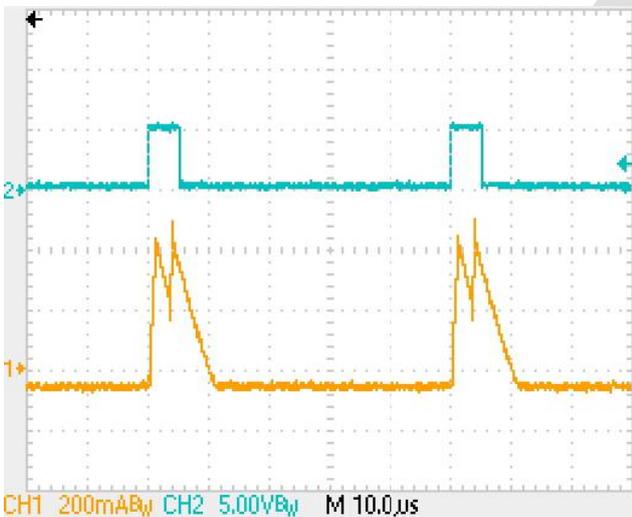
CH1: I_{out} CH2: DIM pin voltage



Dimming waveform. $V_{in}=24V$, $F_{dim}=20KHz$, $Duty=10\%$

$L=47\mu H$, $R_{cs}=0.57\Omega$

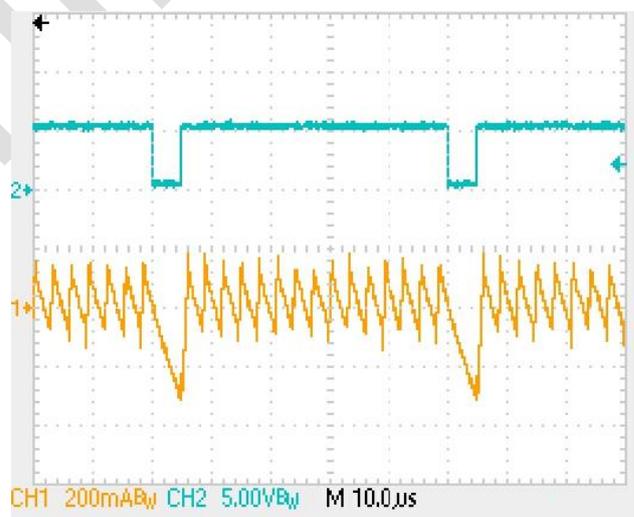
CH1: I_{out} CH2: DIM pin voltage



Dimming waveform. $V_{in}=24V$, $F_{dim}=20KHz$, $Duty=90\%$

$L=47\mu H$, $R_{cs}=0.57\Omega$

CH1: I_{out} CH2: DIM pin voltage



APPLICATION NOTES

Setting nominal average output current with external resistor R_S

The nominal average output current is determined by the value of the external current sense resistor (R_S) connected between VIN and CSN and is given by:

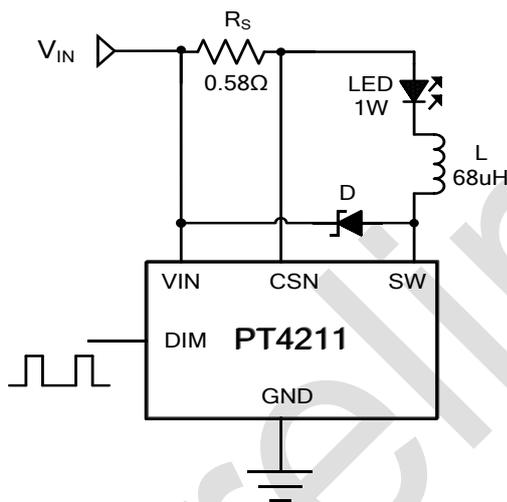
$$I_{OUT} = 0.2 / R_S \quad (R_S \geq 0.17\Omega)$$

This equation is valid when DIM pin is logic high.

Output current adjustment by PWM control

A Pulse Width Modulated (PWM) signal with duty cycle PWM can be applied to the DIM pin, as shown below, to adjust the output current to a value below the nominal average value set by resistor R_S :

$$I_{OUT} = \frac{0.2 \times D}{R_S} \quad (0 \leq D \leq 100\%)$$



PWM dimming provides reduced brightness by modulating the LED's forward current between 0% and 100%. The LED brightness is controlled by adjusting the relative ratios of the on time to the PWM signal cycle time. A 25% brightness level is achieved by turning the LED on at full current for 25% of one cycle. To ensure this switching process between on and off state is invisible by human eyes, the switching frequency must be greater than 100 Hz. Above 100 Hz, the human eyes average the on and off times, seeing only an effective brightness that is proportional to the LED's on-time duty cycle. The advantage of PWM dimming is that the forward current is constant; therefore the LED color does not vary with brightness as it does with analog dimming. Pulsing the current provides precise brightness control while preserving the color purity. The dimming frequency of PT4211 is

depending on the operating frequency. To achieve the best dimming linearity, the dimming frequency is recommended to limited less than 1% of operating frequency.

Shutdown mode

Taking the DIM pin to a voltage below 0.4V will turn off the output and the supply current will fall to a low standby level of 95μA nominal.

Inherent open-circuit LED protection

If the connection to the LED(s) is open-circuited, the coil is isolated from the SW pin of the chip, so the device and LED will not be damaged. When the LED(s) load is connected the device will enter normal operation.

Capacitor selection

A low ESR capacitor should be used for input decoupling, as the ESR of this capacitor appears in series with the supply source impedance and lowers overall efficiency. This capacitor has to supply the relatively high peak current to the coil and smooth the current ripple on the input supply. A minimum value of 4.7μF is acceptable if the DC input source is close to the device, but higher values will improve performance at lower input voltages, especially when the source impedance is high. For the rectified AC input, the capacitor should be higher than 100μF and the [tantalum](#) capacitor is recommended. The input capacitor should be placed as close as possible to the IC.

For maximum stability over temperature and voltage, capacitors with X7R, X5R, or better dielectric are recommended. Capacitors with Y5V dielectric are not suitable for decoupling in this application and should NOT be used.

A suitable Murata capacitor would be GRM42-2X7R475K-50.

The following web sites are useful when finding alternatives:

www.murata.com
www.t-yuden.com
www.avxcorp.com

Inductor selection

Recommended inductor values for the PT4211 are in the range 47μH to 100μH.

Higher values of inductance are recommended at lower output current in order to minimize errors due to switching delays, which result in increased ripple and

lower efficiency. Higher values of inductance also result in a smaller change in output current over the supply voltage range. (See graphs). The inductor should be mounted as close to the device as possible with low resistance connections to the SW and VIN pins.

The chosen coil should have a saturation current higher than the peak output current and a continuous current rating above the required mean output current.

Following table gives the guideline on inductor selection:

V _{in}	1LED	2LEDs	3LEDs	Saturation current
5V-10V	47uH	68uH		1.3-1.5 times of load current
10V-20V	68uH	68uH	47uH	
20V-30V	100uH	68uH	47uH	

Suitable coils for use with the PT4211 are listed in the table below:

Part No.	L (uH)	DCR (Ω)	I _{SAT} (A)	Manufacturer
MSS1038-473	47	0.128	2	CoilCraft www.coilcraft.com
MSS1038-683	68	0.213	1.6	
MSS1038-104	100	0.304	1.3	

The inductor value should be chosen to maintain operating duty cycle and switch 'on'/'off' times within the specified limits over the supply voltage and load current range.

The following equations can be used as a guide.

SW Switch 'On' time

$$T_{ON} = \frac{L \times \Delta I}{V_{IN} - V_{LED} - I_{avg} \times (R_s + rL + R_{sw})}$$

SW Switch 'Off' time

$$T_{OFF} = \frac{L \times \Delta I}{V_{LED} + V_D + I_{avg} \times (R_s + rL)}$$

Where:

L is the coil inductance (H)

rL is the coil resistance (Ω)

R_s is the current sense resistance (Ω)

I_{avg} is the required LED current (A)

Δ I is the coil peak-peak ripple current (A) {Internally set to 0.3 x I_{avg}}

V_{IN} is the supply voltage (V)

V_{LED} is the total LED forward voltage (V)

R_{sw} is the switch resistance (Ω) {=1Ω nominal}

V_D is the diode forward voltage at the required load current (V)

Diode selection

For maximum efficiency and performance, the rectifier (D) should be a fast low capacitance Schottky diode with low reverse leakage at the maximum operating voltage and temperature.

They also provide better efficiency than silicon diodes, due to a combination of lower forward voltage and reduced recovery time.

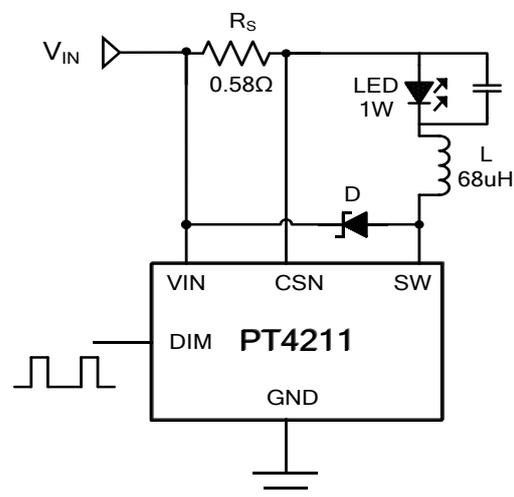
It is important to select parts with a peak current rating above the peak coil current and a continuous current rating higher than the maximum output load current. It is very important to consider the reverse leakage of the diode when operating above 85 °C. Excess leakage will increase the power dissipation in the device and if close to the load may create a thermal runaway condition.

The higher forward voltage and overshoot due to reverse recovery time in silicon diodes will increase the peak voltage on the SW output. If a silicon diode is used, care should be taken to ensure that the total voltage appearing on the SW pin including supply ripple, does not exceed the specified maximum value.

The following web sites are useful when finding alternatives: www.onsemi.com

Reducing output ripple

Peak to peak ripple current in the LED(s) can be reduced, if required, by shunting a capacitor C_{LED} across the LED(s) as shown below:



A value of 1 μ F will reduce the supply ripple current by a factor three (approx.). Proportionally lower ripple can be achieved with higher capacitor values. Note that the capacitor will not affect operating frequency or efficiency, but it will increase start-up delay and reduce the frequency of dimming, by reducing the rate of rise

Operation at low supply voltage

With the supply voltage below the output voltage, the switch duty cycle will be high and the device power dissipation will be at a maximum. Care should be taken to avoid operating the device under such conditions in the application, in order to minimize the risk of exceeding the maximum allowed die temperature.

Thermal considerations

When operating the device at high ambient temperatures, or when driving maximum load, care must be taken to avoid exceeding the package power dissipation limits. Note that the device power dissipation will most often be a maximum at minimum supply voltage. It will also increase if the efficiency of the circuit is low. This may result from the use of unsuitable coils, or excessive parasitic output capacitance on the switch output.

Thermal shutdown protection

To ensure the reliability, the PT4211 is built with a soft over temperature protection function. When junction temperature excess 135°C the output current begin to decrease until to zero at 150°C. The soft over temperature function protects the IC and avoid the flicker when operation at high temperature.

Layout considerations

of LED voltage.

By adding this capacitor the current waveform through the LED(s) changes from a triangular ramp to a more sinusoidal version without altering the mean current value.

Careful PCB layout is critical to achieve low switching losses and stable operation. Use a multilayer board whenever possible for better noise immunity. Minimize ground noise by connecting high-current ground returns, the input bypass-capacitor ground lead, and the output-filter ground lead to a single point (star ground configuration).

SW pin

The SW pin of the device is a fast switching node, so PCB tracks should be kept as short as possible. To minimize ground 'bounce', the ground pin of the device should be soldered directly to the ground plane.

Coil and decoupling capacitors and current sense resistor

It is particularly important to mount the coil and the input decoupling capacitor as close to the device pins as possible to minimize parasitic resistance and inductance, which will degrade efficiency. It is also important to minimize any track resistance in series with current sense resistor RS. It's best to connect VIN directly to one end of RS and CSN directly to the opposite end of RS with no other currents flowing in these tracks. It is important that the cathode current of the Schottky diode does not flow in a track between RS and VIN as this may give an apparent higher measure of current because of track resistance.

TYPICAL APPLICATION CIRCUIT

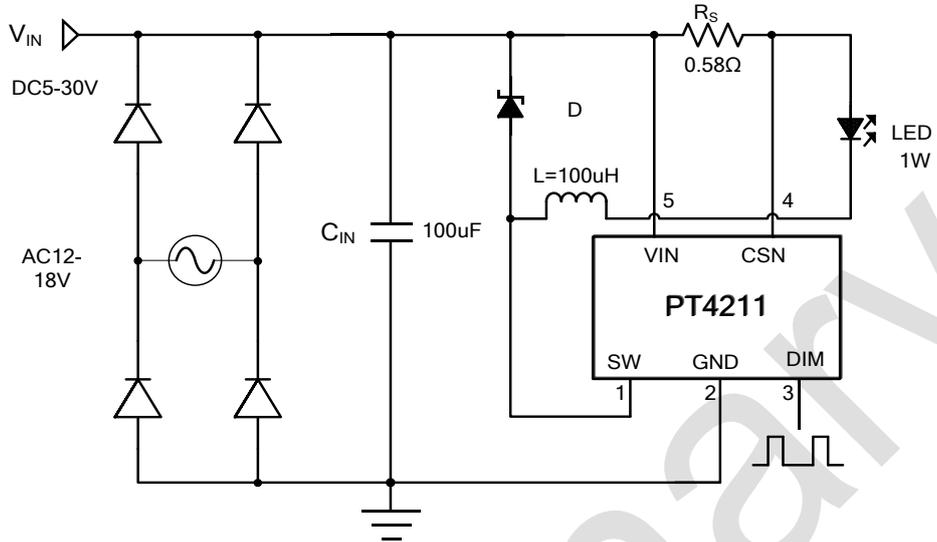


Fig1 : 1W application

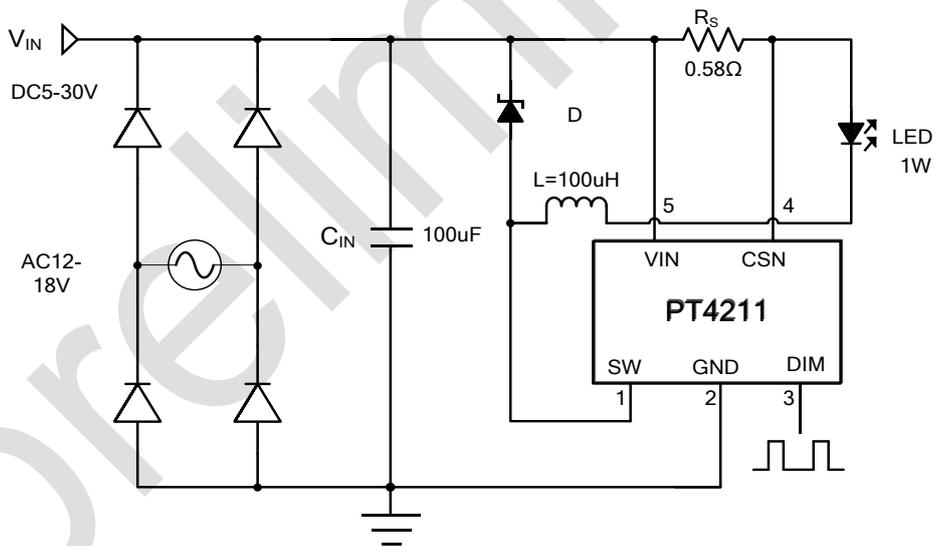
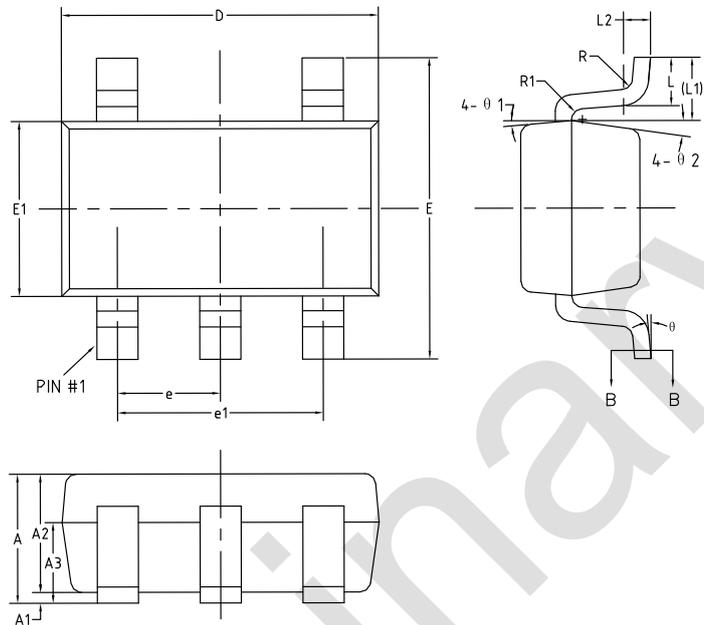


Fig 2: 3W application

PACKAGE INFORMATION

SOT23-5



SYMBOL	MILLIMETERS		
	MIN	TYP	MAX
A	-	-	1.25
A1	0	-	0.15
A2	1.00	1.10	1.20
A3	0.60	0.65	0.70
b	0.36	-	0.50
b1	0.36	0.38	0.45
c	0.14	-	0.20
c1	0.14	0.15	0.16
D	2.826	2.926	3.026
E	2.60	2.80	3.00
E1	1.526	1.626	1.726
e	0.95BSC		
e1	1.90BSC		
L	0.35	0.45	0.60
L1	0.59REF		
L2	0.25BSC		
R	0.10	-	-
R1	0.10	-	0.25
θ	0°	-	8°
θ1	3°	5°	7°
θ2	6°	8°	10°