600mA High Dimming Ratio LED Constant Current Driver

GENERAL DESCRIPTION

The FC1360S is a continuous conduction mode inductive step-down converter, designed for driving single or multiple series connected LEDs efficiently from a voltage source higher than the total LEDs chain voltage. Using a few external components, FC1360S provides a high cost effective solution to the following applications: MR16 LEDs cup lighting, LEDs stage lighting, LEDs automotive lighting, LEDs solar lighting and LEDs Street lighting. The device operates from an input supply between 5V and 30V and the nominal average output current is set by an external current sense resistor. The device provides an externally adjustable output current of up to 500mA for a single LED. Using the patent pending technique, the accuracy of constant LED current can be within ±3%. A dedicated DIM pin accepts either a DC voltage (0.5V~2.5V) dimming or a wide range of pulsed dimming. Applying a voltage of 0.3V or lower to the DIM pin turns the output off and switches the device into a low current standby state.

FC1360 has a build-in power switch, based on different input voltage, FC1360S can drive several 1W or 2W LEDs. The device has the function of thermal shutdown protection and LED short-circuit/open-circuit protection.

The FC1360S is available in SOT-25 packages.

APPLICATIONS

- Low voltage halogen replacement MR16/11 LEDs
- Automotive LED lighting
- LED stage lighting
- Solar LED lighting
- LED signal lighting
- LED Street lighting

FEATURES

- Simple low parts count
- Wide input voltage range: 5V to 30V
- Typical ±3% output current accuracy
- LED open-circuit protection
- LED short-circuit protection
- Internal thermal shutdown protection.
- Up to 600mA output current
- Single DIM pin on/off and brightness control using DC voltage or PWM signal
- High efficiency (up to 97%)
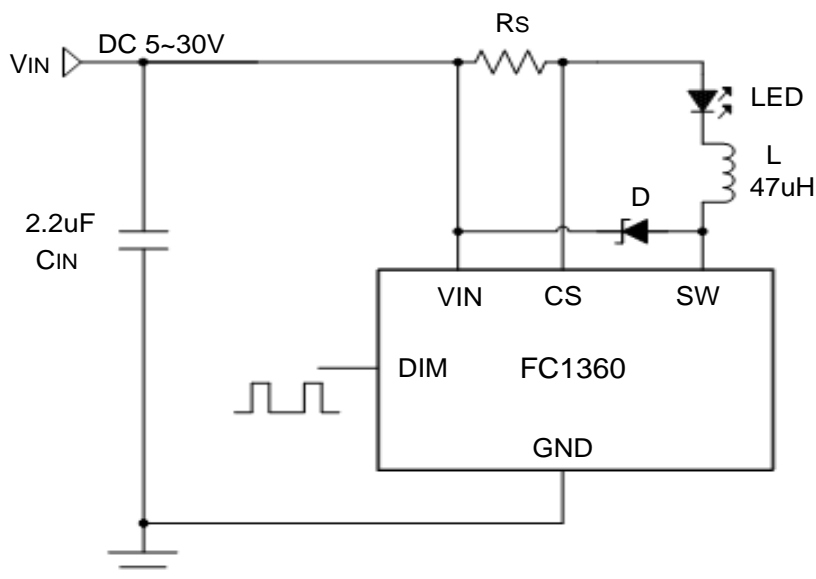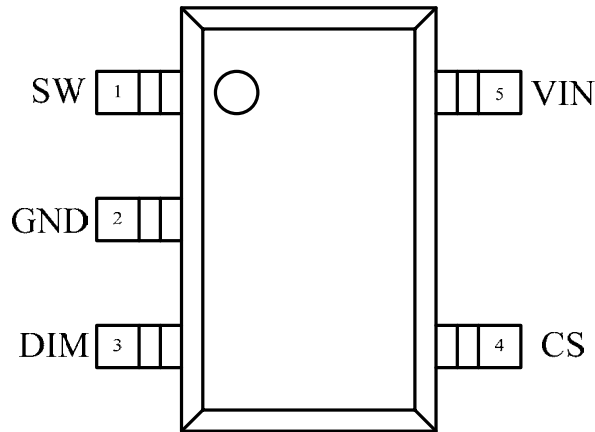- Adjustable Constant LED Current

TYPICAL APPLICATION CIRCUIT

Figure 1 Typical Application Circuit

PIN ASSIGNMENT

```
        ┌─────────────────┐
SW  ┤1│  ○             │5├ VIN
        │                 │
GND ┤2│                 │
        │                 │
DIM ┤3│               │4├ CS
        └─────────────────┘
```

SOT-25

PIN DESCRIPTIONS

PIN No.	PIN NAMES	DESCRIPTION
1	SW	Switch Output. SW is the drain of the internal N-Channel MOSFET switch.
2	GND	Signal and power ground. Connect directly to ground plane.
3	DIM	Enable switch, analog and PWM dimming input.
4	CS	Current sense input, sampling resistor connected between CS and VIN
5	VIN	Input Supply Pin. Must be locally bypassed.

ORDERING INFORMATION

ORDERING PART	PACKAGE	TEMPERATURE RANGE	TRANSPORT MEDIA	MARKING
FC1360	SOT-25	-40 ^{o}C to 85 ^{o}C	Tape and Reel	1360

ABSOLUTE MAXIMUM RATINGS (Note1)

SYMBOL	ITEMS	VALUE	UNIT
V_{IN}	Supply Voltage	-0.3~40	V
SW	Drain Voltage of the internal power switch	-0.3~40	V
CS	Current sense input (Respect to VIN)	+0.3~(-6.0)	V
DIM	Logic level dimming input	-0.3~6	V
I_{SW}	Switch output current	1.0	A
P_{DMAX}	Power Dissipation (Note 2)	0.8	W
P_{TR}	Thermal Resistance, SOT-25 θ_{JA}	200	^{o}C /W
T_J	Operation Junction Temperature Range	-40 to 150	^{o}C
T_{STG}	Storage Temperature	-55 to 150	^{o}C
	ESD Susceptibility (Note 3)	2	kV

Note 1: **Absolute Maximum Ratings indicate** that operating beyond these ratings may damage the device. **Recommended Operating Range indicates** that the device is functional in that range, 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 decreasing with elevating temperatures and is dictated by T_{JMAX}, θ_{JA}, and the ambient temperature T_A. The maximum allowable power dissipation is $P_{DMAX} = (T_{JMAX} - T_A)/ \theta_{JA}$ or the lower number given in Absolute Maximum Ratings.

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

RECOMMENDED OPERATING RANGE

SYMBOL	ITEMS	VALUE	UNIT
V_{IN}	V_{DD} Supply Voltage	0 ~ 30	V
T_{OPT}	Operating Temperature	-40 to +85	^{o}C

ELECTRICAL CHARACTERISTICS (Note 4, 5)

(The following specifications apply for V_{IN}=12V, T_A=25°C, unless specified otherwise.)

SYMBOL	ITEMS	CONDITIONS	Min.	Typ.	Max.	UNIT
V_{IN}	Input Voltage		5		30	V
V_{UVLO}	Under voltage lock out	V_{IN} falling		4.7		V
$V_{UVLO, HYS}$	UVLO hysteresis	V_{IN} rising		100		mV
Current Sense						
V_{CS}	Mean current sense threshold voltage	V_{IN}-V_{CS}	97	100	103	mV
V_{CS_HYS}	Sense threshold hysteresis			±15		%
I_{CS}	CS Pin Input Current	V_{IN}-V_{CS}=50mV		8		µA
Operating Frequency						
F_{SW}	Maximum operation frequency				1	MHz
Operating Current						
I_{OFF}	Quiescent supply current with output off	V_{DIM}<0.3V		100		µA
DIM Input						
V_{DIM}	Internal supply voltage	DIM floating		5		V
V_{DIM_H}	DIM input voltage High		2.5			V
V_{DIM_L}	DIM input voltage Low				0.3	V
R_{DIM}	DIM pull up resistor to internal supply voltage			150		kΩ
I_{DIM_L}	DIM input leakage to ground	V_{DIM} = 0		33		uA
DIM Brightness Dimmer						
V_{DIM_DC}	DC brightness control range		0.5		2.5	V
f_{DIM}	Max. DIM Frequency	f_{OSC}=500kHz			50	kHz
D_{PWM_LF}	Duty cycle range of low frequency dimming	f_{DIM} =100Hz	0.05%		1	
	Brightness control ratio			2000:1		
D_{PWM_HF}	Duty cycle range of high frequency dimming	f_{DIM} =20KHz	10%		1	
	Brightness control ratio			10:1		
Output Power Switch						
R_{SW}	SW On Resistance			0.8		Ω
I_{SWmean}	Continuous SW Current				0.5	A
I_{LEAK}	SW Leakage Current			0.5	5	µA
Thermal Shutdown						
T_{SD}	Thermal Shutdown Threshold			150		℃
T_{SD}-hys	Thermal Shutdown hysteresis			20		℃

Note 4: Typical parameters are measured at 25℃ and represent the parametric norm.
Note 5: Datasheet min/max specification limits are guaranteed by design, test, or statistical analysis.

OPERATION DESCRIPTION

FC1360S 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 firstly 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 an internal switch and switches the SW pin to low, causing current to flow from VIN to ground, via RS, L and the LEDs. The current rises at a rate determined by VIN and L to produce a voltage ramp (V_{CS}) across RS. When $(V_{IN}-V_{CS}) > 115mV$, the output of CS comparator is low and the switch turns off. The current flowing on the RS decreases at another rate. When $(V_{IN}-V_{CS}) < 85mV$, the switch turns on again and the mean current on the LEDs is determined by

$$I_{OUT} = \frac{0.085 + 0.115}{2 \times Rs} = 0.1/Rs$$

The high-side current-sensing scheme and on-board current-setting circuitry minimize the number of external components while delivering LEDs current with ±3% accuracy, using a 1% sense resistor.

The FC1360S allows dimming with a PWM signal at the DIM input. A logic level below 0.3V at DIM input forces FC1360S to turn off the LEDs current and the logic level at DIM input must be at least 2.5V to turn on the full LEDs current. The frequency of PWM dimming ranges from 100Hz to more than 20 kHz. When the high voltage is in the range of 0.5V to 2.5V, PWM dimming is available as well. (The detail is in the following application notes.)

The DIM pin can be driven by an external DC voltage (V_{DIM}) to adjust the output current to a value below the nominal average value defined by RS. The DC voltage (V_{DIM}) is valid from 0.5V to 2.5V. When the dc voltage is higher than 2.5V, the output current keeps constant. The LEDs current also can be adjusted by a resistor connected to the DIM pin. An internal pull-up resistor (typical 150kΩ) is connected to a 5V internal regulator. The voltage of DIM pin is divided by the internal and external resistor.

DIM pin can be floated in normal operation. When the voltage applied to DIM falls below the threshold (0.3V nom.), the power switch is turned off and LEDs current decrease to zero. 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 100uA.

Additionally, to ensure the reliability, the FC1360 is built with a thermal shutdown (TSD) protection and can link a NTC closing to LEDs by the DIM pin. As a result, the FC1360S can detect the temperature of LEDs and change the LEDs current to protect LEDs. (The detail is in the following application notes.)

APPLICATION NOTES

Setting nominal Average Output Current with External Resistor: RS

The nominal average output current though the LEDs is determined by the value of the external current sense resistor (RS) connected between VIN and CS and is given by:

$$I_{OUT} = 0.1/Rs \quad (Rs \geq 0.12\Omega)$$

This equation is valid when DIM pin is floating or applied with a voltage higher than 2.5V (must be less than 5V). Actually, RS sets the maximum average current which can be adjusted to a less one by DIM pin.

Output Current Adjustment by External DC Control Voltage

The DIM pin can be driven by an external dc voltage (VDIM), as shown, to adjust the output current to a value below the nominal average value defined by 0.1/RS.
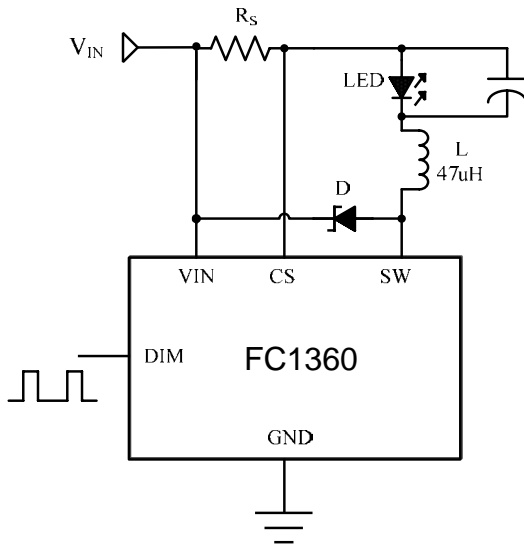
The average output current is given by:

$$I_{OUT} = \frac{0.1 \times (V_{DIM} - 0.5)}{2 \times Rs}$$

$$(0.5V \leq V_{DIM} \leq 2.5V)$$

Note that 100% brightness setting current equaling

to $I_{OUT} = 0.1/Rs$, which corresponds to VDIM:

$$(2.5V \leq V_{DIM} \leq 5V)$$

Output Current Adjustment by PWM Control

The maximum mean LEDs current is determined by the resistor RS connecting between VIN and CS. A Pulse Width Modulated (PWM) signal with duty cycle modulation can be applied to the DIM pin, in order to adjust the output current to a value below the maximum average value, set by resistor RS:

$$I_{OUT} = \frac{0.1 \times D}{Rs}$$

$$(0 \leq D \leq 100\%, 2.5V < V_{pulse} < 5V)$$

If the high voltage is below 2.5V,

$$I_{OUT} = \frac{(V_{pulse} - 0.5) \times 0.1 \times D}{2 \times Rs}$$

$$(0 \leq D \leq 100\%, 0.5V < V_{pulse} < 2.5V)$$

PWM dimming provides reduced brightness by modulating the LEDs forward current between 0% and 100%. The LEDs brightness is controlled by adjusting the relative ratios of the on time to the off time. For example, a 25% pulse width can set LEDs average current to 25% of the nominal value defined by 0.1/Rs. To ensure this switching process between on and off is invisible by human eyes, the switching frequency must be greater than 120 Hz. The advantage of PWM dimming is that the forward current is always constant; therefore the LEDs color does not vary with brightness as it does with analog dimming. The dimming frequency of FC1360S can be as high as 20 kHz.

Shutdown Mode

Taking the DIM pin to a voltage below 0.3V will turn off the output and the supply current will fall to a low standby level of 100μA nominally.

Soft-Start

An external capacitor, connecting between the DIM pin and ground pin, will provide an additional soft-start delay on the DIM pin, so LEDs current will increase slowly and soft-start can be done. Normally, the relation of soft-start delay and external capacitance is about 150us/nF.

Inherent Open-Circuit and Short-Circuit LED Protection

If the connection to the LEDs is open-circuited, FC1360S will operate in safely low power mode. If LEDs is short-circuited, FC1360S will operate in the safe mode with low frequency current limitation protection.

Bypass Capacitor Selection

A low ESR bypass capacitor should be used for input decoupling. The larger ESR value will lead to the lower efficiency. This capacitor has to support the relatively high peak current to the coil and smooth the current ripple on the input supply. The minimum value of 2.2uF is acceptable in the case of DC input source. For the rectified AC input or low voltage input, the bypass capacitor should be 100uF and the tantalum capacitor is recommended. The input capacitor should be placed as close as possible to the input pin.

For guarantee the stability over temperature and voltage, capacitors with X7R, X5R, or better dielectric are recommended.

Inductor Selection

Recommended inductor value for the FC1360S is 47uH. The inductor saturation current must be 30% ~ 50% higher than the output current.

Diode Selection

To maximize efficiency and performance, the Diode should be Schottky diode with a fast recovery, low forward voltage, low capacitance and low current leakage. The current and voltage ability depend on the application. Note that diode should have 30% design buffer for stable and reliable operation.

It is very important to consider the reverse leakage current of the diode when operating above 85°C. Excess leakage current will increase the system power dissipation.

The rectifier diode, rectifying AC12V, must use low forward voltage Schottky diode to reduce diode dissipation.

Reducing Output Ripple

Peak to peak ripple current in the LEDs can be reduced, if required, by shunting a capacitor across the LEDs:

A capacitor value of 1uF will reduce the supply ripple current by a factor three approximately. 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 change the frequency of dimming.

Operation Notation at Low Input Voltage

The internal regulator disables the internal power switch until the input voltage is above the startup threshold (V_{UVLO}+100mV). Above the threshold, the system will start to operate. However, there is an especial case that if the input voltage is above the threshold and is too close to the output voltage, then the switch duty cycle will be high and the device power dissipation will enlarge. When device operates in this case for a long time, the device will trigger thermal shutdown (See detail in section of thermal shutdown TSD). In practical application, it's necessary to keep the voltage potential difference between input and output. The switch will be turned off when the input voltage falls below the under-voltage threshold (V_{UVLO}).

Thermal Considerations

When the device operates at high ambient temperature, or drives the maximum load current, care must be taken to avoid exceeding the power limitation. The larger copper area around the chip pin is good to radiate heat. In practical application, the device mounted on a 25mm^2 PCB must have 1oz copper in current density. Note that the system efficiency will decrease, if utilizing unsuitable coils or excessive parasitic output capacitance on the switch output.

Thermal Compensation of Load Current

High luminance LEDs often need to be supplied with a temperature compensated current in order to maintain stable and reliable operation at all drive levels. FC1360 can use an external temperature sensing network, normally using Negative Temperature Coefficient (NTC) thermal resistors and/or diodes, mounted very close to the LEDs detecting temperature of LEDs and changing LEDs current. The output of the sensing network can be used to drive the DIM pin in order to reduce output current with increasing temperature.

Thermal Shutdown Protection

To ensure the reliability, the FC1360S is built with a thermal shutdown (TSD) protection function. The TSD protects the IC from over temperature (150℃). When the chip temperature decreases below (130℃), the IC recovers again.

PCB Layout Considerations

Careful PCB layout is critical to achieve low switching losses and stable operation. Using a multilayer board is an efficient way for better noise immunity. In order to minimize current loop noise, the input bypass capacitor should have an isolate ground plane.

SW Pin

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

Coil and Bypass Capacitors and Current Sense Resistor

It is particularly important to mount the coil as away to chip as possible to decrease the coil radiation and the input bypass capacitor as close to the device pins as possible to minimize parasitic resistance and inductance, otherwise system efficiency will be degraded. Depending on PCB design, more copper tracks between coil and GND/VCC are useful for lowering the interface of coil skein. It is also important to minimize any track resistance in series with current sense resistor RS, to keep the accuracy of sampling current.
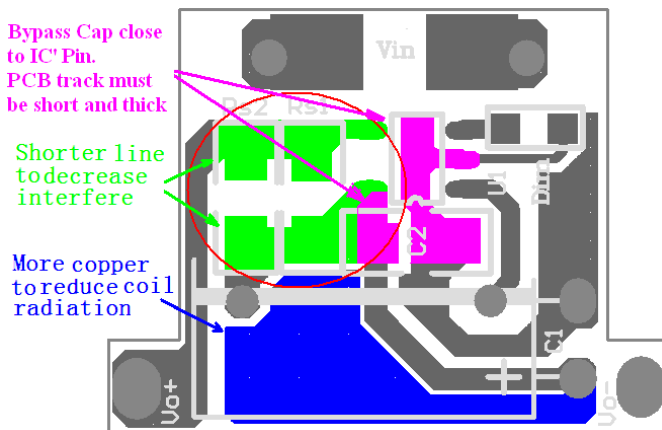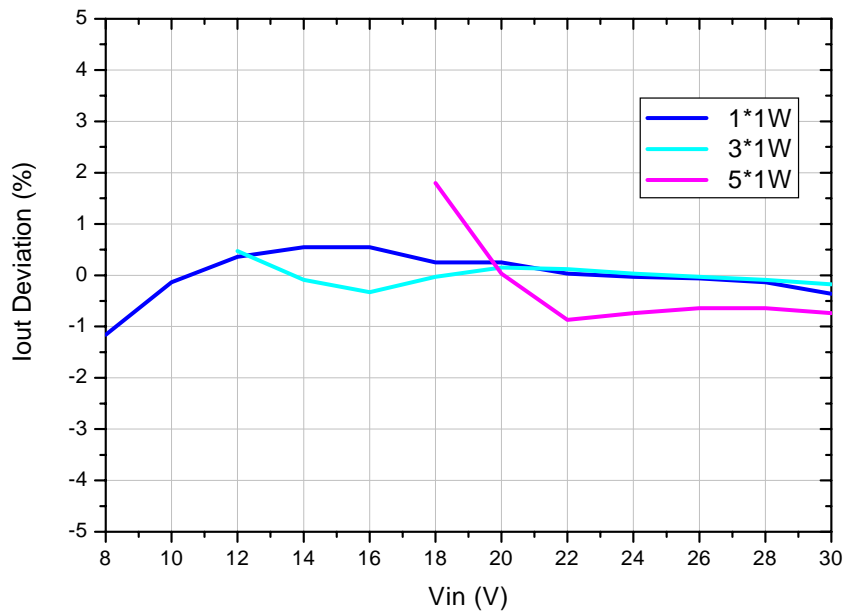
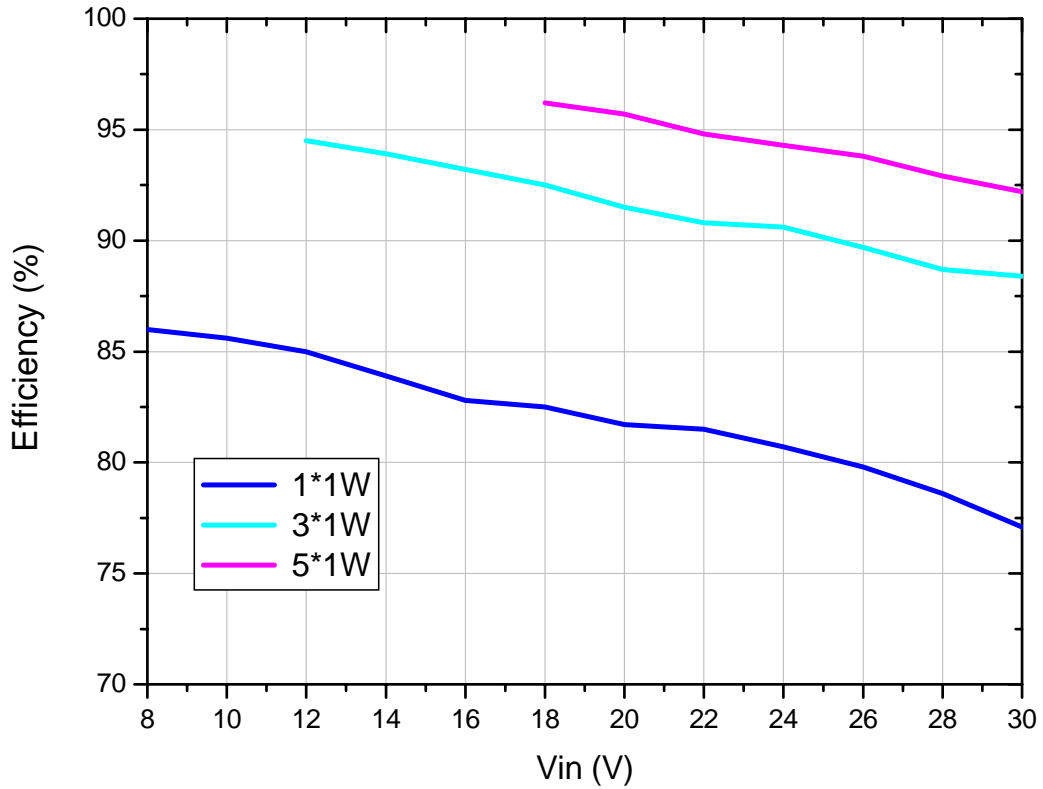## TYPICAL PERFORMANCE CHARACTERISTICS

(Inductor is 47uH, Temp=25℃)
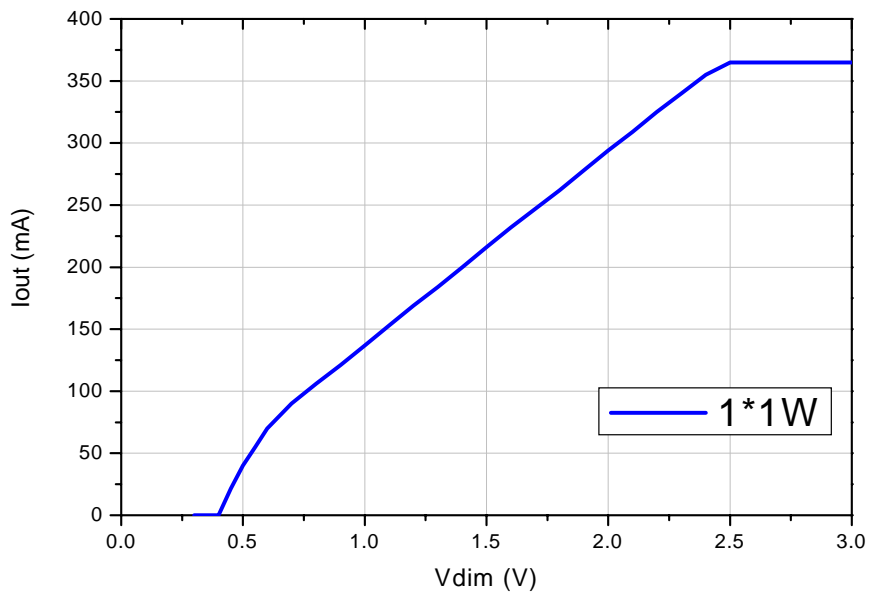
1) Output Current vs Input Voltage of 1W LED
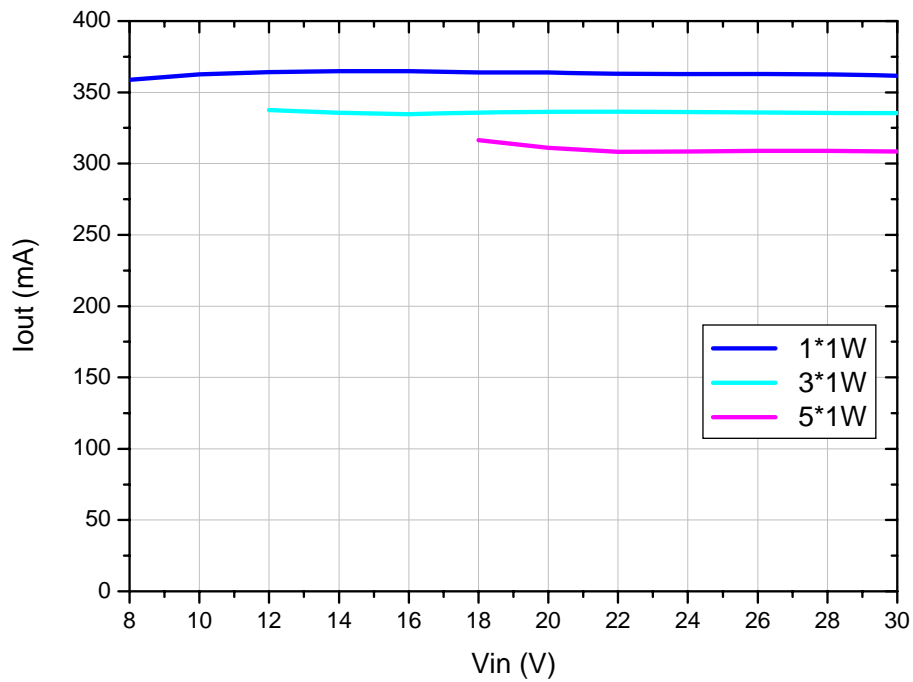
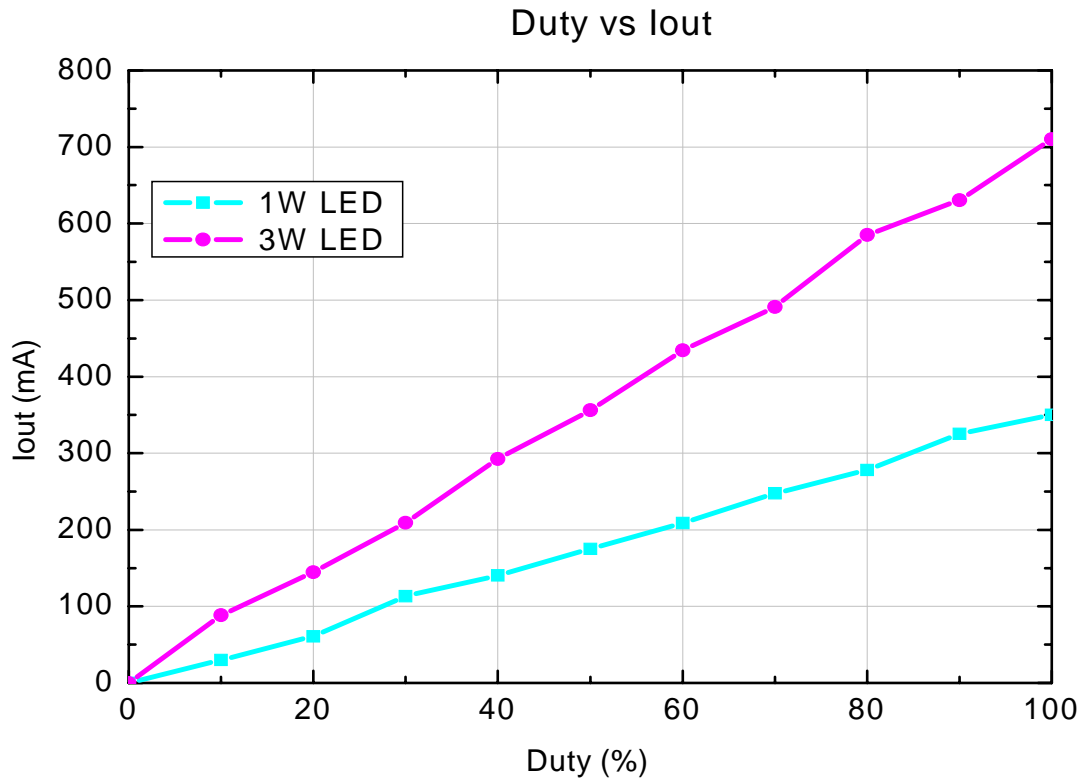2）Output Current Deviation vs Input Voltage of 1W LED
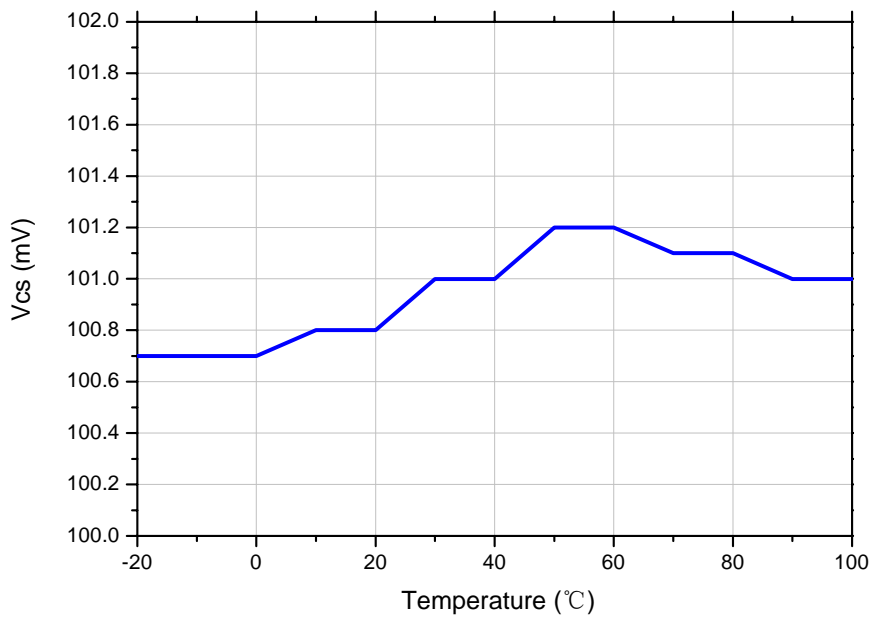
3）System Efficiency vs Input Voltage of 1W LED

4) DC Voltage Dimming

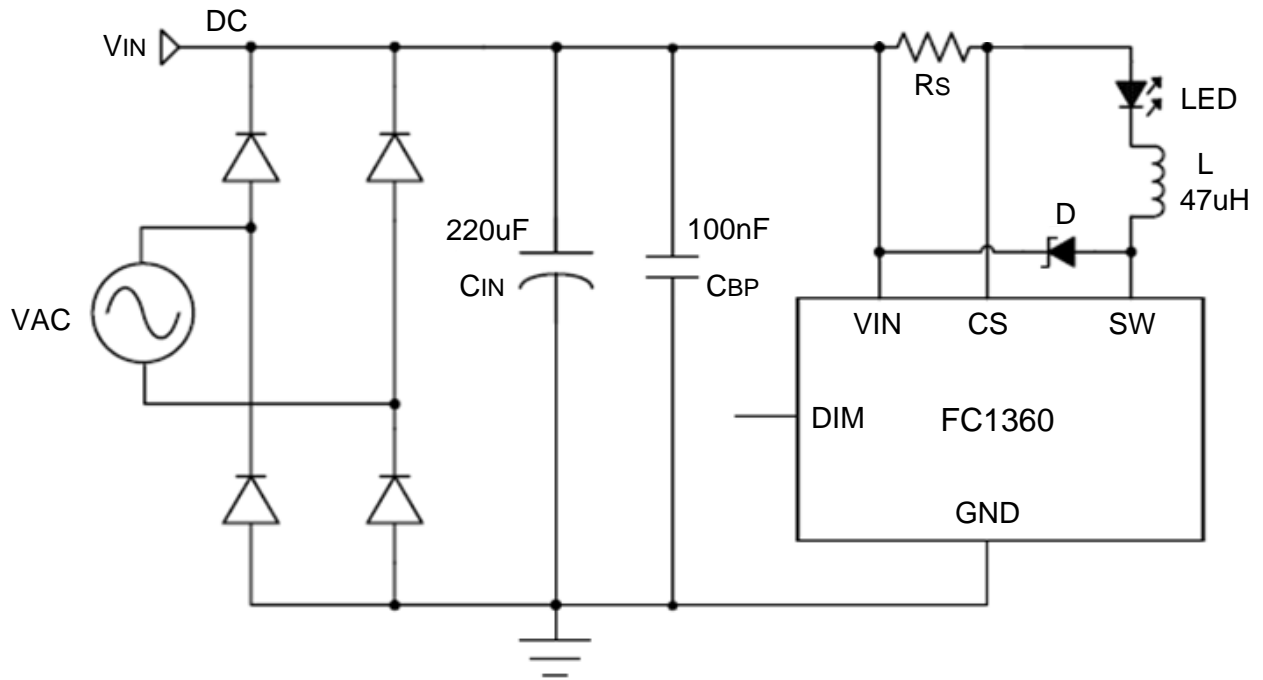5) PWM Dimming (10% Duty Cycle, 50%Duty Cycle, 90%Duty Cycle, 200Hz)

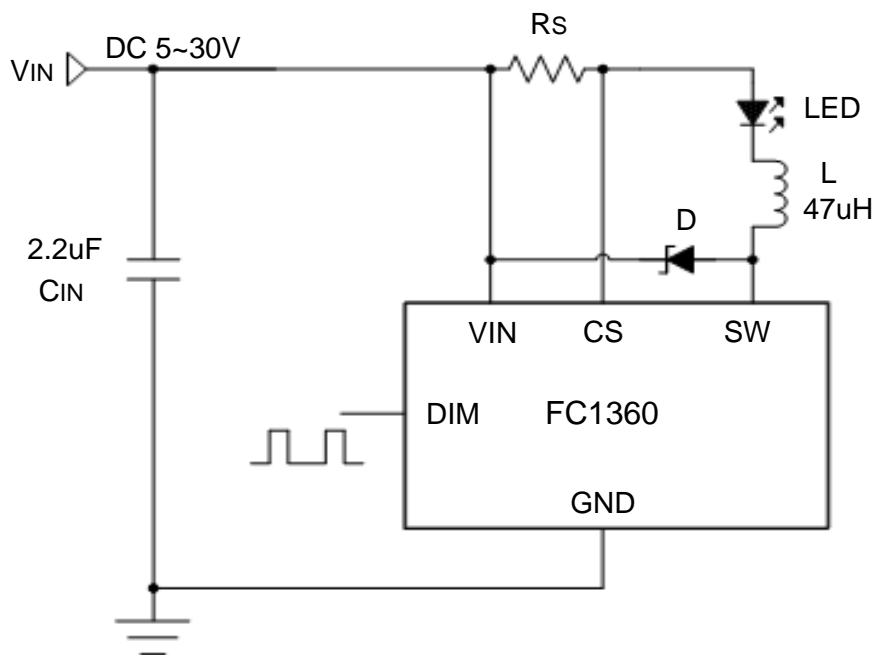## Duty vs Iout

6) Vcs vs Temperature

FC1360S

TYPICAL APPLICATION CIRCUIT of MR16

TYPICAL APPLICATION CIRCUIT of DC Input

2019. 10. 01   Revision No : 0   **First Silicon**   12/13

SOT-25 PACKAGE OUTLINE DIMENSIONS
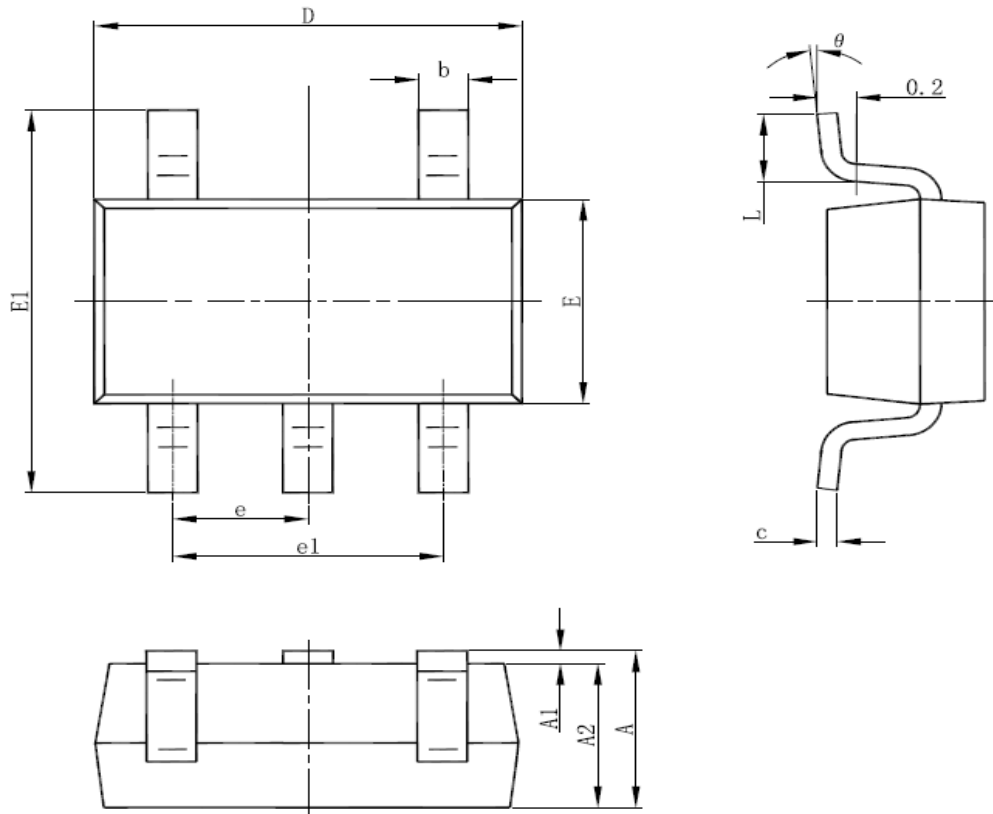
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950(BSC)		0.037(BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°