DESCRIPTION

PT6903 is a PFM high brightness LED driver control IC. It allows efficient operation of driver current up to 1.0A output, and the input range is from 7V to 36V. Moreover, PT6903 controls the internal MOS at a modulated switch frequency up to 1MHz. PT6903 drives a single or multiple series LEDs at a constant-current control method; thus, providing constant current light output and enhanc

PT6903 has linear and PWM dimming functions. Output current to an LED string can be programmed to any value between its minimum value to its maximum value at the linear dimming control input of PT6903. PT6903 provides a low-frequency PWM dimming input that can accept an external control signal with a duty cycle of 0~100% and a frequency between 100Hz and a few KHz.

PT6903 integrates more protection functions. The reliability of LEDs and device can be promoted by these protection functions. PT6903 provides over current protection when output short-circuit or LEDs current rises up about two times setting current. PT6903 must be power-up again if over current protection happens. PT6903 also provides over temperature protection. There are two ways to protect LEDs and device when temperature rises up to limited level. One is internal thermal-shutdown function.
If internal temperature rises up about 135℃, PT6903 will turn off switch. It will turn-on again when internal temperature falls down about 115℃. Another is temperature compensation function. This function is only used for SOP8 package. An NTC thermistor temperature monitoring 240mV and LED current will fall under value. This function can reduce the temperatur setting

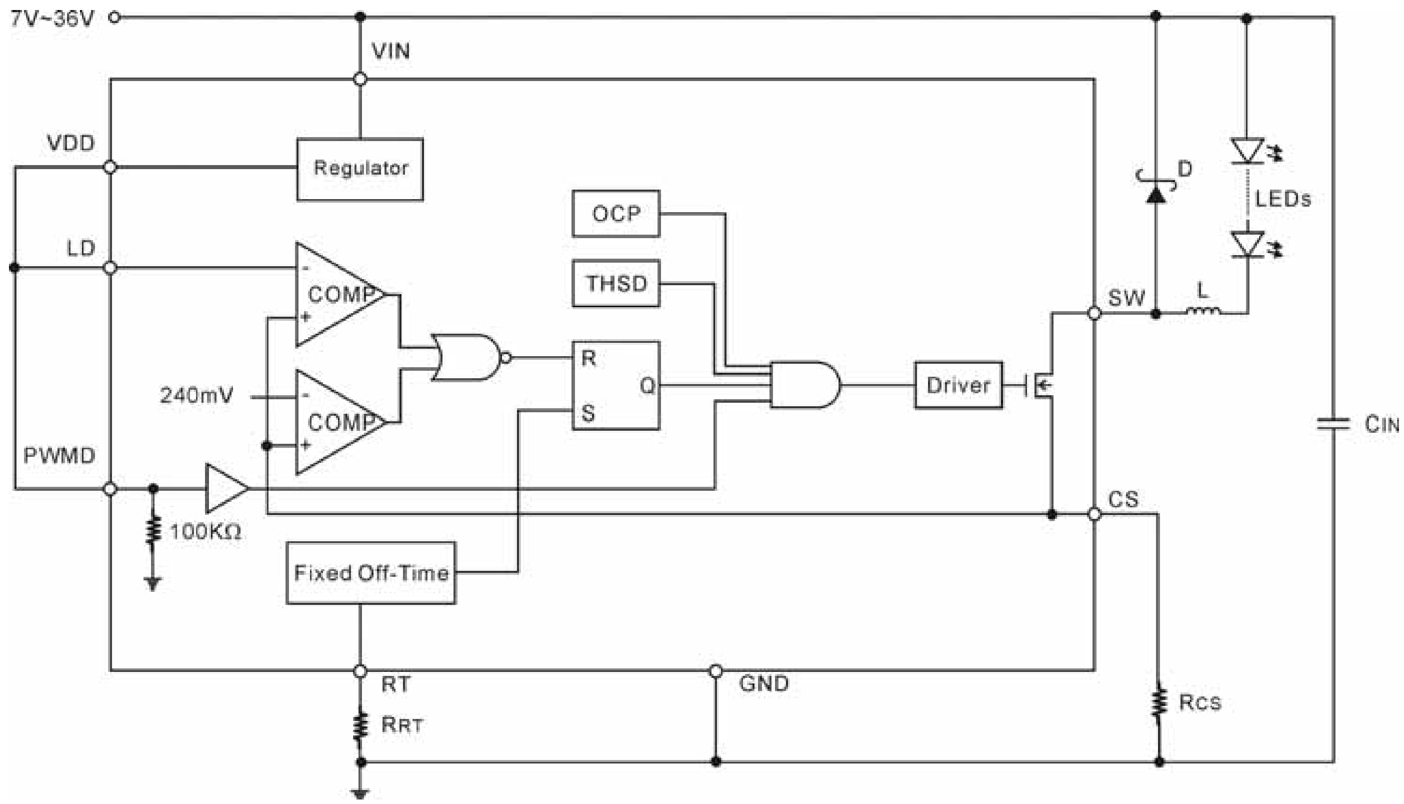
FEATURES

- >90% Efficiency
- Wide input voltage range: 7V to 36V
- Constant current driver
- Applications up to 1.0A
- Linear & PWM dimming
- Thermal shutdown protection
- Over current protection
- Internal 40V power NMOS switch

APPLICATIONS

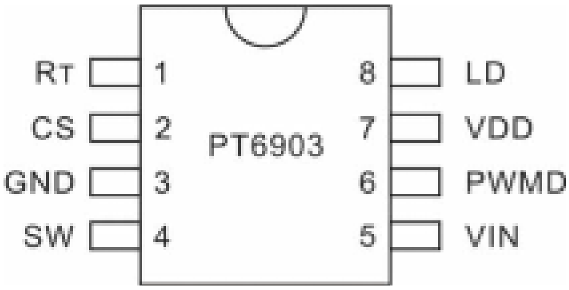
- DC/DC LED driver
- Low voltage industrial LED lighting
- Low voltage halogen replacement LEDs
- Decorative LED lighting

BLOCK DIAGRAM

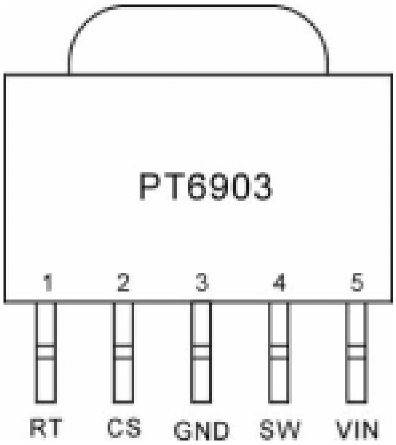


PIN CONFIGURATION

8 PINS, SOP



5 PINS, TO252



PIN DESCRIPTION

Pin Name	Description	Pin No.	
		SOP8	TO252
RT	Fixed off-time setting resistor	1	1
CS	LED string current sense	2	2
GND	Ground	3	3
SW	Internal switch	4	4
VIN	Positive input supply voltage	5	5
PWMD	PWMD dimming & enable input	6	
VDD	Internal regulated voltage	7	
LD	Linear dimming	8	

FUNCTION DESCRIPTION

PIN FUNCTIONS

RT (PIN1): Setting Switch Off-Time. The internal switch off-time is set by connecting a resistor, R_T, to ground. This pin servos to 1.18V typical. The switch off-time can be calculated by following formula:

$$T_{OFF} = 12.7 \times 10^{-12} \times R_T$$

CS (PIN2): LED String Current Sense. This pin is used to sense LED string current. When switch is turned-on, LED current flows through CS sensing resistor and the voltage of CS pin will rise up. CS is detected by an internal comparator. Internal switch will be turned-off when the voltage on this pin reaches 240mV. So, the peak current of LED string can be calculated by following formula:

$$I_{PK} = \frac{240mV}{R_{CS}}$$

GND (PIN3): IC Ground

SW (PIN4): Internal Switch. This pin is the drain of power NMOS. Connect inductor and schottky diode here and minimize the metal trace area connected to this pin to minimize EMI.

VIN (PIN5): Positive Input Supply Voltage. The input supply voltage range is from 7V to 36V. The input voltage must be about 2V larger than the voltage of LEDs string to keep PT6903 working normally. This pin should be bypassed with a filter capacitor.

PWMD (PIN6): PWM Dimming & Enable Input. PWMD pin is only used in SOP-8 package. This pin has two functions. One function is enable input. A logic high on this pin enable the driver. A logic low on this pin places the driver into shutdown mode. An internal 100kΩ pull-down resistor to ground defaults the driver to its shutdown mode. Another function is PWM dimming. A PWM signal drives this pin and internal NMOS switch provides accurate dimming control. PWMD pin should be connected with VDD pin if these functions are not used.

VDD (PIN7): Internal Regulated Voltage. VDD pin is only used in SOP-8 package. The voltage on this pin is about 4.8V typical. This voltage is regulated by internal regulator. The regulated voltage acts as power supply of internal control circuit. It also provides a supply voltage for external circuit. It doesn’t need filter capacitor if this pin is floating. The current source capability is limited less than 1mA. A filter capacitor can be used if an external dynamitic circuit is connected to this pin.

LD (PIN8): Linear Dimming. LD pin is only used in SOP-8 package. It will be disabling if the voltage on this pin is larger than 240mV typical. So, this pin should be connected to VDD pin if linear dimming is not need. If the voltage on this pin is less than 240mV, the peak current of LEDs string will be determined by both the voltage of LD and CS resistor. The peak current of LEDs string under linear dimming can be calculated by following formula:

$$I_{PK} = \frac{V_{LD}}{R_{CS}}$$

OPERATION

The PT6903 is optimized to drive buck LED drivers using open-loop peak current mode control. This architecture enables fairly accurate LED current control without the need for high side current sensing or the design of any closed loop controllers. The PT6903 uses very few external components and enables both linear and PWM dimming of the LED current. A resistor connected to the RT pin programs the off-time of power switch. The oscillator produces pulses at regular intervals. The same pulses also start the blanking timer which inhibits the reset input of the SR flip-flop and prevent false turn-offs due to the turn-on spike. When the switch turns on, the current through the inductor starts ramping up. This current flows through the external sense resistor R_{CS} and produces a ramp voltage at

the CS pin. The internal comparators are constantly comparing the CS pin voltage to both the voltage at the LD pin and the internal 240mV. Once the blanking timer is complete, the output of these comparators is allowed to reset the flip-flop. When the output of either one of the two comparators goes high, the flip-flop is reset and the power switch turns-off. The switch turns-on until

The PT6903 is a fixed off-time control LED driver. The off-time of power switch is only set by RT resistor. But the on-time of power switch is set by more factors such as input supply voltage, loading, inductor. So, the frequency is a dynamitic change by these factors. The fixed off-time peak current control scheme can easily operate at duty cycles greater than 0.5 and also gives inherent input voltage rejection making the LED current almost insensitive to input voltage variations.

APPLICATION INFORMATION

INPUT VOLTAGE RANGE

The input voltage range of PT6903 is from 7V to 36V. It means PT6903 can work under this range. But PT6903 need about 2V voltage across input voltage and output voltage to work correctly. If the input voltage doesn't fulfill this condition, the LED current will become two states. One state is the LED current is less than the setting average current when input voltage is lower than output voltage. The switch keeps on-state under this condition. Another state is the LED current is larger than the setting average current when input voltage is larger than output voltage but not fulfilling 2V space. Due to the peak current control principle, the switch keeps on-state because LED current doesn't reach peak current threshold.

CURRENT SENSE

The current sense input of the PT6903 goes to the non-inverting inputs of two comparators. The inverting terminal of one comparator is tied to an internal 240mV reference whereas the inverting terminal of the other comparator is connected to the LD pin.

The outputs of the comparators also include a blanking time circuit which prevents spurious turn-offs of the switch due to the turn-on spike normally present in peak current mode control. The blanking time is 1/10th the off-time of switch. Some factors such as PCB layout, loading and so on make the spike's amplitude and holding time too bad. Maybe, less blanking time can't shield the spike. It will lead the switch turns-off early and the LED current will be less than the setting average value. In serious condition, the spike of CS pin leads fault over-current protection and the switch will be locked. It needs power-on again to light LEDs. So, a larger blanking time should be considered. A suggested off-time is larger than 1uS, the blanking time will be larger than 100nS. It is

An external filter capacitor can be added between the CS pin and GND. Please note that the
comparators are fast. Filter circuit maybe cause an obvious delay time. A proper layout minimizing

PROGRAMMABLE OFF-TIME

The off-time of switch is controlled by a single resistor connected at the RT pin. It can be calculated by following formula:

$$T_{OFF} = 12.7 \times 10^{-12} \times R_T$$

When the voltage on CS pin reaches 240mV, internal comparator will turns-off the switch. The off-time is set by RT resistor. After the off-time, oscillator will force the switch turn-on in blankir time. In blanking-time, CS can't change the switch states. The blanking-time is:

$$T_{BLK} = 12.7 \times 10^{-13} \times R_T$$

INDUCTOR SELECTION

The inductor used with the PT6903 should have a saturation current rating of 1.5 times of the LED average current or greater. For buck-mode LED drivers, the inductor value should be chosen to give a ripple current "△I" of 30% of the LED current. In the buck-mode, the inductor value can be estimated using the formula:

$$L = \frac{(V_{LEDs} + V_D) \times T_{off}}{0.3 \times I_{LED}}$$

V_{LEDs} is the voltage across the LEDs string. V_D is the forward voltage of schottky diode. Toff is the switch off-time. 0.3 is a ratio of ripple current of the LED current. I_{LED} is the average LED current.

CAPACITOR SELECTION

For Proper operation, it is necessary to place a bypass capacitor to GND close to the VIN pin of the PT6903. A 4.7µF or greater capacitor with low ESR should be used. A ceramic capacitor is usually the best choice. During the switching, the capacitor at the input to the power converter has large pulsed currents due to the current returned through the schottky diode when the switch is off. For best reliability, this capacitor should have low ESR and ESL and have an adequate ripple current rating. The RMS input current is:

$$I_{IN(RMS)} = I_{LED} \times (1 - D) \times D$$

Where D is the switch duty cycle.
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.

The selection of output capacitor depends on the load and switch frequency. The output capacitor is not indispensable for PT6903 application. But the output capacitor is recommended to use. It can reduce the ripple voltage of LEDs.

DIODE SELECTION

The schottky diode conducts current during the interval when the switch is turned-off. Select a diode rated for the maximum SW voltage. If using the PWM feature for dimming, it is important to consider diode leakage, which increases with the temperature from the output during the PWM low interval. Therefore, choose the schottky diode with sufficiently low leakage current.

PARAMETERS CALCULATION

The PT6903 is peak current mode control. The peak current is different with the average current of LED. Following description can be used as a reference for parameters calculation.

LED current, I_{LED}, should be defined firstly. Then the ripple current of inductor can be chosen 30% of LED current.

$$\Delta I_L = 0.3 \times I_{LED}$$

And, the peak current is:

$$I_{PK} = I_{LED} + \frac{1}{2} \times 0.3 \times I_{LED} = 1.15 \times I_{LED}$$

So, CS sense resistor can be calculated:

$$R_{CS} = \frac{240mV}{I_{PK}} = \frac{240mV}{1.15 \times I_{LED}}$$

The voltage across LEDs string should be known. The LED features information provides the I-V characteristic. Assuming V_{LED} is the voltage across LEDs string, and V_{IN} is the input supply voltage.

$$D_R = \frac{V_{LED}}{V_{IN}}$$

Depending on application condition, a base operating frequency, f, can be defined. So, the off-time is:

$$T_{OFF} = \frac{1}{f} \times (1 - D) = \frac{1}{f} \times \left(\frac{V_{IN} - V_{LED}}{V_{IN}} \right)$$

This off-time calculation formula is only used for estimating whether it is reasonable for operating frequency, off-time, and blanking-time. If blanking-time is too small and maybe affected by spike, operating frequency has to be re-defined.

If f, T_{OFF}, and T_{BLK} are all reasonable, T_{OFF} will be chosen around the estimated value definitely. And, RT resistor is:

$$R_{RT} = \frac{T_{OFF} \times 10^{12}}{12.7}$$

When switch is off, the voltage across inductor is:

$$\Delta V_L = V_{LED} + V_D$$

Where VD is the forward voltage of schottky diode, the value can be got from its datasheet. Now, the inductor is :

$$L = \frac{\Delta V_L \times \Delta T}{\Delta I_L} = \frac{(V_{LED} + V_D) \times T_{OFF}}{0.3 \times I_{LED}}$$

Now, the related part values are all calculated. The output current can be re-calculated depend on these part values:

$$I_{LED} = \frac{(V_{LED} + V_D) \times_{OFF}}{\quad}$$

LINEAR DIMMING

The linear dimming pin is used to control the LED current. It is only used in SOP-8 package. An external 0-240mV voltage can be connected to the LD pin to adjust the LED current during operation. The LED current is proportional to the voltage on LD pin. To use the internal 240mV, the LD pin can be connected to VDD pin.

Note:
Although the LD pin can be pulled to GND, the output current will not go to zero. This is due to the presence of a minimum on-time (which is equal to the sum of the blanking time and the delay to output time). This current is also dependent on the input voltage, inductance value, forward voltage of the LEDs and circuit parasitic. To get zero LED current, the PWMD pin has to be used.

PWM DIMMING

PWM dimming is only used for SOP-8 package. PWM dimming can be achieved by driving the PWMD pin with a low frequency square wave signal. When the PWM signal is zero, the switch is turned off and when the PWMD signal is high, the switch is enabled. Since the PWMD signal does not turn off the other parts of the PT6903, the response of the PT6903 to the PWMD signal is almost instantaneous. The rate of rise and fall of the LED current is thus determined solely by the rise and fall times of the inductor current. To disable PWM dimming and enable the PT6903 permanently, connect the PWMD pin to VDD.

OPEN CIRCUIT PROTECTION

If the connection to the LEDs is open-circuited, the coil is isolated from the SW pin of the chip, so the device will not be damaged. Unlike in many boost converters, where the EMF may damage the internal switch by forcing the drain above its break down voltage.

OVER CURRENT PROTECTION

The over current protection threshold is set about two times the LED current typical. The threshold may be changed a little range with LED current changing. It does not mean that PT6903 must protect when output short-circuited. In some applications, because of the output parasitic resistance, the output current will be balanced to some level which is between normal value and protection threshold.
If the input supply voltage is high enough, the over current protection will be enabled. When over

THERMAL CONSIDERATIONS

Careful attention must be paid to the internal power dissipation of the PT6903 at lower voltage across input voltage and output voltage. Under this condition, the switching duty cycle is nearly unit. If the output current is high enough, the power dissipation of switch is high and the junction temperature rises

THERMAL SHUTDOWN

When the temperature of chip rises up to 135°Ctypical, the PT6903 will turns-off the switch. It is about 20℃ hysteresis space to turn-on switch again. This function can prevent the device be damaged in high temperature and enhance the reliability of the device.

THERMAL COMPENSATION

If output current compensation is required, it is possible to use an NTC (Negative Temperature Coefficient) thermistor temperature monitoring circuit to LD pin. The output of thermal compensation circuit can drive the LD pin in order to reduce the output current with increasing

SOFT START

For many applications, it is necessary to minimize the inrush current at start-up. An RC delay circuit can be connected to LD pin. Resistor is connected between VDD and LD and capacitor is connected between LD and GND.

BOARD LAYOUT

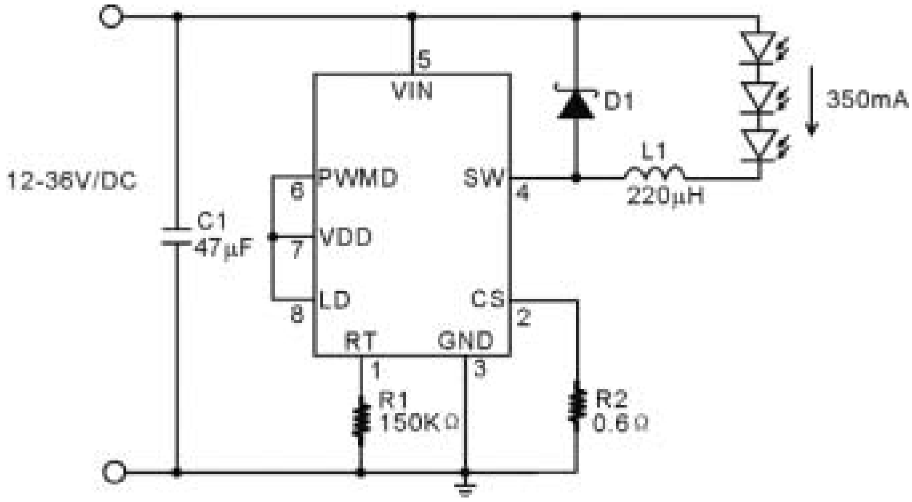
The high speed operation of the PT6903 demands careful attention to board layout and component placement. The exposed pad (for TO-252-5L) of the package is the only GND terminal of the IC and is also important for thermal management of the IC. It is crucial to achieve a good electrical and thermal contact between the exposed pad and the ground plane of the board. To reduce electromagnetic interference (EMI), it is important to minimize the area of the SW node. Use a GND plane under SW and minimize the length of traces in the high frequency switching path between SW and GND through

The bypass capacitor on the VIN supply to the PT6903 should be placed as close as possible to the VIN terminal of the device.

To minimize ground 'bounce', the CS sense resistor should be separated from the GND of IC and soldered directly to the ground plane.

It is also important to minimize any track resistance in series with CS sense resistor R_{CS}. It's best to connect CS directly to one end of R_{CS} and ground plane directly to the opposite end of R_{CS} with no other currents flowing in these tracks.

TYPICAL APPLICATION



ABSOLUTE MAXIMUM RATINGS

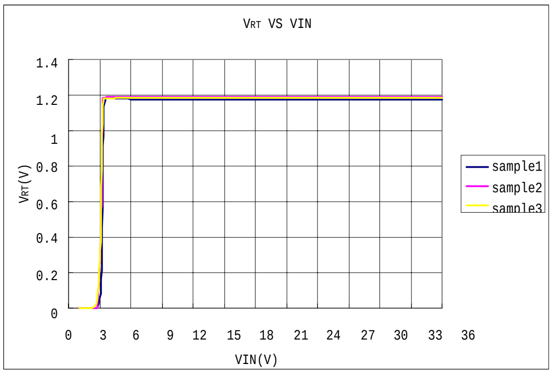
Parameter	Symbol	Rating	Unit
R_T to GND	R_T	-0.3 ~ +6	V
CS to GND	CS	-0.3 ~ +0.6	V
SW to GND	SW	-0.3~+40	V
VIN to GND	VIN	-0.3 ~ +40	V
PWMD to GND	PWMD	-0.3 ~ +6	V
VDD to GND	VDD	-0.3 ~ +6	V
LD to GND	LD	-0.3 ~ +6	V
Operating temperature	Topr	-40 ~ +85	℃
Storage temperature	Tstg	-65 ~ +150	℃

ELECTRICAL CHARACTERISTICS

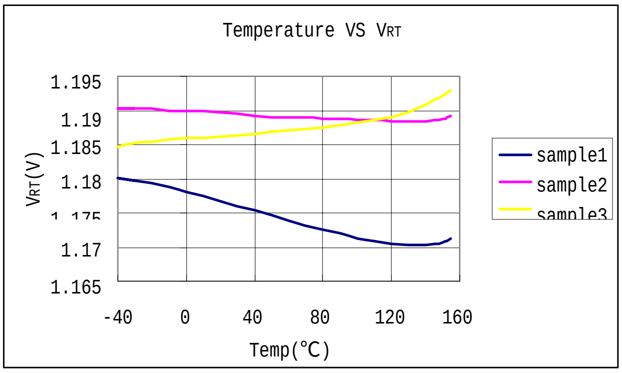
(Unless otherwise specified, VIN=24V, Ta=25℃)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Input DC supply voltage	V_{IN}	DC input voltage	7	24	36	V
Active supply current	I_{INAC}	VIN=7~36V	0.5	1.5	2.5	mA
Shutdown supply current	I_{INSD}	VIN=7~36V	200	500	800	μA
SW sink current	I_{SW}	VIN=24V			1	A
VDD current source capability	I_{VDD}	VIN=7~36V			1	mA
Current sense threshold voltage	V_{CS}	Ta=-40~+85℃	220	240	260	mV
PWMD pull-down resistor	R_{PWMD}		80	100	120	KΩ
PWMD enable logic high	V_{EH}	VIN=24V	1.3			V
PWMD enable logic low	V_{EL}	VIN=24V			0.5	V
Thermal shutdown temperature	T_{SD}			135		℃
Hysteresis temperature	T_{HYS}			20		℃
Over current protection	I_{OC}	VIN>15V,RRT=100KΩ RCS=0.28Ω(ILED=700mA)	1.2		1.4	A
RT voltage	V_{RT}	VIN=7~36V, RT=56KΩ	1.16	1.18	1.20	V
VDD voltage	VDD	VIN=12V	4.5	4.8	5.2	V
Fixed off-time	T_{OFF}	VIN=24V, RT=220KΩ	2.0	2.8	3.6	μS
Internal blank time	T_{BLK}	RT=220KΩ	0.24	0.28	0.32	μS
Minimum switch off-time	T_{OFFMIN}	VIN=7~36V	1			μS
Maximum duty cycly	D_{MAX}	VIN=7~36V			100	%
Internal NMOS turn-on resistor	R_{ON}	VIN=24V		0.6	1	Ω
SW leakage current	I_{SW_LC}	VIN=36V, VSW=36V			0.1	μA

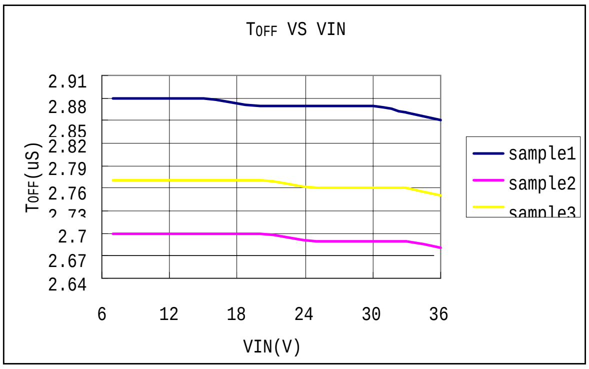
TYPICAL PERFORMANCE CHARACTERISTICS



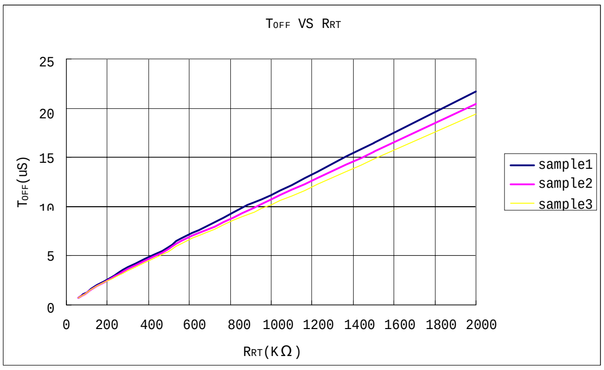
RT Voltage vs Supply Voltage
(RRT=220kΩ)



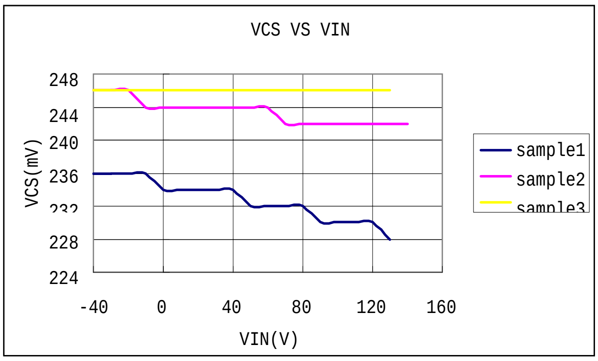
RT Voltage vs Temp
(RRT=220kΩ)



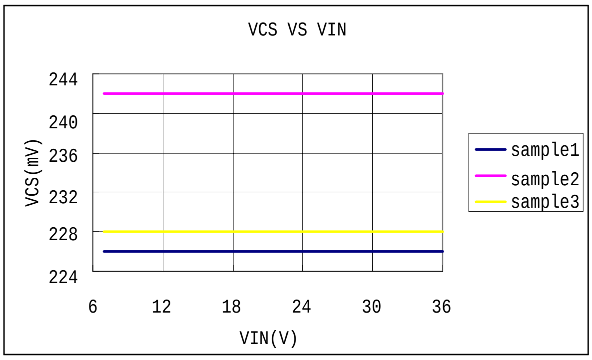
Off-Time vs Supply Voltage
(RRT=220kΩ)



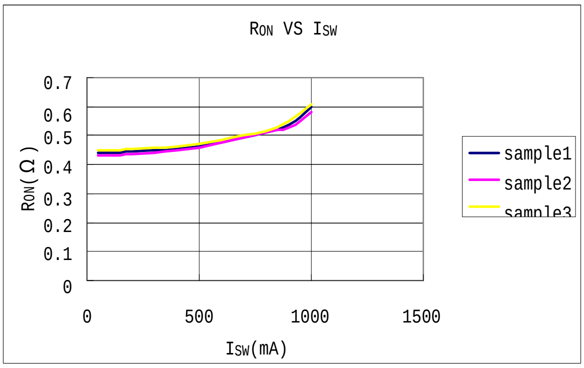
Off-Time vs RT resistor
(VIN=12V)



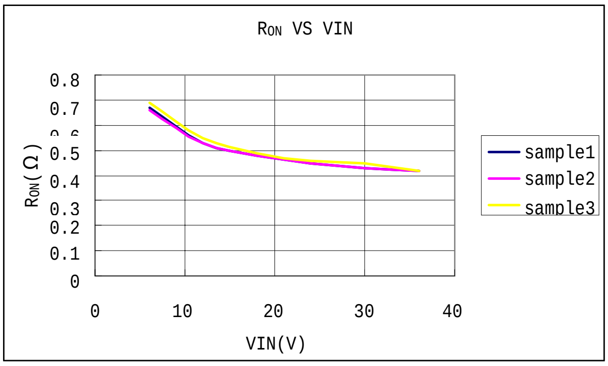
CS Voltage vs Temp
(VIN=7-36V)



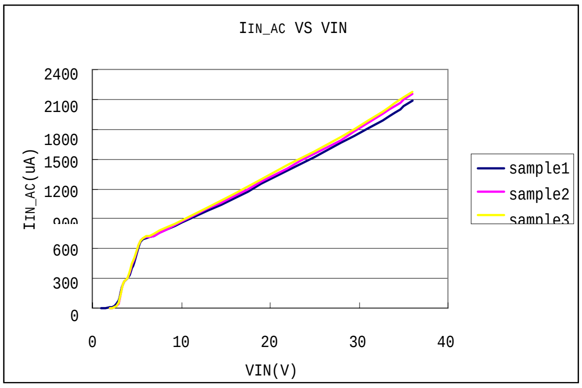
CS Voltage vs Supply Voltage



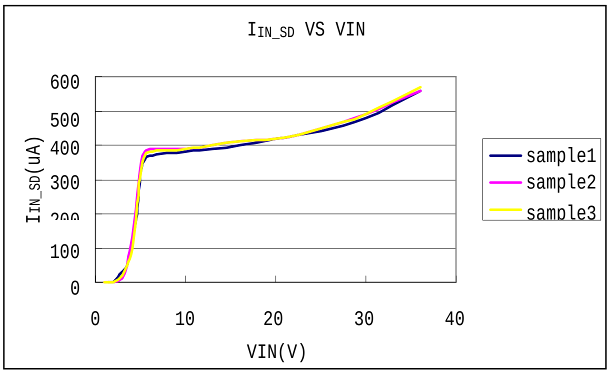
Ron of Switch vs Current of Switch (VIN=24V)



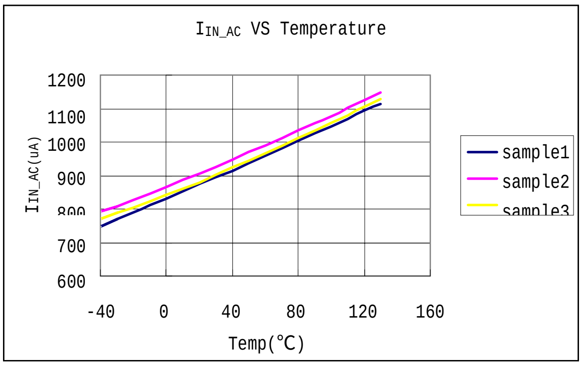
Ron of Switch vs Supply Voltage



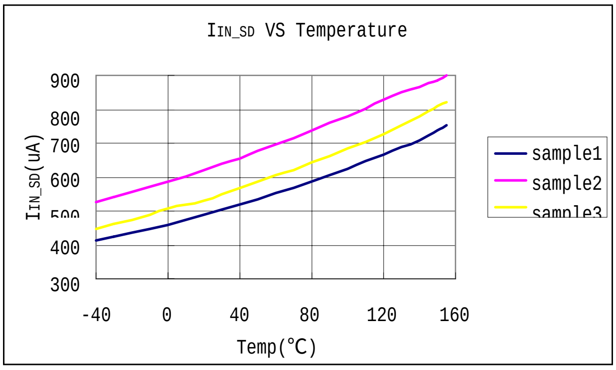
Active Supply Current vs Supply Voltage



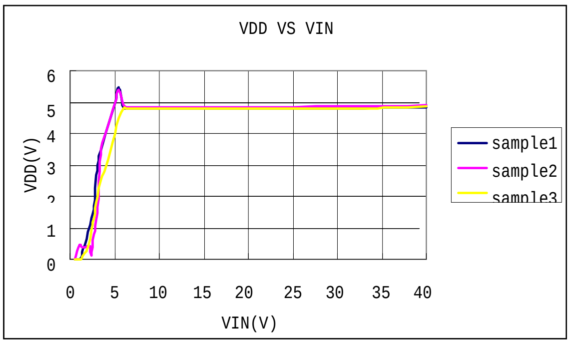
Shutdown Supply Current vs Supply Voltage



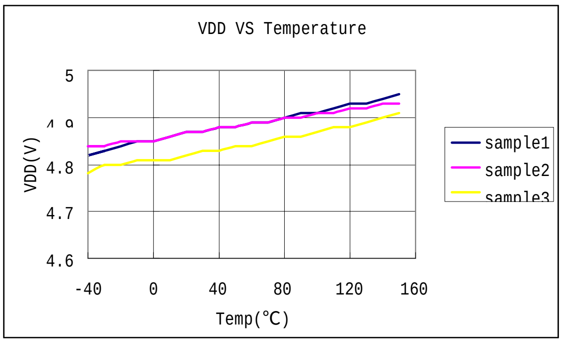
Active Supply Current vs Temp (VIN=12V)



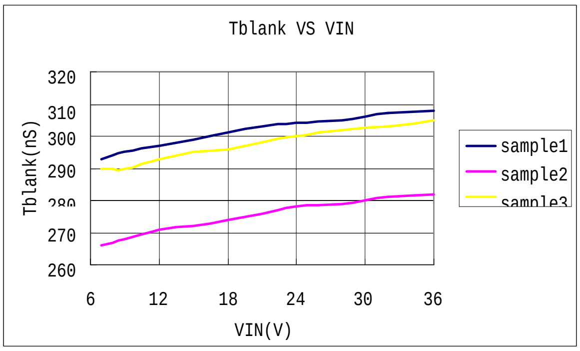
Shutdown Supply Current vs Temp (VIN=36V)



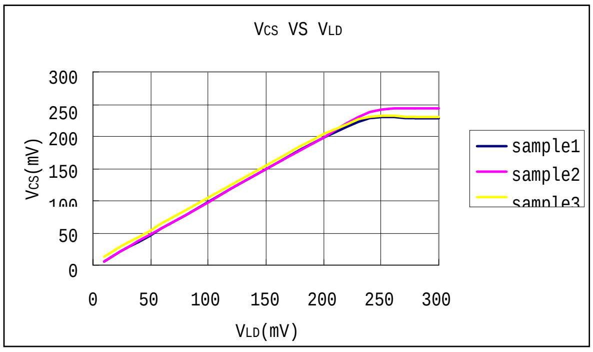
VDD Voltage vs Supply Voltage



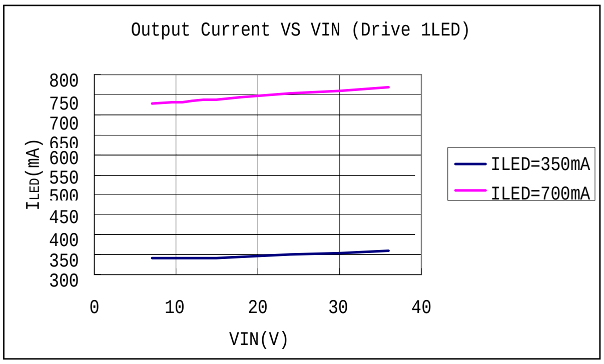
VDD Voltage vs Temp (VIN=36V)



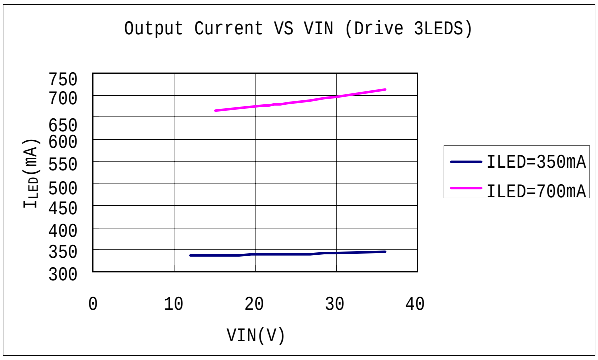
Blank Time vs Supply Voltage (R_{RT}=220kΩ)



CS Voltage vs LD Voltage (VIN=24V)



Output Current vs Supply Voltage (1 LED)



Output Current vs Supply Voltage (3 LEDs)

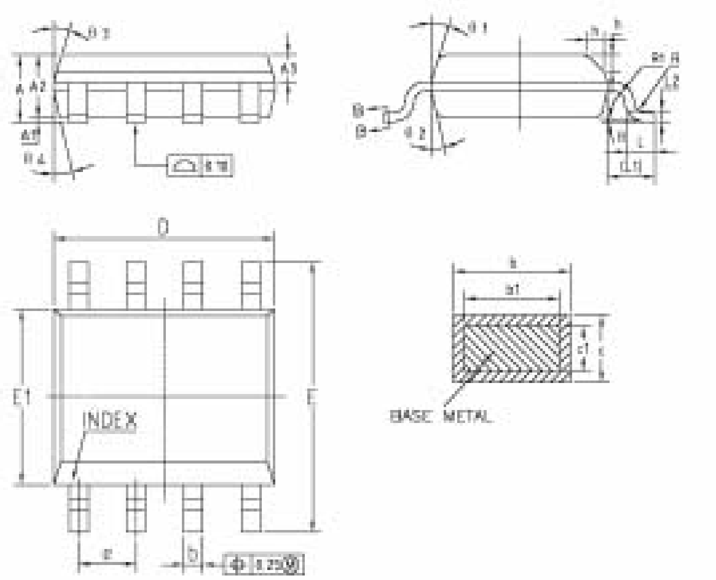
ORDER INFORMATION

Valid Part Number	Package Type	Top Code
PT6903-S (L)	8 Pins, SOP, 150 MIL	PT6903-S
PT6903-TO (L)	5 Pins, TO252	PT6903

Notes:
1. (L), (C) or (S) = Lead Free.
2. The Lead Free mark is put in front of the date code.

PACKAGE INFORMATION

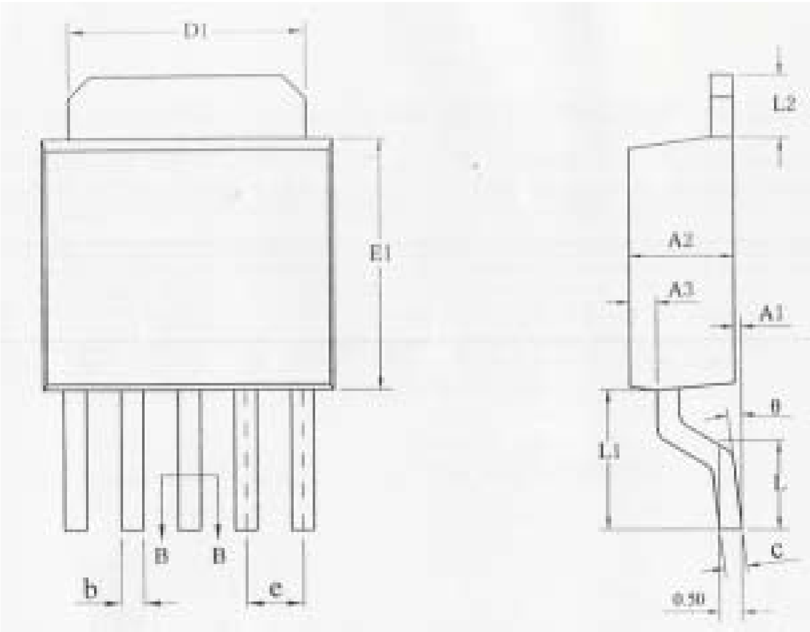
8 PINS, SOP, 150MIL

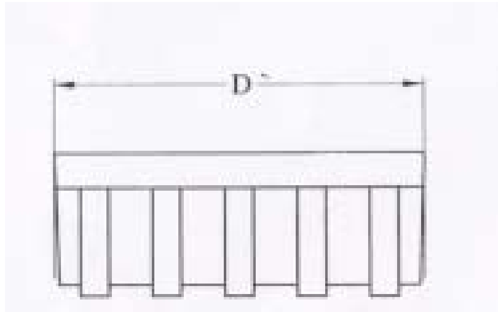


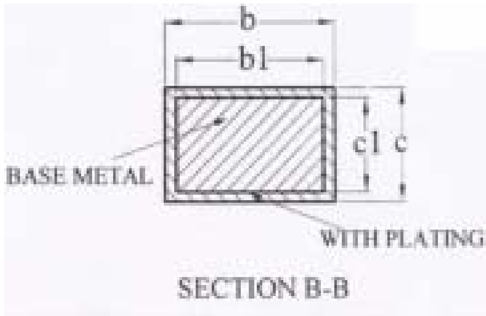
Symbol	Min.	Typ.	Max.
A	1.35	1.55	1.75
A1	0.05	0.15	0.25
A2	1.25	1.40	1.65
A3	0.50	0.60	0.70
b	0.38	-	0.51
b1	0.37	0.42	0.47
c	0.17	-	0.25
c1	0.17	0.20	0.23
D	4.80	4.90	5.00
E	5.80	6.00	6.25
E1	3.80	3.90	4.00
e	1.27 BSC.		
L	0.45	0.60	0.80
L1	1.04 REF.		
L2	0.25 BSC.		
R	0.07	-	-
R1	0.07		-
h	0.30	0.40	0.50
θ	0°	-	8°
θ1	15°	17°	19°
θ2	11°	13°	15°
θ3	15°	17°	19°
θ4	11°	13°	15°

Note: Refer to JEDEC MS-012 Variation AA

5 PINS, TO-252







Symbol	Millimeter		
	Min.	Nom.	Max.
A1	0.05	0.15	0.25
A2	2.10	2.30	2.50
A3	0.50	0.60	0.70
b	0.46	-	0.60
b1	0.45	0.50	0.55
c	0.49	-	0.56
c1	0.48	0.50	0.52
D	6.30	6.50	6.70
D1	5.30REF		
E1	5.30	5.50	5.70
e	1.27BSC		
L	1.40	1.50	1.60
L1	3.00	3.10	3.20
L2	1.40BSC		
θ	0°	-	8°

Note:

1. All dimensions refer to Jedec standard TO-252 AD do not include mold flash or protrusions.