PT16972
4-Channel 100mA LED Driver
with DC-DC Controller

DESCRIPTION

PT16972 is a 4-Channel constant current LED driver with current-mode switching DC-DC controller. The output current range can be externally programmed for 10mA~100mA per channel. Also, the output voltage can be up to 36V. The PT16972 supports the boost, coupled-inductor boost-buck or SEPIC topologies and operates in an adjustable switching frequency between 200kHz and 2.1MHz.
High PWM dimming ratio 2500:1 can be achieved by internal fast response time 2μS with 200Hz PWM dimming frequency.
The PT16972 allows to detect and manage the open and shorted LED faults and to let unused channel floating. Also, the device includes output over-voltage protection, thermal shutdown protection and internal power MOSFET over-current protection. Two fault indication pins are provided to separate the failure mode.

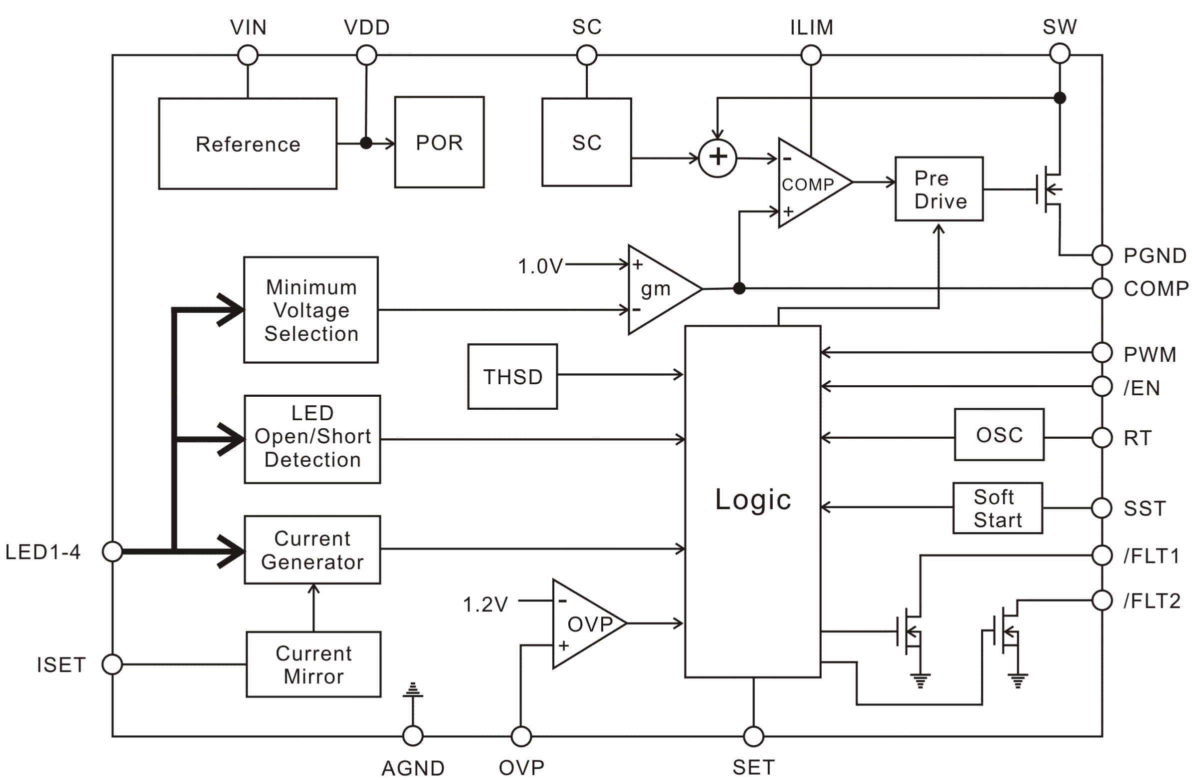
APPLICATIONS

- Automotive Navigation LCD Panel Backlight
- Desktop and Notebook LCD Panel Backlight
- PDAs Panel Backlight

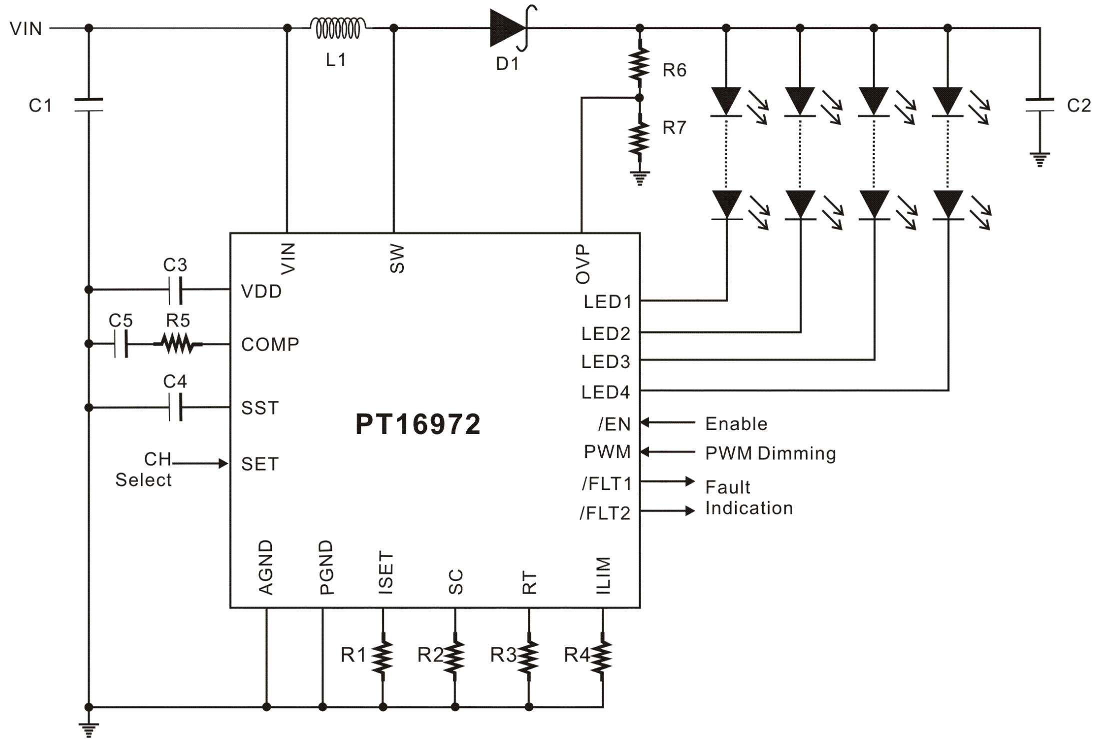
FEATURES

- Automotive AEC-Q100, Grade 1 (-40℃~+125℃) Qualified
- 6V~36V Input Voltage
- Output Voltage Up to 36V
- Output Current Range 10mA~100mA/CH
- ±1% LED Current Matching at 20mA or Higher
- Programmable Frequency 200KHz~2.1MHz
- 2uS Minimum PWM Dimming on Time
- Support Boost, Coupled-Inductor Boost-Buck or SEPIC Topologies
- Selectable Output Channels
- Low Standby Current
- Adjustable Internal MOSFET Current Limitation and Soft-Start
- LED Open / Short Protection
- Output Over-Voltage Protection
- Thermal Shutdown Protection at 150℃
- Two Fault Indication Pins
- HTSSOP(173mil) with Exposed PAD Package

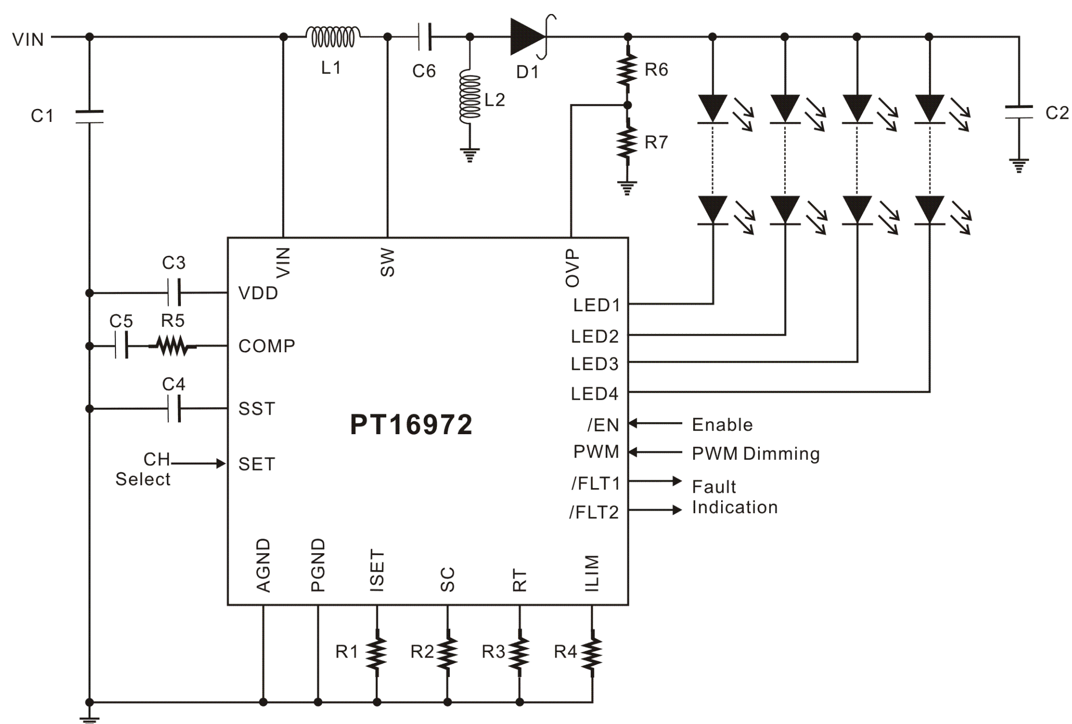
BLOCK DIAGRAM



TYPICAL APPLICATION



Boost Configuration

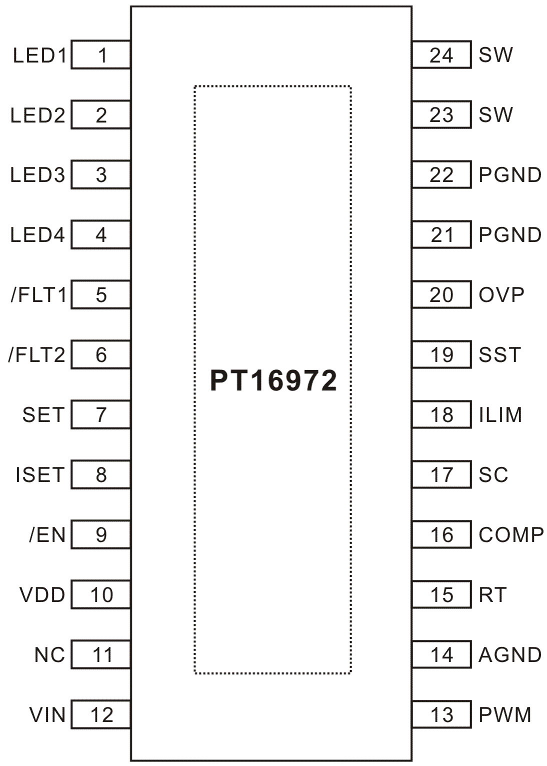


SEPIC Configuration

ORDER INFORMATION

Valid Part Number	Package Type	Top Code
PT16972	HTSSOP24	PT16972-HT

PIN CONFIGURATION



PIN DESCRIPTION

Pin Name	Description	Pin No.
LED1	LED String Driver Output 1.	1
LED2	LED String Driver Output 2.	2
LED3	LED String Driver Output 3.	3
LED4	LED String Driver Output 4.	4
/FLT1	Fault Signal Open Drain Output. /FLT1 will be low when LED open or shorted is detected.	5
/FLT2	Fault Signal Open Drain Output. /FLT2 will be low when thermal shutdown or output over-voltage is detected.	6
SET	Channel Selection. Pin logic level will set the output channels: SET=0 or floating, 4 channels are used; SET=1, LED4 is not used. An internal 100kΩ pull-low resistor is used.	7
ISET	LED Current Setting. A resistor to AGND to program the output current per channel.	8
/EN	Enable Control. /EN=0 or floating, the device is turn on. /EN=1, the device is turned off. An internal 100KΩ pull-low resistor is used.	9
VDD	Internal 5V Regulator Output. Bypass to AGND with a 10μF ceramic capacitor.	10
NC	Non-Connection.	11
VIN	Input Supply Voltage.	12
PWM	External PWM Dimming Input. PWM=0 or floating, the switching and the current generators are turned off. PWM=1, the switching and the current generators operate normally. An internal 100KΩ pull-low resistor is used.	13
AGND	Analog Ground.	14
RT	Switching Frequency Setting. A resistor to AGND which programs the switching frequency between 200KHz and 2.1MHz.	15
COMP	Error Amplifier Output pin. Tie the external compensation network.	16
SC	Slope Compensation Setting. A resistor between this pin and AGND is needed. It can avoid sub-harmonic instability.	17
ILIM	Internal Switch Current Limit Setting. A resistor to AGND to program the current limit level of power MOSFET.	18
SST	Soft-Start. Connect a capacitor to AGND to set the soft-start time.	19
OVP	Over Voltage Protection. When V_{OVP}>1.2V, the over-voltage protection occurs.	20
PGND	Power Ground. Source of internal power MOSFET.	21
PGND	Power Ground. Source of internal power MOSFET.	22
SW	Switching pin. Drain of internal power MOSFET.	23
SW	Switching pin. Drain of internal power MOSFET.	24

FUNCTION DESCRIPTION

OPERATION

The PT16972 is a LEDs driver with four channels for the backlight of LCD panel and it consists of a boost converter and four PWM dimmable current generators. Each channel is able to drive multiple LEDs in series and to sink up to 100mA maximum current.

The boost converter operates in constant switching frequency, peak current-mode topology to provide excellent line and load regulation. It converts the input voltage to a higher output voltage for driving LEDs. The LED strings are connected to current sources where the current level is set with an external resistor on the ISET pin. The boost output voltage is controlled by the lowest LED pin voltage, referred to AGND, which is equal to an internal reference voltage (1V typical).

During normal operation, when all channels are used, the LED1 to LED4 voltages are monitored for output voltage regulation. The minimum voltage selection circuit automatically selects the lowest voltage drop among all the LED pins, and the voltage is used to regulate the output voltage to ensure all LED strings have enough voltage to run the programmed current. In fact, once the reference generator has been detected, the error amplifier compares its voltage drop to the internal reference voltage and varies the COMP output. The COMP pin voltage determines the inductor peak current at each switching cycle. The output voltage of the boost regulator is thus determined by the total forward voltage of the LEDs strings.

DEVICE ENABLE

The PT16972 is enabled by the /EN pin. If the /EN pin voltage is lower than 0.9V (Typ.) or left open, the device is turned on. If the /EN pin voltage is higher than 0.9V (Typ.), the device is turned off. Nearly all of the internal circuits are shutdown, and the standby current is only 10μA around.

5V REGULATOR

The PT16972 has internal LDO that supplies the internal circuitry of the device. The input of the LDO is the VIN pin. The VDD pin is the output of LDO, bypassed with a 10μF ceramic capacitor to AGND is recommended. While power on, internal POR block will detect the VDD voltage, to turn on the PT16972, the VDD voltage must exceed 4.2V typical.

CHANNEL SELECTION

In some applications, the user prefers only three channels, the LED4 channel can be disabled through the SET pin. If the voltage level of the SET pin is logic high (i.e., connected to the VDD pin), the LED4 channel is not used. If the SET pin is leaved alone or connected logic low, all four channels are available.

Control Signal	Logic	LED1	LED2	LED3	LED4
SET	0	available	available	available	available
SET	1	available	available	available	not used

If the user prefers only two channels, then two LED pins are connected in parallel (i.e., LED1, 2 and LED3, 4 can be connected together in operation). Please take care that if two channels are connected in parallel, the output current should be set half of the wanted value.

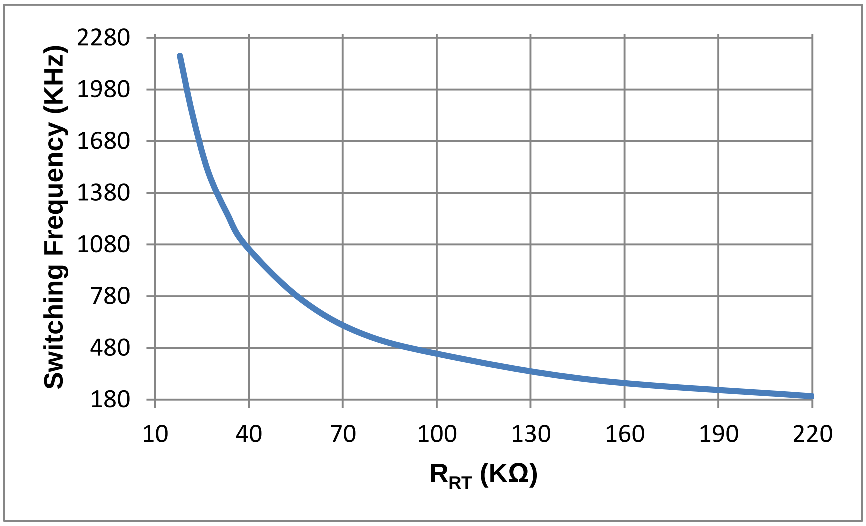
PROGRAMMING SWITCHING FREQEUNCY

The switching frequency of the boost converter can be set in the 200KHz – 2.1MHz range by connecting the RT pin to AGND through a resistor (R_{RT}). The switching frequency is roughly calculated by:

$$f_{SW} = \frac{4.0 \times 10^{10}}{R_{RT}}$$

The calculated result has a deviation because of the internal delay time. For more accurate value, please refer to the table as followed.

R_{RT} (KΩ)	Switching Frequency (KHz)
18	2175
22	1835
27	1504
33	1262
39	1075
56	772
75	571
100	447
150	294
220	200

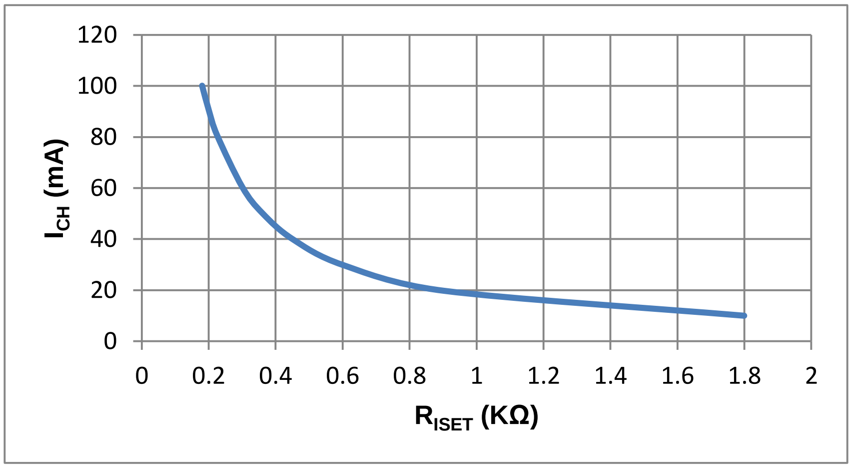


CHANNEL CURRENT SETTING

The channels current can be set by connecting an external resistor (R_{ISET}) between the ISET pin and AGND. The voltage across the ISET pin is internally set to 1.20V and the channels current is proportional to the ISET pin setting current according to the following equation:

$$I_{CH} = \frac{1.2}{R_{ISET}} \times 15$$

R_{ISET} (KΩ)	Channel Current ICH (mA)
1.8	9.946
0.9	19.768
0.6	29.886
0.45	40.027
0.36	50.198
0.3	60.444
0.225	80.656
0.2	90.575
0.18	100.168



SOFT START

The soft-start function is required to control the inrush current to charge the output capacitor and to avoid output voltage overshoot while the system starts-up. The soft-start duration is set connecting an external capacitor (C_{SST}) between the SST pin and AGND. The capacitor is charged with a 5μA (typ.) constant current (I_{SST}), forcing the voltage on the SST pin to ramp up. The SST pin directly limits the rate of voltage rise on the COMP pin, which in turn, limits the peak switch current. When the SST pin voltage increases from zero to nearly 1.2V, the current limit of the internal power MOSFET is proportionally released from zero to its final value. The soft-start capacitor C_{SST} can be calculated as:

$$C_{SST} \approx \frac{I_{SST} \times t_{SST} \times m}{1.2}$$

Where t_{SST} is the desired soft-start duration, *m* is the ratio between programmed peak current limit and normal peak current.

SLOPE COMPENSATION

The constant frequency, peak current mode topology has the advantage of very easy loop compensation and fast transient response, but there is also has an inherit open loop instability when the operating duty cycle is greater than 0.5. This phenomenon known as “Sub-Harmonic Instability” can be avoided by adding an external ramp to the one coming from the sense current. This is called slope compensation and can be realized by connecting a resistor R_{SC} between the SC pin and AGND. The compensation ramp starts at 33% (typ.) of each switching period and its slope is given by the following equation:

$$S_E(A/s) = 1.4 \times 10^{10} \times \frac{1.2}{R_{SC}}$$

To avoid sub-harmonic instability, the compensating slope should be at least half the slope of the inductor current during the off-phase when the duty cycle is greater than 50%. The value of R_{SC} can be calculated according to:

$$R_{SC} \leq \frac{2 \times 1.4 \times 10^{10} \times 1.2 \times L}{V_{OUT} - V_{IN}}$$

LOOP COMPENSATION

The boost section of the PT16972 is a fixed switching frequency, current mode converter. And the device has an internal transconductance error amplifier for LED current regulation. During normal operation, the minimum LEDn pin voltage is selected and provided to the error amplifier. The output voltage of the error amplifier determines the inductor peak current in order to keep its inverting input equal to the reference voltage. The compensation network consists of a simple RC series is added between the COMP pin and AGND. The external inductor, output capacitor, and the compensation resistor (R_C) and capacitor (C_C) determine the loop stability.

PWM DIMMING

The PT16972 supports PWM dimming by adding the digital pulse width modulation signal to the PWM pin. High PWM dimming ratio can be achieved by internal fast response circuit. The minimum PWM on time is 2.0μS, it means when the PWM signal frequency is 200Hz, the maximum dimming ratio is 2500:1.

When the PWM input is low, the switching and the current generators are turned off. The output voltage can be considered almost constant because of the relatively slow discharge of the output capacitor. Also, the error amplifier is turned off and all internal loads on the COMP pin are disabled so that the state of the COMP pin is maintained on the external compensation capacitor. These features reduce transient recovery time. When the PWM input turns high again, the switching peak current returns to the correct value.

PROTECTION MANAGEMENT

SWITCHING CURRENT LIMIT

A DC-DC controller current-limit circuit integrated to improve the reliability of critical components. The peak current which goes through internal switch MOSFET and external inductor, flywheel diode is programmable. A resistor (R_{ILIM}) connected between the ILIM pin and AGND sets the desired value. The voltage at the ILIM pin is internally fixed to 1.2V and the current limit is proportional to the current flowing through the setting resistor. If we neglect the decrease contributed by the slope compensation, the current limit can be calculated according to the following equation:

$$I_{PEAK} = \frac{1.2}{R_{ILIM}} \times 1.2 \times 10^4$$

Actually, the current limitation works by clamping the COMP pin voltage, and it is active cycle by cycle. Once the peak current exceeds the limit threshold, the switch MOSFET is turned off, and will be turned on while the next pulse from internal oscillator comes. Other circuits still operate normally when this condition happens.

LED OPEN

When a string LEDs is not connected or a LED fails open, the current of open channel drops to zero, and the corresponding LED pin voltage is lower than 0.2V. The output voltage will increase as long as the output voltage reaches the floating channel detection threshold (92% of over-voltage threshold). Then the related channel will be turned off, but the device still works normally with the remaining channels.

LED SHORTED

When a LED is shorted, the voltage on the related current generator LEDn is increases. The increased amount is equal to the voltage drop of the faulty LED. When the voltage of the LEDn terminal is higher than 3.0V, the related channel will be turned off, but the device keeps on working normally with the other channels.

OVER VOLTAGE PROTECTION

Over-voltage protection can be achieved by the OVP pin. A resistor divider (R_{OV1}, R_{OV2}) is connected between output and AGND. The sampled voltage is fed into the OVP pin. When the voltage of the OVP pin is higher than internal threshold voltage 1.2V (typ.), the converter will be turned off. The PT16972 will latch this condition until user restarts the device with the /EN pin or power-on reset. Normally, 4V margin is suggested to use for over-voltage protection. The value of R_{OV1} and R_{OV2} can be calculated:

$$\frac{1.2}{R_{OV2}} = \frac{V_{OUT} + 4 - 1.2}{R_{OV1}}$$

THERMAL PROTECTION

In order to avoid damage due to the high junction temperature, the PT16972 integrates the thermal protection function. When the junction temperature of device rises up to 150℃ (typ.), the device will disable most of circuits like DC-DC converter, current generator, control logic and so on. But the VDD regulator still works. The device will automatically recovery when the junction temperature has been reduced 20℃ (typ.).

FAULT INDICATION

The PT16972 has two fault indication pins that are both open-drain output. An external resistor can be connected between the fault pin and a logic power supply. If LED open or shorted fault condition is detected, the /FLT1 pin will be pulled low. If output over-voltage or thermal shutdown fault condition is detected, the /FLT2 pin will be pulled low.

PROTECTION MANAGEMENT SUMMARY

PT16972 Protection Management							
Protection Mode	Detect Point	Protection Mechanism			Output Action		Indication
		Programmable	Trigger Point	Reset	SW	LED1~4	Pin
Internal Power MOSFET Current Limit	Inductor Current	Yes (ILIM pin)	Adjustable	Auto Reset	Shutdown	Working	
LED Open	LED1~4	No	V_{LEDn}<0.2V	Power on Reset	Working	Open row disconnect Other rows working	/FLT1
LED Shorted	LED1~4	No	V_{LEDn}>3.0V	Power on Reset	Working	Shorted row disconnect Other rows working	/FLT1
Output Over-Voltage	LED String Positive Terminal	Yes (OVP pin)	V_{OVP}>1.2V	Power on Reset	Shutdown	Shutdown	/FLT2
Thermal Protection	Internal PN Junction	No	150℃	Auto Reset	Shutdown	Shutdown	/FLT2

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Rating	Unit
VIN, LEDn, /FLT1, /FLT2 to AGND	-	-0.3~+45	V
PGND to AGND	-	-0.3~+0.6	V
SW to PGND		-0.3~+45	V
VDD, SET, ISET, /EN, PWM, RT, COMP, SC, ILIM, SST, OVP, to AGND	-	-0.3~+6.0	V
Internal Switch Maximum Peak Current (Flow through SW node)	I_{SW}	2.0	A
Operating Temperature	T_{OPR}	-40~+105	℃
Storage Temperature	T_{STG}	-50~+150	℃
Continuous Power Dissipation(Ta=25℃)	P_{TOT}	3.0	W

ELECTRICAL CHARACTERISTICS

(Unless otherwise specified, V_{IN}=12V, T_A=25℃)

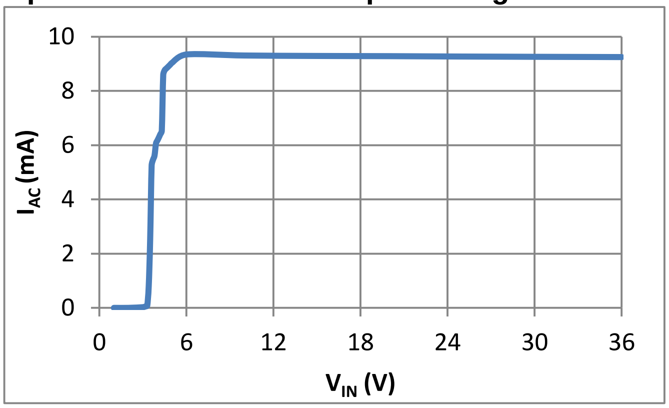
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Input Supply Voltage[1]	V_{IN}		6.0		36	V
Input Standby Current	I_{SD}	$V_{/EN}$=5V		5	15	μA
Input Active Current	I_{AC}	R_{ISET}=1.8KΩ, R_{RT}=220KΩ, R_{SC}=100KΩ, R_{ILIM}=6.8KΩ, PWM=5V		10		mA
VDD Start-up Threshold	V_{ST}	V_{IN} Rising		4.2		V
LDO Output Voltage	V_{VDD}	$V_{/EN}$=0V, I_{VDD}=0mA	4.6	5.0	5.4	V
VDD Line Regulation	$V_{\triangle VDDL}$	6V ≤ V_{IN} ≤ 36V, C_{VDD}=10μF			20	mV
Reference Voltage	V_{ISET}	R_{ISET}=180Ω		1.2		V
Reference Voltage Line Regulation	$V_{\triangle ISETL}$	6V ≤ V_{IN} ≤ 36V, R_{ISET}=1.8KΩ			0.03	%/V
Output Current Range per Channel	I_{CHX}		10		100	mA
Channels Current Matching	OS	I_{LED}≥20mA, -40℃~+105℃		±1	±2	%
		I_{LED}=10mA, -40℃~+105℃		±1.5	±3	%
Feedback Regulation Voltage	V_{MV}			1		V
LED1-4 Leakage Current	I_{LED_LK}	V_{LED}=40V			1	μA
Switch Current Limit	I_{LIM}	R_{ILIM}=6.8KΩ		2.0		A
Internal Switching Blanking Time	T_{BLK}			120		nS
Switching Frequency Range	F_{SW}		200		2100	KHz
Internal MOSFET On-Resistance	R_{ON}			500		mΩ
Switch Leakage Current	I_{SW_LK}	V_{SW}=40V			1	μA
Minimum Dimming On-Time	T_{DIM_ON}	ILED=20mA		2		μS
PWM High Level Threshold	V_{TH_PWMH}	PWM Rising			1.5	V
PWM Low Level Threshold	V_{TH_PWML}	PWM Falling	0.6			V
PWM Pull-Down Resistor	R_{PWMPL}			100		KΩ
/EN Enable/Disable Threshold	V_{TH_EN}	/EN Falling /EN Rising		0.9		V
/EN Pull-Down Resistor	R_{ENPL}			100		KΩ
SET High Level Threshold	V_{TH_SETH}	SET Rising			1.5	V
SET Low Level Threshold	V_{TH_SETL}	SET Falling	0.6			V
SET Pull-Down Resistor	R_{SETPL}			100		KΩ
Soft-Start Current	I_{SST}			5		μA
FLT1, /FLT2On-Resistance	R_{ON_FLT}	/FLT1, /FLT2 Pull Low		250		Ω
LED Open Detection Threshold	V_{TH_OP}			0.2		V
LED Shorted Detection Threshold	V_{TH_ST}			3.0		V
Over-Voltage Protection Threshold	V_{TH_OV}			1.2		V
Thermal Shutdown Turn-off Temperature	T_{SHDN}			150		℃
Thermal Shutdown Hysteresis Temperature	T_{HYS}			20		℃

Note: Although the maximum input voltage can be up to 36V. For Boost and SEPIC topology, the recommended input supply voltage range is 6~24V.

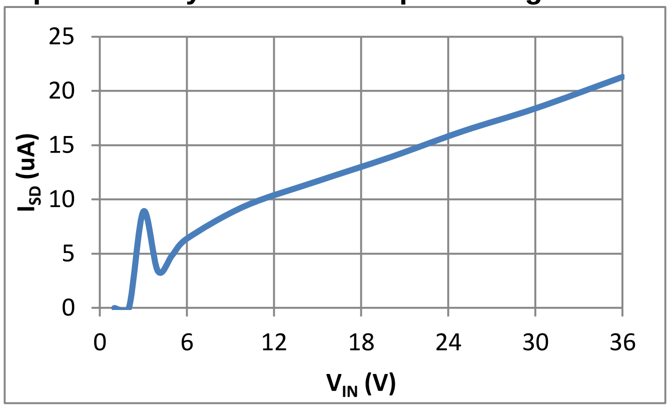
TYPICAL PERFORMANCE CHARACTERISTICS

(V_{IN}=12V, TA=25℃ unless otherwise specified)

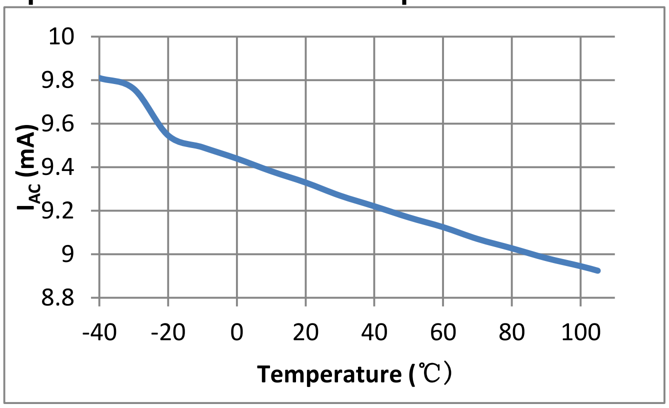
Input Active Current vs. Input Voltage



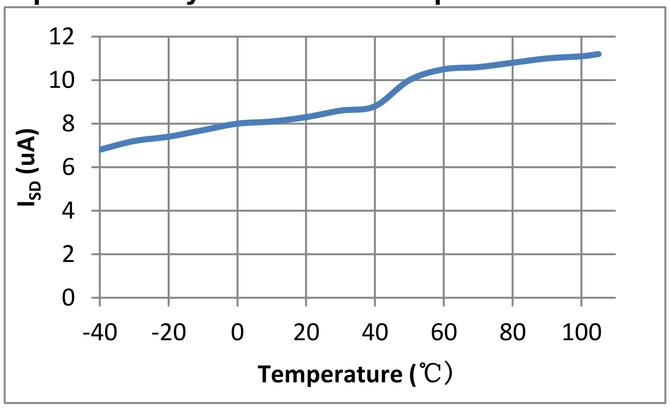
Input Standby Current vs. Input Voltage



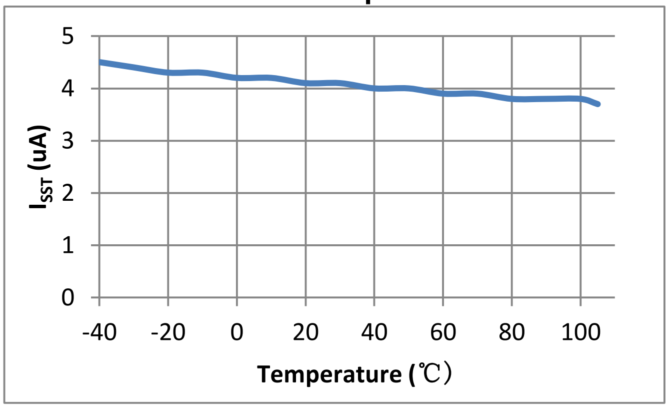
Input Active Current vs. Temperature



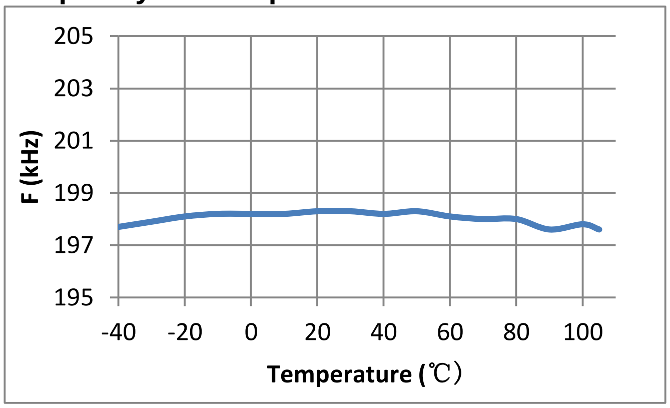
Input Standby Current vs. Temperature



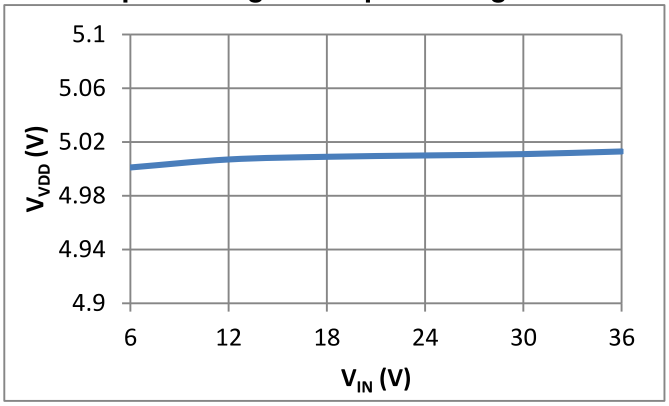
Soft Start Current vs. Temperature



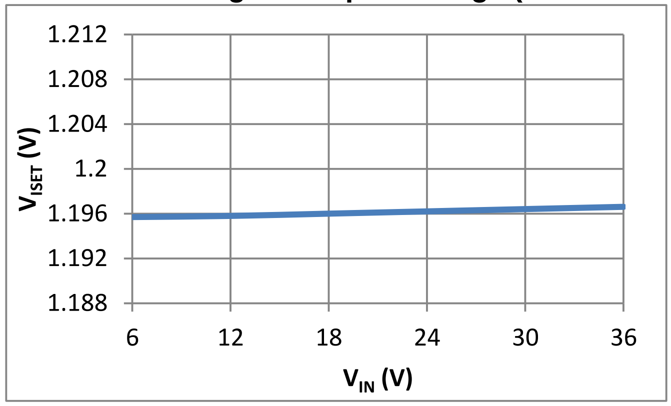
Frequency vs. Temperature



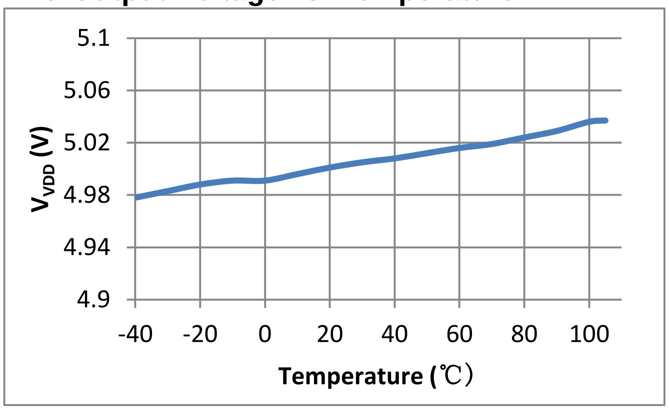
LDO Output Voltage vs. Input Voltage



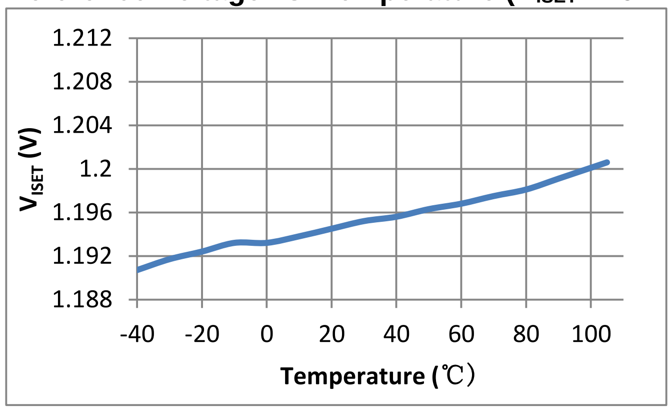
Reference Voltage vs. Input Voltage (R_{ISET}=1.8kΩ)



LDO Output Voltage vs. Temperature

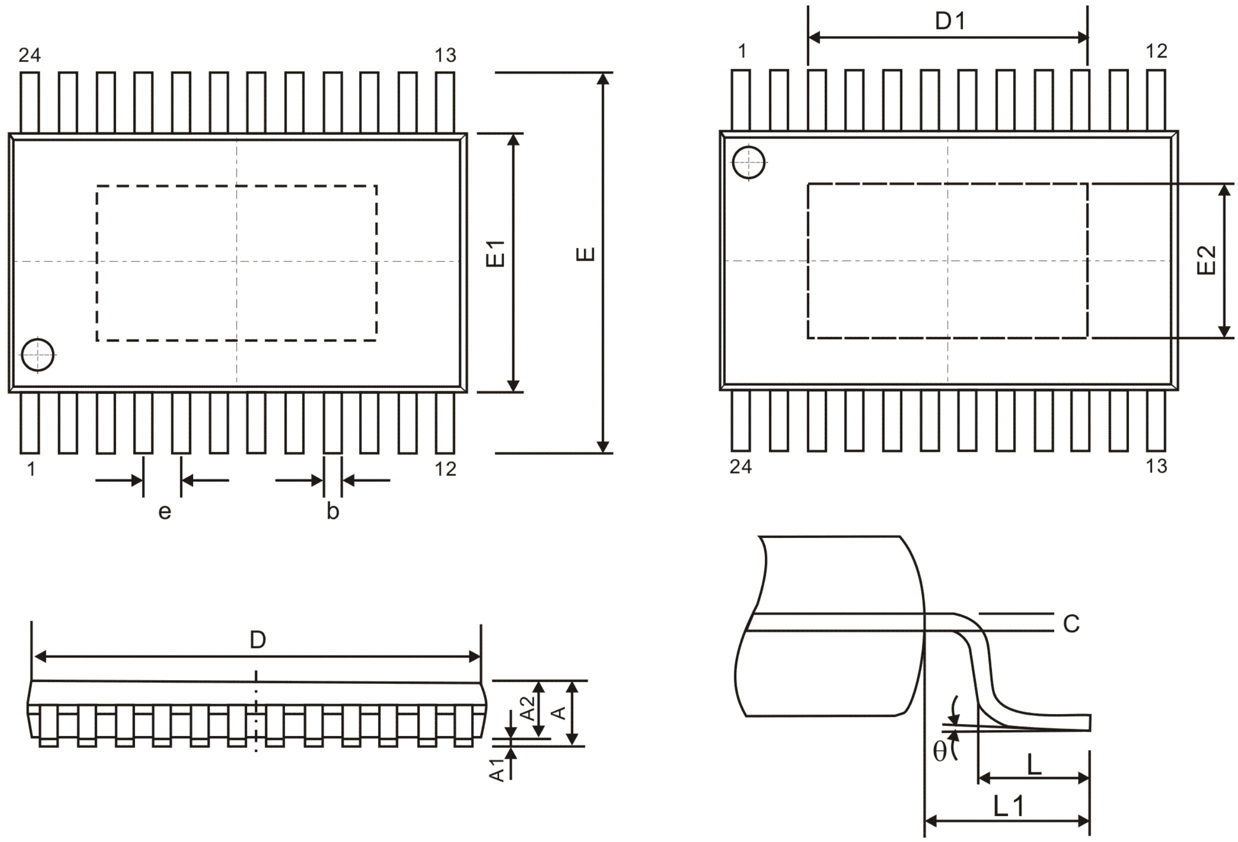


Reference Voltage vs. Temperature (R_{ISET}=1.8kΩ)



PACKAGE INFORMATION

HTSSOP24



Symbol	Min.	Typ.	Max.
A	-	-	1.20
A1	0.05	-	0.15
A2	0.80	1.00	1.05
C	0.09	-	0.20
b	0.19	-	0.30
D	7.70	7.80	7.90
D1	3.70	-	4.75
E	6.30	6.40	6.50
E1	4.30	4.40	4.50
E2	2.28	-	3.00
e	0.65 BSC.		
L	0.45	0.60	0.75
L1	1.0 REF.		
θ	0°		8°

Notes:
1. Refer to JEDEC MO-153
2. Unit: mm

IMPORTANT NOTICE

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