

# High Integrated Dimmable LED Controller with Spread Spectrum Frequency Modulation for Automotive Headlight

## DESCRIPTION

TS19501CB10 is a single channel LED driver of low-side-current sense. This device can operate in DCM, BCM and CCM mode with full protection and diagnostics. This device is dedicated for and ideally suited to automotive headlight. This controller supports typical topologies such as boost, buck-boost and SEPIC.

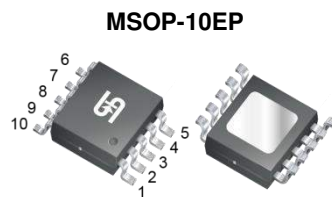
Output current regulation is based on average current mode control supervised by a control loop. The fault flag is connected to pullup resistor from  $V_{DC}$  for highlight the information of fault, fault status flag is latched by the timer when output is low.

## APPLICATION

- Automotive LED Lighting: High and low Beam, Daytime Running Light, Turn indicator, Position Light, Fog Light
- General Lighting Applications
- High Brightness LED Applications

## FEATURES

- Operating Ambient Temperature Range  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$
- Drives LEDs in Boost, Buck-Boost and SEPIC Topology
- Operation in DCM, BCM, CCM mode
- Input Voltage  $4.5\text{V} \sim 38\text{V}$  ( $42\text{V}$  Abs. Max.)
- Adjustable Switching Frequency  $70\text{k} \sim 700\text{kHz}$
- Low-Side Current Sense
- Internal Voltage Reference  $150\text{mV} \pm 3.3\%$
- Both PWM Dimming and Analog Dimming
- Over Voltage Protection (OVP)
- Over Current Protection (OCP)
- Over Temperature Protection (OTP)
- Under Voltage Lockout (UVLO)
- Jitter function for effective spread spectrum to reduce EMI
- Fault Status flag
- Internal Soft Start
- Compliant to RoHS Directive 2011/65/EU and in accordance to WEEE 2002/96/EC.
- Halogen-Free according to IEC 61249-2-21

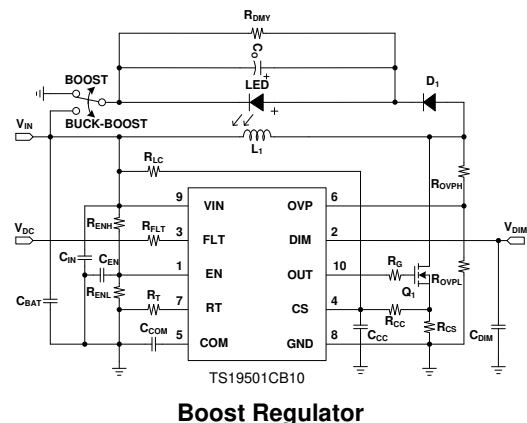
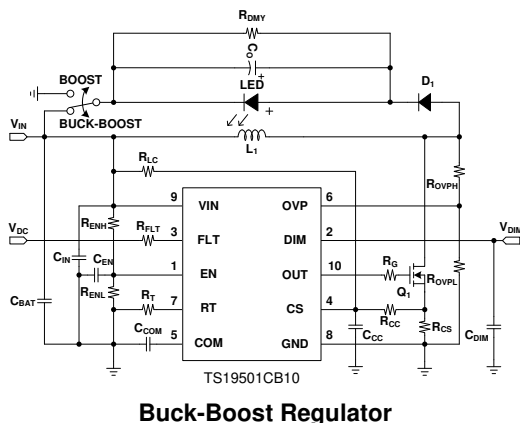


## Pin Definition:

- |        |         |
|--------|---------|
| 1. EN  | 10. OUT |
| 2. DIM | 9. VIN  |
| 3. FLT | 8. GND  |
| 4. CS  | 7. RT   |
| 5. COM | 6. OVP  |

**Notes:** MSL 1 (Moisture Sensitivity Level) per J-STD-020

## TYPICAL APPLICATION CIRCUIT



<b>ABSOLUTE MAXIMUM RATINGS</b> ( $T_A = 25^\circ\text{C}$ unless otherwise specified) <sup>(Note 1)</sup>			
PARAMETER	SYMBOL	LIMIT	UNIT
Battery power input Pin	$V_{IN}$	-0.3 to 42	V
FLT output to GND	$V_{FLT}$	-0.3 to 42	V
OUT voltage to GND	$V_{OUT}$	-0.3 to 20	V
EN voltage to GND	$V_{EN}$	-0.3 to 5.5	V
DIM voltage to GND	$V_{DIM}$	-0.3 to 5.5	V
CS voltage to GND	$V_{CS}$	-0.3 to 5.5	V
COM voltage to GND	$V_{COM}$	-0.3 to 5.5	V
OVP voltage to GND	$V_{OVP}$	-0.3 to 5.5	V
RT voltage to GND	$V_{RT}$	-0.3 to 5.5	V
Junction Temperature Range	$T_J$	-40 to +150	$^\circ\text{C}$
Storage Temperature Range	$T_{STG}$	-65 to +150	$^\circ\text{C}$
Lead Temperature (Soldering 10 sec)	$T_{LEAD}$	260	$^\circ\text{C}$
Power Dissipation @ $T_A=25^\circ\text{C}$	$P_D$	1.1	W
ESD Rating (Human Body Model)	HBM	$\pm 2$	kV
ESD Rating (Charged Device Model)	CDM	$\pm 1$	kV

<b>THERMAL PERFORMANCE</b> <sup>(Note 2)</sup>			
PARAMETER	SYMBOL	TYP	UNIT
Thermal Resistance Junction to Ambient	$R_{\theta JA}$	113	$^\circ\text{C/W}$
Thermal Resistance Junction to Case	$R_{\theta JC}$	38	$^\circ\text{C/W}$

<b>RECOMMENDED OPERATING CONDITION</b> ( $T_A = 25^\circ\text{C}$ unless otherwise specified) <sup>(Note 3)</sup>			
PARAMETER	SYMBOL	LIMIT	UNIT
Battery power input Pin	$V_{IN}$	8 to 38	V
FLT output to GND	$V_{FLT}$	0 to 38	V
OUT voltage to GND	$V_{OUT}$	0 to 18	V
EN voltage to GND	$V_{EN}$	0 to 5	V
DIM voltage to GND	$V_{DIM}$	0 to 5	V
CS voltage to GND	$V_{CS}$	0 to 0.8	V
COM voltage to GND	$V_{COM}$	1.2 to 3.6	V
OVP voltage to GND	$V_{OVP}$	1.6 to 3.1	V
RT voltage to GND	$V_{RT}$	1.2	V
Storage Temperature Range	$T_{STG}$	-55 to +150	$^\circ\text{C}$
Operating Junction Temperature Range	$T_J$	-40 to +150	$^\circ\text{C}$
Operating Ambient Temperature Range	$T_{OPA}$	-40 to +125	$^\circ\text{C}$

<b>ELECTRICAL SPECIFICATIONS</b> ( $V_{IN}=14V$ , $T_A=25^{\circ}C$ unless otherwise specified)						
PARAMETER	SYMBOL	CONDITION	MIN	TYP	MAX	UNIT
<b>Supply Voltage</b>						
$V_{IN}$ Turn-on Threshold	$V_{IN\_ON}$		3.9	4.5	5	V
$V_{IN}$ Hysteresis	$V_{HYS}$		--	0.1	--	V
EN Turn-on Threshold	$V_{EN\_ON}$		1.05	--	1.35	V
EN Hysteresis Current	$I_{HYS\_EN}$		10	20	30	$\mu A$
Quiescent Current	$I_Q$		--	150	240	$\mu A$
Operating Supply Current	$I_{IN}$	$R_{RT}=50k\Omega$	0.3	--	4	mA
<b>GM Amplifier</b>						
Internal Reference Voltage	$V_{REF}$		145	150	155	mV
Transconductance	$G_m$	$I_{COM\_SINK}/0.4$	80	100	120	$\mu A/V$
Sink Current	$I_{COM\_SINK}$	$V_{CS}=400mV$	32	40	48	$\mu A$
Source Current	$I_{COM\_SOUR}$	$V_{CS}=0V$	12	15	18	$\mu A$
<b>Oscillator</b>						
Oscillator Frequency	$F_{OSC}$	$R_{RT}=50k\Omega$	185	200	215	kHz
Jitter Frequency	$F_{JT}$	Design Guarantee	--	$\pm 8.5$	--	%
Soft Start Time	$T_{SS}$		--	1024	--	Clock Cycles
Fault Blank Time	$T_{FB}$		--	2048	--	
Hiccup Time	$T_{HUP}$		--	32768	--	
<b>Driver</b>						
Dropout Voltage	$V_{OH}$	$V_{IN}=12V$ , $C_O=1nF$ , $I_O=10mA$	--	550	--	mV
	$V_{OL}$	$V_{IN}=12V$ , $C_O=1nF$ , $I_O=-10mA$	--	50	--	mV
Output Rising Time	$T_R$	$C_O=1nF$	--	50	--	ns
Output Falling Time	$T_F$	$C_O=1nF$	--	50	--	ns
Output Clamp Voltage	$V_{O\_CLAMP}$	$C_O=1nF$	--	12.5	18	V
<b>Protection</b>						
Output Voltage Protection Short Circuit Protection	$V_{OVP}$		3.0	3.25	3.5	V
	$V_{SCP}$		1.4	--	1.6	V
Current Limit Voltage	$V_{CSL}$		--	800	900	mV
Leading Edge Blanking Time	$LEB_t$	$C_O=1nF$	--	320	--	ns
MOS Current Protection	$V_{MCP}$	$C_O=1nF$	--	1.2	1.35	V
FLT Dropout Voltage	$V_{FLT}$	$I_{FLT}=10mA$	--	200	--	mV
Maximum Duty	$V_{DUTY}$	$C_O=1nF$	--	85	--	%

<b>ELECTRICAL SPECIFICATIONS</b> ( $T_A = 25^\circ\text{C}$ unless otherwise specified)						
<b>PARAMETER</b>	<b>SYMBOL</b>	<b>CONDITION</b>	<b>MIN</b>	<b>TYP</b>	<b>MAX</b>	<b>UNIT</b>
<b>Dimming</b>						
PWM Dimming High Threshold Voltage	$V_{OH\_DIM}$		2.5	--	--	V
Linear Dimming Threshold Voltage of 100% Current Regulation	$V_{MAX\_DIMA}$		--	1.6	--	V
Source Current of DIM	$I_{DIM}$		7.5	10	12.5	$\mu\text{A}$
<b>Thermal Section</b> (Note 4, 5)						
Thermal Shutdown	TSD		--	165	--	$^\circ\text{C}$
Temperature Hysteresis	$T_{HYS}$		--	30	--	$^\circ\text{C}$

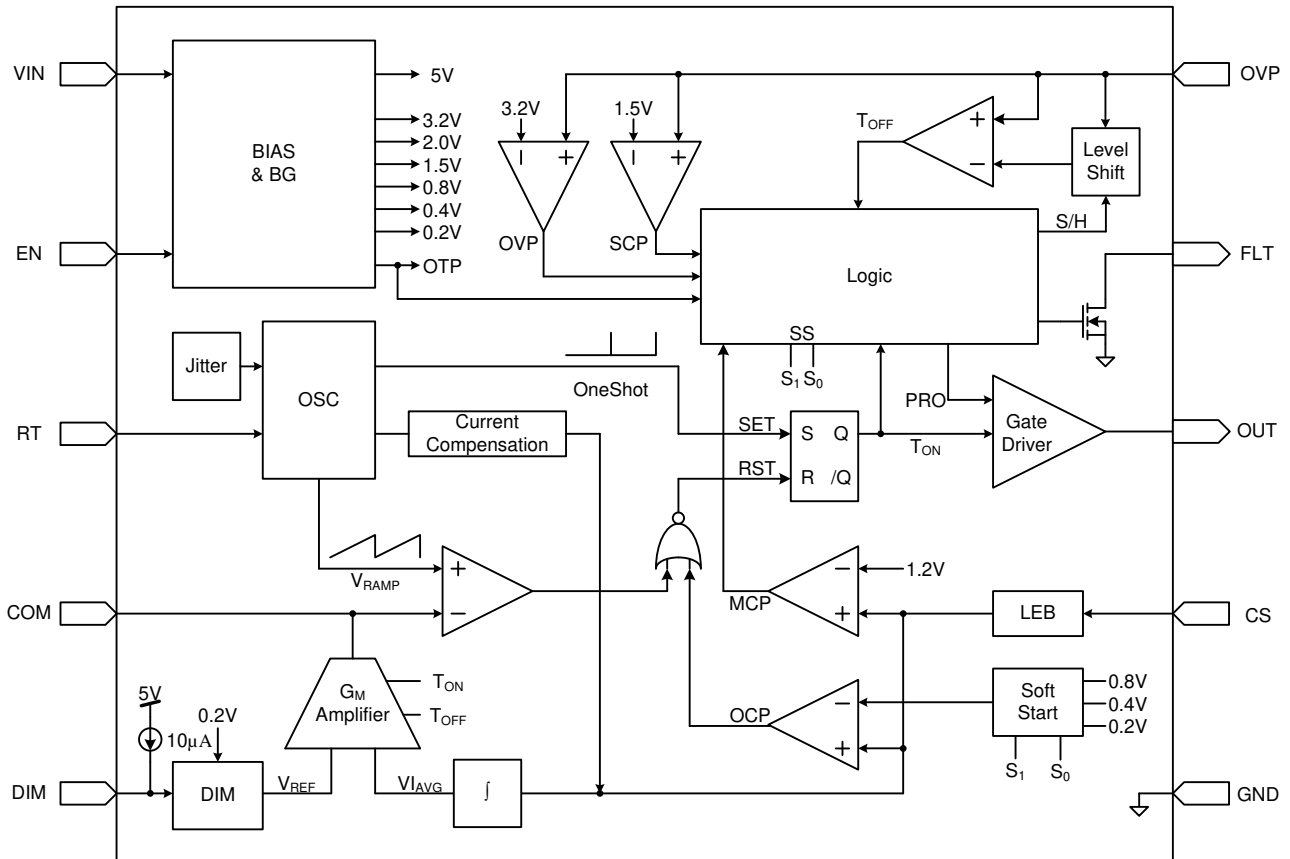
**Note:**

1. Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
2. Test boards conditions:
  - (a) 5.6mm × 4mm, 2 layers, thickness: 1mm.
  - (b) 1-oz copper traces located on the top of the PCB.
  - (c) 1-oz copper ground plane, bottom layer.
  - (d) 5-thermal vias (0.3mm) located under the device package.
3. The device is not guaranteed to function outside its operating conditions.
4. Guaranteed by design.
5. Auto Recovery type.

**ORDERING INFORMATION**

<b>ORDERING CODE</b>	<b>PACKAGE</b>	<b>PACKING</b>
TS19501CB10 RBG	MSOP-10EP	5,000pcs / 13"Reel

**FUNCTION BLOCK**

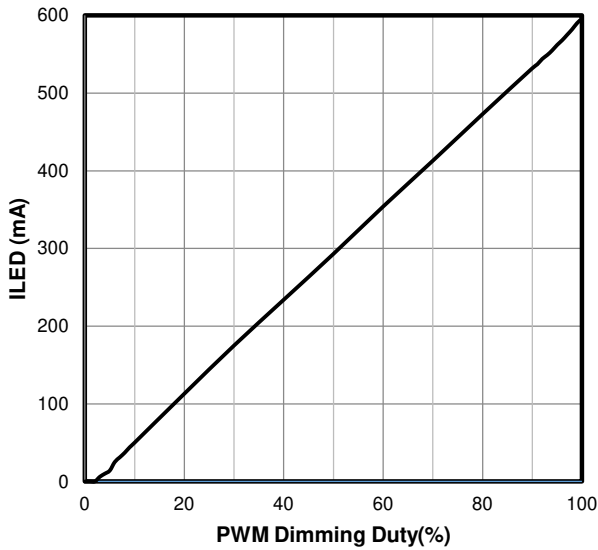


**PIN DESCRIPTION**

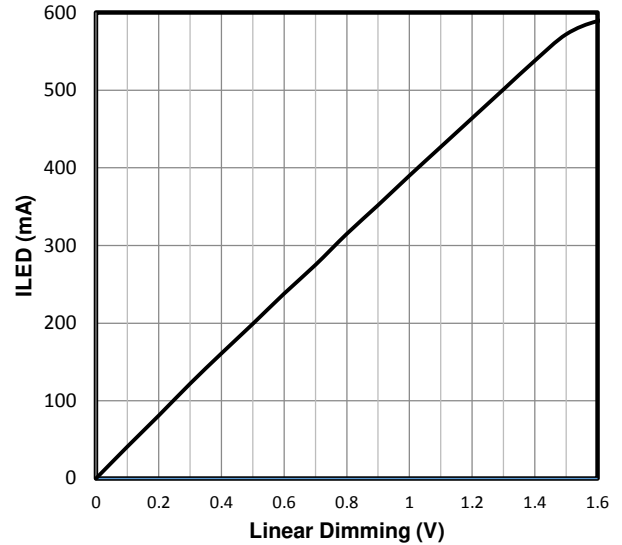
PIN NO.	NAME	FUNCTION
1	EN	Enable and shut down pin
2	DIM	PWM/Linear dimming voltage input
3	FLT	Open drain output pin for fault status flag.
4	CS	Input current sense pin.
5	COM	Compensation output pin of error amplifier.
6	OVP	Over voltage sensing pin
7	RT	Connect external resistor to GND to set frequency.
8	GND	Ground return for all internal circuitry.
9	VIN	Battery power input pin for all internal circuitry.
10	OUT	Power MOS output pin.

**TYPICAL PERFORMANCE CURVES**

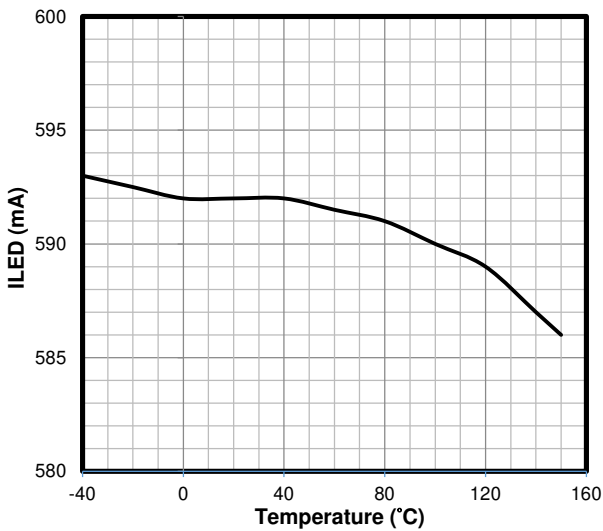
$V_{IN}=12V$ ,  $I_{LED}=600mA$ ,  $V_O=24V$  (8 LEDs) unless otherwise specified.



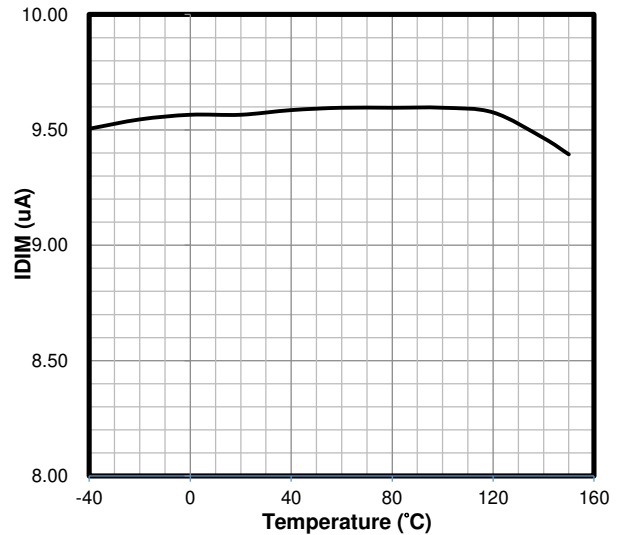
**Figure 1. ILED vs. PWM Dimming Duty**



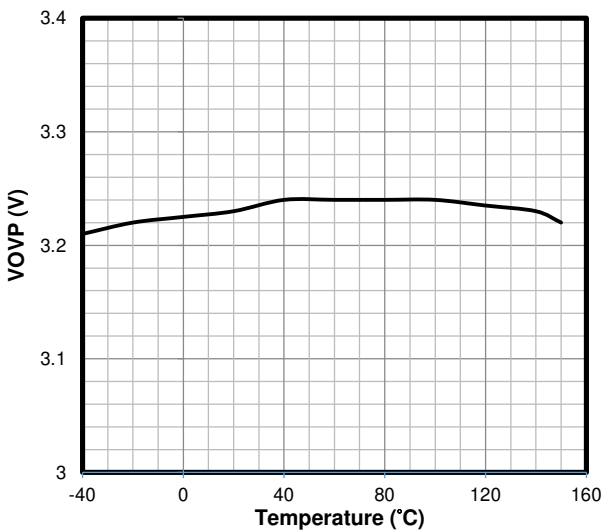
**Figure 2. ILED vs. Linear Dimming**



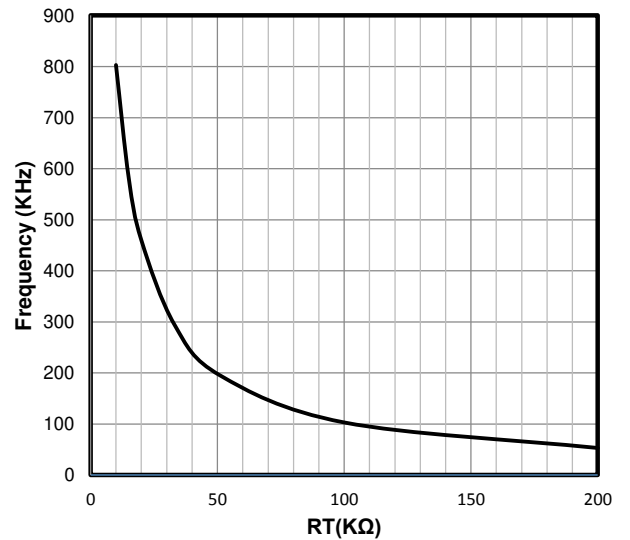
**Figure 3. ILED vs. Temperature**



**Figure 4. IDIM vs. Temperature**

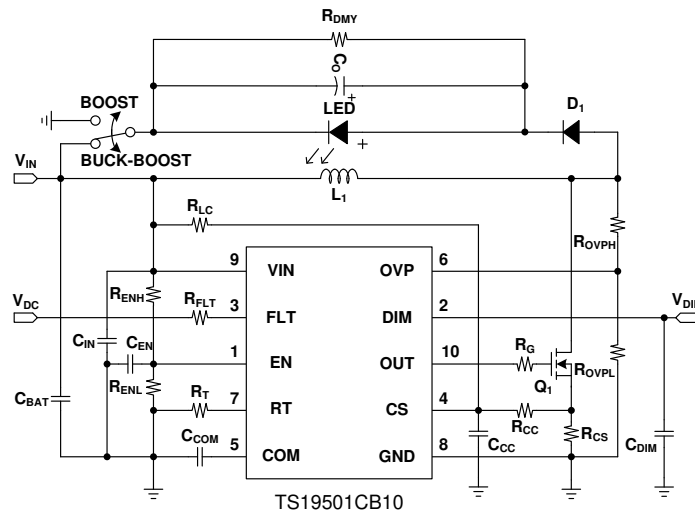


**Figure 5. OVP vs. Temperature**

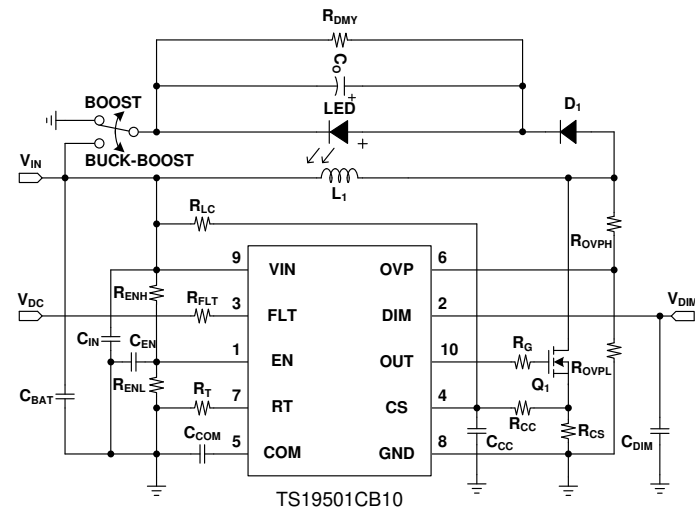


**Figure 6. Frequency vs. RT**

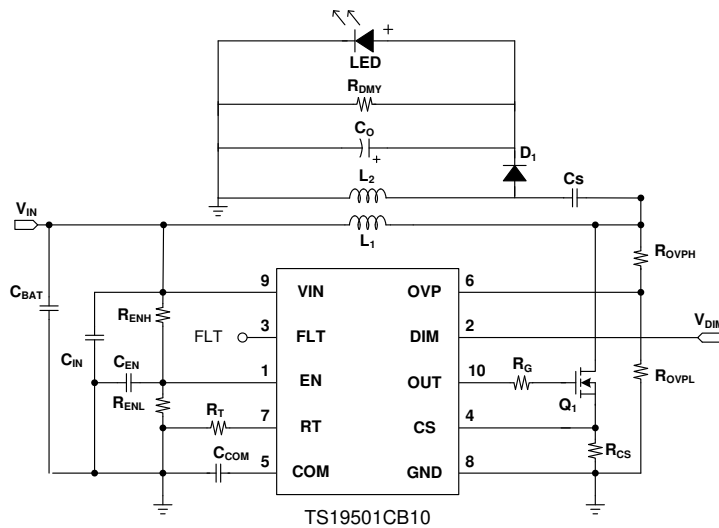
**TYPICAL APPLICATION CIRCUITS**



**Buck-Boost Regulator**



**Boost Regulator**



**SEPIC**

## APPLICATION INFORMATION

The TS19501CB10 uses an external current sense resistor ( $R_{CS}$ ) between the MOSFET source and the GND to convert the input power. The MOSFET ON current signal and  $V_{REF}$  are input to the GM amplifier. The special GM amplifier follow the design formula to combine the  $T_{ON}$  and  $T_{OFF}$  information which are force to be equal potential through system negative feedback.

The average LED current can be expressed as below.

$$I_{LED\_avg} = \frac{V_{REF}}{R_{CS}}$$

Where:

- $I_{LED\_avg}$  is the average LED current
- $V_{REF}$  is the internal reference voltage (150mV)
- $R_{CS}$  is the sensing resistor connected between the MOSFET source and the GND

## Pin Definitions

### EN Pin

The EN pin can sense  $V_{IN}$  information by voltage divider resistor. The hysteresis current ( $I_{EN}$ ) is 20 $\mu$ A when the divider voltage over  $V_{EN\_ON}$ .

### DIM Pin

A PWM and linear dimming function is applied in TS19501CB10. The linear dimming range is an analog voltage from 0V to 1.6V. PWM dimming function is the same pin of linear dimming. The current regulation is decided by duty cycle of external PWM signal. Built-in 10 $\mu$ A source current is for NTC resistance application.

### FLT Pin

Open drain output for fault status flag.

### CS Pin

MOSFET current signal sensing and current limit setting function.

$$I_{CS(LIMIT)} = \frac{0.8}{R_{CS}}$$

Where:

- $I_{CS(LIMIT)}$  is the input current limit
- $R_{CS}$  is the sensing resistor connected between the MOSFET source and GND

### COM Pin

This is the output of the  $G_m$  amplifier. Connect with a suitable RC network to ground.



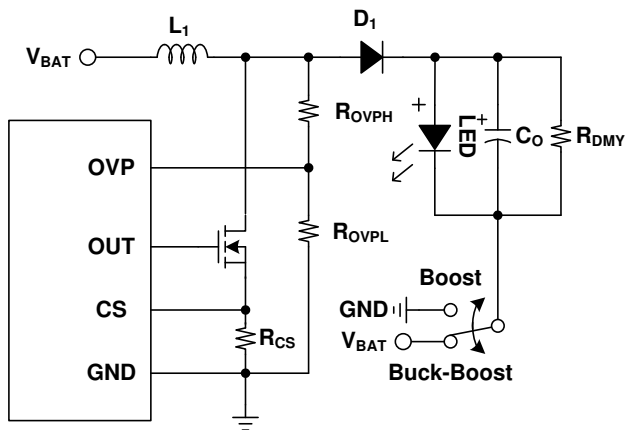
**APPLICATION INFORMATION**

**Pin Definitions (Continue)**

**OVP Pin**

The Output voltage is reflected by inductor voltage. The OVP pin can sense output information to depart from start-up voltage ( $V_{SCP}$ ) and protect voltage ( $V_{OVP}$ ).

When the OVP sense voltage under  $V_{SCP}$  a period of time (8 clock cycles), The short circuit protection (SCP) will work. When the OVP sense voltage over  $V_{OVP}$  a period of time (8 clock cycles), the over voltage protection (OVP) will work. it will attempt to recover after every 32768 clock cycles.



For Boost

$$V_{O\_OVP} = 3.2 \times \frac{R_{OVPH} + R_{OVPL}}{R_{OVPL}}$$

$$V_{O\_SCP} = 1.5 \times \frac{R_{OVPH} + R_{OVPL}}{R_{OVPL}}$$

For Buck-Boost and SEPIC

$$V_{O\_OVP} = \left( 3.2 \times \frac{R_{OVPH} + R_{OVPL}}{R_{OVPL}} \right) - V_{BAT}$$

$$V_{O\_SCP} = \left( 1.5 \times \frac{R_{OVPH} + R_{OVPL}}{R_{OVPL}} \right) - V_{BAT}$$

Where:

- $V_{OVP}$  is the output-over-voltage protection point (3.2V)
- $V_{SCP}$  is the output-short-circuit protection point (1.5V)

**RT Pin**

This pin is to program the operation frequency by connecting a resistor to ground.

Reference formula as below:

$$F_s = \frac{1}{1 \times 10^{-10} \times R_T}$$

**GND Pin**

GND is the reference node of internal circuit.

**VIN Pin**

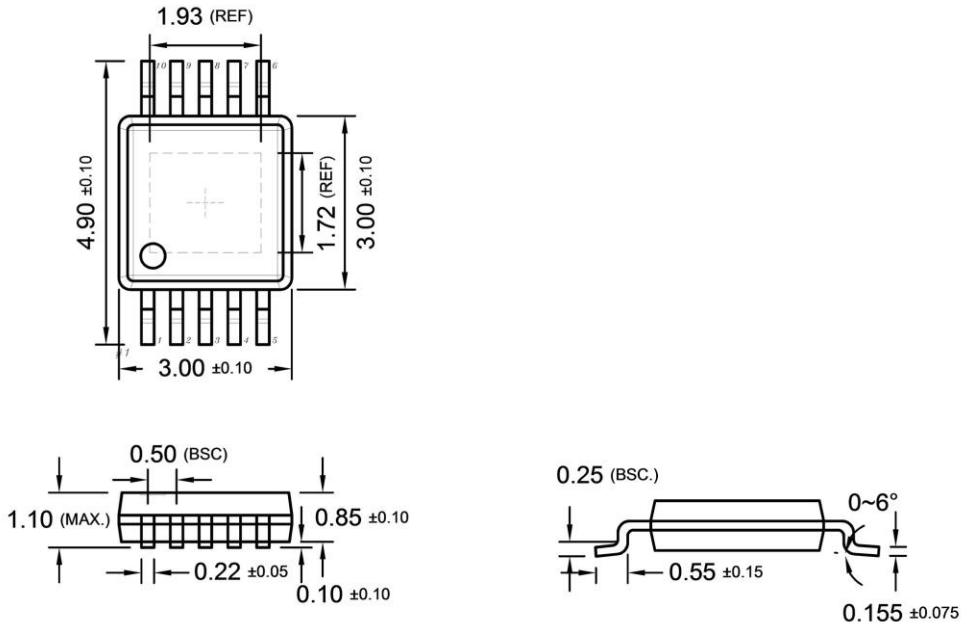
Power supply input for the controller during normal operation. The controller will start up when  $V_{IN}$  reaches 4.2V (typical) and will shut-down when  $V_{IN}$  voltage is below 4.0V (typical) when  $V_{EN}$  over 1.2V. A decoupling capacitor should be connected between the  $V_{IN}$  and GND pin as close as possible.

**OUT Pin**

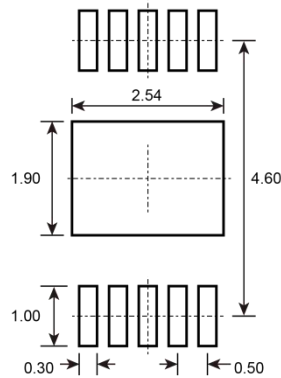
Gate drive for external MOSFET switch and built-in gate clamp function.

**PACKAGE OUTLINE DIMENSIONS** (Unit: Millimeters)

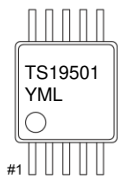
**MSOP-10EP**



**SUGGESTED PAD LAYOUT** (Unit: Millimeters)



**MARKING DIAGRAM**



- Y** = Year Code
- M** = Month Code for Halogen Free Product
  - O** =Jan    **P** =Feb    **Q** =Mar    **R** =Apr
  - S** =May    **T** =Jun    **U** =Jul    **V** =Aug
  - W** =Sep    **X** =Oct    **Y** =Nov    **Z** =Dec
- L** = Lot Code (1~9, A~Z)

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