

## 2A, Step-Down LED Driver with Integrated N-channel FET High-Side Current Sense, PWM and Analog Dimming Capability

### DESCRIPTION

The TS19503 is a continuous conduction mode inductive step-down converter, designed for driving single or multiple LEDs. It operates from an input supply between 4.5V and 75V. It provides a high accuracy output current externally adjustable up to 2A. Depending upon the supply voltage and external components, the TS19503 can provide more than 25 watts of output power.

The TS19503 includes the power switch and a high-side output current sensing circuit, which uses an external resistor to set the nominal average output. A dedicated DIM input accepts a wide range of inputs. Applying a voltage of 0.1V or lower to the DIM pin turns the output off and switches the device into a low current standby state. The device also provides a FLT flag when an open load or over temperature condition is detected.

### APPLICATION

- Automotive exterior lighting applications
- LED general lighting applications

### FEATURES

- AEC-Q100 qualified with the following results:
  - Device temperature grade 1: -40°C to 125°C
  - Device HBM ESD classification level H1C
  - Device CDM ESD classification level C6
- Input voltage range 4.5V to 75V
- Hysteretic Control: No Compensation
- Internal N\_MOSFET with 200mΩ Low R<sub>DS(ON)</sub>
- 2A Output Current
- Up to 97% Efficiency
- Typical ±2% LED Current Accuracy
- DIM Pin for Analog Dimming and PWM Dimming
- 1000:1 Dimming
- Single pin on/off and brightness control using PWM
- Up to 1MHz switching frequency
- High-Side Current Sense
- FLT Pin for MCU
- Over Temperature Protection
- Open Load Flag
- RoHS Compliant
- Halogen-Free according to IEC 61249-2-21

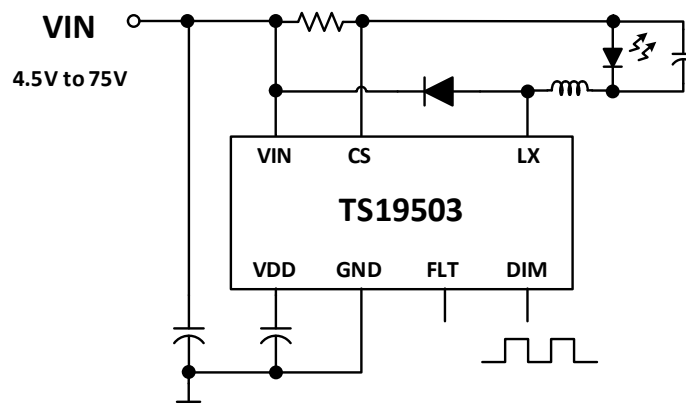


### Pin Definition:

- |                    |         |
|--------------------|---------|
| 1. V <sub>IN</sub> | 6. PGND |
| 2. CS              | 7. PGND |
| 3. V <sub>DD</sub> | 8. FLT  |
| 4. DIM             | 9. LX   |
| 5. AGND            | 10. LX  |

**Notes:** Moisture sensitivity level: level 3. Per J-STD-020

### TYPICAL APPLICATION CIRCUIT



<b>ABSOLUTE MAXIMUM RATINGS</b> ( $T_A=25^\circ\text{C}$ unless otherwise specified) (Note 1)			
<b>PARAMETER</b>	<b>SYMBOL</b>	<b>LIMIT</b>	<b>UNIT</b>
Power Supply Pin	$V_{IN}$	75	V
CS Voltage to GND	$V_{CS}$	-0.3 to $V_{IN}-0.1$	V
FLT Voltage to GND	$V_{FLT}$	-0.3 to 5.5	V
DIM Voltage to GND	$V_{DIM}$	-0.3 to 5.5	V
$V_{DD}$ Voltage to GND	$V_{DD}$	-0.3 to 5.5	V
LX Voltage to GND	LX	75	V
Lead Temperature (Soldering 10 sec)	$T_{LEAD}$	260	$^\circ\text{C}$
Junction Temperature Range	$T_J$	-40 to +150	$^\circ\text{C}$
Storage Temperature Range	$T_{STG}$	-65 to +150	$^\circ\text{C}$
ESD Rating (Human Body Model) (Note 2)	HBM	$\pm 1.5$	kV
ESD Rating (Charged Device Model)	CDM	$\pm 1$	kV

<b>THERMAL PERFORMANCE</b>			
<b>PARAMETER</b>	<b>SYMBOL</b>	<b>TYP</b>	<b>UNIT</b>
Junction to Case Thermal Resistance	$R_{\theta JC}$	31	$^\circ\text{C}/\text{W}$
Junction to Ambient Thermal Resistance	$R_{\theta JA}$	102	$^\circ\text{C}/\text{W}$

**Notes:**  $R_{\theta JA}$  is the sum of the junction-to-case and case-to-ambient thermal resistances. The case thermal reference is defined at the solder mounting surface of the LX pins.  $R_{\theta JC}$  is guaranteed by design while  $R_{\theta CA}$  is determined by the user's board design.  $R_{\theta JA}$  shown below for single device operation on FR-4 PCB in still air. Thermal Resistance is specified with the component mounted on a low effective thermal conductivity test board in free air at  $T_A=25^\circ\text{C}$ .

<b>RECOMMENDED OPERATING CONDITIONS</b> (Note 3)			
<b>PARAMETER</b>	<b>SYMBOL</b>	<b>LIMIT</b>	<b>UNIT</b>
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> ( $V_{IN}=14\text{V}$ , $T_A=25^\circ\text{C}$ unless otherwise noted)						
<b>PARAMETER</b>	<b>CONDITIONS</b>	<b>SYMBOL</b>	<b>MIN</b>	<b>TYP</b>	<b>MAX</b>	<b>UNIT</b>
<b>Supply Voltage</b>						
Supply Voltage	$V_{IN}$ supply range	$V_{IN}$	5	--	70	V
Internal regulator start-up threshold	IC turn on voltage	$V_{SU}$	4.4	4.55	4.7	V
Internal regulator shutdown threshold	IC turn off voltage	$V_{SD}$	3.8	4	4.2	V
Regulator Output Voltage	$V_{DD}$ Voltage	$V_{DD}$	4.7	5	5.3	V
Quiescent supply current	Output switching off	$I_Q$	0.4	0.65	1	mA
Operation current	SW=200kHz	$I_{SW}$	0.5	1	1.5	mA
<b>Mean current sense threshold voltage (Defines LED current setting accuracy)</b>						
Internal Voltage reference	$V_{IN}-V_{CS}$	$V_{SENSE}$	96	100	104	mV

<b>ELECTRICAL SPECIFICATIONS</b> ( $V_{IN}=4V$ , $T_A=25^{\circ}C$ unless otherwise noted)						
PARAMETER	CONDITIONS	SYMBOL	MIN	TYP	MAX	UNIT
<b>Dimming Function</b>						
DIM input voltage high		$V_{DIM\_H}$	1.6	--	--	V
DIM input voltage low		$V_{DIM\_L}$	--	0.1	--	V
DIM input from low to high			--	0.15	--	V
Duty cycle range of PWM dimming	$F_{PWM}=200Hz$	$D_{PWM}$	0.1	--	100	%
Brightness control range			--	1000:1	--	
<b>Switching Frequency</b>						
Minimum On time		$T_{LEB}$	--	0.8	--	$\mu s$
Maximum Duty Cycle		D	--	95	--	%
<b>Output Switch</b>						
Low Side Switch On Resistance	Internal MOS turn on	$R_{DS(on)}$	--	200	--	m $\Omega$
<b>FLT Function</b>						
FLT pull low Resistor		$R_{FLT}$	--	400	--	$\Omega$
Protection to FLT pull high time		$T_{FLT}$	--	50	--	ms
<b>Thermal Section</b>						
Thermal Shutdown (Note 4)			--	170	--	$^{\circ}C$
Thermal Shutdown Release (Note 5)			--	140	--	$^{\circ}C$

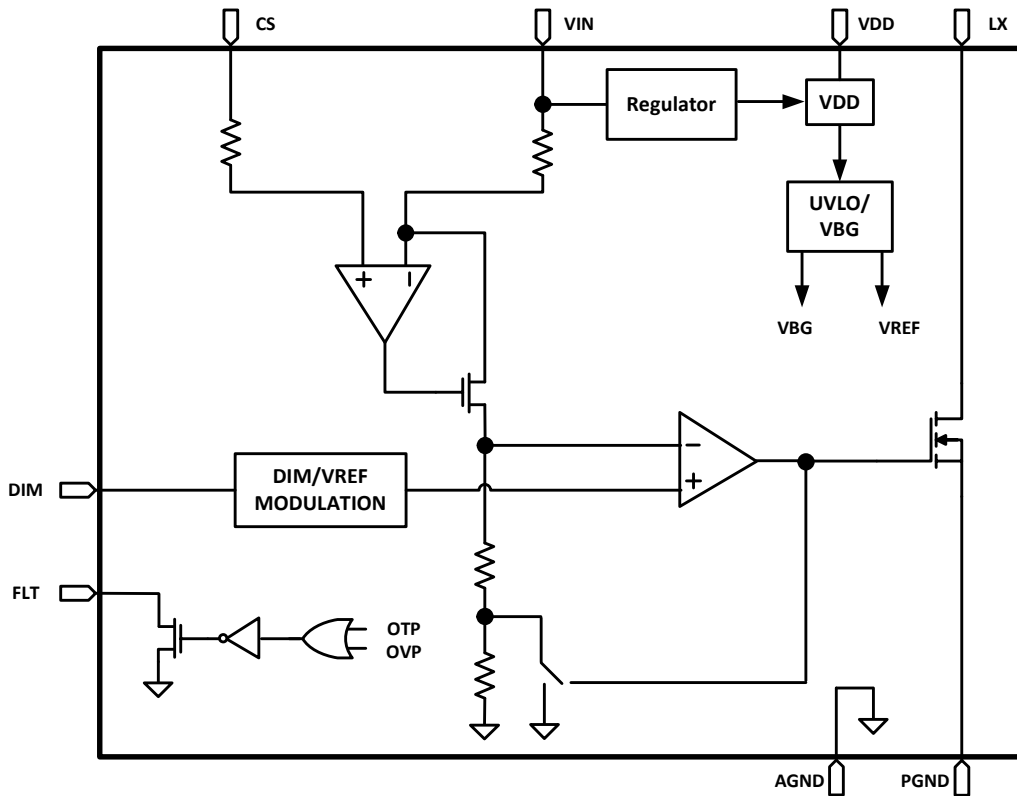
**Note:**

- Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. 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 remain possibility to affect device reliability.
- Devices are ESD sensitive. Handling precaution recommended.
- The device is not guaranteed to function outside its operating conditions.
- Guaranteed by design.
- Auto Recovery Type.

**ORDERING INFORMATION**

ORDERING CODE	PACKAGE	PACKING
TS19503CB10H RBG	MSOP-10EP	5,000pcs / 13"Reel

**BLOCK DIAGRAM**



**PIN DESCRIPTION**

PIN NO.	NAME	FUNCTION
1	V <sub>IN</sub>	Power supply pin for system
2	CS	Input current sense pin
3	V <sub>DD</sub>	Power supply for internal circuit
4	DIM	PWM/Linear DIMMING voltage input
5	AGND	Ground return for all internal circuit
6,7	PGND	Power Ground
8	FLT	Fault Flag
9,10	LX	Internal N-channel MOSFET Drain
-	EP	Exposed Pad. Connect EP to a large-area ground plane for effective power dissipation.

**TYPICAL OPERATING CHARACTERISTICS**

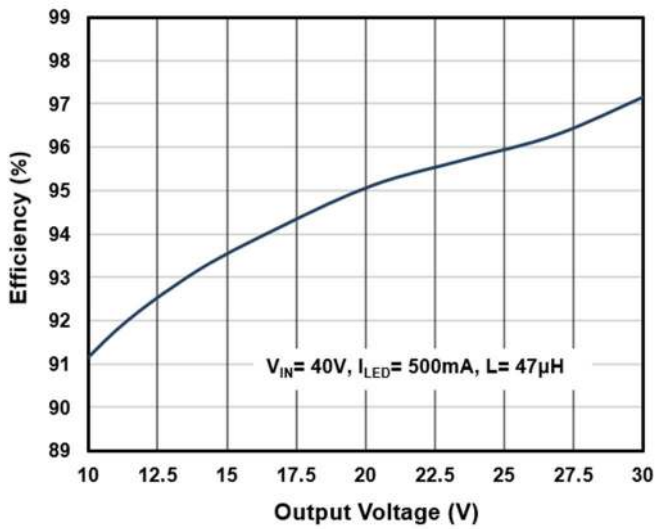


Figure 1. Efficiency vs. Output Voltage

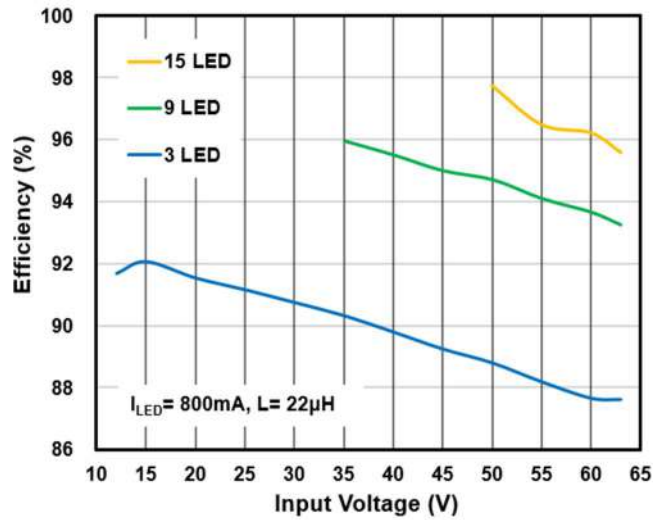


Figure 2. Efficiency vs. Input Voltage

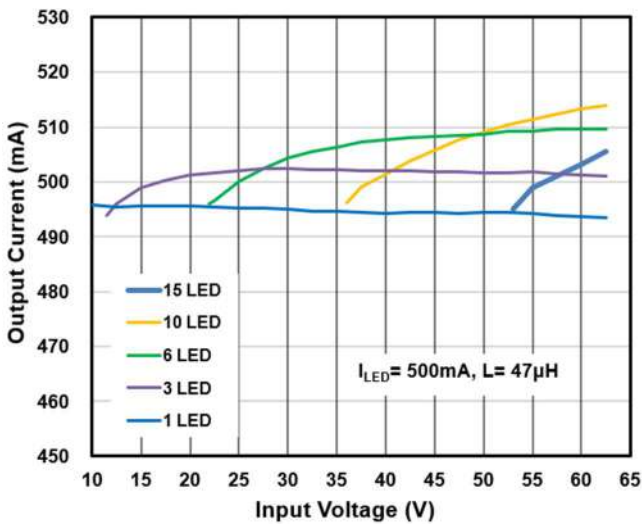


Figure 3. Output Current vs. Input Voltage

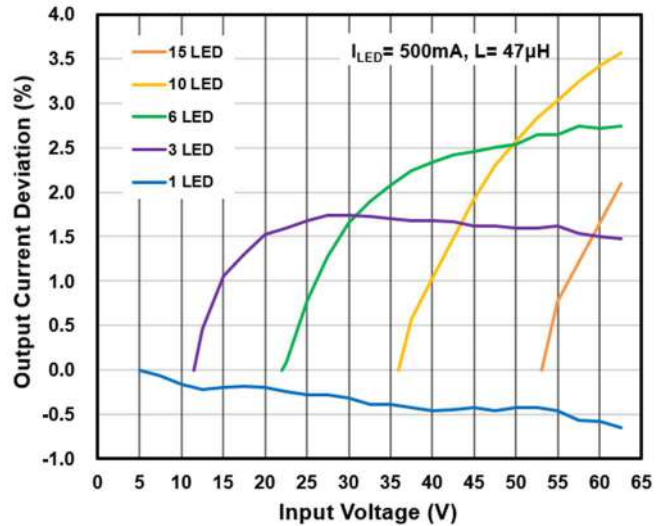


Figure 4.  $I_{OUT}$  Deviation vs. Input Voltage

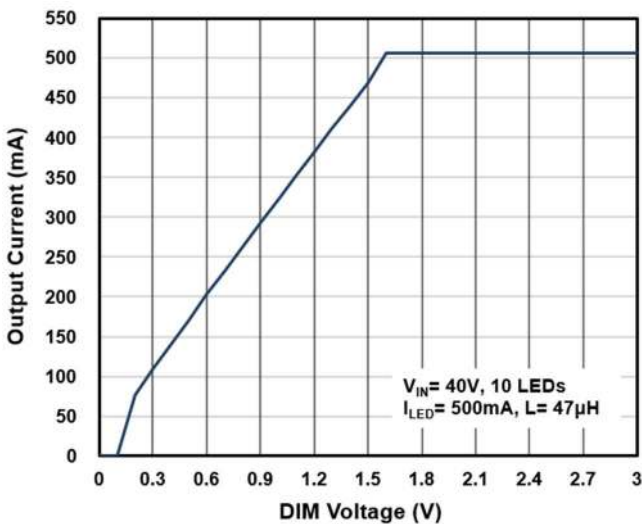


Figure 5. Output Current vs. DIM Voltage

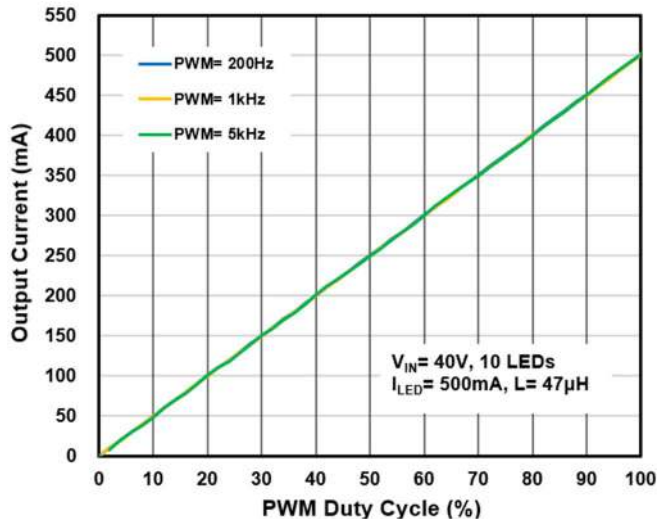


Figure 6. Output Current vs. PWM Duty Cycle

**TYPICAL OPERATING CHARACTERISTICS (CONTINUE)**

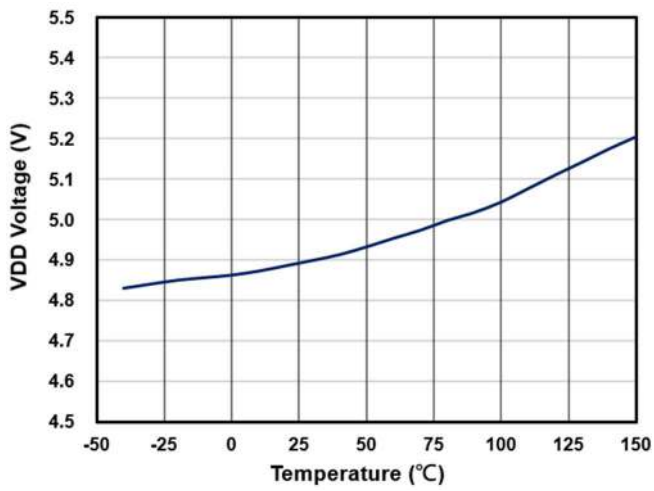


Figure 7. VDD Voltage vs. Temperature

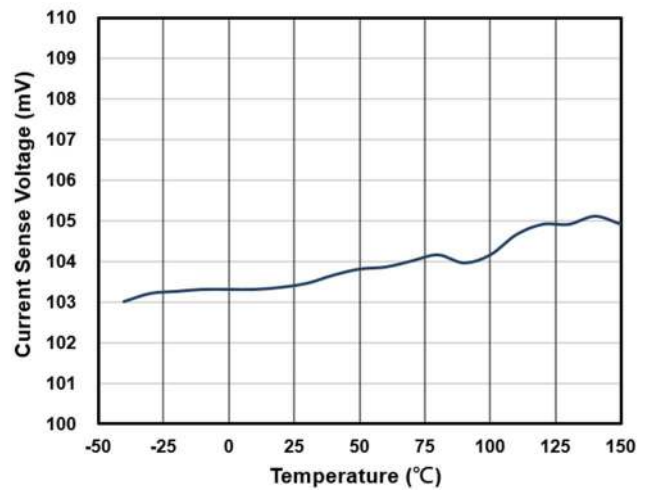


Figure 8. Current Sense Voltage vs. Temperature

## APPLICATION INFORMATION

TS19503 is a high efficiency, hysteretic control LED driver with integrated power MOSFET. The device operates with a wide input voltage from 5V to 75V and up to 2A of output current. It also provides a high accuracy output current for  $\pm 2\%$  in all the load and line regulation.

### Setting nominal average output current with external resistor $R_{CS}$

The nominal average output current in the LED is determined by the value of the external current sense resistor ( $R_{CS}$ ) connected between  $V_{IN}$  and  $V_{CS}$  and is given by:

$$I_{LED} = \frac{0.1V}{R_{CS}}$$

This equation is valid when DIM pin is floating. Actually,  $R_{CS}$  sets the maximum average current which can be adjusted to a lower one by dimming.

### Under Voltage Lockout (UVLO)

The TS19503 includes a UVLO feature with 550mV hysteresis. The internal MOSFET turns off when  $V_{DD}$  falls below 4.0V (typ.).

### PWM / Linear Dimming (DIM)

A Pulse Width Modulated (PWM) signal with duty cycle PWM can be applied to the DIM pin, to adjust the output current to a value below the nominal average value set by resistor  $R_{CS}$ :

$$I_{LED} = \frac{0.1V \times D}{R_{CS}}$$

PWM dimming provides reduced brightness by modulating the LED current between 0% and 100%. The LED brightness is controlled by adjusting the relative ratios of the on time to the off time. To ensure this switching process between on and off state is invisible by human eyes, the switching frequency must be greater than 100Hz. Above 100Hz, 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 always constant; therefore the LED color does not vary with brightness as it does with linear dimming.

A linear signal with analog voltage can be applied to DIM pin too. To adjust the output current to a value below the nominal average value set by resistor  $R_{CS}$ :

$$I_{LED} = \frac{0.1V}{R_{CS}} \times \frac{VDIM}{1.6V}$$

For Example:

$$I_{LED} = \frac{0.1V}{0.1\Omega} \times \frac{0.4V}{1.6V} = 250mA \quad (VDIM = 0.4V, R_{CS} = 0.1\Omega)$$

**APPLICATION INFORMATION (CONTINUE)**

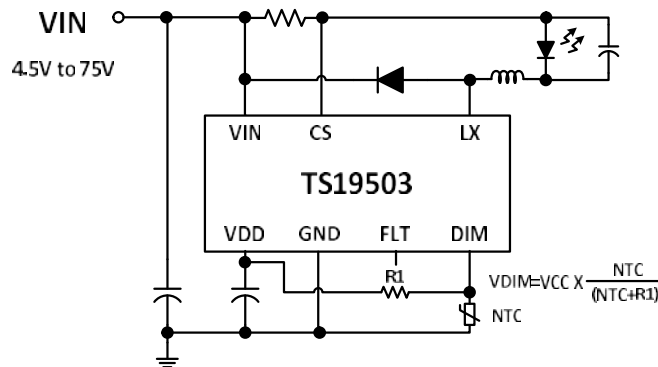
Linear dimming range of LED output current between 6.25% and 100% when DIM voltage from 0.1V to 1.6V. LED current will cutoff when  $V_{DIM} < 0.1V$  and restart if  $V_{DIM} > 0.15V$  which 0.05V hysteresis voltage.

**NTC application**

The TS19503 provides two applications circuits for NTC (thermistor) as below. NTC thermistors are elements whose resistance falls with an increase in temperature and find use in applications such as temperature sensing.

The first application puts an NTC from DIM pin to GND. The device provides a constant current for DIM pin. When the temperature of the LED module or driver increased, the  $V_{DIM}$  will decrease inverse ratio with NTC.

The second application connects a Resistor from  $V_{DD}$  to DIM, and an NTC from DIM to GND.  $V_{DIM}$  is divided across two resistor and NTC. The two applications provide a thermal protection by decreasing the output current by varying  $V_{DIM}$



**Open Load Flag**

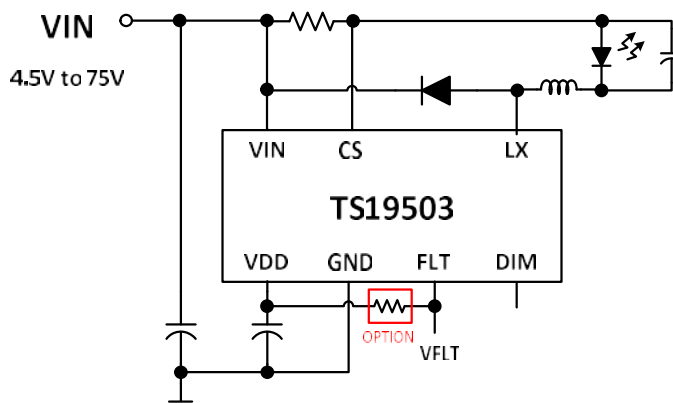
The TS19503 is constant current output with hysteresis function. When  $V_{IN} - V_{CS}$  lower than 1V, the open-load happen, and the fault flag becomes high.

**Over Temperature Protection (OTP)**

Internal 170°C comparator will trigger temperature protection (OTP). OTP will shut down system, until internal temperature back to 140°C.

**Fault flag (FLT) application**

The device provides a FLT pin to notify the user when over temperature protection or open load has happened. Connect to pullup resistor from  $V_{DD}$  or float and N-channel MOSFET open-drain output is high when a fault condition is triggered.





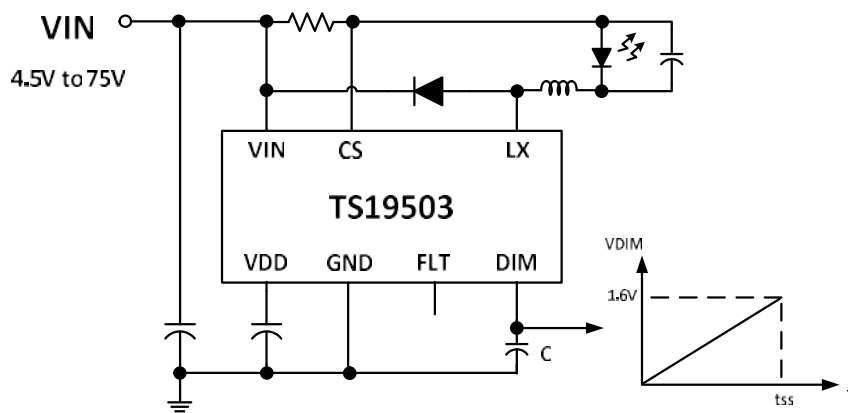
**APPLICATION INFORMATION (CONTINUE)**

**Soft start function**

The TS19503 features an optional soft-start behavior that allows for gradual brightness transition. This is achieved by simply connecting an external capacitor between the DIM pin and GND. An internal current source will then charge this capacitor for soft-start behavior. The soft-start time is calculator as below:

$$t_{ss} = \frac{Cap \times 1.6V}{2\mu A} \quad (2\mu A = IDIM, 1.6V = full\ load\ current)$$

$$If\ set\ t_{ss} = 800ms, \ then\ cap = \frac{2\mu A \times 800mS}{1.6V} = 1\mu F$$

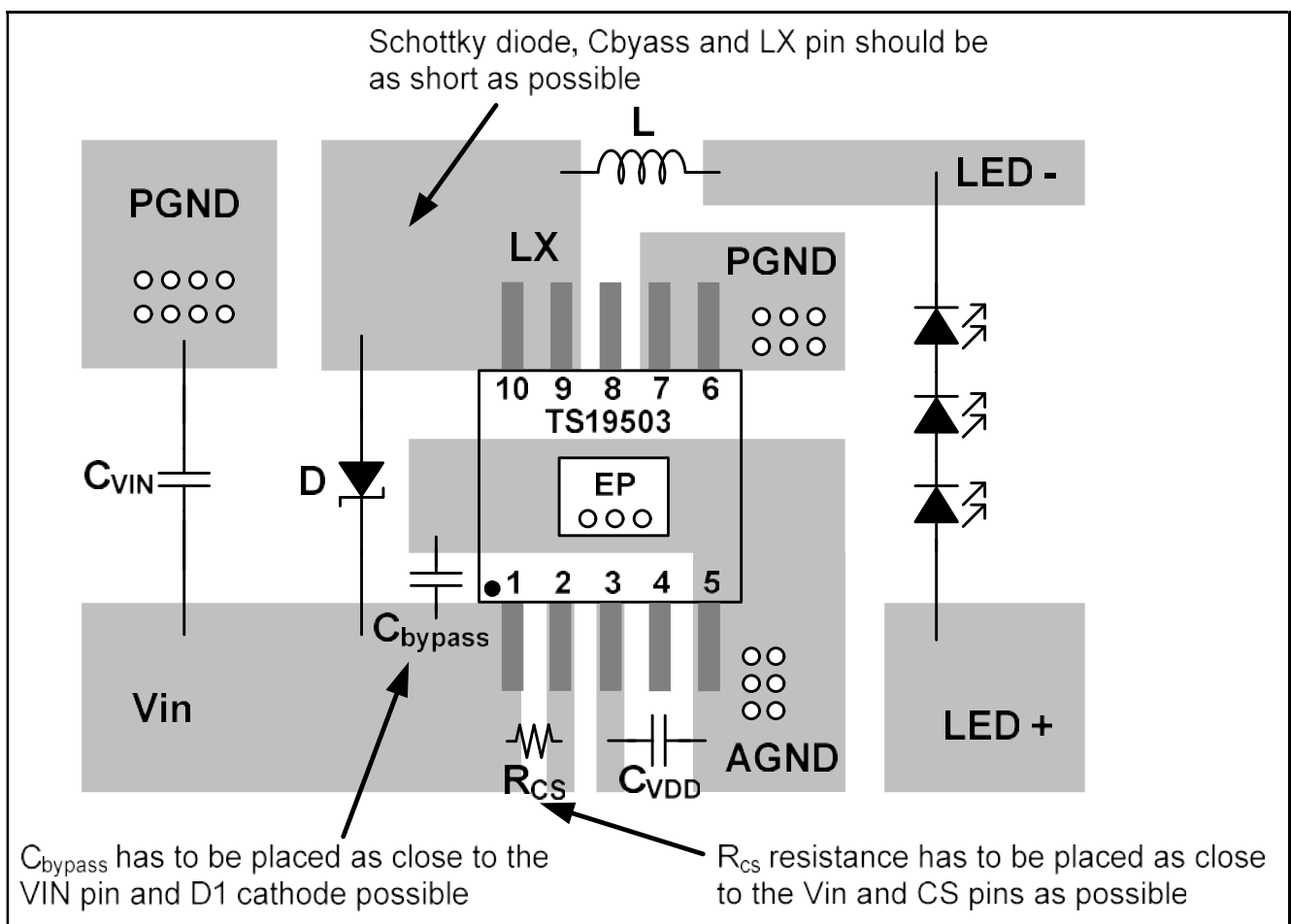


**APPLICATION INFORMATION (CONTINUE)**

**LAYOUT GUIDELINES**

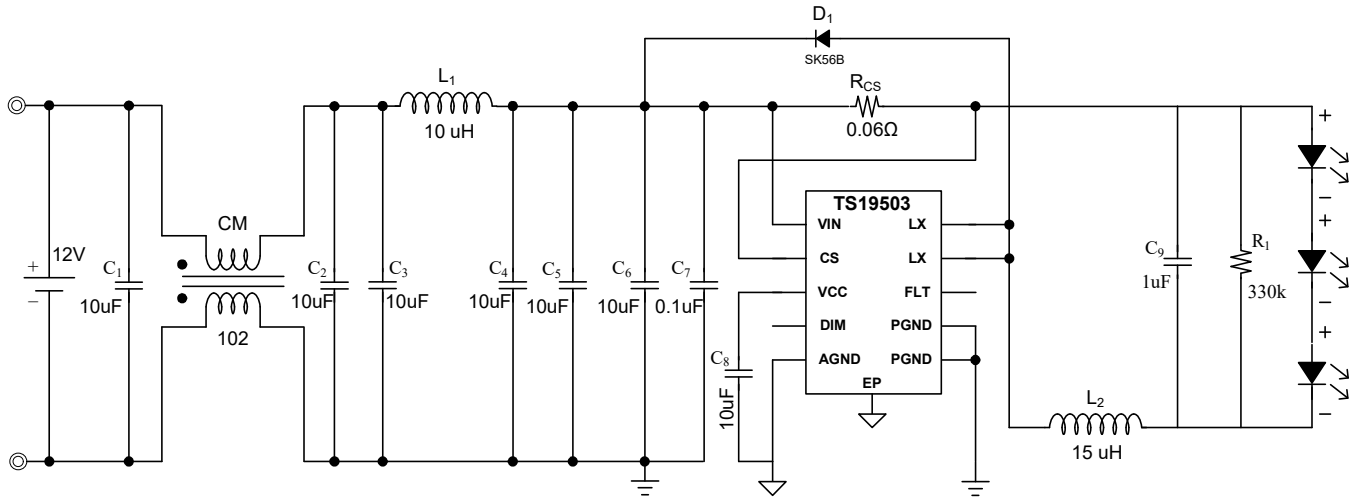
- The current sense  $R_{SENSE}$  must be placed as close to the  $V_{IN}$  and CS pins as possible.
- The decoupling capacitor  $C_{bypass}$  must be placed as close to the  $V_{IN}$  pin and D1 Cathode as possible.
- The input loop includes input capacitor, and Schottky diode. The LX pin should be as short as possible.
- Keep the main current traces as short and wide as possible.
- The DIM pin trace needs to be kept far away from LX terminal.
- The AGND should be connected to a strong ground plane.
- The IC thermal pad should be connected to a large ground copper area, preferably connected to the inner AGND from the thermal vias underneath the IC for optimal cooling.
- AGND and PGND must be separated, It is important that the AGND and PGND of an IC be connected at a single point.

**RECOMMENDED PCB LAYOUT**

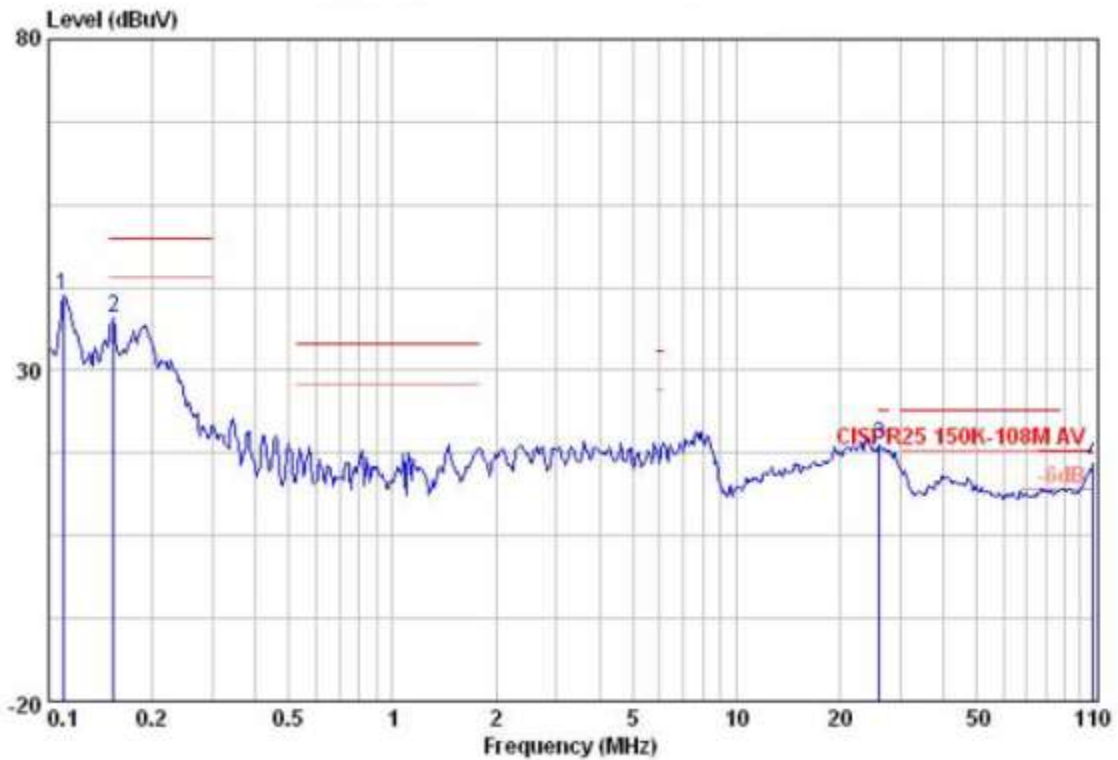


**APPLICATION INFORMATION (CONTINUE)**

**EMI TEST BOARD SCHEMATIC**



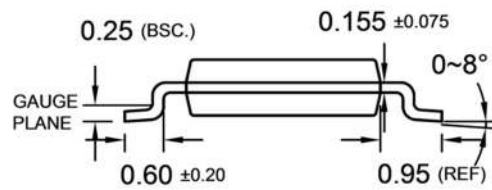
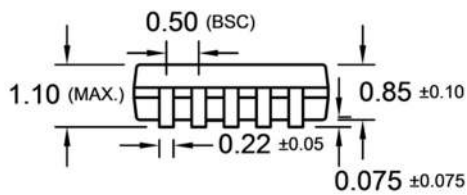
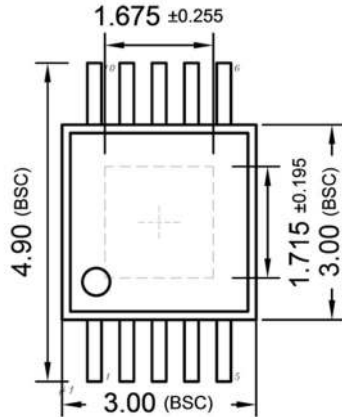
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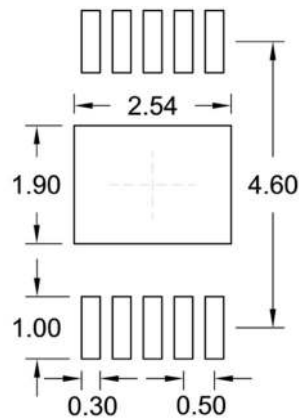
**Conducted Emission**

**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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