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

DESCRIPTION
TS19501CB10H 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 and suited for 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 pull-up resistor from V_DC for highlighting the information of fault and 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
- AEC-Q100 qualified with the following results:
  - Device temperature grade 1: -40°C to 125°C
  - Device HBM ESD classification level H2
  - Device CDM ESD classification level C6
- Drives LEDs in Boost, Buck-Boost and SEPIC Topology
- Operation in DCM, BCM, CCM mode
- Input Voltage 4.5V ~ 42V
- Adjustable Switching Frequency 70k ~ 700kHz
- Low-Side Current Sense
- Internal Voltage Reference 150mV ±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 and Internal Soft Start
- to RoHS Compliant
- 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 3 (Moisture Sensitivity Level) per J-STD-020

TYPICAL APPLICATION CIRCUIT

Buck-Boost Regulator

Boost Regulator
**ABSOLUTE MAXIMUM RATINGS** *(T_A = 25°C unless otherwise specified)* *(Note 1)*

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>LIMIT</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery power input Pin</td>
<td>( V_{\text{IN}} )</td>
<td>-0.3 to 42</td>
<td>V</td>
</tr>
<tr>
<td>FLT output to GND</td>
<td>( V_{\text{FLT}} )</td>
<td>-0.3 to 42</td>
<td>V</td>
</tr>
<tr>
<td>OUT voltage to GND</td>
<td>( V_{\text{OUT}} )</td>
<td>-0.3 to 20</td>
<td>V</td>
</tr>
<tr>
<td>EN voltage to GND</td>
<td>( V_{\text{EN}} )</td>
<td>-0.3 to 5.5</td>
<td>V</td>
</tr>
<tr>
<td>DIM voltage to GND</td>
<td>( V_{\text{DIM}} )</td>
<td>-0.3 to 5.5</td>
<td>V</td>
</tr>
<tr>
<td>CS voltage to GND</td>
<td>( V_{\text{CS}} )</td>
<td>-0.3 to 5.5</td>
<td>V</td>
</tr>
<tr>
<td>COM voltage to GND</td>
<td>( V_{\text{COM}} )</td>
<td>-0.3 to 5.5</td>
<td>V</td>
</tr>
<tr>
<td>OVP voltage to GND</td>
<td>( V_{\text{OVP}} )</td>
<td>-0.3 to 5.5</td>
<td>V</td>
</tr>
<tr>
<td>RT voltage to GND</td>
<td>( V_{\text{RT}} )</td>
<td>-0.3 to 5.5</td>
<td>V</td>
</tr>
<tr>
<td>Junction Temperature Range</td>
<td>( T_J )</td>
<td>-40 to +150</td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>( T_{\text{STG}} )</td>
<td>-65 to +150</td>
<td>°C</td>
</tr>
<tr>
<td>Lead Temperature (Soldering 10 sec)</td>
<td>( T_{\text{LEAD}} )</td>
<td>260</td>
<td>°C</td>
</tr>
<tr>
<td>Power Dissipation @ T_A=25°C</td>
<td>( P_D )</td>
<td>1.1</td>
<td>W</td>
</tr>
<tr>
<td>ESD Rating (Human Body Model)</td>
<td>( \text{HBM} )</td>
<td>±2</td>
<td>kV</td>
</tr>
<tr>
<td>ESD Rating (Charged Device Model)</td>
<td>( \text{CDM} )</td>
<td>±1</td>
<td>kV</td>
</tr>
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**THERMAL PERFORMANCE** *(Note 2)*

<table>
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<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>TYP</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Resistance Junction to Ambient</td>
<td>( R_{\theta JA} )</td>
<td>113</td>
<td>°C/W</td>
</tr>
<tr>
<td>Thermal Resistance Junction to Case</td>
<td>( R_{\theta JC} )</td>
<td>38</td>
<td>°C/W</td>
</tr>
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</table>

**RECOMMENDED OPERATING CONDITION** *(T_A = 25°C unless otherwise specified)* *(Note 3)*

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>LIMIT</th>
<th>UNIT</th>
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</thead>
<tbody>
<tr>
<td>Battery power input Pin</td>
<td>( V_{\text{IN}} )</td>
<td>8 to 38</td>
<td>V</td>
</tr>
<tr>
<td>FLT output to GND</td>
<td>( V_{\text{FLT}} )</td>
<td>0 to 38</td>
<td>V</td>
</tr>
<tr>
<td>OUT voltage to GND</td>
<td>( V_{\text{OUT}} )</td>
<td>0 to 18</td>
<td>V</td>
</tr>
<tr>
<td>EN voltage to GND</td>
<td>( V_{\text{EN}} )</td>
<td>0 to 5</td>
<td>V</td>
</tr>
<tr>
<td>DIM voltage to GND</td>
<td>( V_{\text{DIM}} )</td>
<td>0 to 5</td>
<td>V</td>
</tr>
<tr>
<td>CS voltage to GND</td>
<td>( V_{\text{CS}} )</td>
<td>0 to 0.8</td>
<td>V</td>
</tr>
<tr>
<td>COM voltage to GND</td>
<td>( V_{\text{COM}} )</td>
<td>1.2 to 3.6</td>
<td>V</td>
</tr>
<tr>
<td>OVP voltage to GND</td>
<td>( V_{\text{OVP}} )</td>
<td>1.6 to 3.1</td>
<td>V</td>
</tr>
<tr>
<td>RT voltage to GND</td>
<td>( V_{\text{RT}} )</td>
<td>1.2</td>
<td>V</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>( T_{\text{STG}} )</td>
<td>-55 to +150</td>
<td>°C</td>
</tr>
<tr>
<td>Operating Junction Temperature Range</td>
<td>( T_J )</td>
<td>-40 to +150</td>
<td>°C</td>
</tr>
<tr>
<td>Operating Ambient Temperature Range</td>
<td>( T_{\text{OPA}} )</td>
<td>-40 to +125</td>
<td>°C</td>
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### ELECTRICAL SPECIFICATIONS (VIN= 14V, TA = -40°C ~ 125°C unless otherwise specified)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITION</th>
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<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
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<tr>
<td>Supply Voltage</td>
<td></td>
<td></td>
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<tr>
<td>VIN Turn-on Threshold</td>
<td>VIN_ON</td>
<td></td>
<td>3.8</td>
<td>4.3</td>
<td>4.8</td>
<td>V</td>
</tr>
<tr>
<td>VIN Hysteresis</td>
<td>V_HYS</td>
<td></td>
<td>--</td>
<td>0.2</td>
<td>--</td>
<td>V</td>
</tr>
<tr>
<td>EN Turn-on Threshold</td>
<td>V_EN_ON</td>
<td></td>
<td>1.05</td>
<td>--</td>
<td>1.35</td>
<td>V</td>
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<tr>
<td>EN Hysteresis Current</td>
<td>I_HYS_EN</td>
<td></td>
<td>10</td>
<td>20</td>
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<td>μA</td>
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<tr>
<td>Quiescent Current</td>
<td>I_Q</td>
<td></td>
<td>80</td>
<td>160</td>
<td>240</td>
<td>μA</td>
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<td>Operating Supply Current</td>
<td>I_IN</td>
<td>R_RT=50kohm</td>
<td>1</td>
<td>--</td>
<td>4</td>
<td>mA</td>
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<tr>
<td>GM Amplifier</td>
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<td></td>
<td></td>
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<tr>
<td>Internal Reference Voltage</td>
<td>VREF</td>
<td></td>
<td>140</td>
<td>150</td>
<td>160</td>
<td>mV</td>
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<tr>
<td>Transconductance</td>
<td>Gm</td>
<td>I_COM_SINK/0.4</td>
<td>80</td>
<td>100</td>
<td>120</td>
<td>μA/V</td>
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<tr>
<td>Sink Current</td>
<td>I_COM_SINK</td>
<td>V_CS= 400mV</td>
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<td>40</td>
<td>--</td>
<td>μA</td>
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<tr>
<td>Source Current</td>
<td>I_COM_SOUR</td>
<td>V_CS= 0V</td>
<td>--</td>
<td>15</td>
<td>--</td>
<td>μA</td>
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<td>Oscillator</td>
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<tr>
<td>Oscillator Frequency</td>
<td>F_OSC</td>
<td>R_RT=50kohm</td>
<td>185</td>
<td>200</td>
<td>215</td>
<td>kHz</td>
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<tr>
<td>Jitter Frequency</td>
<td>F_JT</td>
<td>Design Guarantee</td>
<td>--</td>
<td>±8.5</td>
<td>--</td>
<td>%</td>
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<tr>
<td>Soft Start Time</td>
<td>T_SS</td>
<td></td>
<td>--</td>
<td>1024</td>
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<td>Clock Cycles</td>
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<tr>
<td>Fault Blank Time</td>
<td>T_FB</td>
<td></td>
<td>--</td>
<td>2048</td>
<td>--</td>
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<tr>
<td>Hiccup Time</td>
<td>T_HUP</td>
<td></td>
<td>--</td>
<td>32768</td>
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<tr>
<td>Driver</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Dropout Voltage</td>
<td>V_D</td>
<td>VIN=12V, C_O =1nF, I_O= 10mA</td>
<td>--</td>
<td>530</td>
<td>700</td>
<td>mV</td>
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<tr>
<td>Output Rising Time</td>
<td>T_R</td>
<td>C_O =1nF</td>
<td>--</td>
<td>40</td>
<td>--</td>
<td>ns</td>
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<tr>
<td>Output Falling Time</td>
<td>T_F</td>
<td>C_O =1nF</td>
<td>--</td>
<td>30</td>
<td>--</td>
<td>ns</td>
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<tr>
<td>Output Clamp Voltage</td>
<td>V_O_CLAMP</td>
<td>C_O =1nF</td>
<td>--</td>
<td>12.5</td>
<td>12.8</td>
<td>V</td>
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<tr>
<td>Protection</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Output Voltage Protection</td>
<td>V_OVP</td>
<td></td>
<td>3.0</td>
<td>3.25</td>
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<td>V</td>
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<tr>
<td>Short Circuit Protection</td>
<td>V_SCP</td>
<td></td>
<td>1.4</td>
<td>--</td>
<td>1.6</td>
<td>V</td>
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<tr>
<td>Current Limit Voltage</td>
<td>V_CSL</td>
<td></td>
<td>720</td>
<td>820</td>
<td>920</td>
<td>mV</td>
</tr>
<tr>
<td>Leading Edge Blanking Time</td>
<td>LEB</td>
<td>C_O =1nF</td>
<td>--</td>
<td>350</td>
<td>500</td>
<td>ns</td>
</tr>
<tr>
<td>MOS Current Protection</td>
<td>V_MCP</td>
<td>C_O =1nF</td>
<td>1.1</td>
<td>1.23</td>
<td>1.4</td>
<td>V</td>
</tr>
<tr>
<td>FLT Dropout Voltage</td>
<td>V_FLT</td>
<td>I FLT=10mA</td>
<td>--</td>
<td>200</td>
<td>--</td>
<td>mV</td>
</tr>
<tr>
<td>Maximum Duty</td>
<td>V_DUTY</td>
<td>C_O =1nF</td>
<td>--</td>
<td>85</td>
<td>--</td>
<td>%</td>
</tr>
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</table>
ELECTRICAL SPECIFICATIONS (Tₐ = 25°C unless otherwise specified)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITION</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimming</td>
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</tr>
<tr>
<td>PWM Dimming High Threshold</td>
<td>V₉H,DIM</td>
<td></td>
<td>2.5</td>
<td>--</td>
<td>--</td>
<td>V</td>
</tr>
<tr>
<td>Voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Dimming Threshold</td>
<td>V₉MAX,DIM</td>
<td></td>
<td>1.5</td>
<td>1.6</td>
<td>1.7</td>
<td>V</td>
</tr>
<tr>
<td>Voltage of 100% Current</td>
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<tr>
<td>Regulation</td>
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<tr>
<td>Source Current of DIM</td>
<td>I₉DIM</td>
<td></td>
<td>7.2</td>
<td>10</td>
<td>12.8</td>
<td>μA</td>
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<tr>
<td>Thermal Section (Note 4, 5)</td>
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<tr>
<td>Thermal Shutdown</td>
<td>TSD</td>
<td></td>
<td>--</td>
<td>165</td>
<td>--</td>
<td>°C</td>
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<tr>
<td>Temperature Hysteresis</td>
<td>T₉HYST</td>
<td></td>
<td>--</td>
<td>30</td>
<td>--</td>
<td>°C</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>ORDERING CODE</th>
<th>PACKAGE</th>
<th>PACKING</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS19501CB10H</td>
<td>MSOP-10EP</td>
<td>5,000pcs / 13&quot;Reel</td>
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</table>
**FUNCTION BLOCK**

**PIN DESCRIPTION**

<table>
<thead>
<tr>
<th>PIN NO.</th>
<th>NAME</th>
<th>FUNCTION</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>EN</td>
<td>Enable and shut down pin</td>
</tr>
<tr>
<td>2</td>
<td>DIM</td>
<td>PWM/Analog dimming voltage input</td>
</tr>
<tr>
<td>3</td>
<td>FLT</td>
<td>Open drain output pin for fault status flag.</td>
</tr>
<tr>
<td>4</td>
<td>CS</td>
<td>Input current sense pin</td>
</tr>
<tr>
<td>5</td>
<td>COM</td>
<td>Compensation output pin of error amplifier.</td>
</tr>
<tr>
<td>6</td>
<td>OVP</td>
<td>Over voltage sensing pin</td>
</tr>
<tr>
<td>7</td>
<td>RT</td>
<td>Connect external resistor to GND to set frequency.</td>
</tr>
<tr>
<td>8</td>
<td>GND</td>
<td>Ground return for all internal circuitry.</td>
</tr>
<tr>
<td>9</td>
<td>VIN</td>
<td>Battery power input pin for all internal circuitry.</td>
</tr>
<tr>
<td>10</td>
<td>OUT</td>
<td>Power MOS output pin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thermal pad No internal connection</td>
</tr>
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</table>
TYPICAL PERFORMANCE CURVES

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

Figure 1. ILED vs. PWM Dimming Duty

Figure 2. ILED vs. Analog 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 TS19501CB10H 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 follows the design formula to combine the $T_{ON}$ and $T_{OFF}$ information which are forced to be equal potential through system negative feedback.

The average LED current can be expressed as below.

$$I_{LED,\text{avg}} = \frac{V_{REF}}{R_{CS}}$$

Where:
- $I_{LED,\text{avg}}$ 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 20μA when the divider voltage is over $V_{EN,\text{ON}}$.

**DIM Pin**
A PWM and analog dimming function is applied in TS19501CB10H. The analog dimming range is an DC voltage from 0V to 1.6V. PWM dimming function is the same pin of analog dimming. The current regulation is decided by duty cycle of external PWM signal. Built-in 10μA 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.

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

Where:
- $I_{CS(\text{LIMIT})}$ 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 which it departs 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.

\[ V_{OVP} = 3.2 \times \frac{R_{OVPH} + R_{OVPL}}{R_{OVPL}} \]
\[ V_{O_SCP} = 1.5 \times \frac{R_{OVPH} + R_{OVPL}}{R_{OVPL}} \]

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:
\[ F_s = \frac{1}{L \times 10^{-10} \times R_T} \]

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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