

## WD3139

High Efficiency, 38V Step-Up White LED Driver

[Http://www.sh-willsemi.com](http://www.sh-willsemi.com)

### Descriptions

The WD3139 is a constant current, high efficiency LED driver. Internal MOSFET can drive up to 10 white LEDs in series with 1.2A current limit and 38V OVP. A Pulse-Width-Modulation (PWM) signal can be applied to the EN pin for LED dimming. The device operates at 1MHz fixed switching frequency to reduce output ripple, improve conversion efficiency, and allows using small external components.

The WD3139 is available in TSOT-23-6L Package. Standard product is Pb-free and Halogen-free.

### Features

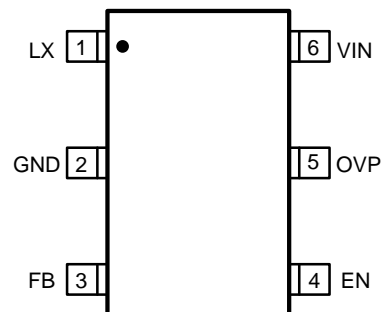
- Input voltage range : 2.7~5.5V
- Open LED Protection : 38V (Typ.)
- Reference Voltage : 200mV (±5%)
- Switching frequency : 1MHz (Typ.)
- Efficiency : Up to 92%
- Main switch current limit : 1.2A (Typ.)
- PWM Dimming frequency : 5KHz to 200KHz
- PWM Dimming Duty Cycle : 0.5% ~ 100%

### Applications

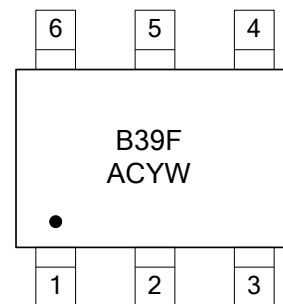
- Smart Phones
- Tablets
- Portable games



**TSOT-23-6L**



**Pin configuration (Top view)**



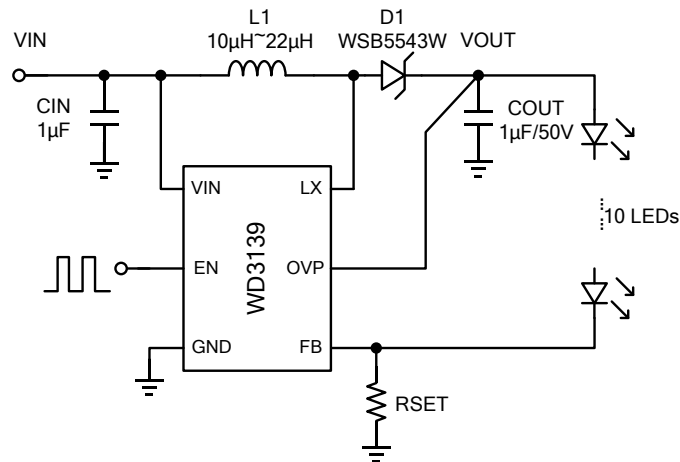
**TSOT-23-6L**

**B39F** = Device code  
**Y** = Year code  
**W** = Week code  
**Marking**

### Order information

Device	Package	Shipping
WD3139F-6/TR	TSOT-23-6L	3000/Reel&Tape

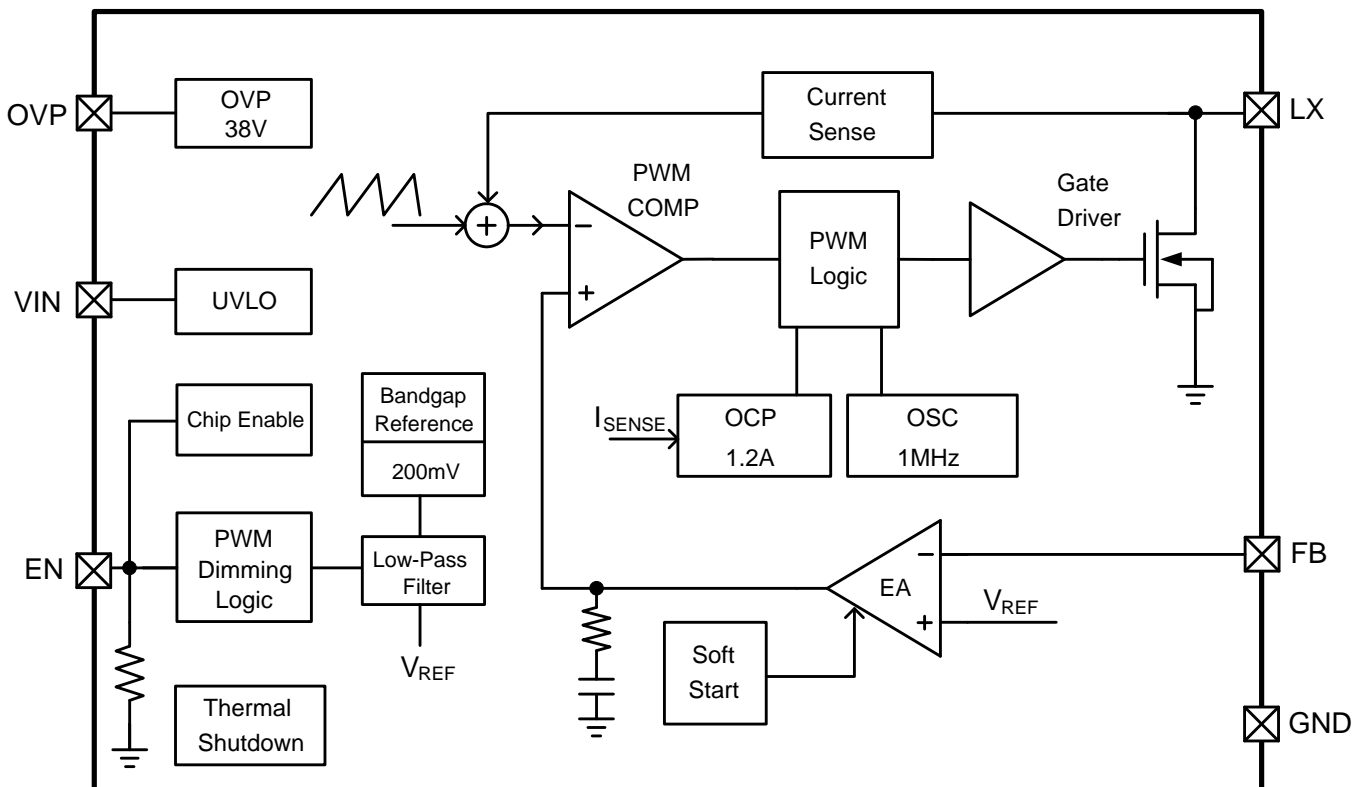
### Typical applications



### Pin descriptions

Symbol	Pin No.	Descriptions
LX	1	Switch node
GND	2	Ground
FB	3	Feedback
EN	4	Enable, Active High
OVP	5	OVP Pin, Connect to VOUT
VIN	6	Power Supply

### Block diagram



**Absolute maximum ratings**

Parameter	Symbol	Value	Unit
VIN pin voltage range	$V_{IN}$	-0.3~6.5	V
OVP pin voltage range	$V_{OVP}$	-0.3~40	V
EN pin voltage range	-	-0.3~ $V_{IN}$	V
LX pin voltage range (DC)	-	-0.3~40	V
Power Dissipation – SOT-23-6L (Note 1)	$P_D$	0.5	W
Power Dissipation – SOT-23-6L (Note 2)		0.3	W
Junction to Ambient Thermal Resistance – SOT-23-6L (Note 1)	$R_{\theta JA}$	250	°C/W
Junction to Ambient Thermal Resistance – SOT-23-6L (Note 2)		416	°C/W
Junction temperature	$T_J$	150	°C
Lead temperature(Soldering, 10s)	$T_L$	260	°C
Operation temperature	$T_{opr}$	-40 ~ 85	°C
Storage temperature	$T_{stg}$	-55 ~ 150	°C

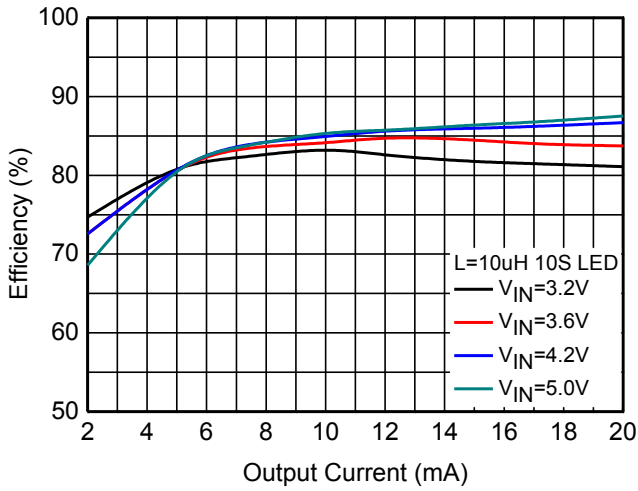
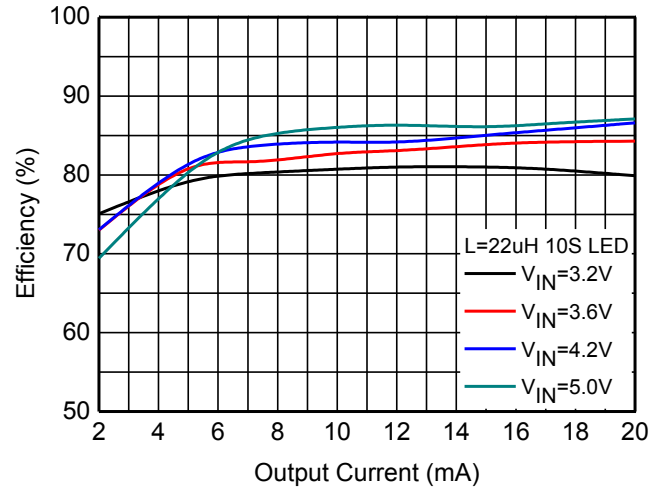
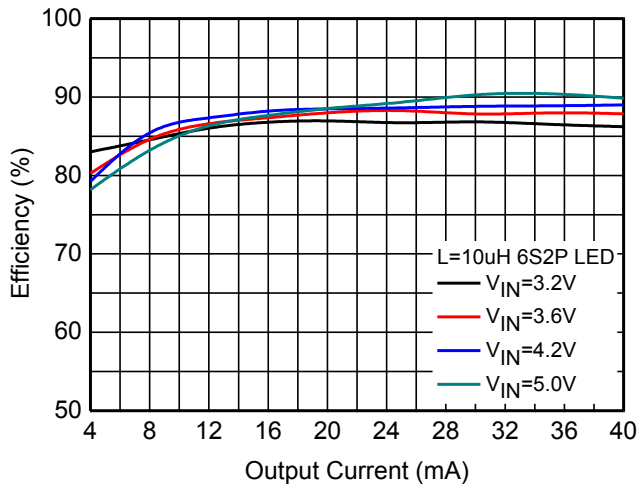
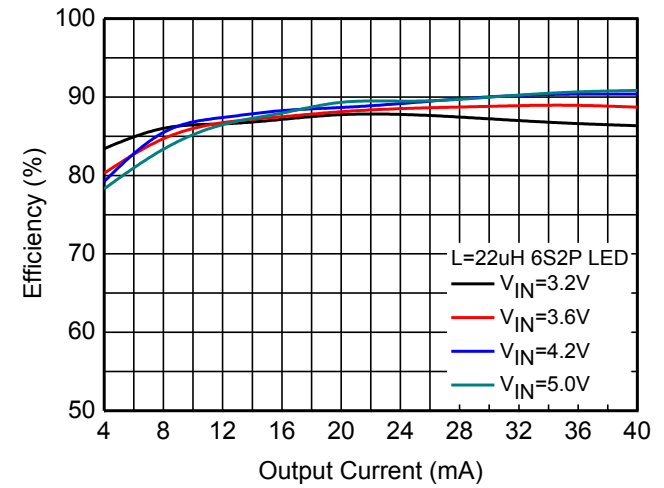
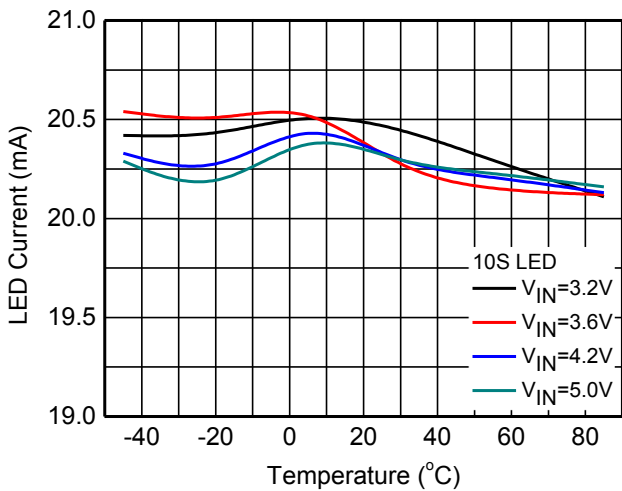
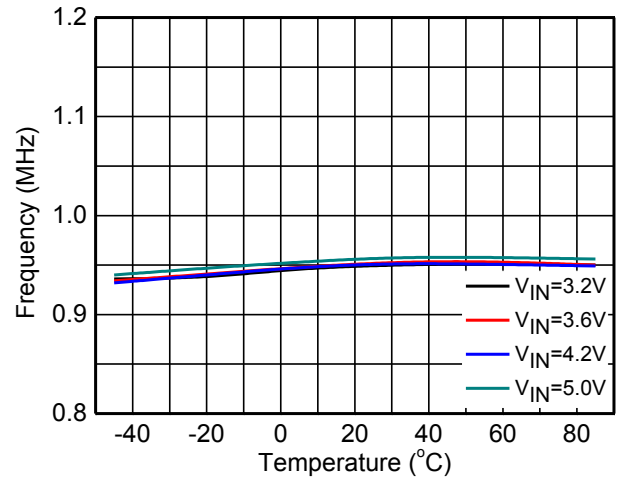
These are stress ratings only. Stresses exceeding the range specified under “Absolute Maximum Ratings” may cause substantial damage to the device. Functional operation of this device at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect device reliability.

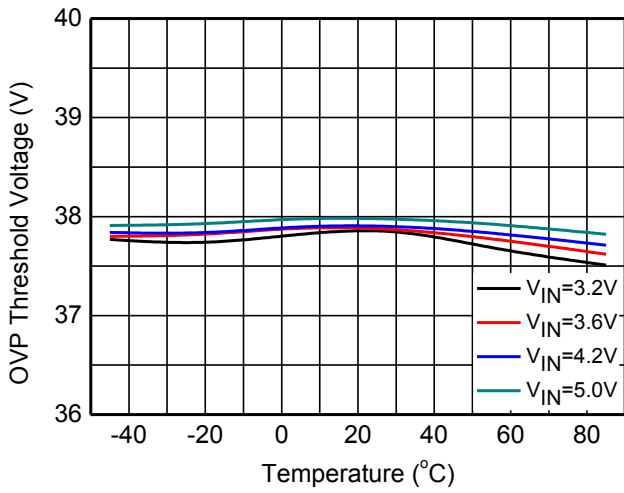
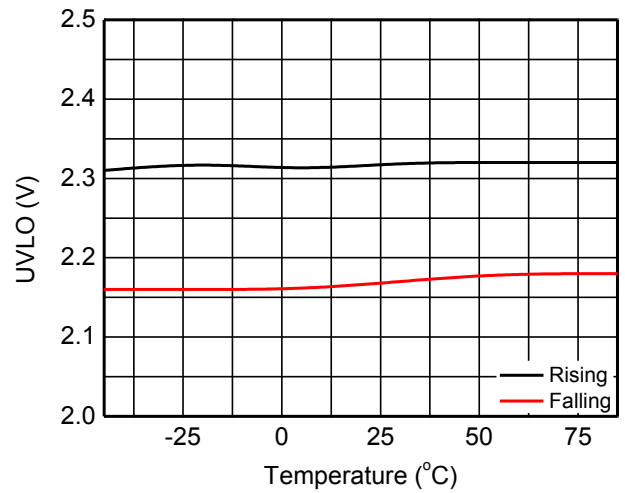
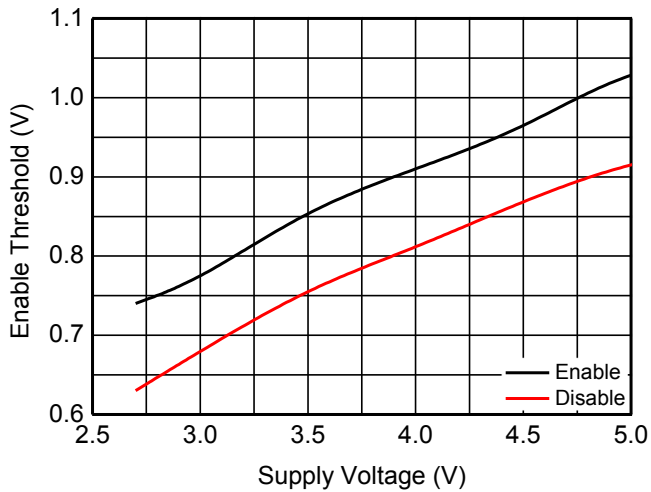
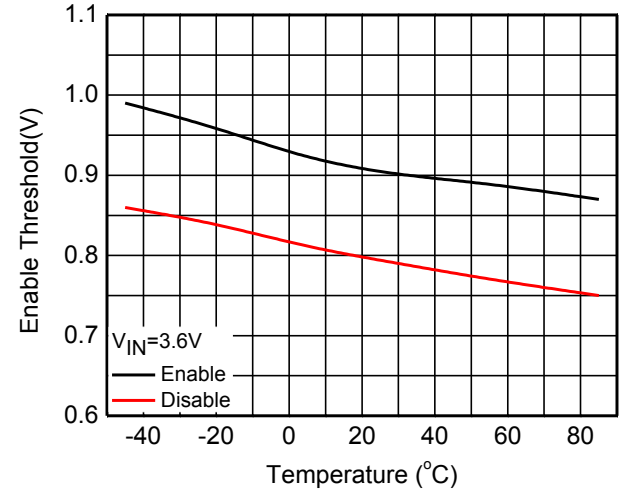
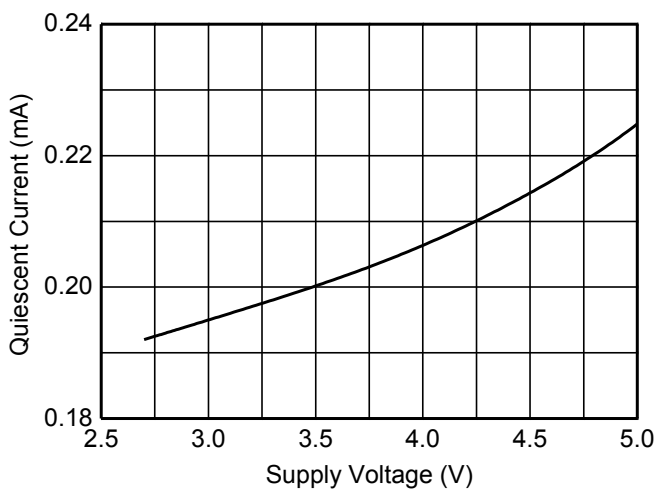
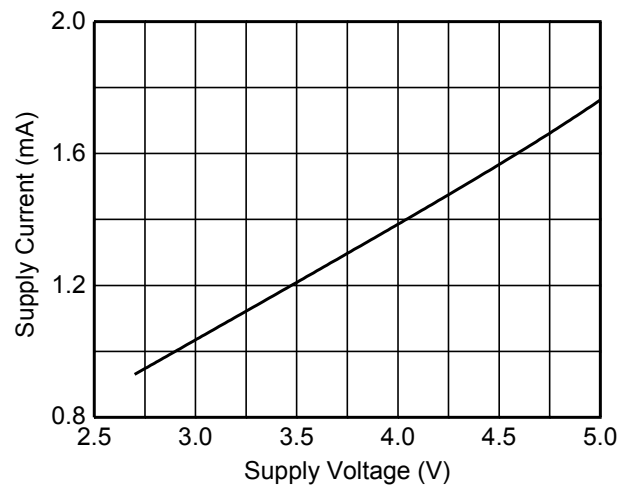
**Note 1:** Surface mounted on FR-4 Board using 1 square inch pad size, dual side, 1oz copper

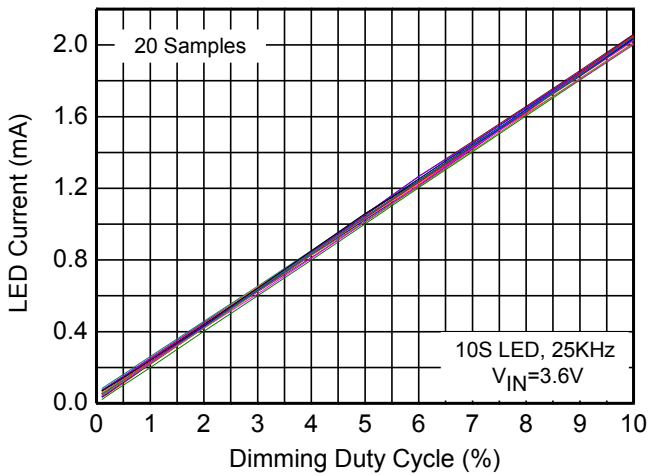
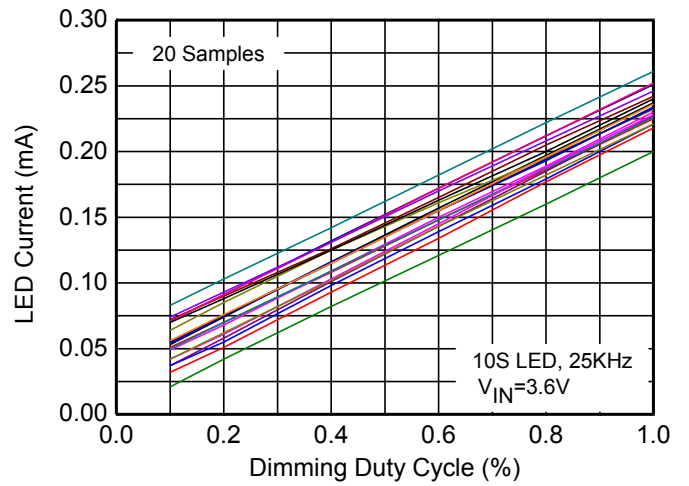
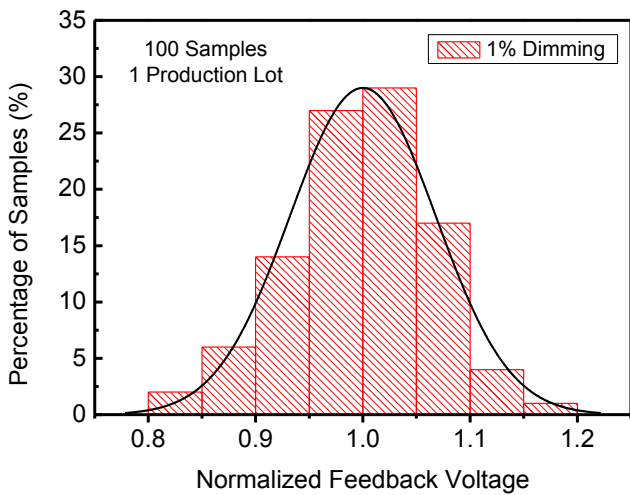
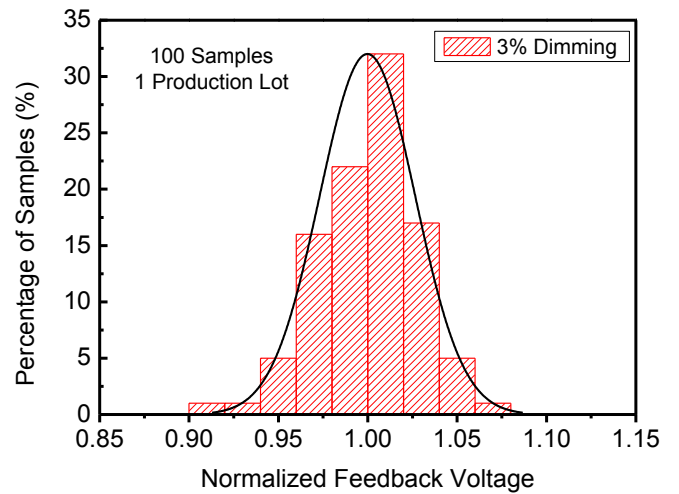
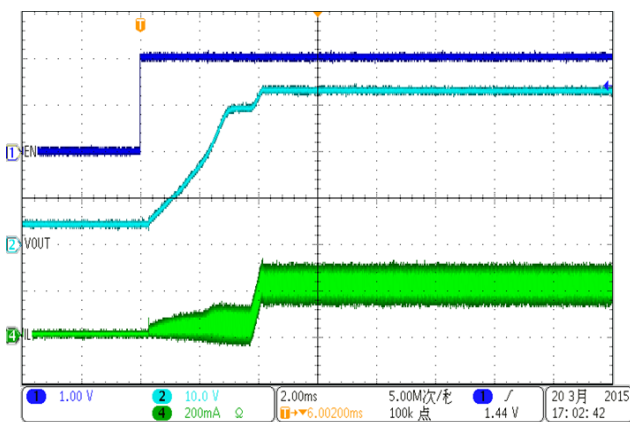
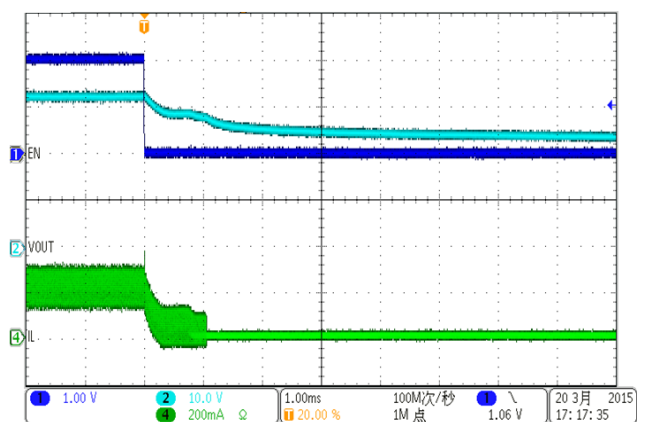
**Note 2:** Surface mounted on FR-4 board using minimum pad size, 1oz copper

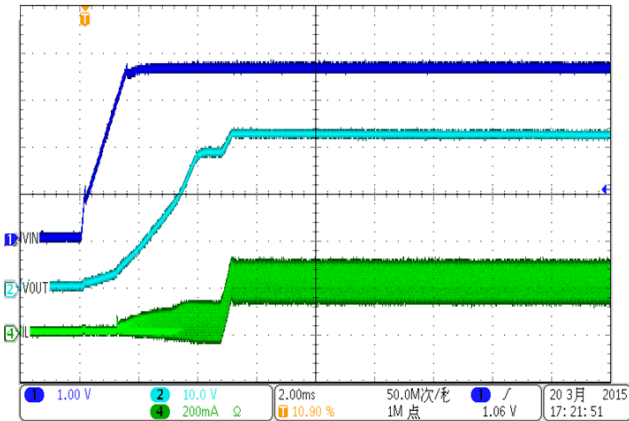
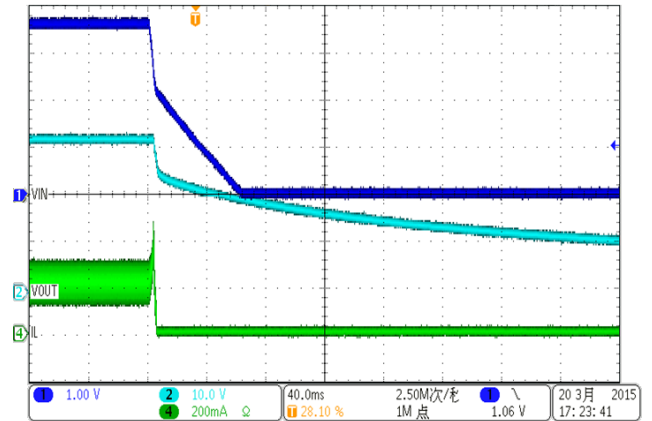
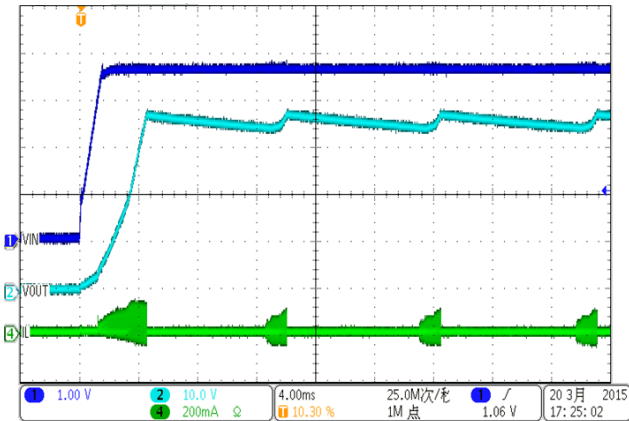
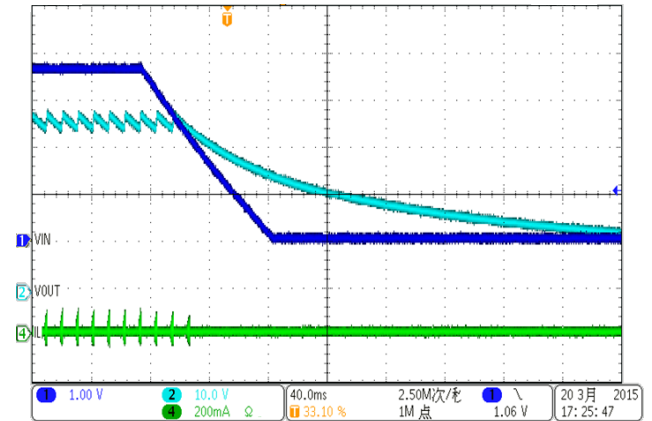
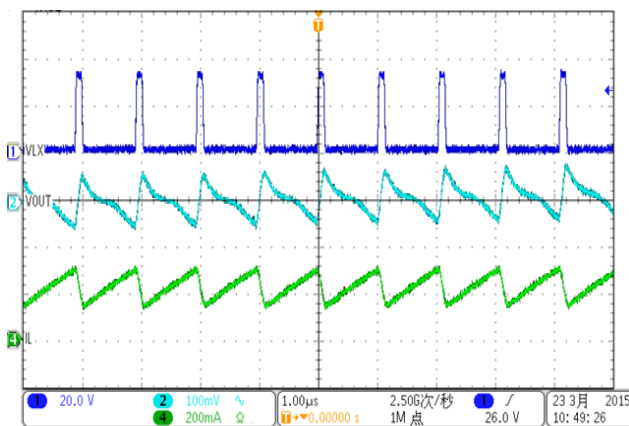
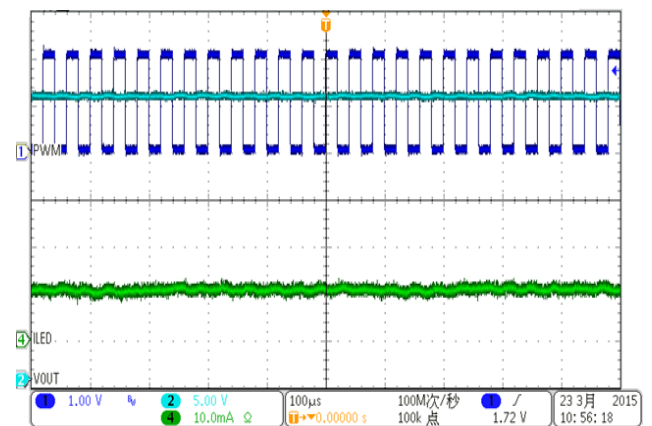
**Electronics Characteristics** ( $T_a=25^{\circ}\text{C}$ ,  $V_{IN}=3.6\text{V}$ ,  $V_{EN}=V_{IN}$ ,  $C_{IN}=C_{OUT}=1\mu\text{F}$ , unless otherwise noted)

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
Operation Voltage Range	$V_{IN}$		2.7	--	5.5	V
Under Voltage Lockout	$V_{UVLO}$	$V_{IN}$ Rising	1.8	2.3	2.5	V
UVLO Hysteresis	$V_{UVLO-HYS}$			0.15		V
Over-Voltage Threshold	$V_{OVP}$		36	38	40	V
Quiescent Current	$I_Q$	No Switching		0.2	1	mA
Supply Current	$I_S$	Switching		1.2	3	mA
Shutdown Current	$I_{SD}$	$V_{EN} < 0.4\text{V}$			1	$\mu\text{A}$
Operation Frequency	$f_{OSC}$		0.8	1	1.2	MHz
Maximum Duty Cycle	$D_{MAX}$		91	93		%
PWM Dimming Clock Rate		Recommended	5		200	KHz
PWM Dimming Duty Cycle			0.5		100	%
Feedback Reference	$V_{REF}$	100% Full Scale	190	200	210	mV
		1% Dimming Duty		2		
On Resistance	$R_{ON}$	$I_{LX}=100\text{mA}$		0.45		$\Omega$
Current Limit	$I_{LIM}$			1.2		A
EN Threshold Voltage	$V_{ENL}$				0.4	V
	$V_{ENH}$		1.5			V
EN Pull-down Resistance	$R_{EN}$			1		$\text{M}\Omega$
Thermal Shutdown Temperature	$T_{SD}$			160		$^{\circ}\text{C}$
$T_{SD}$ Hysteresis	$T_{SD-HYS}$			30		$^{\circ}\text{C}$
Shutdown Delay	$t_{SHDN}$			1		ms

**Typical Characteristics (Ta=25°C, unless otherwise noted)**

**Efficiency vs. Output Current**

**Efficiency vs. Output Current**

**Efficiency vs. Output Current**

**Efficiency vs. Output Current**

**LED Current vs. Temperature**

**Frequency vs. Temperature**


**OVP Threshold vs. Temperature**

**UVLO vs. Temperature**

**Enable Threshold vs. VIN**

**Enable Threshold vs. Temperature**

**Quiescent Current vs. VIN**

**Supply Current vs. VIN**


**LED Current Dimming Linearity**

**LED Current Dimming Linearity**

**Distribution of  $V_{FB}$  Dimming at 1%**

**Distribution of  $V_{FB}$  Dimming at 3%**

**Start-Up from EN**

**Shut-Down from EN**


**Start-Up from VIN**

**Shut-Down from VIN**

**Start-Up with LED Open**

**Shut-Down with LED Open**

**Operation Waveforms**

**PWM Dimming Waveforms**



## Operation Information

### Normal Operation

The WD3139 is a high efficiency, high output voltage boost converter. The device is ideal for driving white LED. The LED connection provides even illumination by sourcing the same output current through all LEDs. The device integrates 38V/1.2A switch FET and operates in pulse width modulation (PWM) with 1MHz fixed switching frequency. The beginning of each cycle turns on the Power MOSFET. A slope compensation ramp is added to the current sense amplifier and the result is fed into the positive input of the comparator (COMP). When this voltage goes above the output voltage of the error amplifier (EA), the Power MOSFET is turned off. The FB voltage can be regulated to the reference voltage of bandgap with EA block. The feedback loop regulates the FB pin to a low reference voltage (200mV typical), reducing the power dissipation in the current sense resistor.

### Soft-Start

The WD3139 Build-in Soft-Start function limits inrush current while the device turn-on.

### Cycle-by-Cycle Current Limit

The WD3139 uses a cycle-by-cycle current limit circuitry to limit the inductor peak current in the event of an overload condition. The current flow through inductor in charging phase is detected by a current sensing circuit. As the value comes across the current limiting threshold the N- MOSFET turns off, so that the inductor will be forced to leave charging stage and enter in discharging stage. Therefore, the inductor current will not increase over the current limiting threshold.

### Over-Voltage-Protection (OVP)

The Over Voltage Protection is detected by OVP block, prevents IC damage as the result of white LED disconnection.

Once output voltage goes over the OVP threshold 38V, LX pin stops switching and the N-MOSFET will be turned off. Then, the output voltage will be clamped to be near OVP. Until the OVP eliminate the N-MOSFET will be turned on.

### UVLO Protection

To avoid malfunction of the WD3139 at low input voltages, an under voltage lockout is included that disables the device, until the input voltage exceeds 2.3V (Typ.).

### Shutdown Mode

Drive EN to GND to place the WD3139 in shutdown mode. In shutdown mode, the reference, control circuit, and the main switch turn off. Input current falls to smaller than 1 $\mu$ A during shutdown mode.

### Over-Temperature-Protection (OTP)

As soon as the junction temperature ( $T_J$ ) exceeds 160°C (Typ.), the WD3139 goes into thermal shutdown. In this mode, the main N-MOSFET is turned off until temperature falls below typically 130°C. Then the device starts switching again.

## Application Information

External component selection for the application circuit depends on the load current requirements. Certain trade-offs between different performance parameters can also be made.

### LED Current Setting

The loop of Boost structure will keep the FB pin voltage equal to the reference voltage  $V_{REF}$ . Therefore, when  $R_{SET}$  connects FB pin and GND, the current flows from  $V_{OUT}$  through LED and  $R_{SET}$  to GND will be decided by the current on  $R_{SET}$ , which is equal to following equation:

$$I_{LED} = \frac{V_{FB}}{R_{SET}} = \frac{200mV}{R_{SET}}$$

Where

$I_{LED}$  = output current of LEDs

$V_{FB}$  = regulated voltage of FB

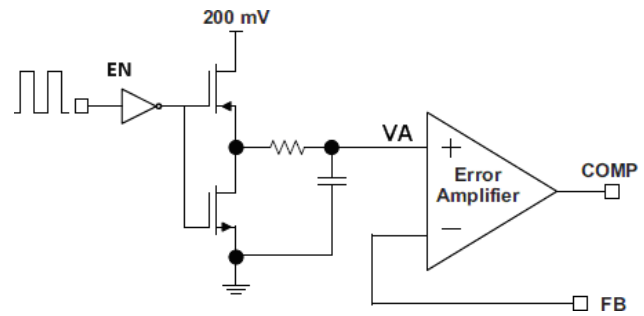
$R_{SET}$  = current sense resistor

The output current tolerance depends on the FB accuracy and the current sensor resistor accuracy.

### Dimming Control

For the brightness dimming control of the WD3139, the IC provides typically 200mV feedback voltage when the EN pin is pulled constantly high. However, EN pin allows a PWM signal to reduce this regulation voltage by changing the PWM duty cycle to achieve LED brightness dimming control.

As shown in Figure 1, the duty cycle of the PWM signal is used to chop the internal 200mV reference voltage. An internal low pass filter is used to filter the pulse signal. And then the reference voltage can be made by connecting the output of the filter to the error amplifier for the FB pin voltage regulation.



**Figure 1**

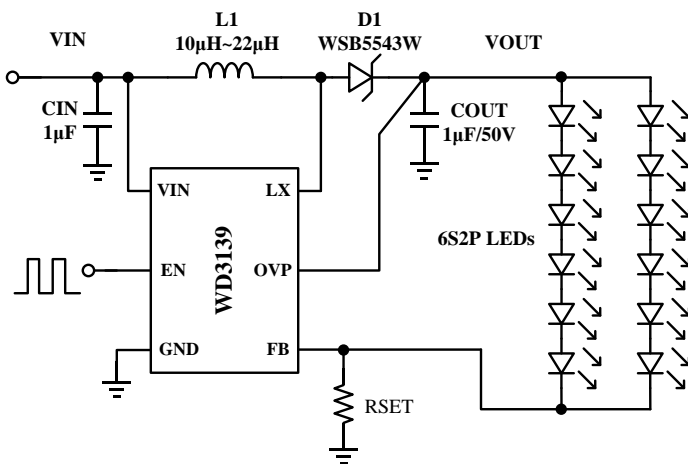
Therefore, although a PWM signal is applied for dimming, but only the WLED DC current is modulated. This help to eliminate the audible noise which often occurs when the LED current is pulsed in replica of the frequency and the duty cycle of PWM control. The minimum dimming frequency is limited by EN shutdown delay time. For optimum performance, recommend to select PWM dimming frequency in the range of 5kHz~200kHz. And the recommended minimum PWM Duty Cycle is 0.5% for stable LED driving and no blind dimming.

The EN shutdown delay time is set to 1ms. This means the IC needs to be shutdown by pulling the EN low for 1ms.

### Applications for Driving 3S9P LEDs

The WD3139 can drive different WLEDs topology. For example, the Figure 2 shows the 6S2P WLEDs as output load. The total WLEDs current can be set by the RSET which is equal to following equation. With  $V_{IN} > 3.4V$ , The WD3139 could drive maximum 3S9P with total 27 LEDs.

$$I_{Total} = \frac{V_{REF}}{R_{SET}}$$



**Figure 2**

### Boost Inductor Selection

The selection of the inductor affects steady state operation as well as transient behavior and loop stability. Inductor values can have  $\pm 20\%$  tolerance with no current bias. When the inductor current approaches saturation level, its inductance can decrease 20% to 35% from the 0A value depending on how the inductor vendor defines saturation current. Using an inductor with a smaller inductance value forces discontinuous PWM when the inductor current ramps down to zero before the end of each switching cycle. This reduces the boost converter's maximum output current, causes large input voltage ripple and reduces efficiency. Large inductance value provides much more output current and higher conversion efficiency. The inductor should have low core loss at 1MHz and low DCR for better efficiency. For these reasons, the recommended value of

inductor for 10 series WLEDs applications is from 10µH to 22µH. A 22µH inductor with Low DCR optimized the efficiency for most application while maintaining low inductor peak to peak ripple.

### Input Capacitor Selection

Connect the input capacitance from  $V_{IN}$  to the reference ground plane. Input capacitance reduces the ac voltage ripple on the input rail by providing a low-impedance path for the switching current of the boost converter. The capacitor in the range of 1µF to 10µF / X7R or X5R is recommended for input side.

### Output Capacitor Selection

The output capacitor is mainly selected to meet the requirements for the output ripple and loop stability. This ripple voltage is related to the capacitor's capacitance and its equivalent series resistance (ESR). The recommended minimum capacitor on Output is 1µF/50V, X5R or X7R ceramic capacitor.

### Diode Selection

The rectifier diode supplies current path to the inductor when the internal MOSFET is off. Use a schottky with low forward voltage to reduce losses. The diode should be rated for a reverse blocking voltage greater than the output voltage used. The average current rating must be greater than the maximum load current expected, and the peak current rating must be greater than the peak inductor current.

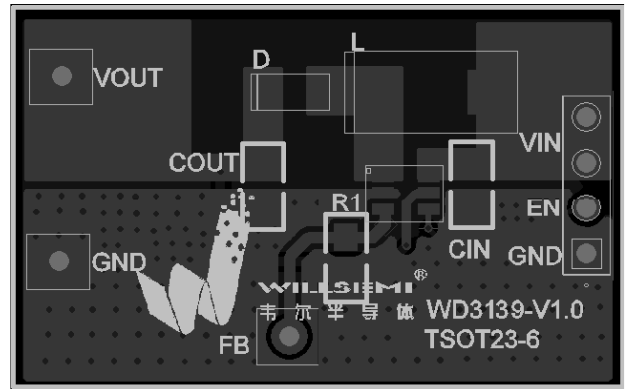
Diode the following requirements:

- Low forward voltage
- High switching speed : 50ns max.
- Reverse voltage :  $V_{OUT} + V_F$  or more
- Rated current :  $I_{PK}$  or more

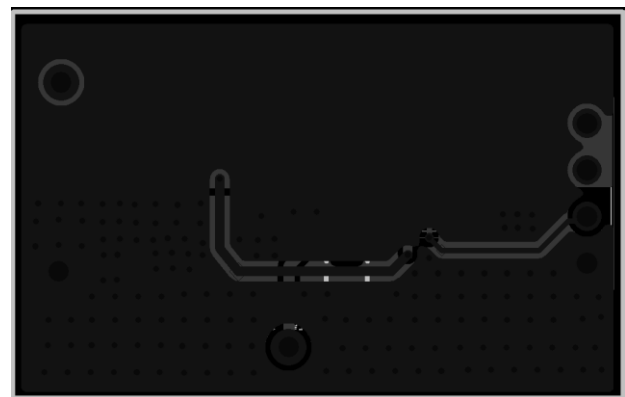
### PCB Layout Considerations

A good circuit board layout aids in extracting the most performance from the WD3139. Poor circuit layout degrades the output ripple and the electromagnetic interference (EMI) or electromagnetic compatibility (EMC) performance. The evaluation board layout is optimized for the WD3139. Use this layout for best performance. If this layout needs changing, use the following guidelines:

1. Use separate analog and power ground planes. Connect the sensitive analog circuitry (such as voltage divider components) to analog ground; connect the power components (such as input and output bypass capacitors) to power ground. Connect the two ground planes together near the load to reduce the effects of voltage dropped on circuit board traces. Locate  $C_{IN}$  as close to the  $V_{IN}$  pin as possible, and use separate input bypass capacitors for the analog.
2. Route the high current path from  $C_{IN}$ , through  $L$  to the LX and GND pins as short as possible.
3. Keep high current traces as short and as wide as possible.
4. The output filter of the boost converter is also critical for layout. The Diode and Output capacitors should be placed to minimize the area of current loop through Output –GND–LX.
5. Avoid routing high impedance traces, such as Output, near the high current traces and components or near the Diode node.
6. If high impedance traces are routed near high current and/or the LX node, place a ground plane shield between the traces.
7. Place the RSET resistor as close as possible to FB pin, for the FB is a high impedance input pin which is susceptible to noise.

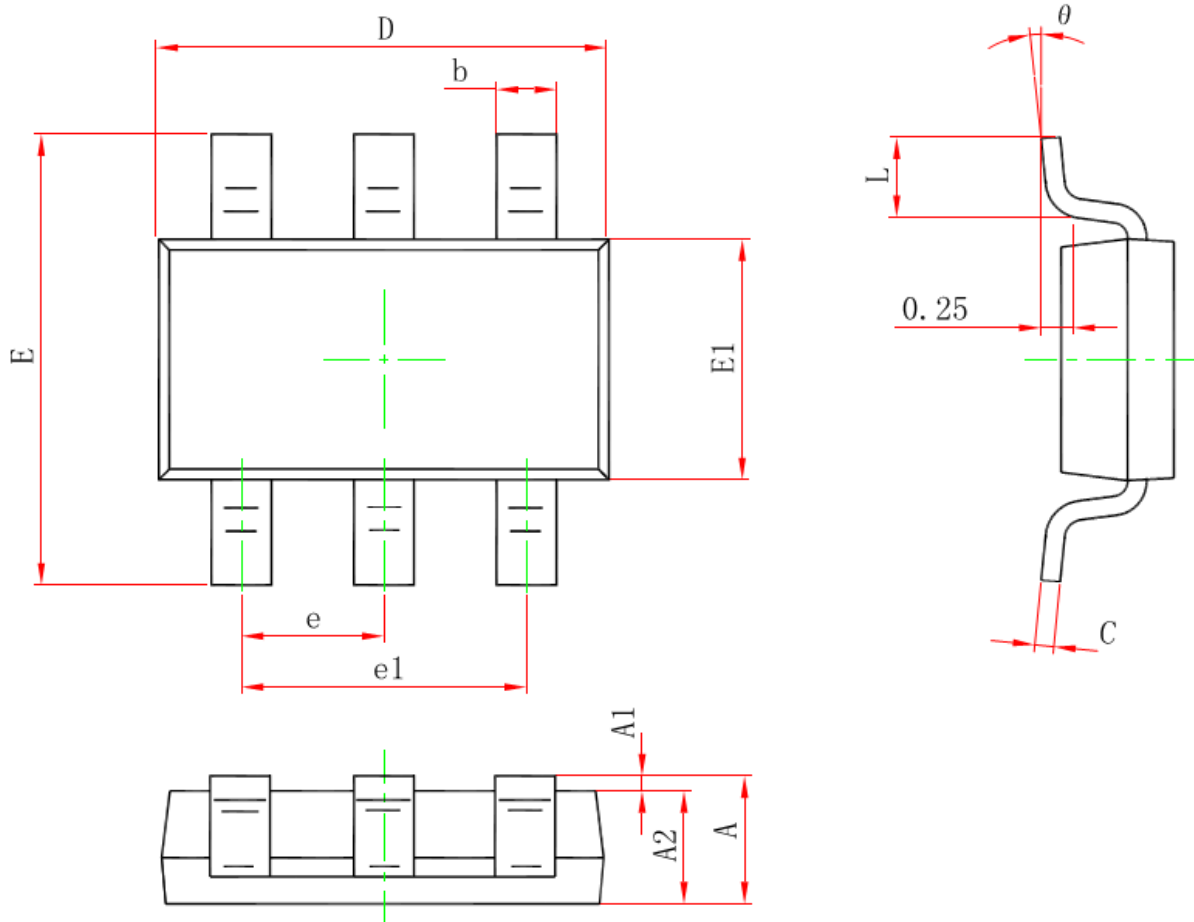


**Top**



**Bottom**

**WD3139 PCB Suggest Layout (Demo)**

**Package outline dimensions**
**TSOT-23-6L**


Symbol	Dimensions in millimeter		
	Min.	Typ.	Max.
A	-	-	0.900
A1	0.000	-	0.100
A2	0.700	-	0.800
b	0.350	-	0.500
c	0.080	-	0.200
D	2.820	2.900	3.020
E1	1.600	1.650	1.700
E	2.650	2.800	2.950
e	0.950 (BSC)		
e1	1.900 (BSC)		
L	0.300	-	0.600
θ	0°	-	8°