

## White LED Driver with PWM Brightness control in Small Package

### FEATURES

- 2.7 to 5.5V Input Voltage Range
- 38V OVP, 1MHz Switching Frequency
- Content Adaptive Backlight Control (CABC)
- Adaptive Boost Output to WLED Voltages
- 1% Typical Current Matching and Accuracy
- Supports Low to 0.1% Stable PWM Dimming
- Up to 9-Bit Dimming Resolution
- Up to 90% Efficiency
- PFM Mode at Light Load
- Built-in WLED Open/Short Protection
- Over-current and Over-temperature Protection
- Built-in Soft-start Limits Inrush Current
- WLCSP-1.36mm x 1.36mm-9B Package

### APPLICATION

- Smart Phones
- PDAs, Handheld Computers
- GPS Receivers
- Backlight for Small and Media Form-Factor LCD  
Display with Single-Cell Battery Input

### GENERAL DESCRIPTION

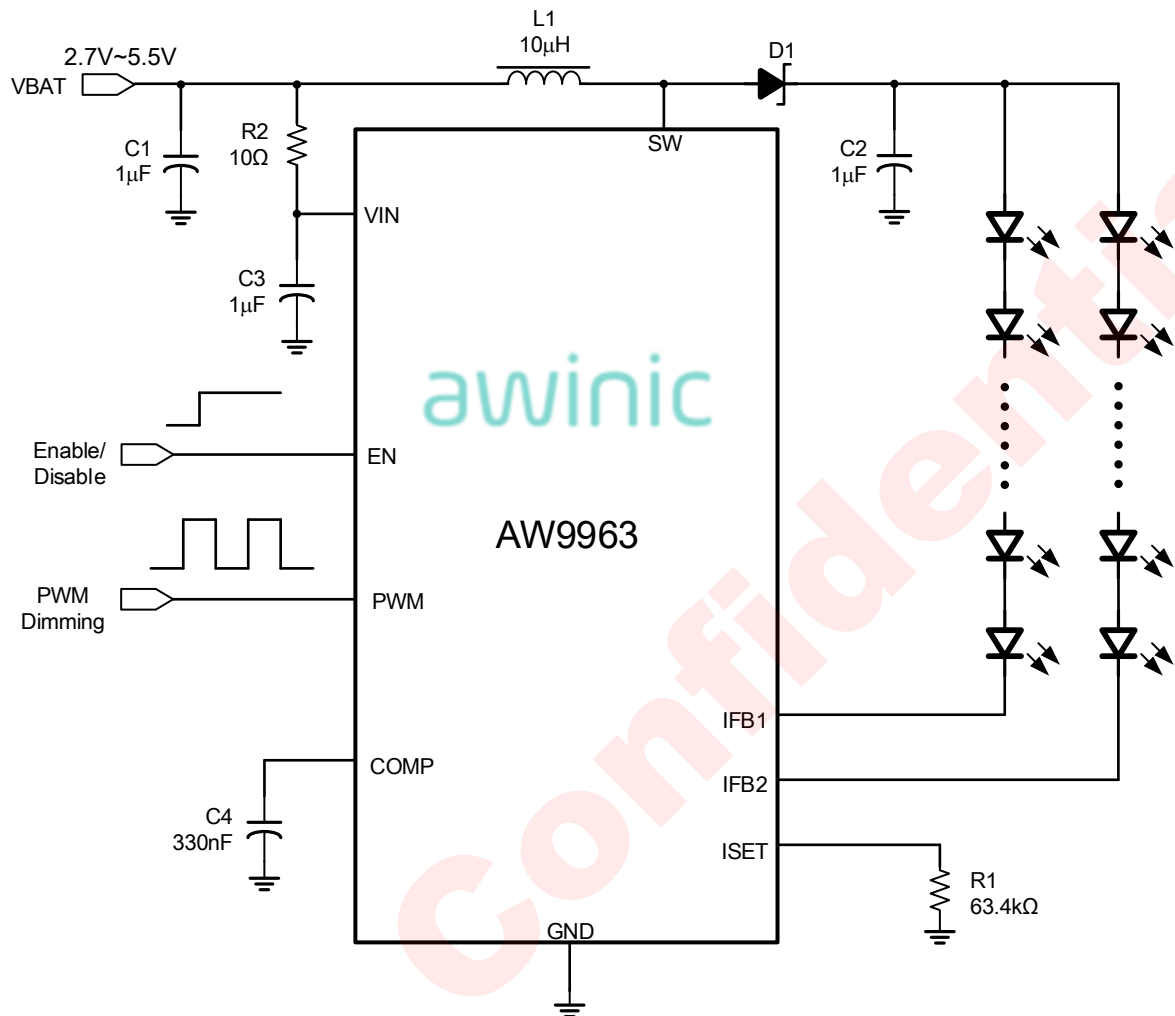
The AW9963 is dual-channel WLED driver which provides highly integrated solutions for single-cell Li-ion battery powered smartphone backlight.

The AW9963 built-in a 2A/40V power MOSFET which can drive up to 2p10s WLED diodes with Li-ion battery power supply. It also integrates two high accuracy and matching current sink regulators which can significantly improve uniformity of backlight, very low feedback voltage and PFM mode at light load bring AW9963 higher efficiency.

The AW9963 supports 10kHz to 100kHz PWM input range, can provide low to 0.1% stable current.

The AW9963 integrates built-in soft start, as well as overvoltage, overcurrent, and thermal shutdown protections.

## TYPICAL APPLICATION CIRCUIT

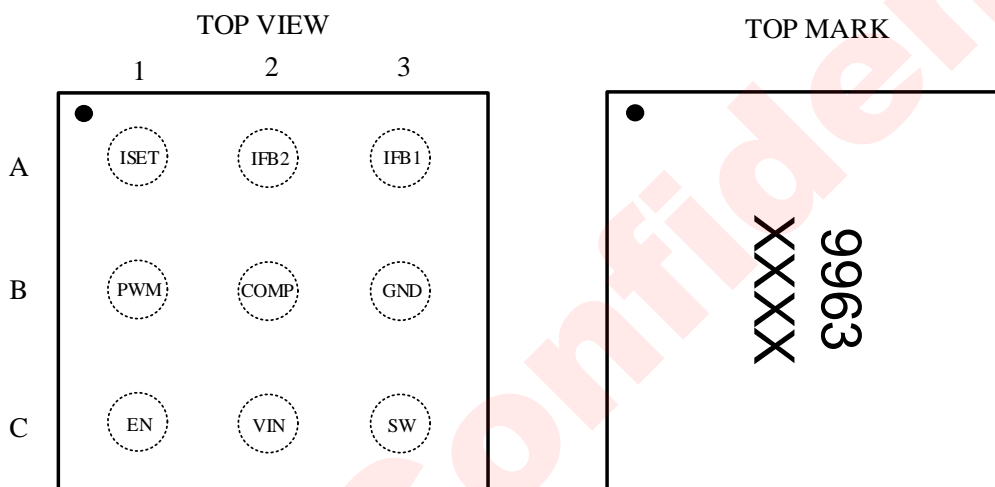


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## ORDERING INFORMATION

Part Number	Temperature	Package	Marking	Moisture Sensitivity Level	Environmental Information	Delivery Form
AW9963CSR	-40°C~85°C	WLCSP- 1.36x1.36-9B	9963 XXXX	MSL1	ROHS+HF	3000 units/ Tape and Reel

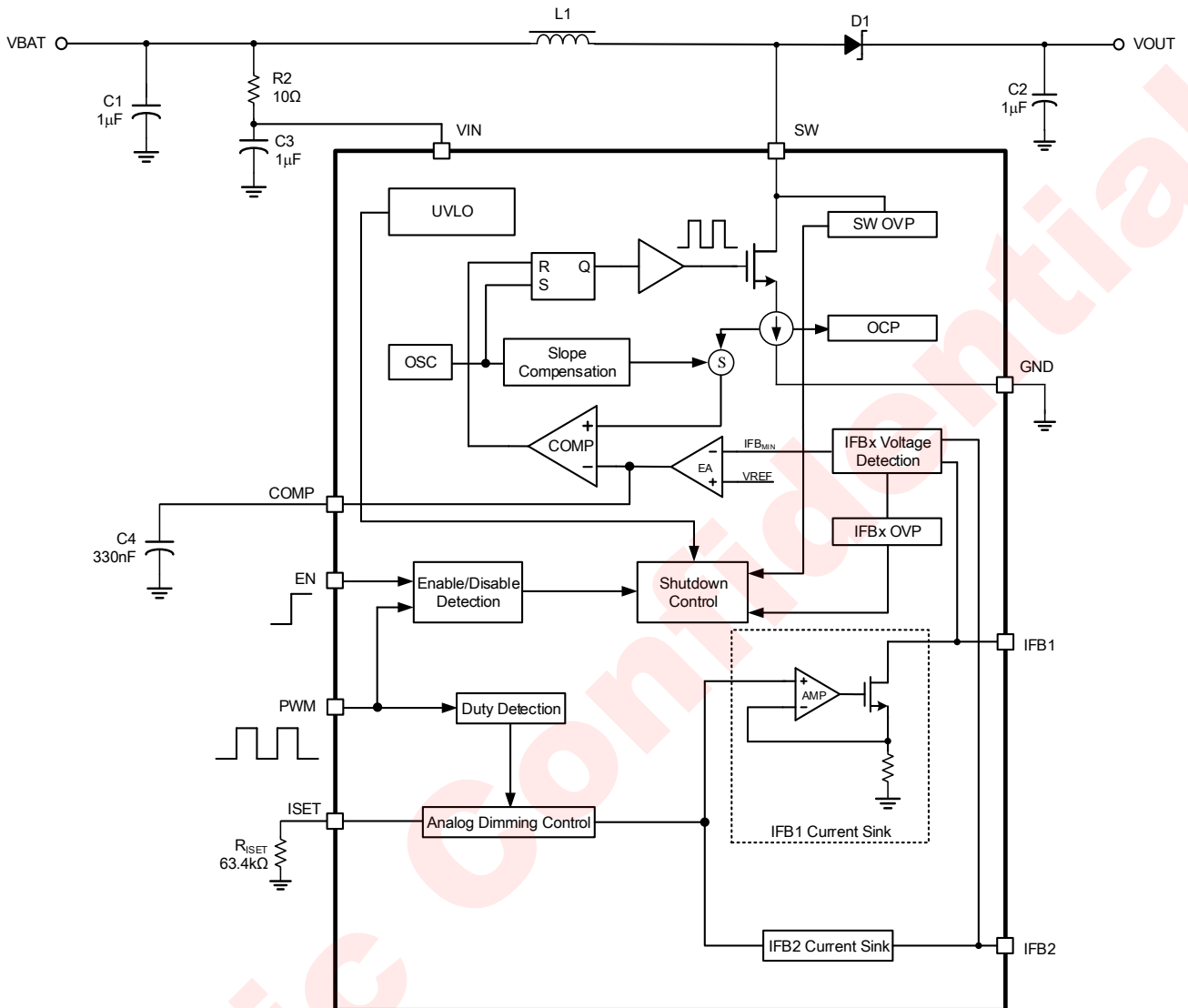
## Pin Configuration and Top Mark



## PIN DEFINITION

PIN	NAME	I/O	DESCRIPTION
A1	ISET	I	Connecting a resistor to the pin programs the full-scale LED current.
A2	IFB2	I	Current Sink Input Pin.
A3	IFB1	I	Current Sink Input Pin.
B1	PWM	I	PWM Dimming Signal Input.
B2	COMP	O	Output of the Transconductance Error Amplifier. Connect external capacitor to this pin to compensate the boost loop.
B3	GND	O	Ground.
C1	EN	I	Enable Control.
C2	VIN	I	Power Pin.
C3	SW	I	Switching node. Connect inductor and schottky.

## FUNCTIONAL BLOCK DIAGRAM



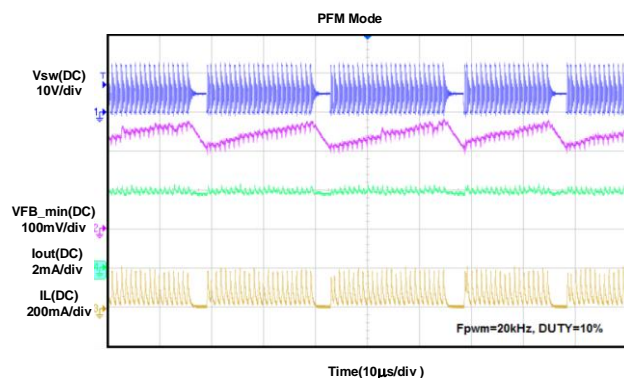
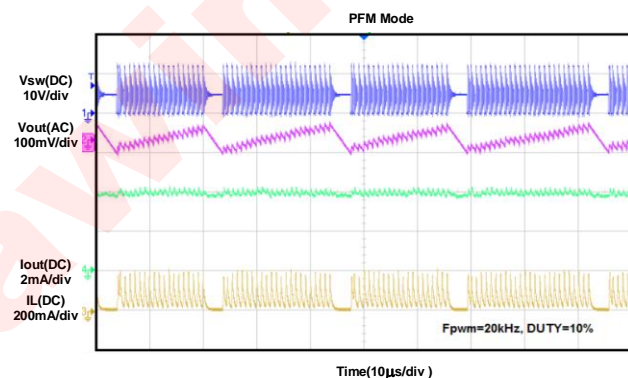
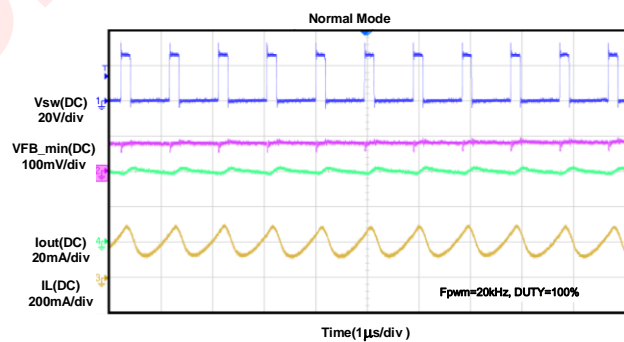
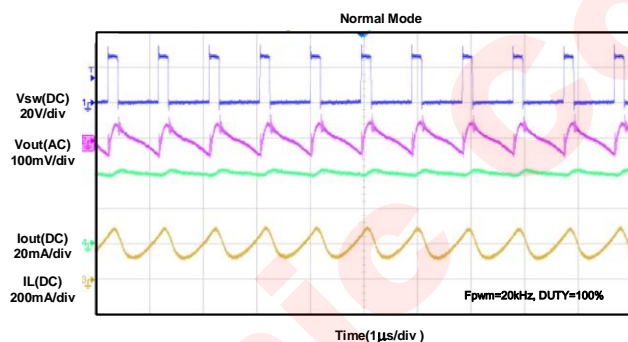
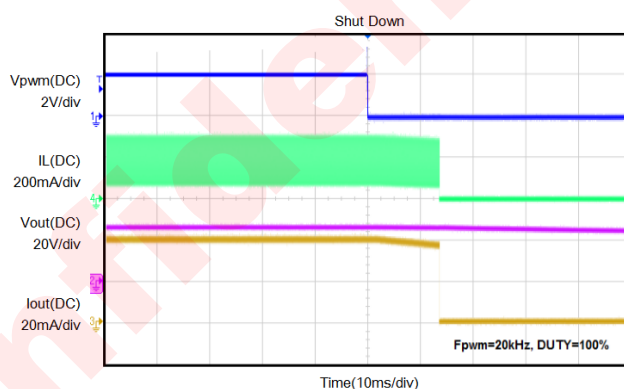
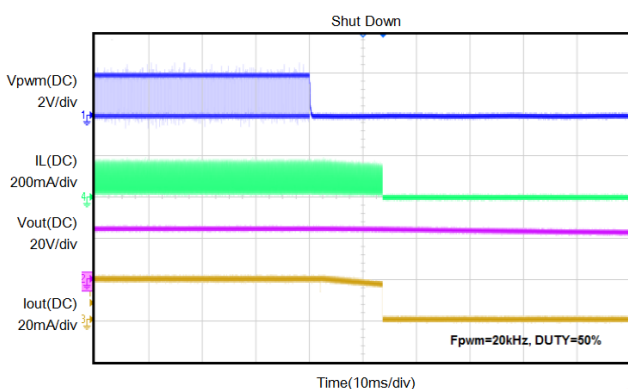
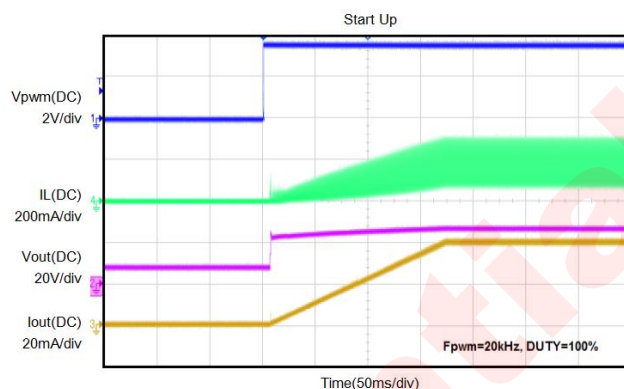
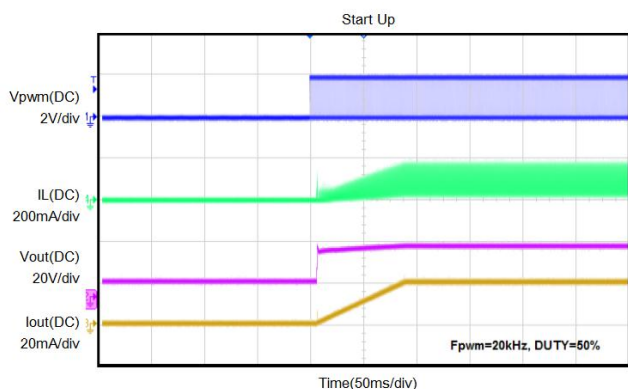
## ELECTRICAL CHARACTERISTICS

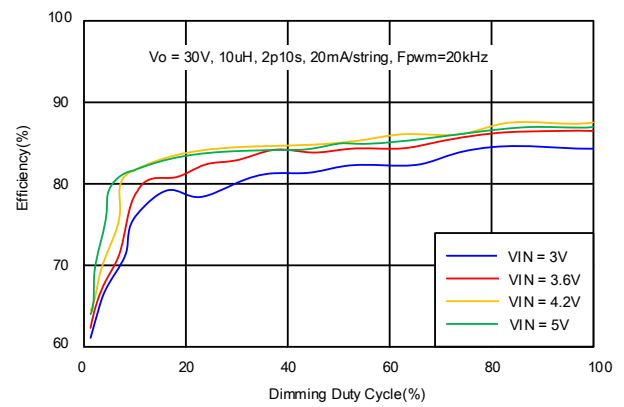
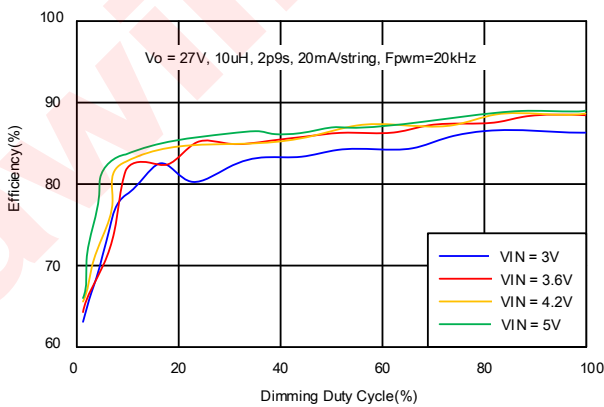
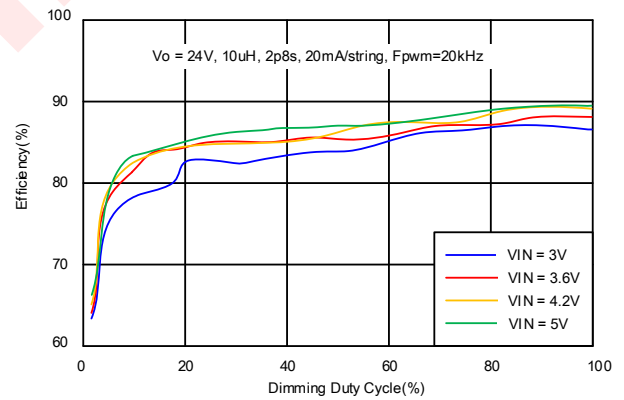
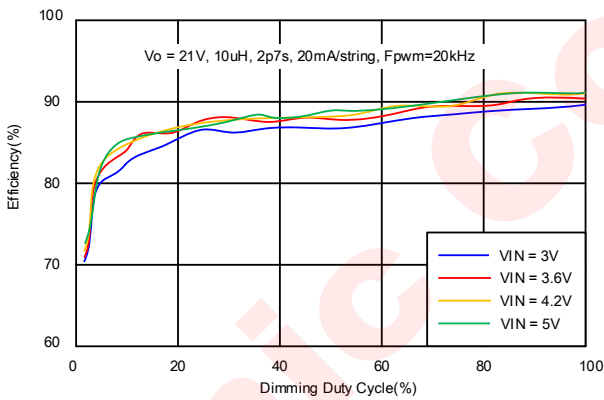
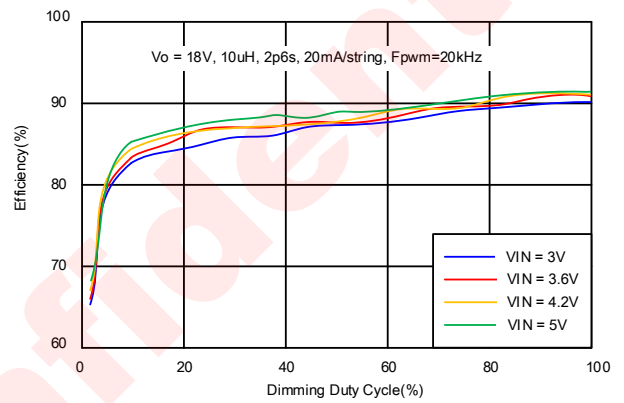
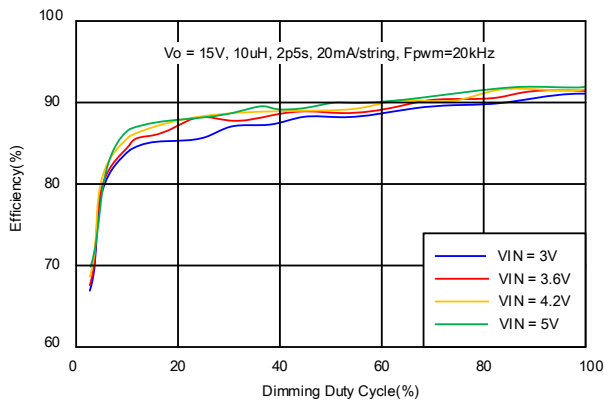
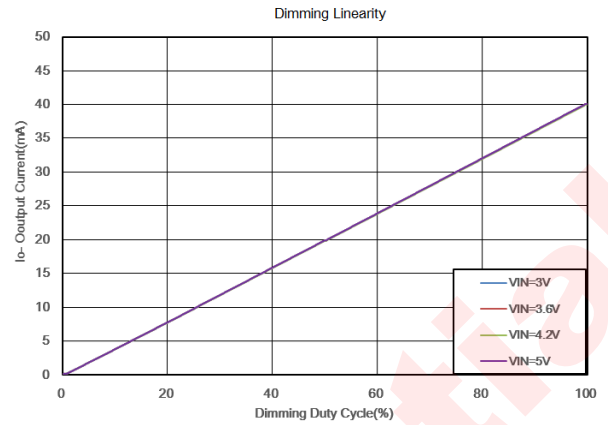
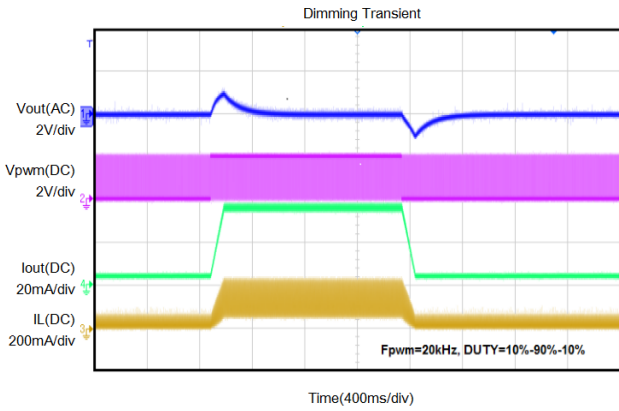
$V_{IN}=3.6V$ , EN=high, PWM=high, IFB current = 20 mA, typical values are at  $T_J = 25^{\circ}C$ (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>POWER SUPPLY</b>						
$V_{IN}$	Input voltage range		2.7		5.5	V
$V_{VIN\_UVLO}$	Under-voltage lockout voltage	$V_{IN}$ falling		2	2.2	V
		$V_{IN}$ rising			2.45	V
$V_{VIN\_HYS}$	Under-voltage lockout hysteresis			150		mV
$I_Q$	Operating quiescent current into $V_{IN}$	Device enable, switching 1MHz and no load, $V_{IN}=3.6V$		1.2		mA
$I_{SD}$	Shutdown current	EN=low		0.1	1	$\mu A$
<b>EN and PWM</b>						
$V_H$	EN pin logic high		1.5			V
$V_L$	EN pin logic low				0.3	V
$V_H$	PWM pin logic high		1.5			V
$V_L$	PWM pin logic low				0.3	V
$R_{PD}$	EN pin and PWM pin internal pull-down resistor		400	800	1600	k $\Omega$
$F_{PWM}$	PWM signal dimming frequency		10		100	kHz
$D_{PWM}$	Duty cycle of PWM signal		0.1		100	%
$t_{PWM\_SD}$	PWM logic low width to shutdown		20			ms
$t_{EN\_SD}$	EN logic low width to shutdown		2.5			ms
<b>CURRENT REGULATION</b>						
$V_{ISET\_FULL}$	ISET pin voltage	Full brightness	1.204	1.229	1.253	V
$K_{ISET\_FULL}$	Current multiplier	Full brightness		1030		
$I_{FB\_AVG}$	Current accuracy	$I_{ISET}=20\mu A, D=100\%$	-3%		3%	
$K_M$	$(I_{MAX}-I_{AVG})/I_{AVG}$	D=100%		1%		
		D=25%		1%		
$I_{IFB\_MAX}$	Current sink max output current	$I_{ISET}=35\mu A$ , each IFBx pin	30			mA
$R_{DS(on)}$	Switch MOSFET on-resistance	$V_{IN}=3.6V$		0.3		$\Omega$
		$V_{IN}=3V$		0.4		
$I_{LEAK\_SW}$	Switch MOSFET leakage current	$V_{SW}=35V, T_J=25^{\circ}C$			1	$\mu A$
$F_{SW}$	Oscillator frequency			1000		kHz
$D_{MAX}$	Maximum duty cycle	Measured on drive signal of switch MOSFET	90	95		%

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V <sub>IFB_REG</sub>	IFBx feedback regulation voltage	I <sub>FB</sub> =20mA, measured on IFBx pin which has low voltage		100		mV
<b>PROTECTION</b>						
I <sub>LIM</sub>	Switch MOSFET current limit	D=D <sub>MAX</sub>	1.5	2	2.5	A
I <sub>LIM_HALF</sub>	Switch MOSFET start up current limit	D=D <sub>MAX</sub>		0.8		A
t <sub>HALF_LIMIT</sub>	Time window for half current			5		ms
V <sub>OVP_SW</sub>	SW pin over voltage threshold			38		V
V <sub>OVP_IFB</sub>	IFBx pin over voltage threshold			4.5		V
T <sub>OTP</sub>	Thermal shutdown threshold			160		°C
T <sub>HYS</sub>	Thermal shutdown threshold hysteresis			15		°C

## TYPICAL CHARACTERISTICS







## DETAILED DESCRIPTION

### BOOST CONVERTER

The AW9963 includes a peak current mode boost regulator and 2-channel matching current sources to drive WLED arrays of LCD backlight. The full-scale LED current is programmable through a resistor.

The duty cycle of boost regulator is set by the error amplifier output and the inductor current signal applied to the PWM comparator. When duty cycle exceeds 50%, slope compensation is added to the current signal for current loop stableness .

### LED strings Unused

If only one channel is needed, user can disable the unused string by connecting its IFBx pin to ground or floating. If both IFBx pins are connected to ground, the device will not start up.

### Enable and Start-up

Either pulling EN pin low for more than 2.5ms or pulling PWM pin low for more than 20ms can disable the device to shutdown mode.

1. UVLON( $V_{IN}$  voltage is higher than  $V_{VIN\_UVLO}$  threshold),
2. Logic high on EN pin,
3. PWM signal (logic high or PWM pulses) on PWM pin.

When all above conditions are met, the AW9963 can start up and begins to check the status of IFBx pins. If one IFBx pin is detected to connect to ground, this channel will be disabled and removed from the control loop. Then the boost converter starts switching. If all IFBx pins are shorted to ground, the device will not start up.

### Soft start

When the device is enabled, the error amplifier output ramps up to the target voltage in a specific time. This ensures that the output voltage rises slowly to reduce the input inrush current.

### Full-Scale Current Program

The AW9963 can provide up to 30mA current each. The full-scale current (current when dimming duty cycle is 100%) of each channel should be programmed by an external resistor  $R_{ISET}$  at the ISET pin according to [EQUATION 1](#).

$$I_{FB\_full} = \frac{V_{ISET\_full}}{R_{ISET}} \times K_{ISET\_full} \quad (1)$$

where

- $I_{FB\_full}$ , full-scale current of each channel
- $K_{ISET\_full} = 1030$ (current mutiple when dimming duty cycle = 100%)
- $V_{ISET\_full} = 1.229$  V(ISET pin voltage when dimming duty cycle = 100%)
- $R_{ISET}$  = ISET pin resistor

### PWM Control Interface

AW9963 includes internal dimming signal duty detection circuit automatically changes the internal reference lineally to regulate the current with 10k~100kHz range PWM signal. If EN pin is connected to High, PWM pin is used to enable or disable the device. Only after both EN and PWM signals are applied, the AW9963 can start-up. Refer to [FIGURE 1](#).

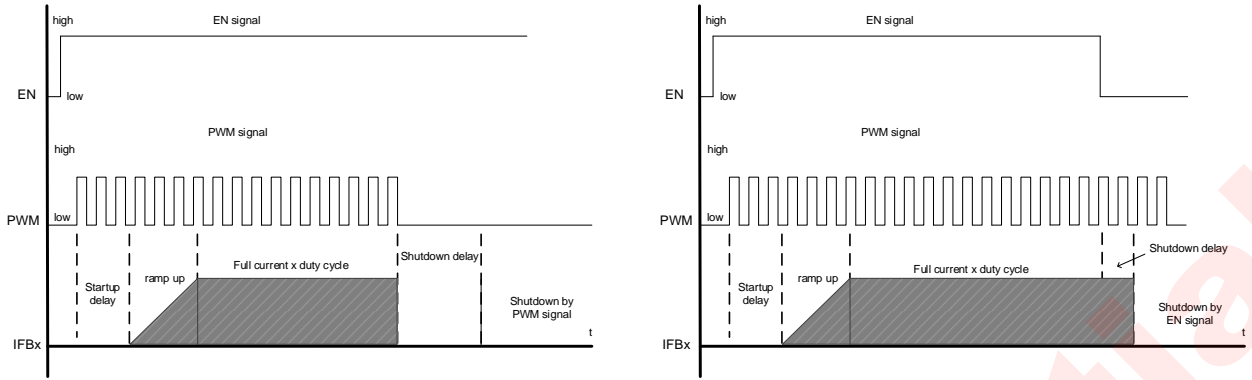


Figure 1 Control Interface Detection

When the PWM pin is high, each channel current is regulated to full scale according to [EQUATION 1](#). The relationship between the PWM duty cycle and IFBx current is given by [EQUATION 2](#).

$$I_{FBx} = I_{FB\_full} \times \text{Duty} \quad (2)$$

where

- $I_{FBx}$  is the current of each current sink
- $I_{FB\_full}$ , full-scale current of each channel
- Duty is the duty cycle information detected from the PWM signals

### Undervoltage Lockout

When the input voltage is lower than the UVLO threshold (2.0V typ.), the driver will turn off. If the input voltage rises by under-voltage lockout hysteresis, the IC restarts.

### Open LED Protection

The AW9963 auto detects the voltages at SW pin in each switching cycle. If both LED strings are open, both IFBx pins' voltages drop to ground, and the boost output voltage is increased by the control loop until reaching the SW OVP threshold  $V_{OVP\_SW}$ , the SW OVP protection circuitry is triggered, and the device is latched off.

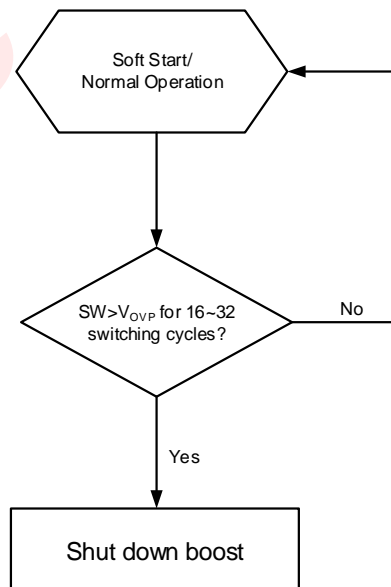


Figure 2 SW OVP Action

### IFBx Protection

The AW9963 monitors the IFBx pin voltage to judge if the short string occurs. If one string IFBx pin voltage is higher than IFBx OVP threshold  $V_{OVP\_FB}$ , then the protection circuitry is triggered.

If one LED string is open, its IFBx pin voltage drops to zero by current sink, the boost loop auto selects this pin as feedback and the boost output voltage is increased to regulate this lower IFBx voltage to the target value. For the other string, its current is still low but its IFBx voltage increases along with the output voltage. During the situation, either the SW voltage reaches OVP threshold  $V_{OVP\_SW}$  or the normal string's IFBx pin voltage reaches the IFBx OVP threshold  $V_{OVP\_FB}$ , the protection will be triggered.

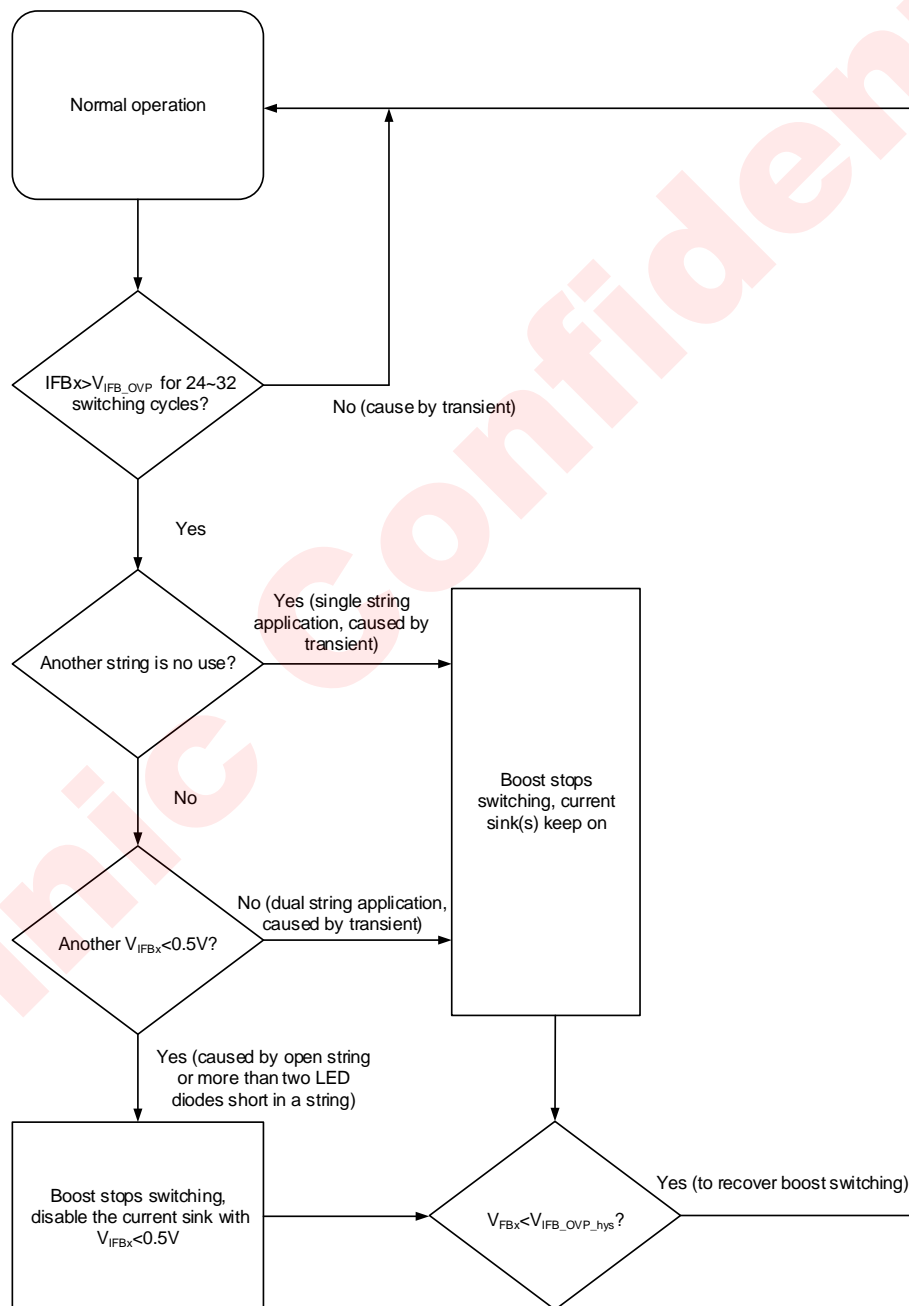


Figure 3  $V_{IFBx}$  OVP Action

### **Cycle-by-Cycle Current Limit**

AW9963 provides cycle-by-cycle current limit protection to avoid too large current. During soft start, the current limit is limit to 0.8A for around 5ms to avoid output overshoot and inrush current. After that, the current limit returns back to normal 2A.

### **Thermal Shutdown**

An internal thermal shutdown turns off the device when the typical junction temperature exceed 165°C. The device will restart when the junction temperature decreases by 15°C.

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## APPLICATION INFORMATION

### INDUCTOR SELECTION

Because the selection of inductor affects power supply's steady state operation, transient behavior, loop stability and the boost converter efficiency, the inductor is one of the most important components in switching power regulator design. There are three important inductor specifications, inductor value, DC resistance and saturation current.

The inductor DC current can be calculated as:

$$I_{IN\_DC} = \frac{V_{OUT} \times I_{out}}{V_{IN} \times \eta} \quad (3)$$

The inductor current peak to peak ripple can be calculated as

$$I_{PP} = \frac{1}{L \times F_s \times \left( \frac{1}{V_{OUT} + V_F - V_{IN}} + \frac{1}{V_{IN}} \right)} \quad (4)$$

Therefore, the peak current  $I_P$  seen by the inductor is calculated as

$$I_P = I_{IN\_DC} + \frac{I_{PP}}{2} \quad (5)$$

The inductor saturation current rating should be considered to cover the inductor peak current. Smaller size and better efficiency are the major concerns for portable devices. The inductor should have low core loss at 1000kHz and low DCR for better efficiency. For these reasons, a 4.7μH to 10μH inductor value range is recommended. A 10μH inductor optimized the efficiency for most application while maintaining low inductor peak to peak ripple. [TABLE 2](#) lists the recommended inductor for the AW9963. When recommending inductor value, the factory has considered -40% and +20% tolerance from its nominal value.

Table 2 Recommended Inductors for AW9963

Part Number	L (μH)	DCR Max (Ω)	Saturation Current (mA)	Size (L x W x H mm)	Vendor
MRSC252A10-100M-N	10	0.5	900	2.5 x 2 x 1	Chilisin
LQH3NPN100NM0	10	0.3	750	3 x 3 x 1.5	Murata
CDH3809/SLD	10	0.3	570	4 x 4 x 1.0	Sumida
LPS4018-472ML	4.7	0.125	1900	4 x 4 x 1.8	Coilcraft

### SCHOTTKY DIODE SELECTION

To optimize the efficiency, a high-speed and low reverse-recovery current Schottky diode are recommended. Make sure the diode's average and peak current ratings exceed the output average LED current and the peak inductor current. In addition, the diode's break-down voltage rating must exceed the maximum voltage across the diode. Usually, unexpected high-frequency voltage spikes can be seen across the diode when the diode

turns off. Therefore, leaving some voltage rating margin is always needed to guarantee normal long-term operation when selecting a diode. The MBR0540 and the NSR05F40 are recommended for AW9963.

## INPUT AND OUTPUT CAPACITORS SELECTION

The output capacitor keeps the output voltage ripple small and ensures feedback loop stability. This ripple voltage is related to the capacitor's capacitance and its equivalent series resistance (ESR). Assuming ESR of a capacitor is zero, the minimum capacitance needed for a given ripple can be calculated by:

$$C_{OUT} = \frac{(V_{OUT} - V_{IN}) \times I_{out}}{V_{OUT} \times F_S \times V_{ripple}} \quad (6)$$

Where,  $V_{ripple}$  represents peak-to-peak output ripple. The additional output ripple caused by ESR can be calculated as:

$$V_{ripple\_ESR} = I_{out} \times R_{ESR} \quad (7)$$

$V_{ripple\_ESR}$  can be neglected for ceramic capacitors due to its low ESR, but must be considered if tantalum or electrolytic capacitors are used.

Note that the ceramic capacitance is dependent on the voltage rating. With a DC bias voltage, the capacitance can lose as much as 50% of its value at its rated voltage rating. Leave a large enough voltage rating margin when selecting the component. Therefore, leave enough margin on the voltage rating to ensure adequate capacitance at the required output voltage.

An X5R or X7R capacitor of 10 $\mu$ F is recommended for input side. The output requires a X5R or X7R capacitor in the range of 0.47 $\mu$ F to 4.7 $\mu$ F. A 100nF capacitor and a 33 pF capacitor are recommended to use in parallel with the input capacitor and the output capacitor to suppress high frequency noise.

The output capacitor affects the loop stability of the boost regulator. If the output capacitor is below the range, the boost regulator can potentially become unstable.

Note that capacitor degradation increases the ripple much. Select the capacitor with 50V rated voltage to reduce the degradation at the output voltage. If the output ripple is too large, change a capacitor with less degradation effect or with higher rated voltage could be helpful.

## POWER DISSIPATION

The maximum IC junction temperature should not be exceed 125°C under normal operating conditions. This restriction limits the power dissipation of the AW9963. It is recommended to keep the actual dissipation less than or equal to  $P_{D(max)}$ . The maximum-power-dissipation limit is determined by using the following equation:

$$P_{D(max)} = \frac{T_{Jmax} - T_A}{\theta_{ja}}$$

Where,  $T_{Jmax}$  is the Maximum Junction Temperature,  $T_A$  is the maximum ambient temperature for the application.  $\theta_{ja}$  is the thermal resistance junction-to-ambient given in Power Dissipation Table.

The  $\theta_{ja}$  of the DFN package greatly depends on the PCB layout and thermal pad connection. The thermal pad must be soldered directly to the analog ground on the PCB. After soldering, the PCB can be used as a heat sink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane, or alternatively, can be attached to a special heat sink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit(IC).

Using thermal vias underneath the thermal pad as illustrated in the layout example.

## PCB LAYOUT CONSIDERATION

PCB layout is an important design step for those high frequency, high current switching power regulators in order to minimize noise and keep loop stable. To reduce switching losses, it is better to make the SW pin rise and fall times as short as possible. Minimizing the length and area of all traces connected to the SW pin and using a ground plane under the switching regulator are strongly recommended to minimize inter-plane coupling. The input capacitor should be very close to the IC to get the best decoupling. The path of the inductor, schottky diode and output capacitor should be kept as short as possible to minimize noise and ringing. FB is a sensitive node and it should be kept separate from the SW pin in the PCB layout.

Connect the exposed paddle to the PCB ground plane using at least two vias. The input and the output bypass capacitors should be placed as close to the IC as possible. Minimize trace lengths between the IC and the inductor, the diode and the output capacitor; keep these traces short, direct, and wide.

### Additional Application Circuits

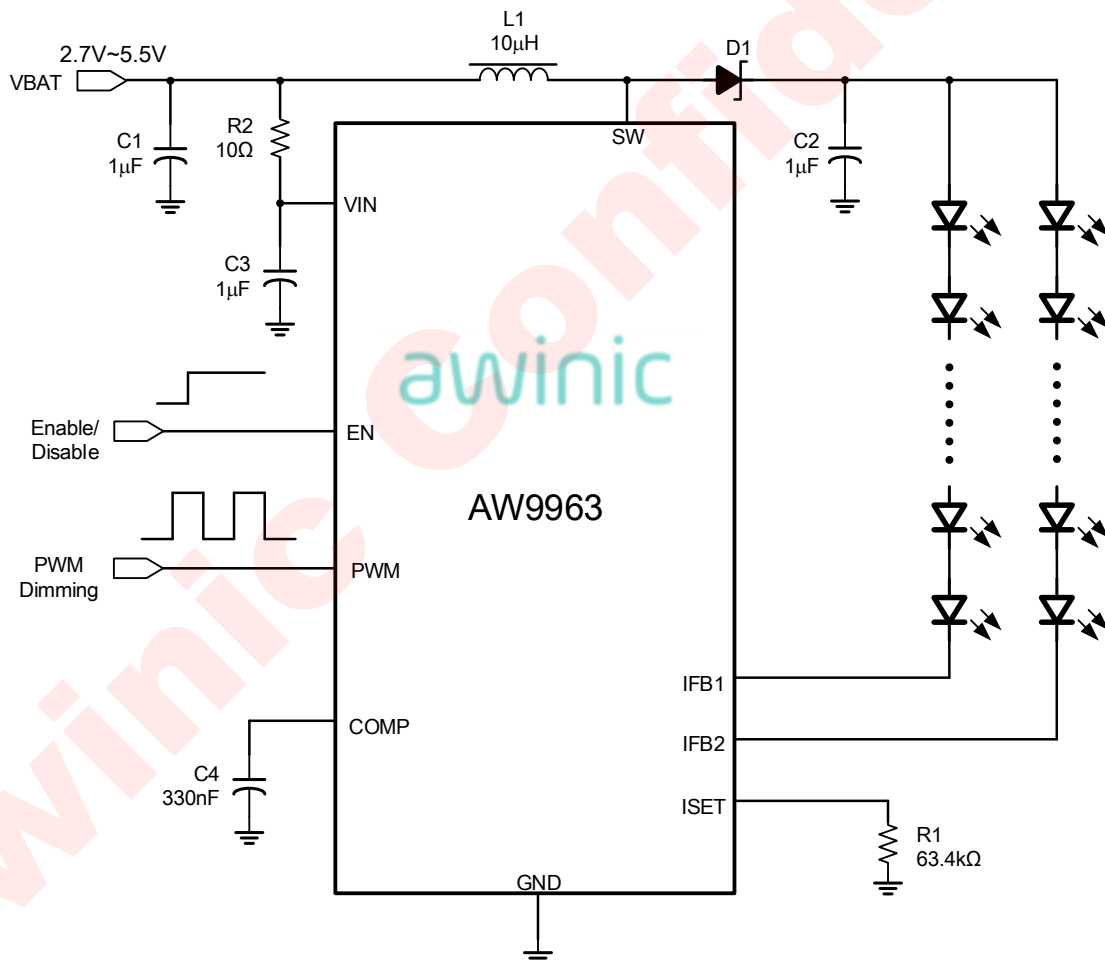
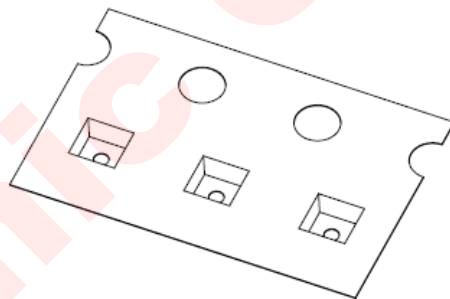
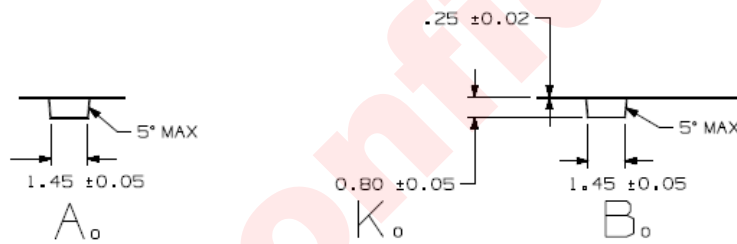
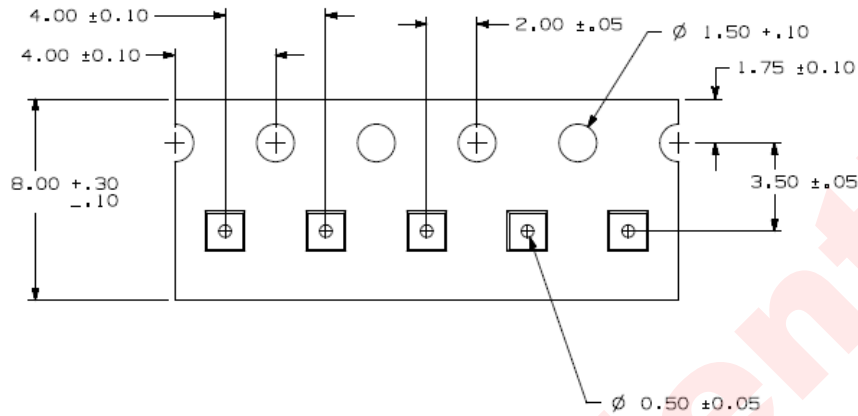


Figure 4 AW9963 Typical Application

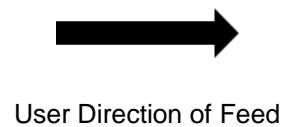
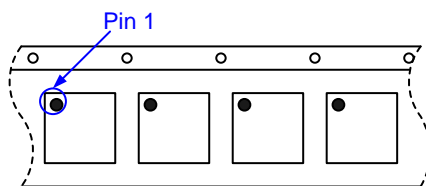
## TAPE AND REEL INFORMATION

### Carrier Tape



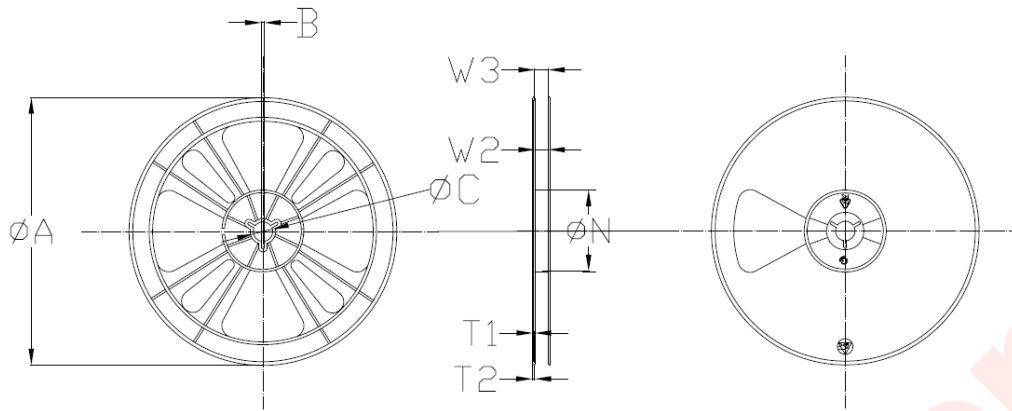
Unit: mm

### Pin 1 direction





Reel



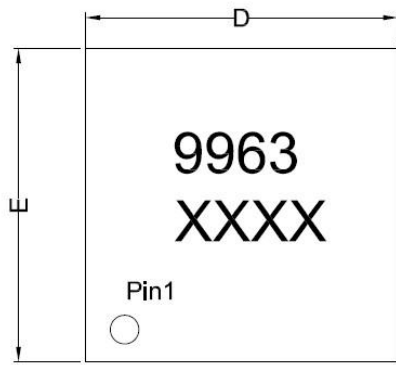
Item	Value&Tolerance
A	179±1.0
B	2.0±0.1
C	13.5±0.2
N	54.8±0.2
W2	9.0±0.2
W3	9.2±1.0
T1	1.2±0.2
T2	1.5±0.2

Note:

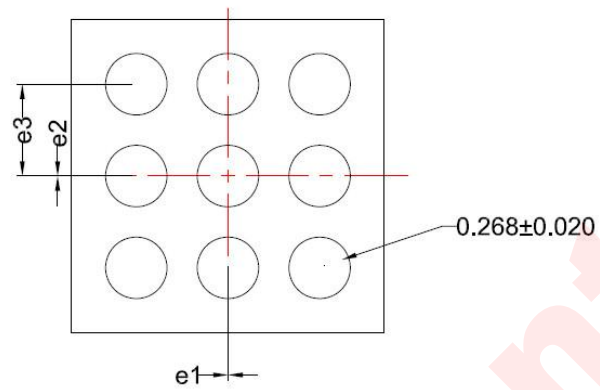
1. surface resistivity:  $10^5$  to  $10^{11}$  ohms/sq.
2. Restriction criterion of hazardous substance for packing material follow GP-M001.

Unit: mm

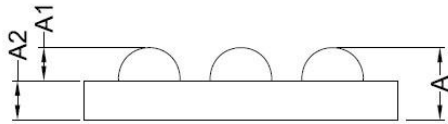
PACKAGE DESCRIPTION



Top View



Bottom View



Side View

Symbol	NOM	Tolerance
A	0.585	±0.045
A1	0.195	±0.020
A2	0.390	±0.025
D	1.360	±0.025
E	1.360	±0.025
e1	0	NA
e2	0	NA
e3	0.400	NA

Unit: mm

## REVISION HISTORY

Vision	Date	Change Record
V1.0	June 2017	Datasheet V1.0 Released
V1.1	January 2018	1. Added ORDERING INFORMATION 2. Added TAPE AND REEL INFORMATION 3. Added User Direction of Feed 4. Added Reflow
V1.2	December 2018	5. Added Unit
V1.3	January 2019	6. Correct some description.

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