APW7500

24V Buck with 1.6A Current Source for IR-LED Driver

Features

- **Wide range input is from 4.5V to 24V**
- **Synchronous Buck Converter.**
- **200uS Soft-start Time.**
- **1MHz Switching Frequency.**
- **Support 5 KHz Dimming.**
- **Adjustable LED1/2 Current Source 0.1A to 0.8A by I2C Register Setting**
- **±5% ILED1/2 Current Source Accuracy**
- **Thermal Shutdown Protection**
- **Available in WLCSP1.42x1.52-12**
- **Lead Free Green Devices Available (RoHS Compliant)**

General Description

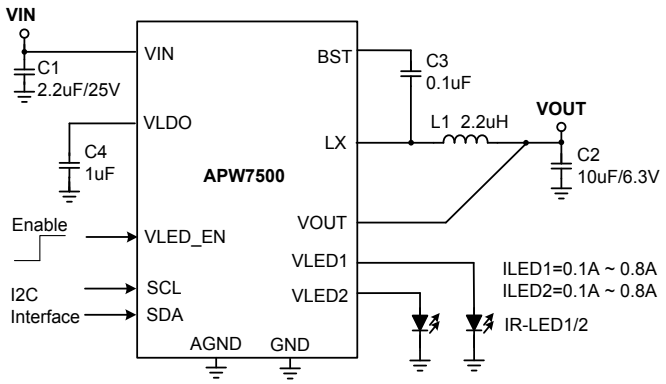
The APW7500 is 1MHz buck converter with a 7-bit current DAC to provide a well regulated current source for IR_LED application.

The APW7500 owns wide range input voltage is from 4.5V to 24V adjustment and 2 channels output current source for IR_LED, the current source can be from 100mA change to 800mA by I2C interface control.

The APW7500 integrates protections such as over voltage, under voltage and current limit of buck converter output. The VLED1/2 has under voltage protection only. In addition; The APW7500 has over-temperature protection. When the buck converter output is overloaded or short circuited, the device limits the current at a safety level to prevent catastrophic failure. The over-temperature protection shuts down the device when junction temperature reaches 150°C and will automatically resume operating when junction temperature cools down by 30°C.
The cathode of the flash LED is referenced to GND, which Improves thermal performance.

The APW7500 is available in WLCSP1.42x1.52-12 package.

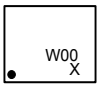
Simplified Application Circuit



Applications

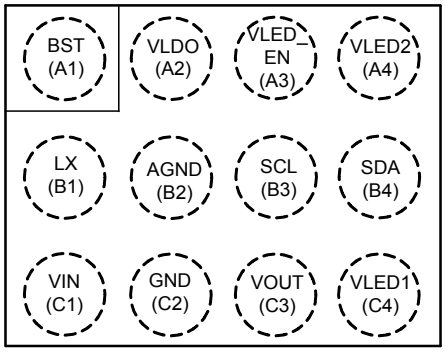
- **IR-LED Driver**

Ordering and Marking Information

APW7500 □□□-□□□ Assembly Material Handling Code Temperature Range Package Code	Package Code HA: WLCSP 1.42x1.52- 12 Operating Ambient Temperature Range I : -40 to 85°C Handling Code TR : Tape & Reel Lead Free Code L : Lead Free Device G : Halogen and Lead Free Device
APW7500 HA : 	X - Date Code

Note: ANPEC lead-free products contain molding compounds/die attach materials and 100% matte tin plate termination finish; which are fully compliant with RoHS. ANPEC lead-free products meet or exceed the lead-free requirements of IPC/JEDEC J-STD-020D for MSL classification at lead-free peak reflow temperature. ANPEC defines "Green" to mean lead-free (RoHS compliant) and halogen free (Br or Cl does not exceed 900ppm by weight in homogeneous material and total of Br and Cl does not exceed 1500ppm by weight)

Pin Configuration



WLCSP1.42x1.52-12
Top View

Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Rating	Unit
V_{IN}	VIN Supply Voltage (VIN to PGND)	-0.3 ~ 27	V
V_{BST}	BST to LX Voltage	-0.3 ~ 6	V
	BST to GND Voltage > 20ns pulse width	-0.3 ~ VIN+VLDO	V
V_{LX}	LX to GND Voltage > 20ns pulse width	-0.3 ~ VIN+0.3	V
$V_{I/O}$	LX to BST, VLDO, VLED_EN, VLED1, VLED2, SCL, SDA to GND	-0.3 ~ 6	V
V_{GND}	AGND to GND	-0.3 ~ +0.3	V
T_J	Junction Temperature	150	°C
T_{STG}	Storage Temperature	-55 ~ 150	°C
T_{SDR}	Maximum Lead Soldering Temperature(10 Seconds)	260	°C

Note 1: Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under” recommended operating conditions” is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability

Thermal Characteristics

Symbol	Parameter	Typical Value	Unit
θ_{JA}	Junction-to-Ambient Resistance in free air (Note 2)	160	°C/W

Note 2: θ_{JA} is measured with the component mounted on a high effective thermal conductivity test board in free air

Recommended Operating Conditions (Note 3)

Symbol	Parameter	Range	Unit
V_{IN}	Input Supply Voltage	4.5 ~ 24	V
I_{LED}	LED Current	0.1 ~ 1.6	A
C_{IN}	Converter Input Capacitor (MLCC)	2.2~	uF
C_{OUT}	Output Capacitor (MLCC)	10~	uF
C_{LDO}	LDO Output Capacitor (MLCC)	1~	uF
L	Inductor	2.2	uH
T_A	Ambient Temperature	-20 ~ 85	°C
T_J	Junction Temperature	-20 ~ 125	°C

Note 3: Refer to the typical application circuit

Electrical Characteristics

Unless otherwise specified, these specifications apply over V_{IN}=12V and VLED_EN=3.3V,T_A= -40 to 85°C. Typical values are at T_A=25°C

Symbol	Parameter	Test Condition	APW7500			
			Min.	Typ.	Max.	Unit
V_{IN}	Input Voltage Range		4.5	-	24	V
LDO Voltage						
V_{LDO}	LDO Voltage Regulation Output	V_{IN}=12V,VLED_EN=High	4.9	5	5.1	V
Supply Current						
I_{SD}	VIN shutdown current	VLED_EN=Low	-	10	30	uA
I_{STB}	VIN Standby Current	V_{IN}=12V,VLED_EN=High,Setting OK=0	-	200	-	uA
Power On Reset (POR)						
V_{IN-POR}	VIN Power On Reset Level	VLED_EN=high , VIN Rising	-	4.2	-	V
$V_{IN\_POR\_HYS}$	POR Hysteresis	VLED_EN=high , VIN Falling	-	0.2	-	V
Power Switch						
F_{SW}	Switching Frequency		0.75	1	1.25	MHz
	High side FET on-resistance	V_{IN}=12V, L_X=0.5A	-	220	264	mΩ
	Low side FET on-resistance	V_{IN}=12V L_X=0.5A	-	150	180	mΩ
T_{SS}	Soft start time	VOUT=0 to 90%	-	200	-	us
D_{MAX}	Maximum converter's duty		90	94	-	%
I_{LX_LEK}	LX pin leakage current	V_{IN}=12V, LX pin to 12V	-	-	1	uA
Boostrap Diode						
V_{BST}	Boostrap forward voltage	V_{VLDO}-V_{BOOT}, I_{BOOT}=10mA, T_A=25°C	-	0.1	0.3	V
	Reverse leakage current	V_{BOOT}=30V, V_{LX}=25V, V_{VLDO}=5V, T_A=25°C	-	-	0.9	uA
LED_EN Input						
$V_{LED\_EN\_H}$	VLED_EN rising threshold voltage	VLED_EN rising, $V_{IN,}$=4.5V ~ 24V	1.5	-	-	V
$V_{LED\_EN\_L}$	VLED_EN falling threshold voltage	VLED_EN falling, V_{IN}=4.5V ~ 24V	-	-	0.4	V
	Pull down resistance at VLED_EN pin		-	100	-	KΩ
LED Driver						
I_{LED1}	Current source 1	0x00:001_1001=350mA (Default)	332.5	350	367.5	mA
I_{LED2}	Current source 2	0x00:001_1001=350mA (Default)	332.5	350	367.5	mA
V_{OS}	Current source offset voltage (VOUT-VLED1/2)	0x00:001_1001=350mA,T_A=25°C	-	200	-	mV
T_{RAMP_UP}	LED current ramp up time	STEP=10mA, Default=4us	-	2.5	-	mA/us
T_{RAMP_DOWN}	LED current rap down time		-	10	-	Us
Protection						
I_{LIM}	High side FET switch current limit	V_{IN}=12V	3	3.5	-	A
T_{OTP}	Thermal shutdown threshold	T_J Rising	-	150	-	°C
	Thermal shutdown hysteresis	T_J Falling	-	30	-	°C
OVP	VOUT over voltage protection	V_{IN}=12V, VOUT rising	-	4.5	-	V
UVP	VOUT under voltage protection	Hiccup, V_{IN}=12V,VOUT falling	-	70	-	%
T_{UVP_DEB}	VOUT UVP debounce time	Hiccup, V_{IN}=12V,VOUT < 70%*VREF	-	20	-	uS
V_{UVP_LED}	VLED under voltage protection	Hiccup, V_{IN}=12V,VLED Falling	-	1	-	V
$T_{UVP\_LED\_DEB}$	LED driver UVP debounce time	Hiccup, V_{IN}=12V,VLED < 0.7V	-	20	-	uS

Electrical Characteristics (Cont.)

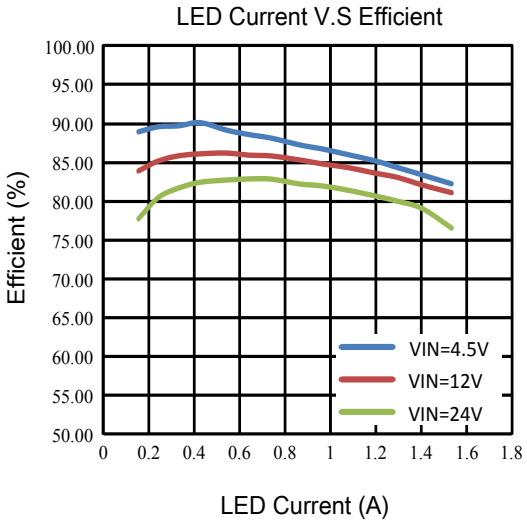
Unless otherwise specified, these specifications apply over V_{IN}=12V and VLED_EN=3.3V,T_A= -40 to 85°C. Typical values are at T_A=25°C

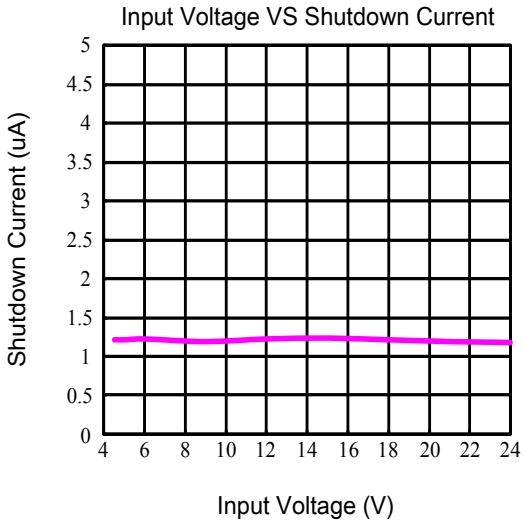
Symbol	Parameter	Test Condition	APW7500			
			Min.	Typ.	Max.	Unit
I²C INTERFACE						
	Consumption Current	Standby Mode	-	100	150	uA
	Input Capacitance	SDA, SCL	-	5	-	pF
V_{IL}	Input Low Voltage	SDA, SCL	-	-	0.4	V
V_{IH}	Input High Voltage	SDA, SCL	1.5	-	-	V
F_{SCL}	SCL Frequency		-	-	400	kHz
t_{HIGH}	SCL High Time		600	-	-	nS
t_{LOW}	SCL Low Time		1300	-	-	nS
t_R	SDA, SCL Rise Time	C_{BUS} = Total Bus Line Capacitance (pF)	20+	-	300	nS
			$10xC_{BUS}$			nS
t_F	SDA, SCL Fall Time	C_{BUS} = Total Bus Line Capacitance (pF)	20+	-	300	nS
			$10xC_{BUS}$			nS
$t_{HD:STA}$	START Hold Time	10% of SDA to 90% of SCL	600	-	-	nS
$t_{SU:STA}$	START Setup Time		600	-	-	nS
$t_{HD:DAT}$	Data Input Hold Time		100	-	-	nS
$t_{SU:DAT}$	Data Input Setup Time		100	-	-	nS
$t_{SU:STO}$	STOP Setup Time		600	-	-	nS
t_{BUF}	Bus Free Time		1300	-	-	nS
	Input Spike Suppression	SDA, SCL	-	-	50	nS
$t_{TIMEOUT}$	SDA Reset Low Time (note 5)		-	-	50	mS

Pin Descriptions

Pin	Pin Name	Description
A1	BST	High Side Gate Driver Boost Input.
A2	VLDO	For digital circuit and anlong circuit power.
A3	VLED_EN	Enable Pin Control. This pin is high level enables devices.
A4	VLED2	Current source2 output pin to drive external LED(s). Connect the anode of LED(s) to LED pin.
B1	LX	Power Switch Note Of Buck Converter.
B2	AGND	Analog Ground.
B3	SCL	I2C Serial Clock Input.
B4	SDA	I2C Serial Data Input/Output.
C1	VIN	Input Supply Voltage.
C2	GND	Power Stage Ground.
C3	VOUT	Buck converter's feedback pin. Connect this pin to the output of buck converter for voltage regulation.
C4	VLED1	Current source1 output pin to drive external LED(s). Connect the anode of LED(s) to LED pin.

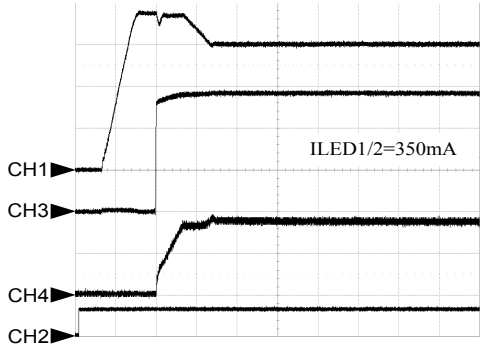
Typical Operating Characteristics





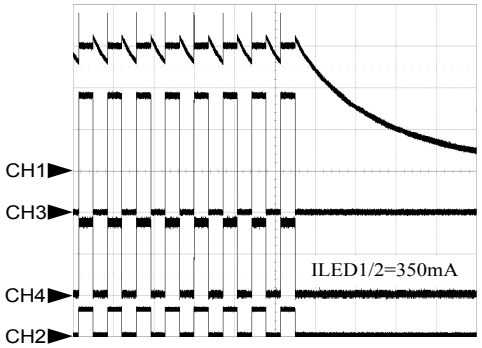
Operating Waveforms

Power On VLED_EN



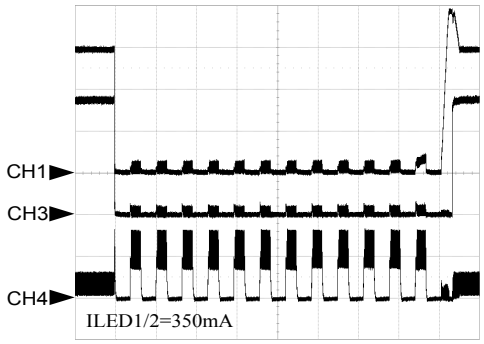
CH1:V_{OUT} -1V/div
CH2:V_{LED_EN}-5V/div
CH3:V_{LED1}-1V/div
CH4:I_{LED1}-200mA/div
Time:200us/div

Power Off VLED_EN



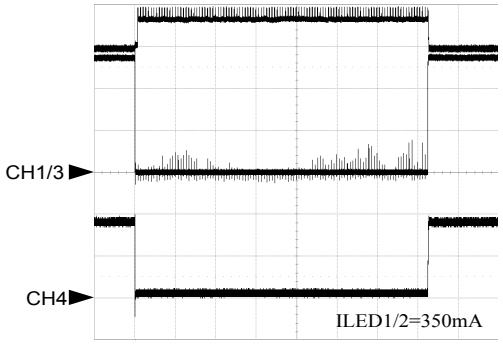
CH1:V_{OUT}-1V/div
CH2:V_{LED_EN}-5V/div
CH3:V_{LED1}-1V/div
CH4:I_{LED1}-200mA/div
Time:200ms/div

VOUT Shorted to GND



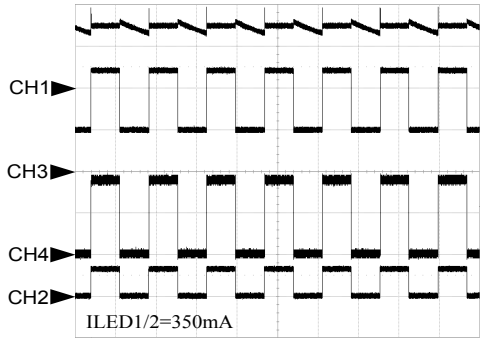
CH1:V_{OUT}-1V/div
CH2:-
CH3:V_{LED1}-1V/div
CH4:I_L-2A/div
Time:1ms/div

VLED1 Shored to GND



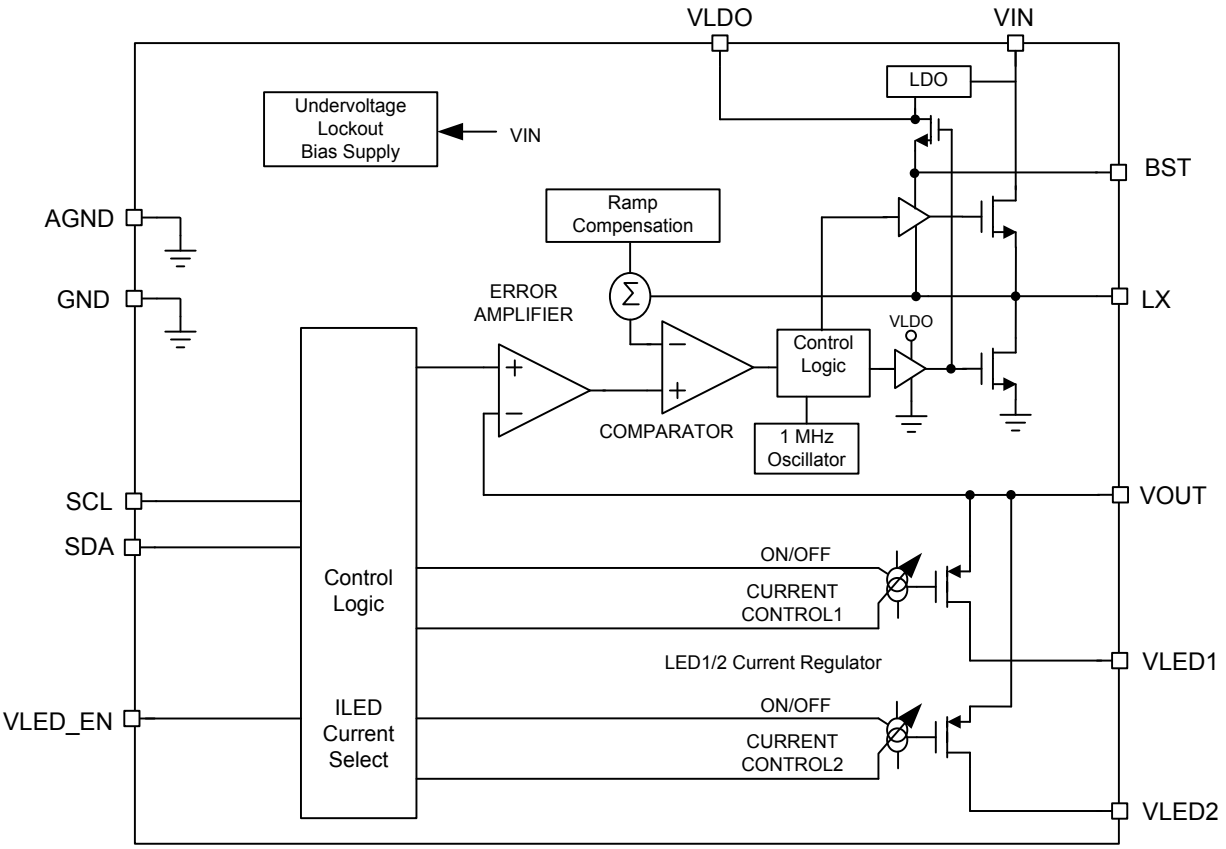
CH1:V_{OUT}-1V/div
CH2:-
CH3:V_{LED1}-1V/div
CH4:I_{LED1}-200mA/div
Time:10ms/div

Normal Operation
(VLED_EN Duty=7Hz/50%)



CH1:V_{OUT}-2V/div
CH2:V_{LED_EN}-5V/div
CH3:V_{LED1}-2V/div
CH4:I_{LED1}-200mA/div
Time:100ms/div

Block Diagram



Typical Application Circuit

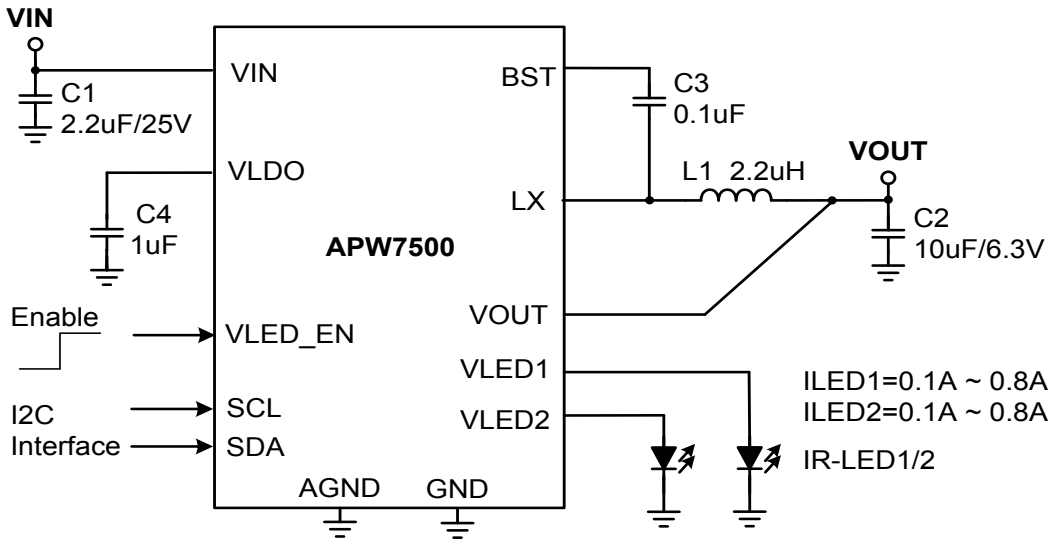


Figure 1: for independent LED application

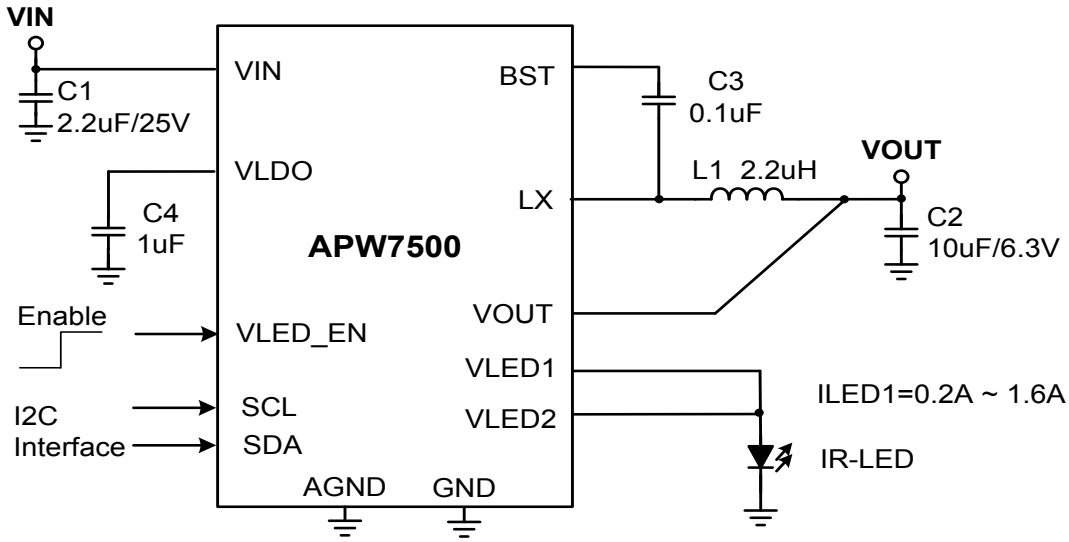


Figure 2: for parallels LED application

Function Descriptions

Power sequence and power on reset (POR)

The APW7500 integrates MOSFET of buck converter and 2 channels LED driver and wide input voltage range.

The APW7500 using power sequence as below figure 1:

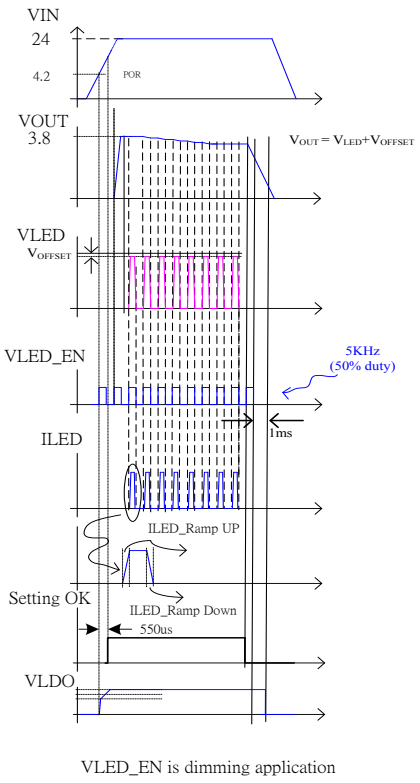


Figure 1

The APW7500 must have three conditions established the IC can be working, first and 2'nd condition is VIN voltage exceeds input POR level and VLED_EN have high level, 3'rd condition is "setting OK" signal was go to "1" . As above condition have any one condition is not exist then IC is shutdown or standby status. At this time, when VIN reached to 2.7V and LED_EN existing then the I2C commend can be reading / writing after must waiting LDO voltage build up to finished. (When the VLED_EN signal is to high level, it must wait for 550us before setting OK signal.)
When the APW7500 was normal operation status occur VLED_EN signal was low to more than 1ms then LED output current and buck converter will be turned off.

Current limit and Hiccup

The IC monitors the current through the high-side power MOSFET to limits the peak inductor current to prevent IC from being damaged in the event of an overload or short circuit. When the current limit protection is activated, the output current will be limited and the output voltage will drop. When the output voltage drops below the UVP threshold, UVP is triggered and the converter enters hiccup mode. In hiccup mode, the converter will restart periodically. This protection mode is especially useful when the output is shorted to ground. The average short-circuit current is greatly reduced to alleviate thermal issues and protect the IC. Once the over current condition is removed, the IC will exit the hiccup mode. The current limit value is 3.5A (typ).

Over voltage protection

The output voltage should increase over 4.5V (typ) of the reference voltage due to the high-side MOSFET failure or for other reasons, and the over voltage protection will force the low-side MOSFET gate driver to be high. This action actively pulls down the output voltage. When the OVP occurs, it's latch-off the converter. Once an over-voltage fault condition is set, toggling power-on-reset signal can only reset it.

Under voltage protection

In the operational process, if a short circuit occurs, the output voltage will drop quickly. Before the current-limit circuit responds, the output voltage will fall out of the required regulation range. The under-voltage continually monitors the FB voltage after soft-start is completed. If a load step is strong enough to pull the output voltage lower than the under-voltage threshold, the IC output will be hiccup mode.

Over-Temperature Protection (OTP)

The over-temperature circuit limits the junction temperature of the APW7500. When the junction temperature exceeds T_J =+150°C, a thermal sensor turns off the power MOSFET, allowing the device to cool down. The thermal sensor allows the converter to start a start-up process and regulate the output voltage again after the junction temperature cools by 30°C.

ILED Current Source

The address 0x00 bit [6:0] is setting ILED current, the current is from 100mA change to 800mA of ILED1 and ILED2.

Address	Bit	Name	Description
00h	[6:0]	ILED Source Current	Note

Note:
Bit [6:0] =000_0000: 100mA.
Bit [6:0] =000_0001: 110mA.
…
Bit [6:0] =001_1001: 350mA. (Default)
…
Bit [6:0] =100_0101: 790mA.
Bit [6:0] =100_0110: 800mA.
When LED current is normal operation, Suggestion the ILED current registers can't adjustment.

Function Descriptions (Cont.)

Setting OK Signal

The address 0x00 bit [7] is setting Buck converter and current source drivers whether normal operation.

Address	Bit	Name	Description
00h	[7]	Setting OK	Note

Bit [7] =0: it cannot normal operation output. (Default)
Bit [7] =1: it cans normal operation output.

When the bit is enabling after this bit are not unable shut off buck converter output and LED drivers.

ILED Ramp-up time

The address 0x01 bit [1:0] is setting ILED current ramp-up time, ramp up time adjustment range is 10mA/1us to 10mA/8us.

Address	Bit	Name	Description
01h	[1:0]	ILED ramp up time	Note

Note:
Bit [1:0] =00: 10mA/1us.
Bit [1:0] =01: 10mA/2us.
Bit [1:0] =10: 10mA/4us. (Default)
Bit [1:0] =11: 10mA/8us.

Enable setting

The address 0x02 bit [1:0] is setting devices enable method.

Address	Bit	Name	Description
02h	[1]	EN_HW	Note
02h	[0]	EN_SW	Note

Note:
Bit [1] =0: ILED source control by I2C register.
Bit [1] =1: ILED source control by external EN pin. (Default)

Bit [0] =0: Disable. (Default)
Bit [0] =1: Enable.
When 0x02 bit [1] is setting to 0 then 0x02 bit [0] can use.

VOUT to VLED offset voltage selection

The address 0x02 bit [2] is selection between VOUT to VLED voltage. The range is 200mV to 400mV.

Address	Bit	Name	Description
02h	[2]	Offset Voltage Selection	Note

Bit [2] =0: 200mV.
Bit [2] =1: 400mV.

When LED current setting was more than 400mA then VOUT to VLED offset voltage suggestion setting to 400mV level.

Product Version

The address 0x03 bit [2:0] is devices version, its monitor the device status.

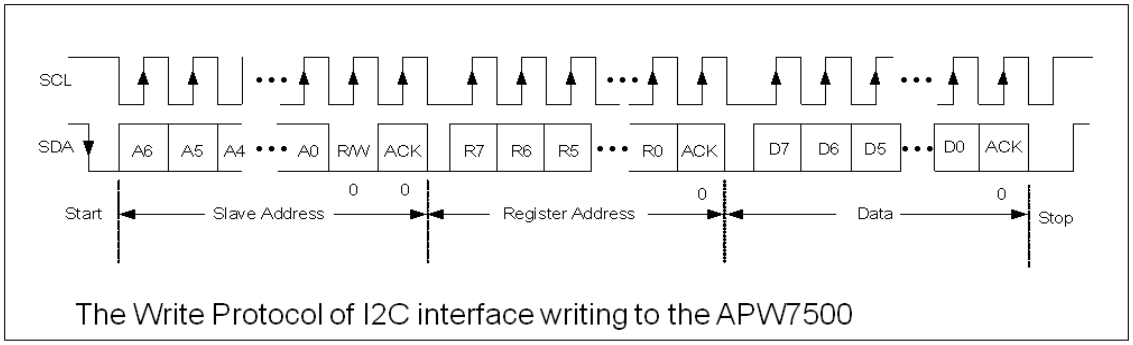
Address	Bit	Name	Description
03h	[2:0]	Product version	Note

Bit [2:0] =000: Version A.
Bit [2:0] =001: Version B.
…
Bit [2:0] =110: Version G.
Bit [2:0] =111: Version H.

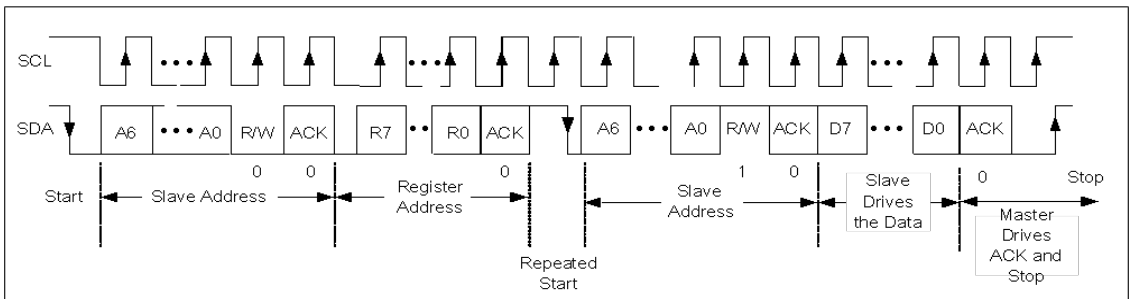
Function Descriptions (Cont.)

I²C Programming

The APW7500's I²C slave address is a hard-coded 7 big address 0000100. The APW7500 supports the following write and read protocol.



The Write Protocol of I2C interface writing to the APW7500



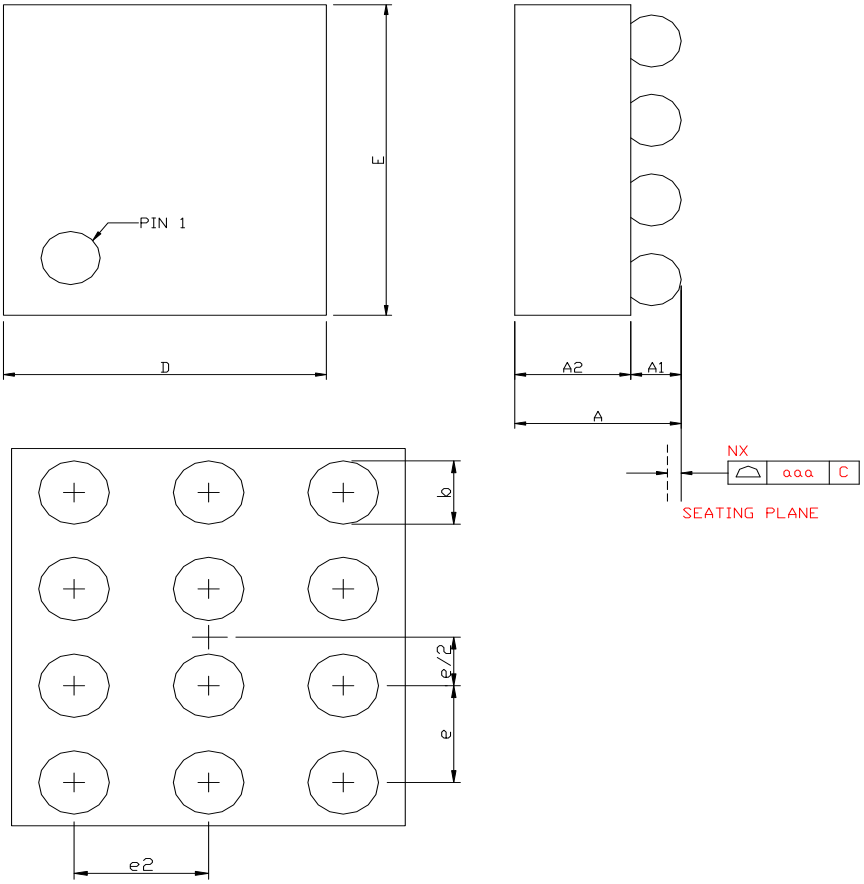
The Read Protocol of I2C interface writing to the APW7500

Register Map

Register Address(HEX)	Name	D7	D6	D5	D4	D3	D2	D1	D0
00	ILED Source Current	Setting OK	ILED6	ILED5	ILED4	ILED3	ILED2	ILED1	ILED0
01	ILED Ramp Up Time	-	-	-	-	-	-	RUT1	RUT0
02	Control Logic	-	-	-	-	-	Offset Setting	EN_HW	EN_SW
03	Product Version	-	-	-	-	-	VER2	VER1	VER0

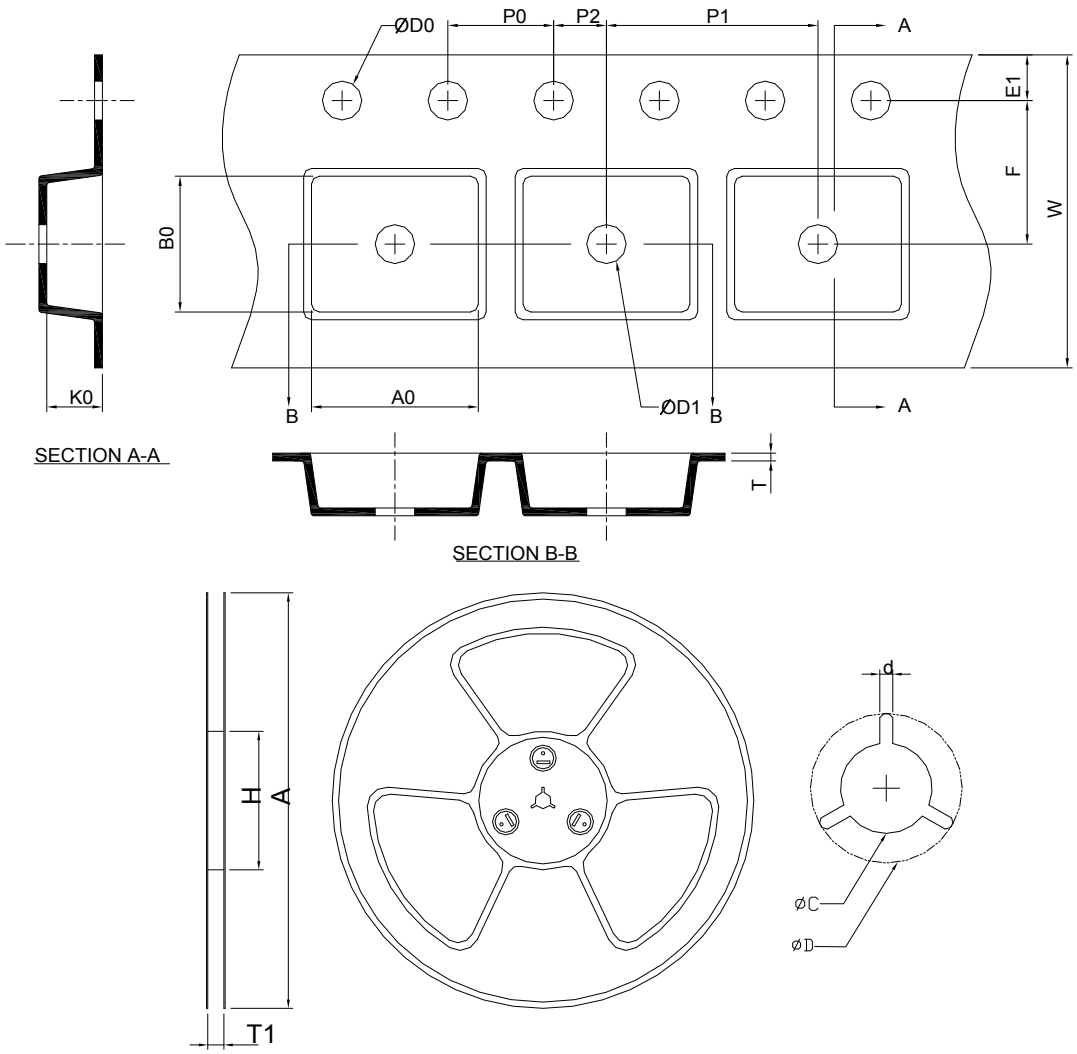
Package Information

WLCSP 1.42x1.52-12



SYMBOL	WLCSP1.42x1.52-12			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A		0.57		0.023
A1	0.18	0.22	0.007	0.009
A2	0.28	0.33	0.011	0.013
b	0.20	0.30	0.008	0.012
D	1.42	1.50	0.056	0.058
E	1.52	1.60	0.060	0.062
e	0.40 BSC		0.016 BSC	
e2	0.50 BSC		0.020 BSC	
aaa	0.05		0.002	

Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
WLCSP1.42x1.52	178.0±2.00	50 MIN.	8.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	8.0±0.30	1.75±0.10	3.5±0.05
	P0	**P1**	**P2**	**D0**	**D1**	**T**	**A0**	**B0**	**K0**
	4.0±0.10	4.0±0.10	2.0±0.05	1.5+0.10 -0.00	0.5 MIN.	0.6+0.00 -0.45	1.79±0.20	1.58±0.20	0.63±0.20

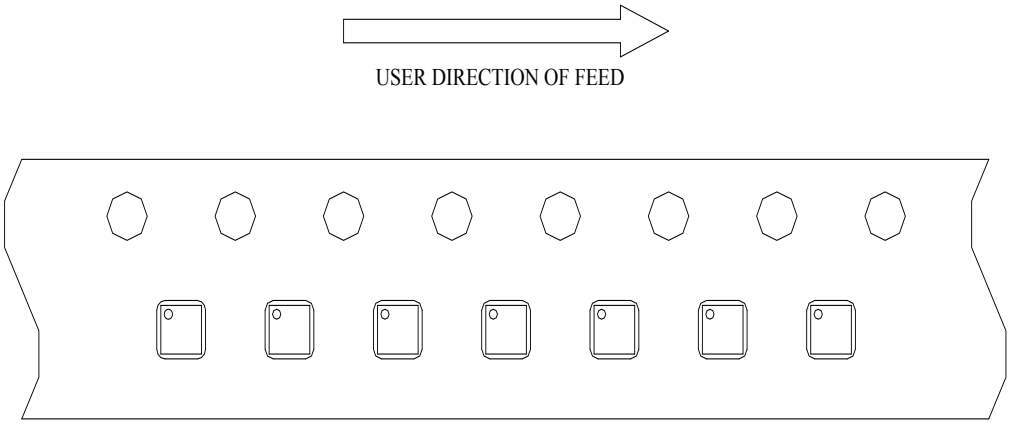
(mm)

Devices Per Unit

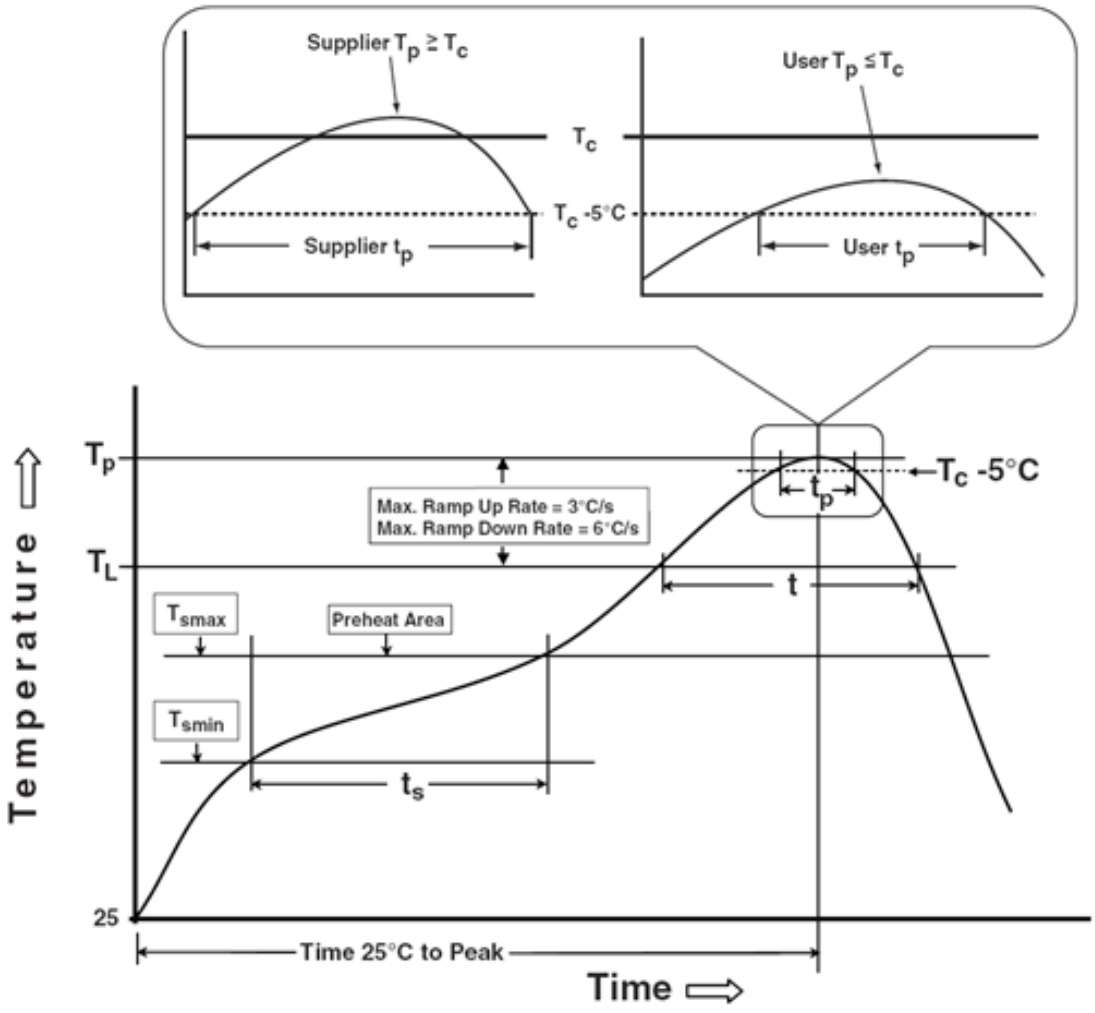
Application	Packing	Devices Per Reel
WLCSP(1.42x1.52)	Tape & Reel	3000

Taping Direction Information

WLCSP 1.42x1.52-12



Classification Profile



Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Preheat & Soak Temperature min (T_{smin}) Temperature max (T_{smax}) Time (T_{smin} to T_{smax}) (t_s)	100 °C 150 °C 60-120 seconds	150 °C 200 °C 60-120 seconds
Average ramp-up rate (T_{smax} to T_P)	3 °C/second max.	3°C/second max.
Liquidous temperature (T_L) Time at liquidous (t_L)	183 °C 60-150 seconds	217 °C 60-150 seconds
Peak package body Temperature (T_p)*	See Classification Temp in table 1	See Classification Temp in table 2
Time (t_P)** within 5°C of the specified classification temperature (T_c)	20** seconds	30** seconds
Average ramp-down rate (T_p to T_{smax})	6 °C/second max.	6 °C/second max.
Time 25°C to peak temperature	6 minutes max.	8 minutes max.
* Tolerance for peak profile Temperature (T_p) is defined as a supplier minimum and a user maximum. ** Tolerance for time at peak profile temperature (t_p) is defined as a supplier minimum and a user maximum.		

Table 1. SnPb Eutectic Process – Classification Temperatures (Tc)

Package Thickness	Volume mm^3 <350	Volume mm^3 ≥350
<2.5 mm	235 °C	220 °C
≥2.5 mm	220 °C	220 °C

Table 2. Pb-free Process – Classification Temperatures (Tc)

Package Thickness	Volume mm^3 <350	Volume mm^3 350-2000	Volume mm^3 >2000
<1.6 mm	260 °C	260 °C	260 °C
1.6 mm – 2.5 mm	260 °C	250 °C	245 °C
≥2.5 mm	250 °C	245 °C	245 °C

Reliability Test Program

Test item	Method	Description
SOLDERABILITY	JESD-22, B102	5 Sec, 245°C
HOLT	JESD-22, A108	1000 Hrs, Bias @ T_j=125°C
PCT	JESD-22, A102	168 Hrs, 100%RH, 2atm, 121°C
TCT	JESD-22, A104	500 Cycles, -65°C~150°C
HBM	MIL-STD-883-3015.7	VHBM ≧ 2KV
MM	JESD-22, A115	VMM ≧ 200V
Latch-Up	JESD 78	10ms, 1_{tr} ≧ 100mA

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