

## Low-Supply-Current Synchronous Step-up DC-DC Converter

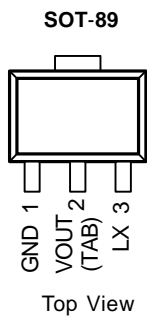
### Features

- **0.9V Typical Start-up Input Voltage**
- **11mA Typical No Load Quiescent Current**
- **PFM Operation**
- **High Efficiency up to 92%**
- **Fixed 1.8V, 2.6V, 2.8V, 3V, 3.3V, 3.8V, 4.5V or 5V Output Voltage**
- **600mA Internal Switch Current**
- **Internal Synchronous Rectifier**
- **SOT-89 Package**
- **Lead Free and Green Devices Available (RoHS Compliant)**

### Applications

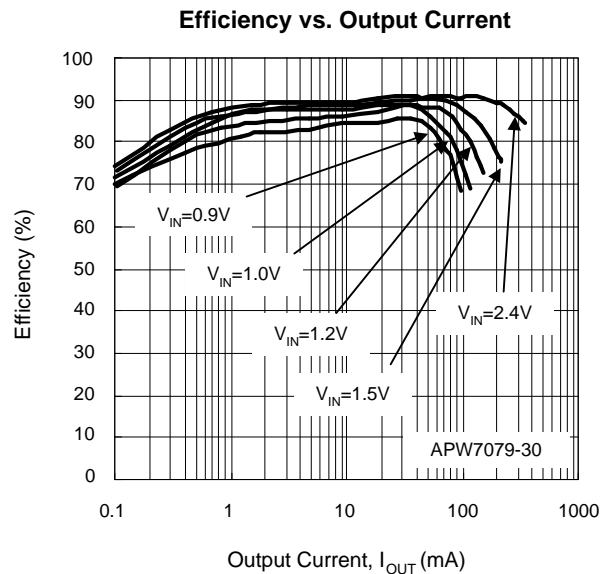
- **Toy**
- **Wireless Mouse**
- **Portable Instrument**

### Pin Configuration

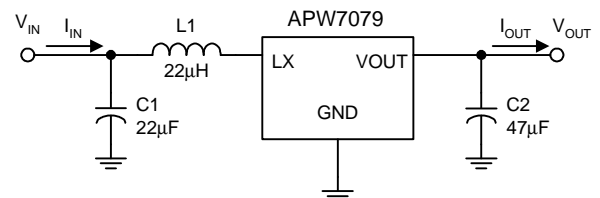


### General Description

The APW7079 is a compact, PFM mode, and step-up DC-DC converter with low quiescent current. The internal synchronous rectifier reduces cost and PCB space by eliminating the need for an external Schottky diode. Low on-resistance of the internal switches improves the efficiency up to 92%. The start-up voltage is guaranteed below 1V. After start-up, the device can operate with input voltage down to 0.7V. The APW7079 is suitable for portable battery-powered applications. Consuming only 11µA quiescent current and an optimized control scheme allows the device to operate at very high efficiency over the entire load current range.



### Simplified Application Circuit



ANPEC reserves the right to make changes to improve reliability or manufacturability without notice, and advise customers to obtain the latest version of relevant information to verify before placing orders.

## Ordering and Marking Information

<p>APW7079 □□□□-□□□□</p> <ul style="list-style-type: none"> <li>□□□□ - Assembly Material</li> <li>□□□□ - Handling Code</li> <li>□□□□ - Temperature Range</li> <li>□□□□ - Package Code</li> <li>□□□□ - Voltage Code</li> </ul>	<p>Package Code D : SOT-89 Operating Ambient Temperature Range I : -40 to 85°C Handling Code TR : Tape &amp; Reel Assembly Material G : Halogen and Lead Free Device Voltage Code 18: 1.8V    26: 2.6V    28: 2.8V    30: 3.0V 33: 3.3V    38: 3.8V    45: 4.5V    50: 5.0V</p>
APW7079-18D: <span style="border: 1px solid black; padding: 2px;">APW7079 XXXXX18</span> XXXXX - Date Code, 18: 1.8V	APW7079-26D: <span style="border: 1px solid black; padding: 2px;">APW7079 XXXXX26</span> XXXXX - Date Code, 26: 2.6V
APW7079-28D: <span style="border: 1px solid black; padding: 2px;">APW7079 XXXXX28</span> XXXXX - Date Code, 28: 2.8V	APW7079-30D: <span style="border: 1px solid black; padding: 2px;">APW7079 XXXXX30</span> XXXXX - Date Code, 30: 3.0V
APW7079-33D: <span style="border: 1px solid black; padding: 2px;">APW7079 XXXXX33</span> XXXXX - Date Code, 33: 3.3V	APW7079-38D: <span style="border: 1px solid black; padding: 2px;">APW7079 XXXXX38</span> XXXXX - Date Code, 38: 3.8V
APW7079-45D: <span style="border: 1px solid black; padding: 2px;">APW7079 XXXXX45</span> XXXXX - Date Code, 45: 4.5V	APW7079-50D: <span style="border: 1px solid black; padding: 2px;">APW7079 XXXXX50</span> XXXXX - Date Code, 50: 5.0V

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-020C 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).

## Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Rating	Unit
$V_{OUT}$	Output Voltage (V <sub>OUT</sub> to GND)	-0.3 ~ 6	V
$V_{LX}$	LX to GND Voltage	-0.3 ~ V <sub>OUT</sub> +1	V
$T_{STG}$	Storage Temperature	-65 ~ 150	°C
$T_{SDR}$	Maximum Lead Soldering Temperature, 10 Seconds	260	°C

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## Thermal Characteristics

Symbol	Parameter	Typical Value	Unit
$\theta_{JA}$	Thermal Resistance -Junction to Ambient <sup>(Note 2)</sup>	180	°C/W

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

## Recommended Operating Conditions (Note 3, 4)

Symbol	Parameter	Range	Unit
$V_{OUT}$	Output Voltage (V <sub>OUT</sub> to GND)	0.7 ~ 5.5	V
$V_{IN}$	Converter Supply Voltage	0.3 ~ V <sub>OUT</sub> +1	V
$V_{LX}$	LX to GND Voltage	-0.3 ~ V <sub>OUT</sub> +0.3	V
$I_{OUT}$	Converter Output Current	0 ~ 0.9 x I <sub>OUT(MAX)</sub>	A
$T_A$	Ambient Temperature	-40 ~ 85	°C
$T_J$	Junction Temperature	-40 ~ 125	°C

Note 3: Refer to the typical application circuit

Note 4: Refer to "Application Information" for detail value.

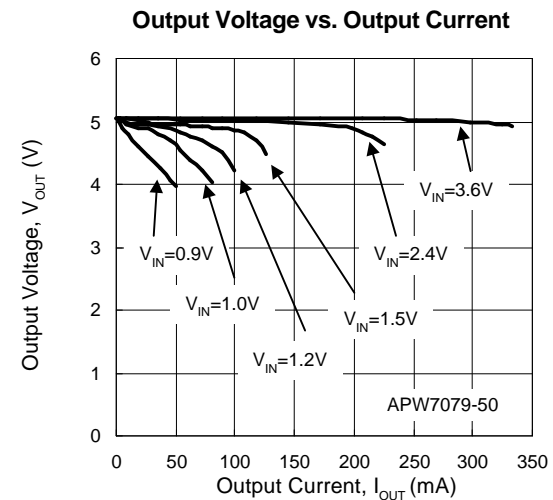
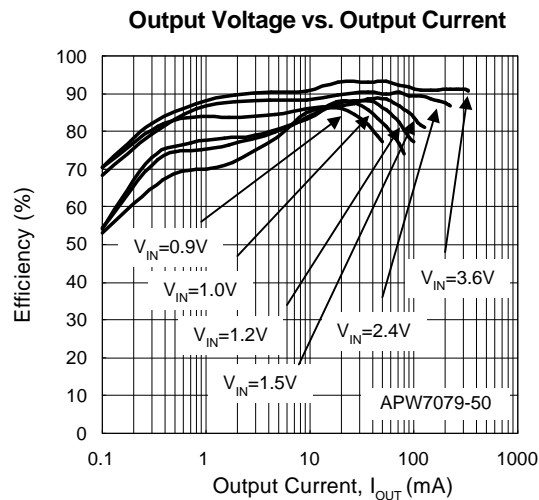
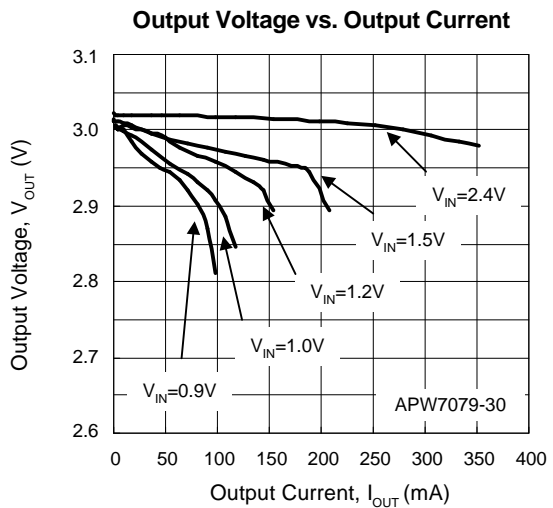
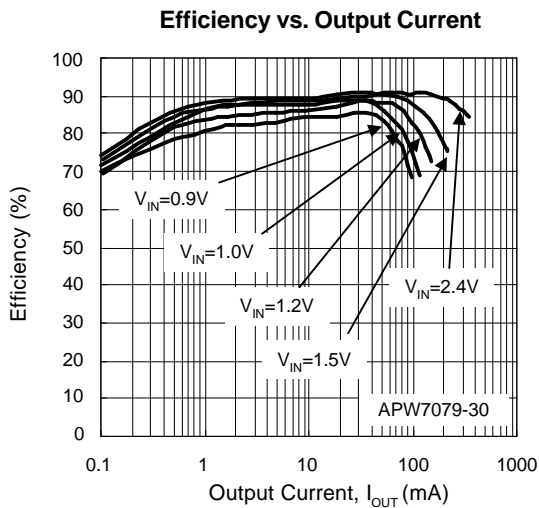
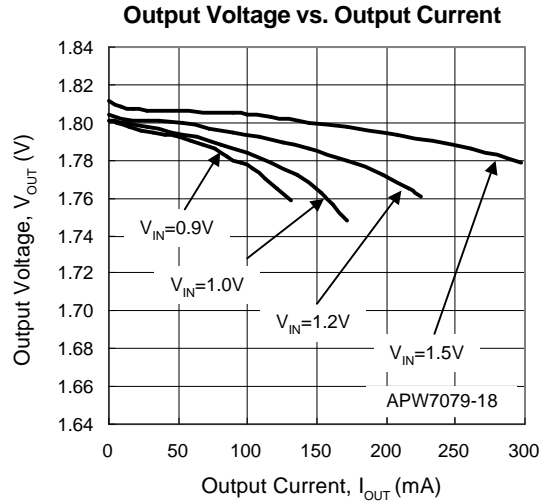
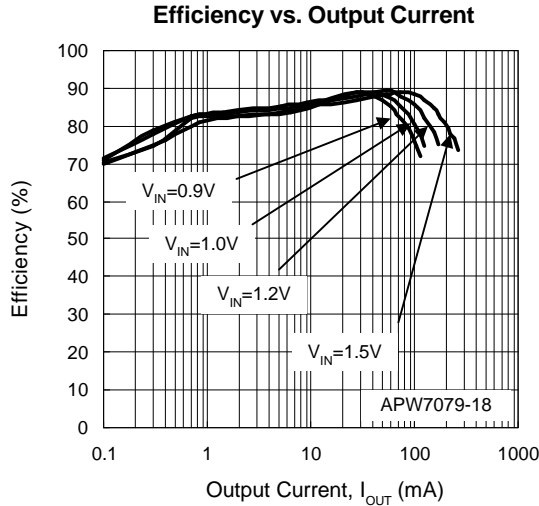
## Electrical Characteristics

Refer to Typical Application Circuits.  $V_{IN}=1.5V$ ,  $R_{LOAD} = \quad$ , and  $T_A = -40 \sim 85^\circ C$ , unless otherwise noted. Typical values are at  $T_A=25^\circ C$ .

Symbol	Parameter	Test Conditions		APW7079			Unit
				Min.	Typ.	Max.	
$V_{IN}$	Converter Supply Voltage			0.7	-	5.5	V
	Start-up Voltage	$R_{LOAD}=3k\Omega$		-	0.9	1	V
$V_{OUT}$	Output Voltage		APW7079-18	1.764	1.8	1.836	V
			APW7079-26	2.548	2.6	2.652	
			APW7079-28	2.744	2.8	2.856	
			APW7079-30	2.94	3.0	3.06	
			APW7079-33	3.234	3.3	3.366	
			APW7079-38	3.724	3.8	3.876	
			APW7079-45	4.41	4.5	4.59	
			APW7079-50	4.9	5.0	5.1	
$I_{DD}$	Supply Current	$V_{OUT} = V_{OUT(Typ.)} + 0.5V$ Measured at $V_{OUT}$ No Inductor Connected		7	11	15	$\mu A$
$T_{OFF(MIN)}$	Main Switch Min. Off-time			0.6	0.9	1.2	$\mu s$
$T_{ON(MAX)}$	Main Switch Max. On-time			3	4	5	$\mu s$
	Main Switch Max. Duty			75	-	85	%
$R_{N-FET}$	Main Switch on Resistance	$I_{LX}=100mA$	APW7079-18	-	0.5	-	$\Omega$
			APW7079-26	-	0.4	-	
			APW7079-28	-	0.4	-	
			APW7079-30	-	0.4	-	
			APW7079-33	-	0.4	-	
			APW7079-38	-	0.4	-	
			APW7079-45	-	0.3	-	
			APW7079-50	-	0.3	-	
$R_{P-FET}$	Synchronous Switch on Resistance	$I_{LX}=100mA$	APW7079-18	-	1	-	$\Omega$
			APW7079-26	-	0.8	-	
			APW7079-28	-	0.8	-	
			APW7079-30	-	0.7	-	
			APW7079-33	-	0.6	-	
			APW7079-38	-	0.5	-	
			APW7079-45	-	0.4	-	
			APW7079-50	-	0.4	-	
$I_{LIM}$	Main Switch Current Limit			500	600	700	mA
	Main Switch Leakage Current			-	-	1	$\mu A$
	Synchronous Switch Leakage Current			-	-	1	$\mu A$
	Over-Temperature Shutdown			-	150	-	$^\circ C$
	Over-Temperature Hysteresis			-	40	-	$^\circ C$

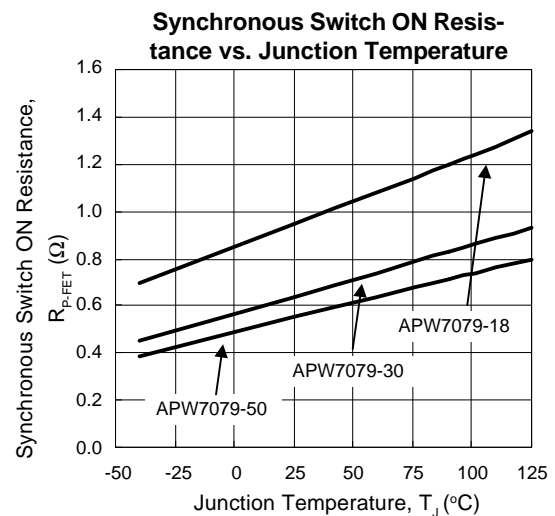
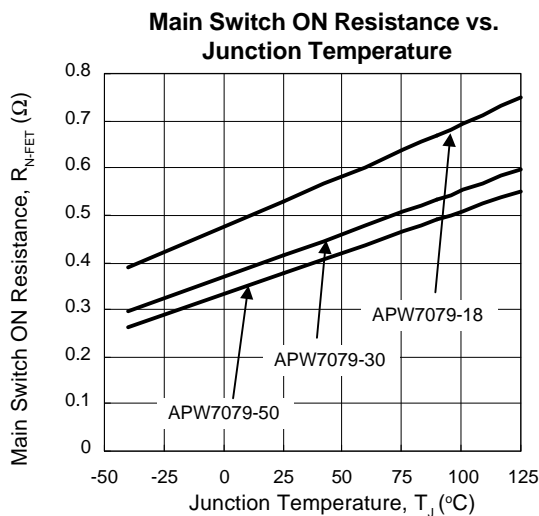
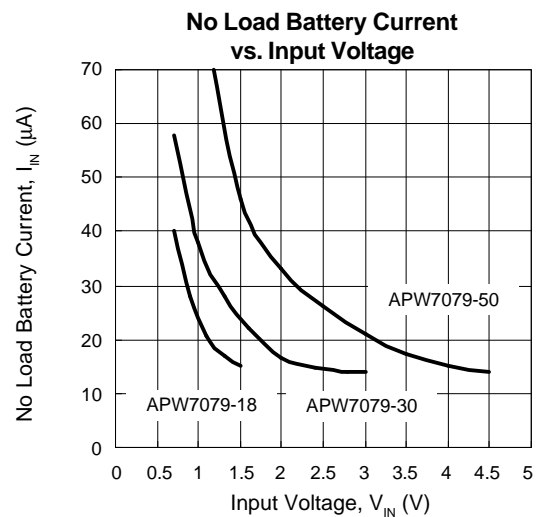
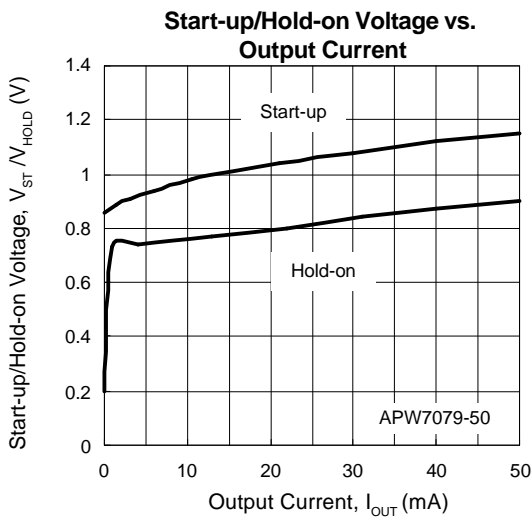
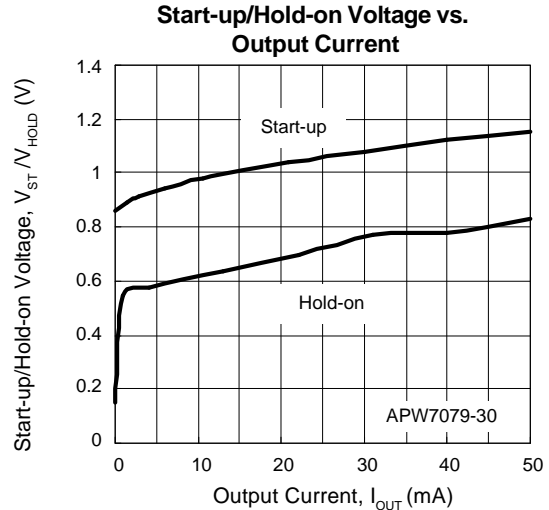
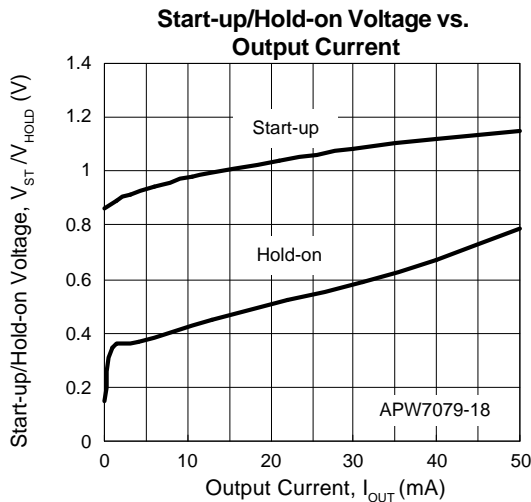
### Typical Operating Characteristics

(Refer to the application circuit in the section "Typical Application Circuit",  $V_{IN}=1.5V$ ,  $L1=22\mu H$ ,  $T_A=25^\circ C$  unless otherwise noted.)



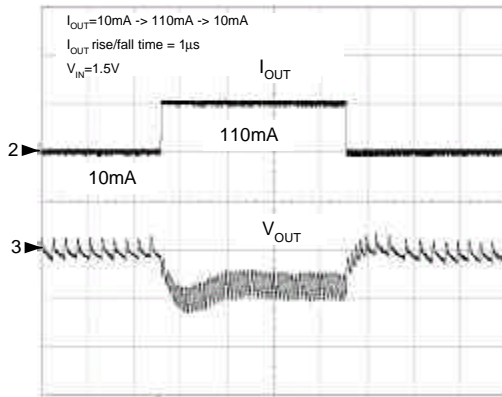
### Typical Operating Characteristics (Cont.)

(Refer to the application circuit in the section "Typical Application Circuit",  $V_{IN}=1.5V$ ,  $L1=22\mu H$ ,  $T_A=25^\circ C$  unless otherwise noted.)



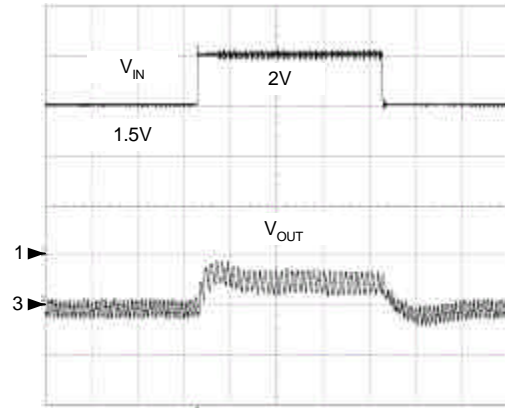
## Operating Waveforms

**Load Transient Response**



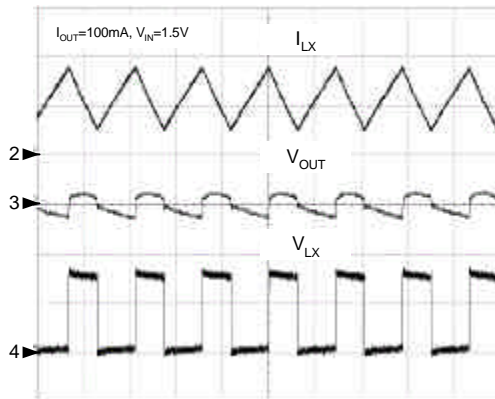
CH2:  $I_{OUT}$ , 100mA/Div, DC  
 CH3:  $V_{OUT}$ , 50mV/Div, AC  
 Time: 0.1ms/Div

**Line Transient Response**



CH1:  $V_{IN}$ , 0.5V/Div, DC  
 CH3:  $V_{OUT}$ , 50mV/Div, AC  
 Time: 0.1ms/Div

**Heavy Load Switching Waveform**

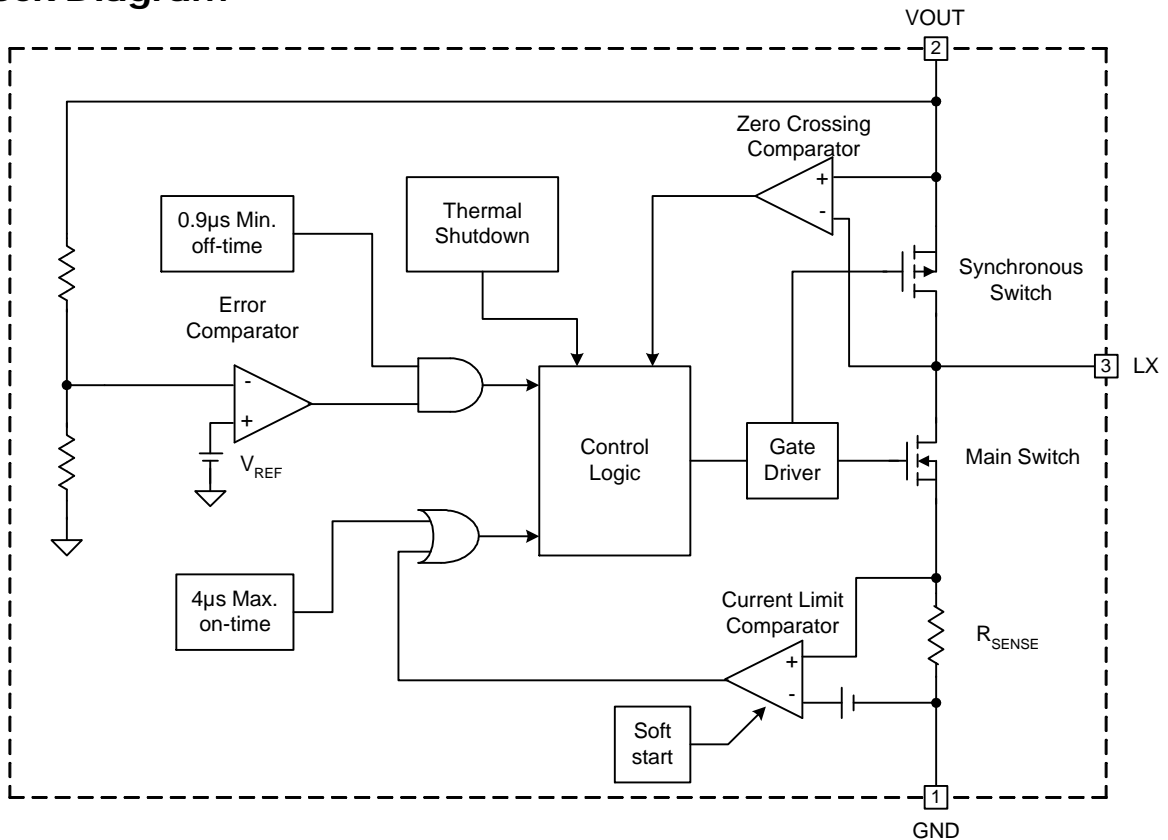


CH2:  $I_{LX}$ , 200mA/Div, DC  
 CH3:  $V_{OUT}$ , 50mV/Div, AC  
 CH4:  $V_{LX}$ , 2V/Div, DC  
 Time:  $5\mu s$ /Div

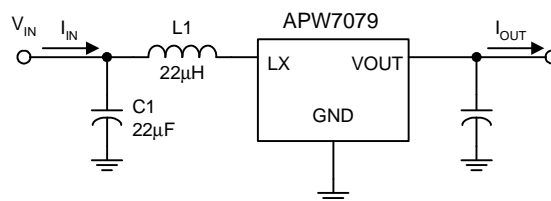
Pin Description

PIN		FUNCTION
NO.	NAME	
1	LX	Junction of N-FET and P-FET Drains. Connect the inductor here and minimize the trace area for lowest EMI.
2	VOUT	Converter output and control circuitry bias supply pin.
3	GND	Ground.

Block Diagram



Typical Application Circuit



## Function Description

### Control Scheme

The converter monitors the output voltage. When the internal feedback voltage falls below the reference voltage, the main switch turns on and the inductor current ramps up. The main switch turns off when the current reaches the peak current limit of typical 600mA. The second criterion that turns off the switch is the maximum on-time of 4 $\mu$ s (typical). As the main switch is turned off, the synchronous switch is turned on and delivers the current to the output. The main switch remains off for a minimum of 900ns (typical), or until the internal feedback voltage drops below the reference voltage. By the control scheme with low quiescent current of 11 $\mu$ A (typical), the converter gets high efficiency over a wide load range.

### Start-Up

A startup oscillator circuit is integrated in the APW7079. When the power is applied to the device, the circuit pumps the output voltage high. Once the output voltage reaches 1.4V (typ), the main DC-DC circuitry turns on and boosts the output voltage to the final regulation point.

### Synchronous Rectification

The internal synchronous rectifier eliminates the need for an external Schottky diode, thus, reducing cost and board space. During the cycle off-time, the P-channel MOSFET turns on and shunts the MOSFET body diode. As a result, the synchronous rectifier significantly improves efficiency without the addition of an external component. Conversion efficiency can be as high as 92%.

### Over-Temperature Protection

The over-temperature circuit limits the junction temperature of the APW7079. When the junction temperature exceeds 150°C, a thermal sensor turns off the power MOSFETs, allowing the devices to cool. The thermal sensor allows the converter to start a start-up process and regulate the output voltage again after the junction temperature cools by 40°C. The OTP is designed with a 40°C hysteresis to lower the average  $T_j$  during continuous thermal overload conditions, increasing lifetime of the device.



## Application Information

### Input Capacitor Selection

The input capacitor is chosen based on the voltage rating and the RMS current rating. For reliable operation, it is recommended to select the capacitor voltage rating at least 1.3 times higher than the maximum input voltage. The maximum RMS current rating of the input capacitor is calculated as the following equation:

$$I_{RMS} = \frac{1}{\sqrt{3}} \cdot \frac{V_{IN} \cdot T_{ON}}{L}$$

where

$T_{ON}$  = main switch max. on-time (4μs typical)

$V_{IN}$  = input voltage

$L$  = inductor value in μH

The capacitors should be placed close to the inductor and the GND.

### Output Capacitor Selection

An output capacitor is required to filter the output and supply the load transient current. The output ripple is the sum of the voltages across the ESR and the ideal output capacitor. The peak-to-peak voltage of the ESR is calculated as the following equations:

$$\Delta V_{ESR} = I_{PEAK} \times ESR$$

$$I_{PEAK} = \frac{V_{OUT} \cdot I_{OUT}}{V_{IN} \cdot \eta} + \frac{V_{IN} \cdot T_{ON}}{2 \cdot L} \leq I_{LIM}$$

Where

$I_{PEAK}$  = peak current of inductor in amp

$\eta$  = efficiency (0.85 typical)

The peak-to-peak voltage of the ideal output capacitor is calculated as the following equation:

$$\Delta V_{COUT} = \frac{I_{OUT} \times T_{ON}}{C_{OUT}}$$

For the applications using tantalum capacitors, the  $\Delta V_{COUT}$  is much smaller than the  $V_{ESR}$  and can be ignored. Therefore, the AC peak-to-peak output voltage ( $\Delta V_{OUT}$ ) is shown as below:

$$\Delta V_{OUT} = I_{PEAK} \times ESR$$

Since the output ripple is the product of the peak inductor current and the output capacitor ESR, using low-ESR tantalum capacitors for the best performance or connecting two or more filter capacitors in parallel is recommended.

### Inductor Selection

The inductor value determines the inductor ripple current and affects the load transient response. It is recommended to select the boost inductor in order to keep the maximum peak inductor current below the current limit threshold of the power switch. For example, the current limit threshold of the APW7079's switch is 600mA. For choosing an inductor which has peak current passed, firstly, it is necessary to consider the output load ( $I_{OUT}$ ), input ( $V_{IN}$ ), and output voltage ( $V_{OUT}$ ). Secondly, the desired current ripple in the inductor also needed to be taken into account. The current was calculated in "Output Capacitor Selection". Since the output ripple is the product of the peak inductor current and the output capacitor ESR, the larger inductor value reduces the inductor current ripple and output voltage ripple but typically offers a larger physical size.

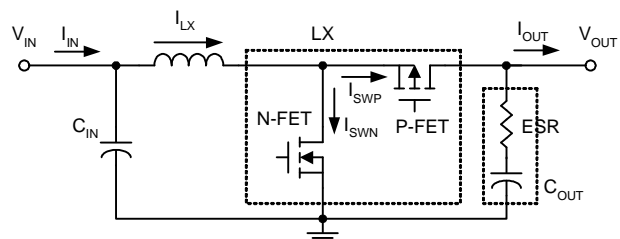
The inductor value also slightly affects the maximum output current. The maximum output current can be calculated as below:

$$I_{OUT(MAX)} = \frac{V_{IN}}{V_{OUT}} \left[ I_{LIM} - T_{OFF} \left( \frac{V_{OUT} - V_{IN}}{2 \times L} \right) \right] \cdot \eta$$

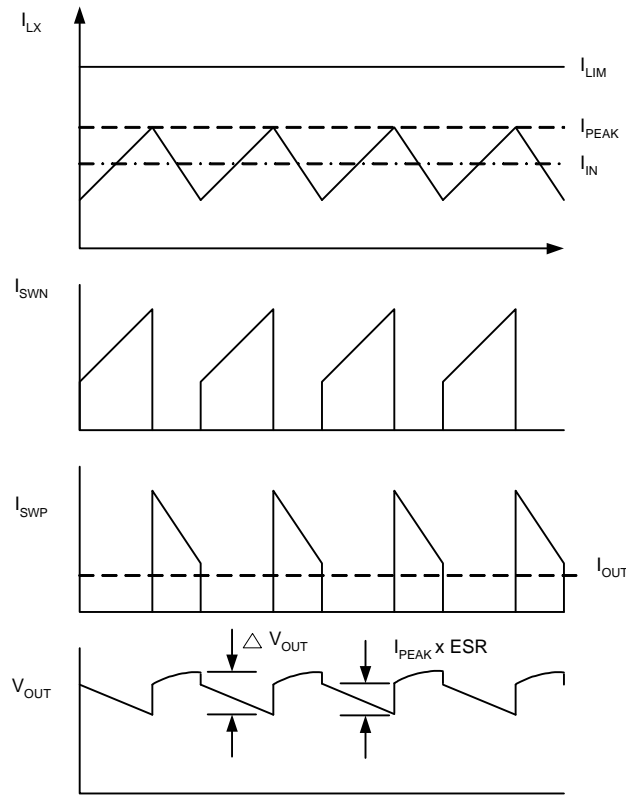
where

$T_{OFF}$  = main switch min. off-time (0.9μs typical)

Therefore, to consider the balance of the efficiency and component size, an inductor value of 22μH to 47μH is recommended in most applications.



**Application Information (Cont.)**



**Thermal Consideration**

In most applications, the APW7079 does not dissipate much heat due to its high efficiency. However, in applications where the APW7079 is running at high ambient temperature with low output voltage, the heat dissipated may exceed the maximum junction temperature of the part. If the junction temperature reaches approximately 150°C, both power switches will be turned off and the LX node will become high impedance. To avoid the APW7079 from exceeding the maximum junction temperature, the user will need to do some thermal analysis. The goal of the thermal analysis is to determine whether the power dissipated exceeds the maximum junction temperature of the part. The temperature rise is given by:

$$T_r = (P_D)(\theta_{JA})$$

where  $P_D$  is the power dissipated by the regulator and  $\theta_{JA}$  is the thermal resistance from the junction of the die to the ambient temperature. The junction temperature,  $T_J$ , is given by:

$$T_J = T_A + T_R$$

where

$T_A$  = the ambient temperature.

The power dissipation can be calculated as below:

$$P_D = P_{OUT} \times (1-\eta)/\eta$$

where

$P_{OUT}$  = Output power ( $V_{OUT} \times I_{OUT}$ )

$\eta$  = Efficiency

As an example, the APW7079-18 converts an input voltage 1.2V to provide a load current of 175mA at ambient temperature of 85°C. Assume the efficiency ( $\eta$ ) is 0.75. Therefore, the power dissipated on the converter is:

$$P_D = 1.8 \times 0.175 \times (1-0.75)/0.75 = 0.105 \text{ Watt}$$

Since the power dissipation includes the loss of external components, the actual value is slightly lower. For the SOT-89 package, the  $\theta_{JA}$  is 180°C/W. Thus, the junction temperature of the regulator is as below:

$$T_J = 85^\circ\text{C} + (P_D)(180) = 104^\circ\text{C}$$

The maximum junction temperature should be less than 125°C. Note that, the junction temperature is lower at higher output voltages due to reduced switch resistance.

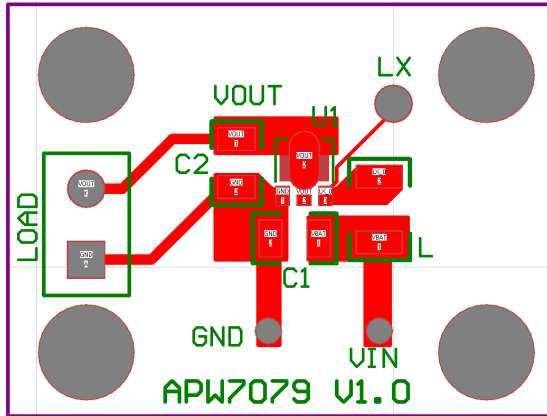
**Layout Consideration**

For all switching power supplies especially with high peak currents and switching frequency, the layout is an important step in the design. If the layout is not carefully done, the regulator may show noise problems and duty cycle jitter.

- 1.The input capacitor should be placed close to the device, which can reduce copper trace resistance and effect input ripple of the IC.
- 2.The inductor should be placed as close as possible to the switch pin to minimize the switching noise.
- 3.The output capacitor should be placed closed to the VOUT and the GND.

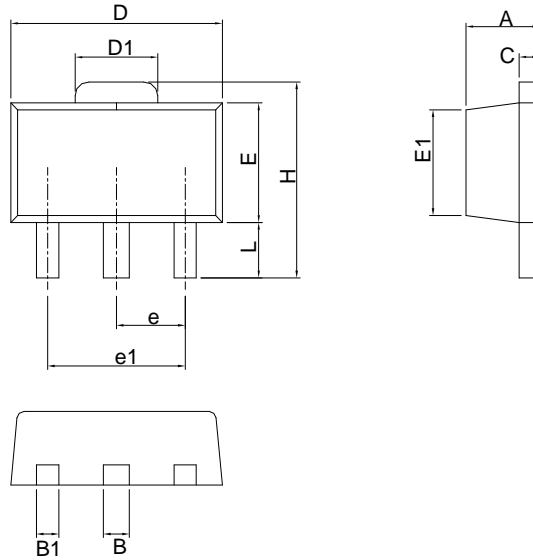
## Application Information (Cont.)

### Layout Consideration (Cont.)



Package Information

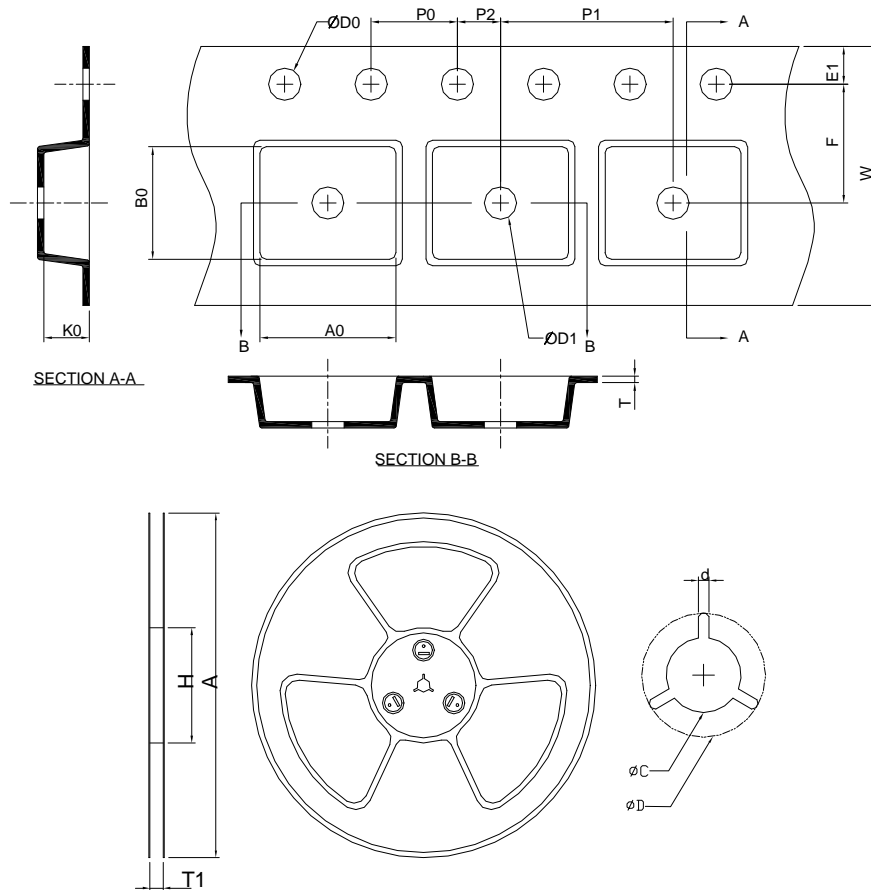
SOT-89



SYMBOL	SOT-89			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	1.40	1.60	0.055	0.063
B	0.44	0.56	0.017	0.022
B1	0.36	0.48	0.014	0.019
C	0.35	0.44	0.014	0.017
D	4.40	4.60	0.173	0.181
D1	1.62	1.83	0.064	0.072
E	2.29	2.60	0.090	0.102
E1	2.13	2.29	0.084	0.090
e	1.50 BSC		0.059 BSC	
e1	3.00 BSC		0.118 BSC	
H	3.94	4.25	0.155	0.167
L	0.89	1.20	0.035	0.047

Note : Follow JEDEC TO-243 AA.

Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
SOT-89	178.0 ±0.00	50 MIN.	12.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	12.0 ±0.30	1.75 ±0.10	5.50 ±0.05
	P0	P1	P2	D0	D1	T	A0	B0	K0
	4.0 ±0.10	8.0 ±0.10	2.0 ±0.05	1.5+0.10 -0.00	1.5 MIN.	0.6+0.00 -0.40	4.80 ±0.20	4.50 ±0.20	1.80 ±0.20

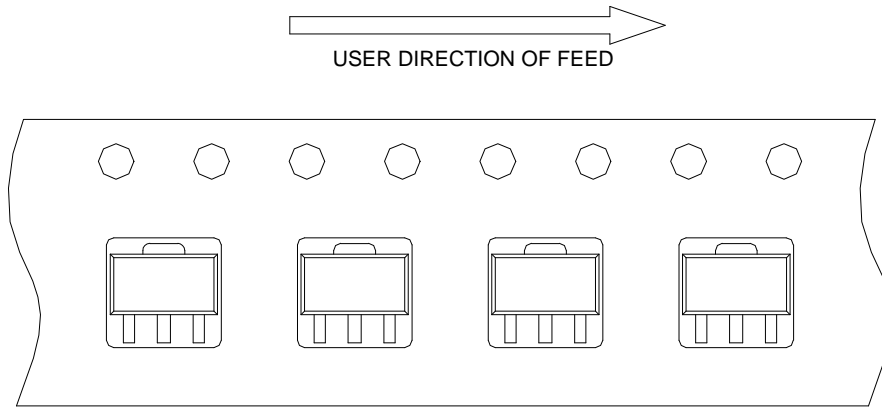
(mm)

Devices Per Unit

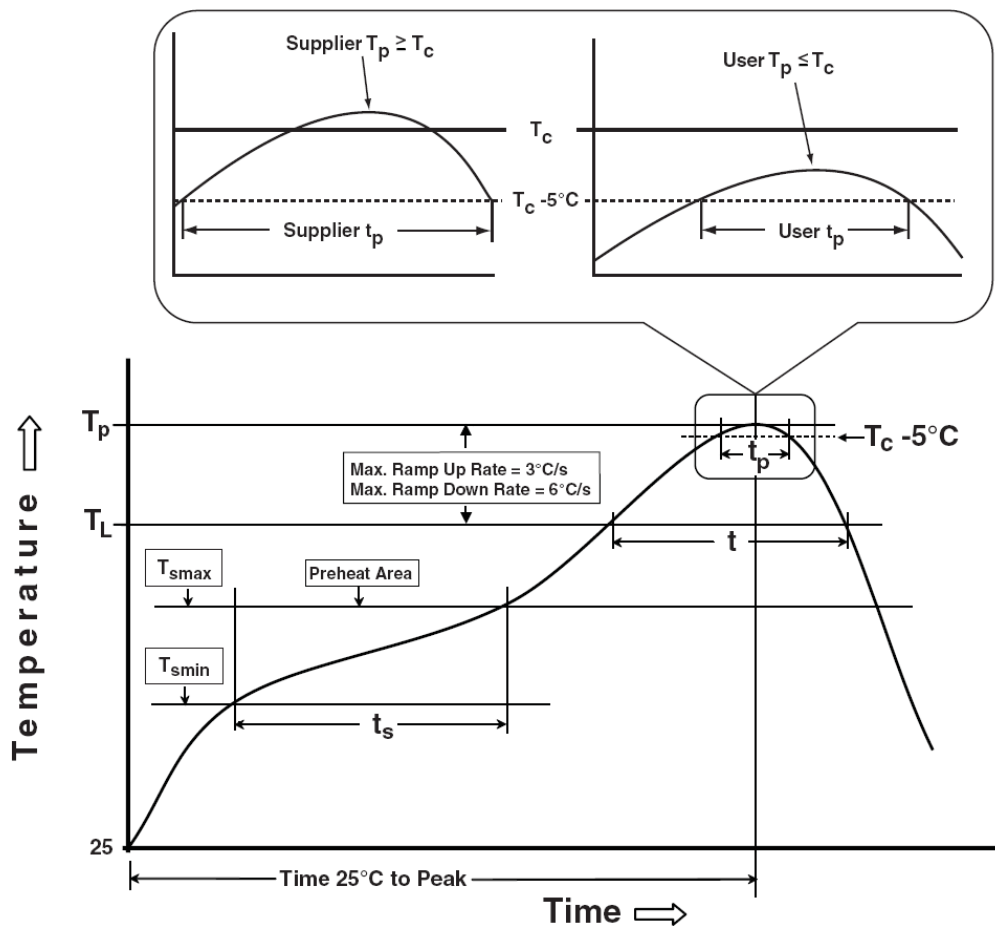
Package Type	Unit	Quantity
SOT-89	Tape & Reel	1000

### Taping Direction Information

SOT-89



### Classification Profile



### Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
<b>Preheat &amp; Soak</b> 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 ( $T_c$ )

Package Thickness	Volume mm <sup>3</sup> <350	Volume mm <sup>3</sup> ≥350
<2.5 mm	235 °C	220 °C
≥2.5 mm	220 °C	220 °C

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

Package Thickness	Volume mm <sup>3</sup> <350	Volume mm <sup>3</sup> 350-2000	Volume mm <sup>3</sup> >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 @ 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 <sub>tr</sub> 100mA

## **Customer Service**

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