Low-Power, 8-bit, 3-Channel Analog to Digital Converters

Features

- **Supply Input Voltages Range: 2.8V to 5.5V**
- **100uA Low Supply Current**
- **3-Ch Analog Voltage Input: AIN1, AIN2, AIN3**
- **High Accuracy Nonlinearity: ±3LSB**
- **High Accuracy A/D Resolution:**
  - 4.6875mV for APL6001
  - 10mV for APL6001A
- **High Accuracy A/D Full Scale Range:**
  - 0 ~ 1.2V for APL6001
  - 0 ~ 2.56V for APL6001A
- **Built-in Alert Flag, I²C Address Programming and EN control Functions**
- **I²C interface with 8-bit AD converter**
- **VTQFN1.5x2-10L with Lead Free & RoHS compliant**

Applications

- **Phone & NB Application**
- **Temperature Measurement**
- **Portable Instrumentation**
- **Consumer Goods**

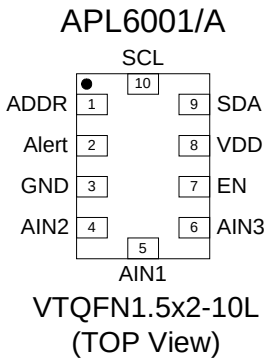
General Description

The APL6001/A is a precision analog-to-digital converters (ADCs) with 8 bits of resolution, which designed with precision, low power and ease of implementation in mind. Data are transferred via an I²C-compatible serial interface. Three voltage sensing inputs are available for monitoring the temperature of the system. It measures voltage form the monitor place to GND by NTC resistor divider voltages. The sensed voltages are digitized and interfaced with microprocessor by I²C bus for advanced power management procedures.

The APL6001/A operates from a single power supply ranging from 2.8V to 5.5V.

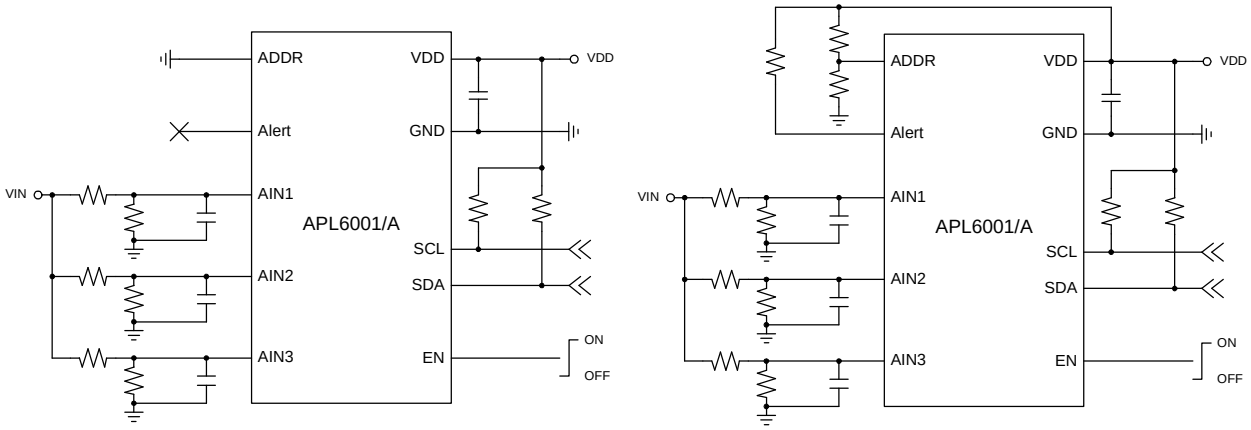
This APL6001/A is available in VTQFN1.5x2-10L package.

Pin Configurations



VTQFN1.5x2-10L
(TOP View)

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

APL6001 □□□—□□□

- Assembly Material
- Handling Code
- Temperature Range
- Package Code

Package Code
QF : VTQFN1.5x2-10L
Operating Ambient Temperature Range
I : -40 to 85°C
Handling Code
TR : Tape & Reel
Assembly Material
G : Halogen and Lead Free Device

APL6001 QF — 6001 / X — X : Date Code

APL6001A QF — 601A / X — 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).

Absolute Maximum Ratings (Note 1)

Symbol	Parameter		Rating	Unit
VDD	VDD Supply Voltage, VDD to GND		-0.3 ~ 6.0	V
$V_{I/O}$	Input & Output or I/O (ADDR, Alert, EN, SCL, SDA, AIN1, AIN2, AIN3) voltages		-0.3 ~ VDD	V
PD	Power Dissipation		Internally Limited	W
T_J	Junction Temperature		150	℃
T_{STG}	Storage Temperature		-65 ~ 150	℃
T_{SDR}	Maximum Lead Soldering Temperature(10 Seconds)		260	℃
V_{ESD}	Minimum ESD Rating	(Human Body Mode) (MM Mode)	±2 0.2	kV

Note1: 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)	TBD	°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
VDD	VDD Supply Voltage, VDD to GND	2.8 ~ 5.5	V
$V_{I/O}$	Input & Output pins (ADD, Alert, EN, SCL, SDA) voltage	0 ~ VDD	V
V_{AIN}	APL6001 input pins (AIN1, AIN2, AIN3) voltage	0 ~ 1.2	V
	APL6001A input pins (AIN1, AIN2, AIN3) voltage	0 ~ 2.56	V
T_A	Ambient Temperature	-40 ~ 85	℃
T_J	Junction Temperature	-40 ~ 125	℃

Electrical Characteristics

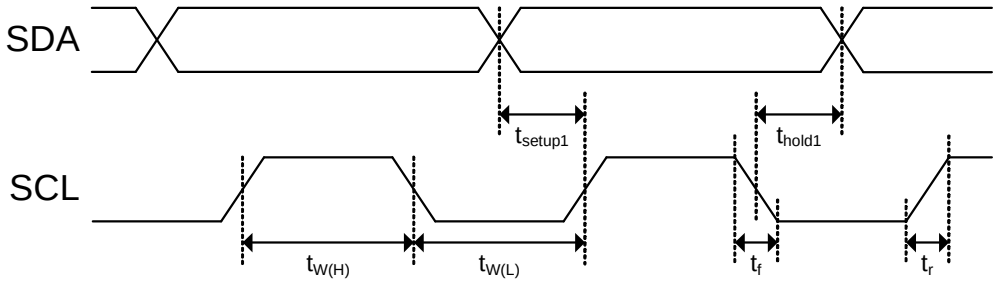
Unless otherwise specified, these specifications apply over V_{DD}=5V, V_{EN}=3V and T_J= -40 to 85°C. Typical values are at T_J=25°C.

Symbol	Parameter	Test condition	Specification			Unit
			Min.	Typ.	Max.	
SUPPLY CURRENT						
I_{VDD}	VDD Input Current		-	80	100	uA
I_{VDD_SHDN}	VDD Shutdown Current	V_{EN}=0V	-	0.1	-	uA
POWER-ON RESET (POR)						
V_{POR}	VDD POR Threshold Voltage	VDD Rising	-	2.35	2.6	V
V_{POR_Hys}	VDD POR Hysteresis Voltage	VDD Falling	-	0.1	-	V
EN threshold						
V_{EN_H}	High Level Input Threshold Voltage		1.4	-	-	V
V_{EN_L}	Low Level Input Threshold Voltage		-	-	0.4	V
R_{PULL_LOW}	Internal Pull Low Resistor		-	700	-	kΩ
Voltage Monitor						
A/D	A/D Resolution	(APL6001)	-	4.6875	-	mV/LSB
		(APL6001A)	-	10	-	mV/LSB
	A/D Full Scale Range	(APL6001)	0	-	1.2	V
		(APL6001A)	0	-	2.56	V
	Differential nonlinearity		-	-	3	LSB
	Integral nonlinearity		-	-	3	LSB
	Input Bias Current		-	-	10	nA
	AIN1, AIN2, AIN3 Monitor Time		-	1.2	2.4	ms
Address Setting						
ADDR	Address Latch Time		-	-	10	ms
	Address 1 Voltage Range	Address = 0x7E (Hex)	92	95	100	%VDD
	Address 2 Voltage Range	Address = 0x7C (Hex)	82	85	88	%VDD
	Address 3 Voltage Range	Address = 0x7A (Hex)	72	75	78	%VDD
	Address 4 Voltage Range	Address = 0x78 (Hex)	63	65	68	%VDD
	Address 5 Voltage Range	Address = 0x76 (Hex)	52	55	58	%VDD
	Address 6 Voltage Range	Address = 0x74 (Hex)	42	45	48	%VDD
	Address 7 Voltage Range	Address = 0x72 (Hex)	32	35	38	%VDD
	Address 8 Voltage Range	Address = 0x70 (Hex)	0	25	28	%VDD
I_{ADDR_LEAK}	ADDR Leakage Current	V_{ADDR}=5V	-	-	100	nA
Alert Output						
ALT	ALT Output Low Voltage	When ALT pin pull low, I_{ALT}=10mA	-	-	0.2	V
		When ALT pin pull low, I_{ALT}=50mA	-	-	0.8	V
	ALT Pull Low Pulse Time	When ALT pin Alert	-	50	-	us
	ALT Pull Low cycle Time	When ALT pin Alert	-	2	-	s
I_{ALT_LEAK}	ALT Leakage Current	V_{ALT}=5V	-	-	100	nA
I^2C Interface						
F_{I2C}	I^2C Clock Rate Range		1	-	400	kHz
	I^2C Input High Voltage		1.4	-	-	V
	I^2C Input Low Voltage		-	-	0.4	V
	I^2C Leakage Current	V_{SCL}=V_{SDA}=5V	-	-	100	nA

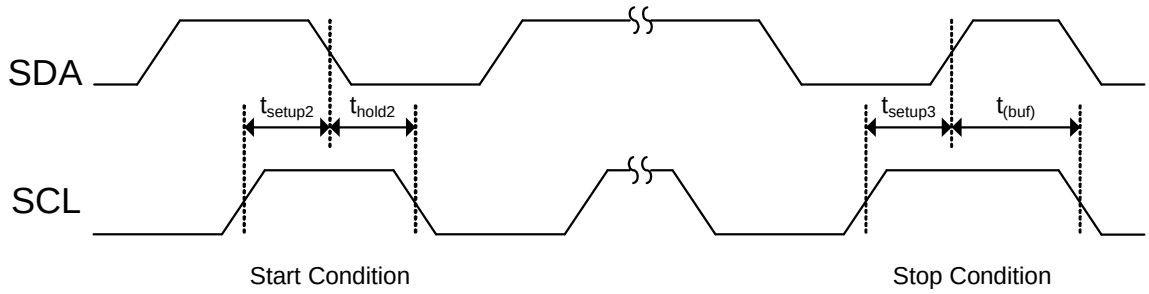
Electrical Characteristics (Cont.)

Timing characteristics for I²C Interface signals over recommended operating conditions (unless otherwise noted)

Symbol	Parameter	Fast Speed		Unit
		Min.	Max.	
f_{SCL}	Frequency, SCL	-	400	kHz
$t_{W(H)}$	Pulse Duration, SCL High	600	-	ns
$t_{W(L)}$	Pulse Duration, SCL Low	1300	-	ns
t_r	Rise Time, SCL and SDA	20+0.1 C_L(pF)	300	ns
t_f	Fall Time, SCL and SDA	20+0.1 C_L(pF)	300	ns
t_{setup1}	Setup Time, SCL to SDA	100	-	ns
t_{hold1}	Hold Time, SCL to SDA	100	-	ns
$t_{(buf)}$	Bus Free Time Between Stop and Start Condition	1300	-	ns
t_{setup2}	Setup Time, SCL to Start Condition	600	-	ns
t_{hold2}	Hold Time, Start condition to SCL	600	-	ns
t_{setup3}	Setup Time, SCL to Stop Condition	600	-	ns
C_L	Load Capacitance for Each Bus Line	-	400	pF



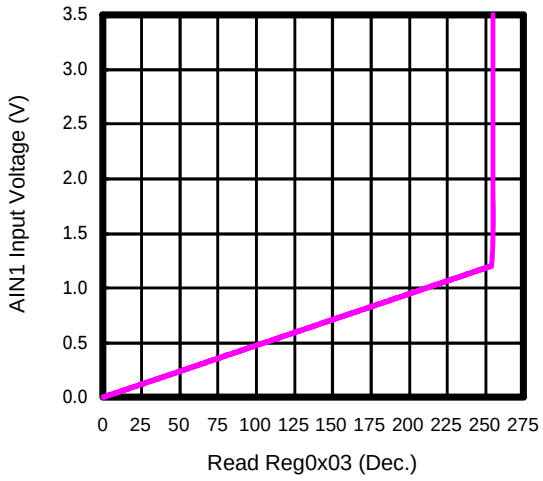
SDA and SCL Timing



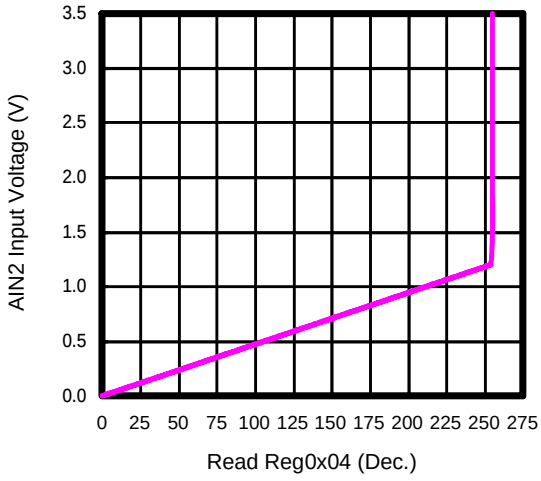
Start and Stop Condition Timing

Typical Operating Characteristics

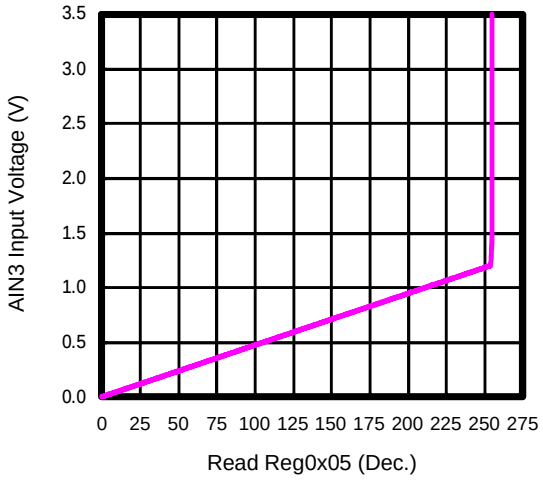
APL6001 AIN1 vs. Reg0x03



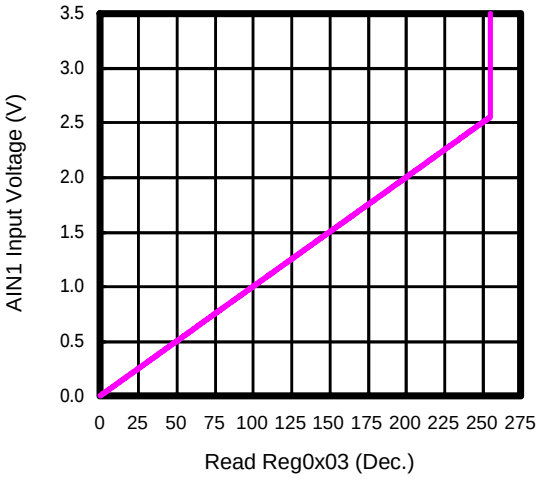
APL6001 AIN2 vs. Reg0x04



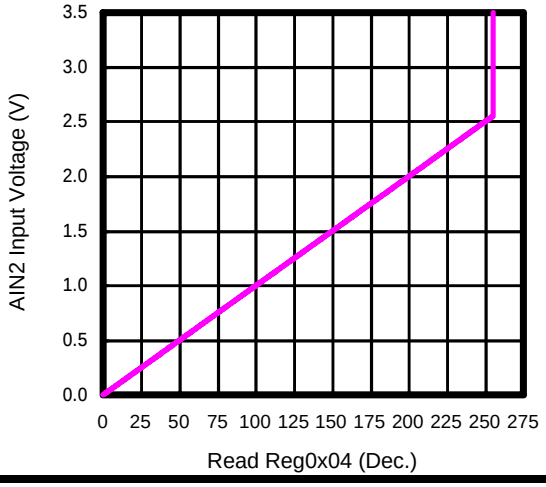
APL6001 AIN3 vs. Reg0x05



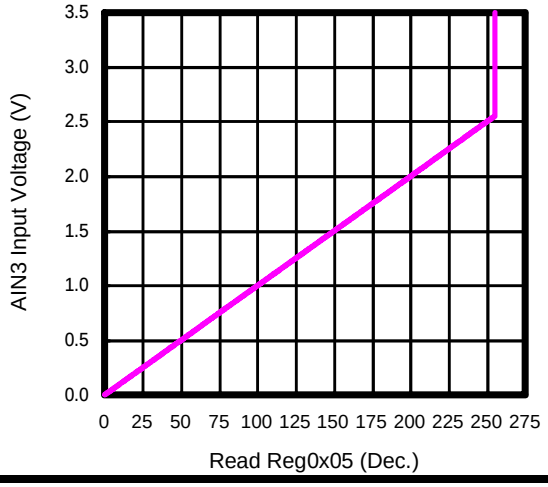
APL6001A AIN1 vs. Reg0x03



APL6001A AIN2 vs. Reg0x04

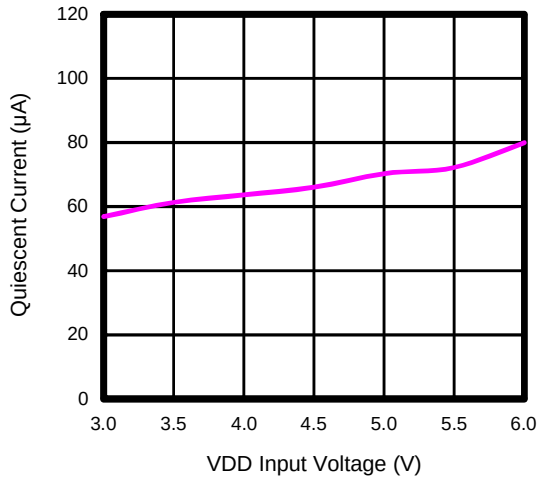


APL6001A AIN3 vs. Reg0x05

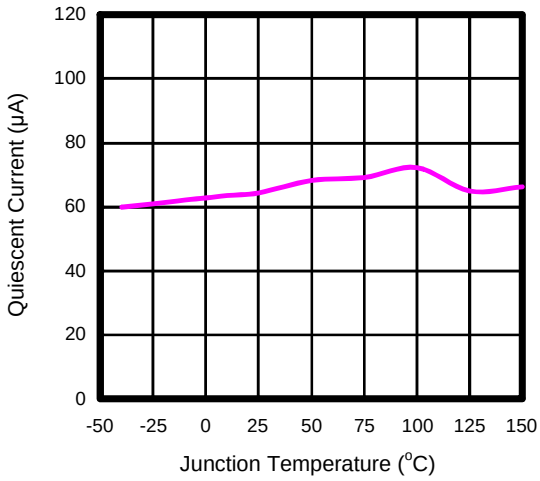


Typical Operating Characteristics

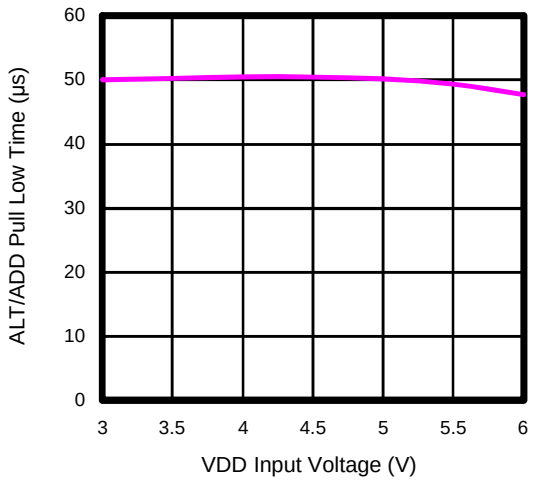
Quiescent Current vs. VDD



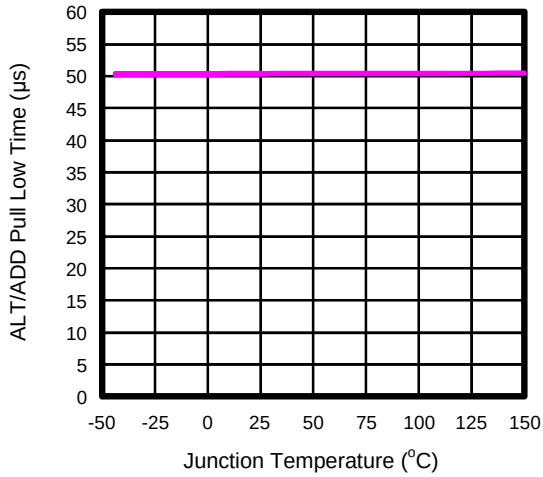
Quiescent Current vs. Temperature



Alert Low Pulse Time vs. VDD



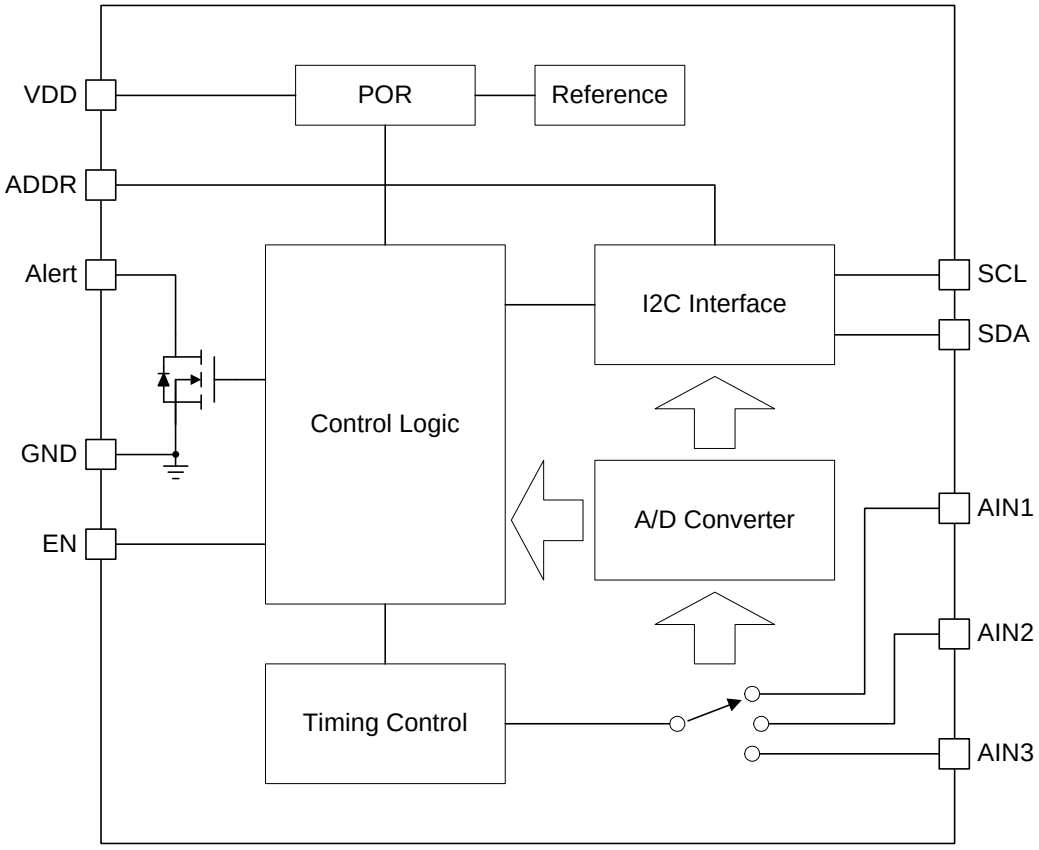
Alert Low Pulse Time vs. Temperature



Pin Description

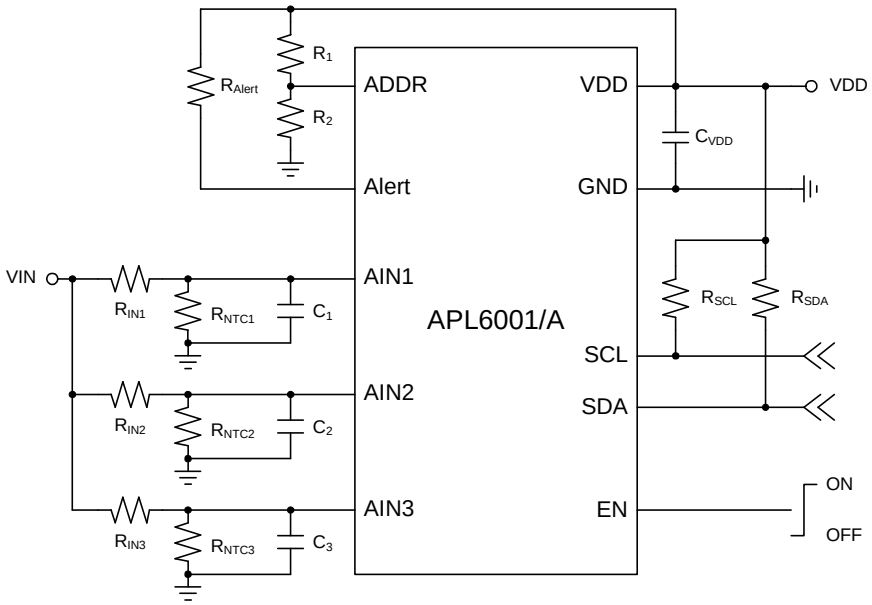
PIN		FUNCTION
NO.	NAME	
1	ADDR	Address Selection. Connect a voltage divider to select the APL6001/A I²C address. Connect this pin to GND definitely for 0x70 address programming. **Do not leave ADDR pin floating.**
2	Alert	Thermal Alert. When anyone of V_{AINx} is lower than setting voltage, it will pull low and send alert signal to the system. If used, connect to VIN via a resistor. Connect this pin without any capacitor.
3	GND	Signal and Power Ground. All the voltage levels are measured by reference to this pin.
4	AIN2	Analog Voltage Input 2.
5	AIN1	Analog Voltage Input 1.
6	AIN3	Analog Voltage Input 3.
7	EN	Enable Control Input. Forcing this pin above 1.4V to enable the device. Forcing this pin below 0.4V to turn off the regulator and reduce quiescent current, and the I²C will be none-ACK. The resistance is internally pulled down by 700kΩ to GND.
8	VDD	Device power supply pin. Connect this pin with 0.1uF capacitor.
9	SDA	I²C interface Data I/O pin. Connect this pin to I²C bus data signal.
10	SCL	I²C interface Clock I/O pin. Connect this pin to I²C bus clock signal.

Block Diagram

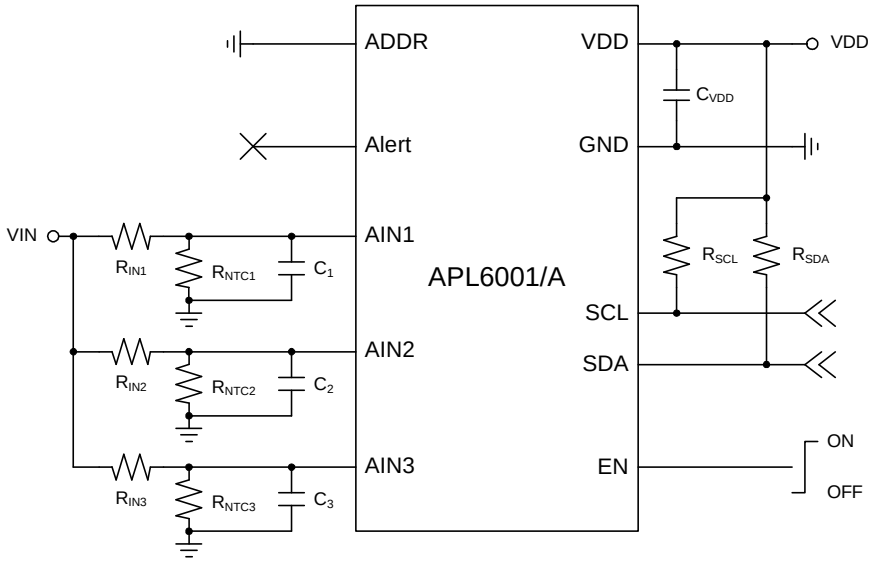


Typical Application Circuit

The I²C Address Programming and Alert Flag functions are used.



The I²C Address is used as default and Alert Flag function is unused.



V_{AINx} = 0~1.2V(for APL6001) or 0~2.56V(for APL6001A) is recommended.
$R_{Alert} \geq 1k\Omega$ is recommended.
R_{INx} and R_{NTCx} = 10kΩ~10MΩ is recommended.
C_{VDD}, C_1, C_2 and $C_3 \geq 0.1uF$ is recommended.
R_{SCL} and R_{SDA} = 1kΩ~10kΩ is recommended.

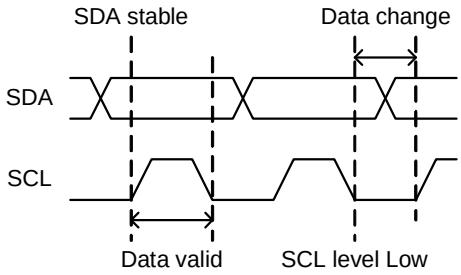
Function Description

Input Voltage and Power-On-Reset

The APL6001/A can work normally and start monitoring the AINx voltage, when the supply voltage VDD is greater than the POR and the EN input control signal is high. The POR threshold is 2.5V typically when the VDD rising.

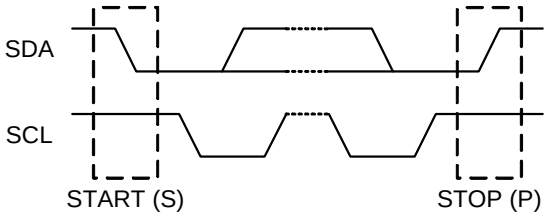
I²C Interface Data Validity

The SCL voltage level can only be changed to Low to High, when the SDA is stable unless the START and STOP status. The SDA can only be changed the voltage level when the SCL voltage is Low.



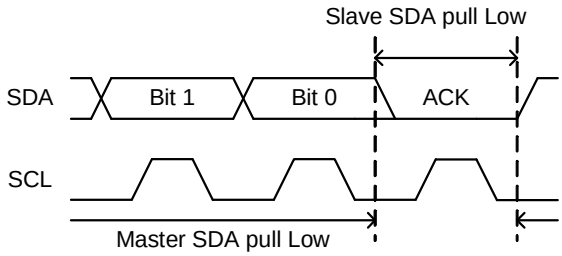
I²C Start and Stop Conditions

The START (S) condition is the SDA transient from High to Low, when SCL is High. The STOP (P) condition is the SDA transient from Low to High, when SCL is High. The STOP condition must send before each START condition.

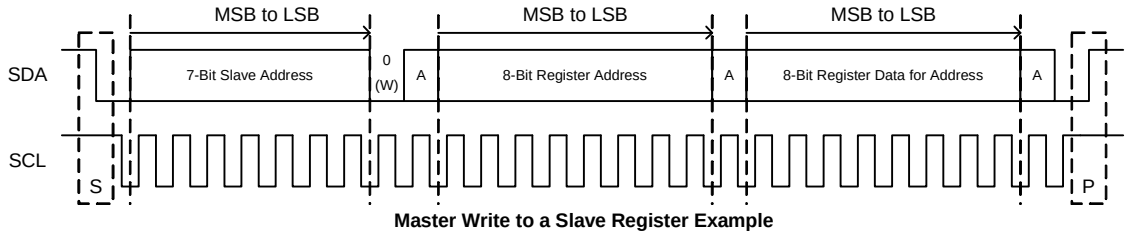


I²C Acknowledge

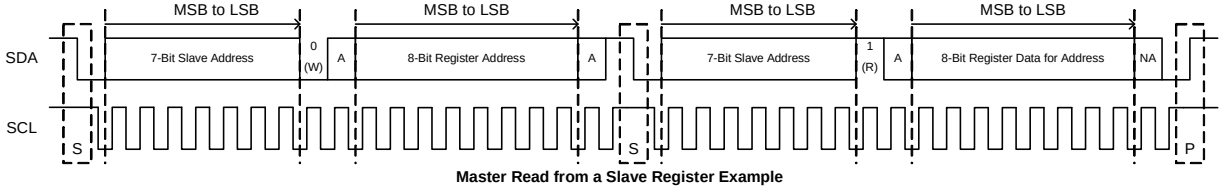
Each Address and Data are transmitted by using 8 clock pulses with 1 clock pulse Acknowledge (A). The Acknowledge is used for two purposes: one is the device that recognizes its own address. Another one is all of the master and slave to acknowledge receipt the register address or data. The SDA will pull Low to acknowledge.



Read and Write Protocol



Master Write to a Slave Register Example



Master Read from a Slave Register Example

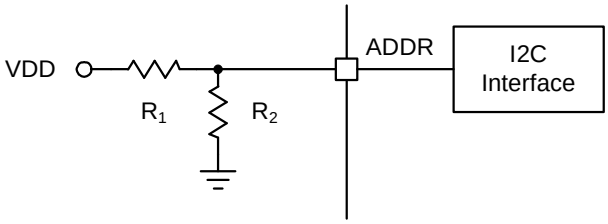
(S=START, P=STOP, A=ACK from Slave, NA=Non-ACK)

Function Description (Cont.)

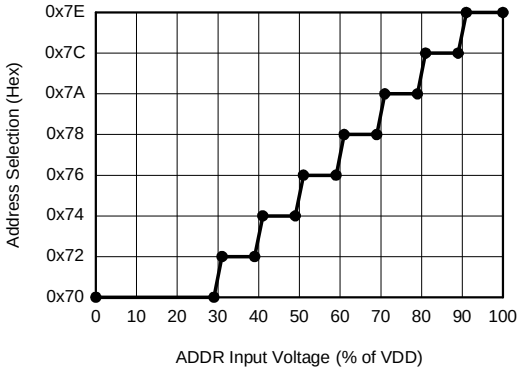
I²C Address Programming

The APL6001/A I²C address is programmable, which can be selected from 0x70h to 0x7Eh by the 7-bit slave address with one R/W bit. The slave device compares the 7-bit slave address with its address and matches. The programmable address is selected by a voltage divider R1 and R2. The ADDR pin voltage is compared with 8 addresses available internal reference voltage for address programming.

Note: If the address programming function is not used, the ADDR pin must be connected to GND and the I²C address is used as default value 0x70h.



Address	0x70	0x72	0x74	0x76	0x78	0x7A	0x7C	0x7E
R1 (kOhm)	Open	5.1	4.3	3.9	3.6	2	1.5	10
R2 (kOhm)	0	2.7	3.6	4.7	6.8	6.2	8.2	Open
ADDR (% of VDD)	0	35	45	55	65	75	85	100



Voltage Monitoring and I²C Programming Interface

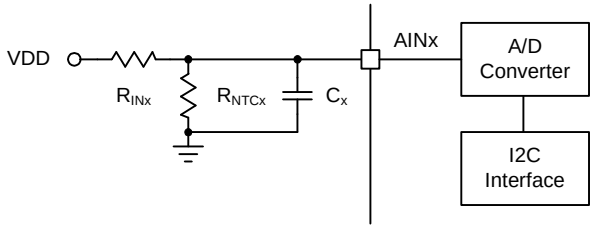
The AINx voltages are digitized directly by high precision A/D converter and interfaced to the I²C bus. The AINx voltages are sensed alternately and take 1.2ms every channel.

When the VDD supply voltage range from 2.8 to 5.5V, the A/D converter have 4.6875mV (for APL6001) or 10mV (for APL6001A) of resolution, and 0 to 1.2V (for APL6001) or 0 to 2.56V (for APL6001A) of full scale range. The A/D converter sensing results are stored in the internal register that shows as follow:

AIN1 A/D data store (TD1): Reg0x03[7] (MSB) ~ Reg0x03 [0] (LSB)

AIN2 A/D data store (TD2): Reg0x04[7] (MSB) ~ Reg0x04 [0] (LSB)

AIN3 A/D data store (TD3): Reg0x05[7] (MSB) ~ Reg0x05 [0] (LSB)



If the internal register code is read as $Code_X$ in integer decimal format, the AINx voltage transition to the internal register Reg0x03, Reg0x04 and Reg0x05 calculation as follows:

$$Code_X = \frac{V_{AINx}}{4.6875mV} \quad or \quad V_{AINx} = 4.6875mV \times Code_X \quad (for\ APL6001)$$

$$Code_X = \frac{V_{AINx}}{10mV} \quad or \quad V_{AINx} = 10mV \times Code_X \quad (for\ APL6001A)$$

The voltage divider at VIN-R_{INx}-R_{NTCx}-GND sets the voltage AINx is calculated as:

$$V_{AINx} = VIN \times \frac{R_{NTCx}}{R_{INx} + R_{NTCx}}$$

According to the above equation:

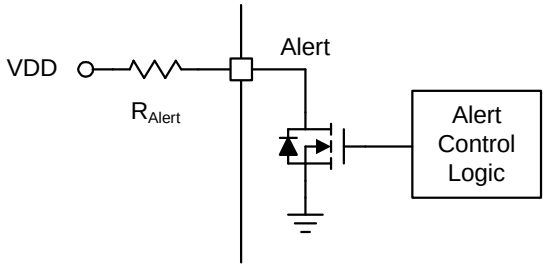
$$Code_X = \frac{VIN \times \frac{R_{NTCx}}{R_{INx} + R_{NTCx}}}{4.6875mV} \quad (for\ APL6001) \quad or \quad Code_X = \frac{VIN \times \frac{R_{NTCx}}{R_{INx} + R_{NTCx}}}{10mV} \quad (for\ APL6001A)$$

Note: If the AINx pin is not used, that must be pulled to the high level. And the C_X is recommended to bypass the AINx pin.

Function Description (Cont.)

Alert Flag

The Alert Flag is used to indicate the system state. When the setting condition is established at the AINx voltage, the APL6001/A will make the internal MOS in the Alert pin turns on and pull low 50us every 2s cycle time.



Alert Threshold Level Setting

The Alert levels are set in the internal register by I²C interface shows as follows:

AIN1 Alert level set-up (TL1): Reg0x00[7] (MSB) ~ Reg0x00[0] (LSB)
AIN2 Alert level set-up (TL2): Reg0x01[7] (MSB) ~ Reg0x01[0] (LSB)
AIN3 Alert level set-up (TL3): Reg0x02[7] (MSB) ~ Reg0x02[0] (LSB)

If one of conditions is established include TL1≥TD1, TL2≥TD2 or TL3≥TD3, the Alert function will be enabled, and the Alert Indication of internal resistor Reg0x06[6:4] will be set to 1 that shows as below:

If the Reg0x00 (TL1) ≥ Reg0x03 (TD1), than the bit Reg0x06[4] = 1, else the bit Reg0x06[4] = 0
If the Reg0x01 (TL2) ≥ Reg0x04 (TD2), than the bit Reg0x06[5] = 1, else the bit Reg0x06[5] = 0
If the Reg0x02 (TL3) ≥ Reg0x05 (TD3), than the bit Reg0x06[6] = 1, else the bit Reg0x06[6] = 0

Chip ID: Reg0xB2[7:0] = 0x1A

I²C Registers Summary

Register Address	Register Name	Bits								Read/ Write	Default Value
		D7	D6	D5	D4	D3	D2	D1	D0		
0x00	TL1	TL1[7:0]								R/W	00h
0x01	TL2	TL2[7:0]								R/W	00h
0x02	TL3	TL3[7:0]								R/W	00h
0x03	TD1	TD1[7:0]								R	00h
0x04	TD2	TD2[7:0]								R	00h
0x05	TD3	TD3[7:0]								R	00h
0x06	ALT	Reversed	AM3	AM2	AM1	Reversed				R	00h
0xB2	Chip ID	Chip ID = 0x1A								R	1Ah

Manufature Information

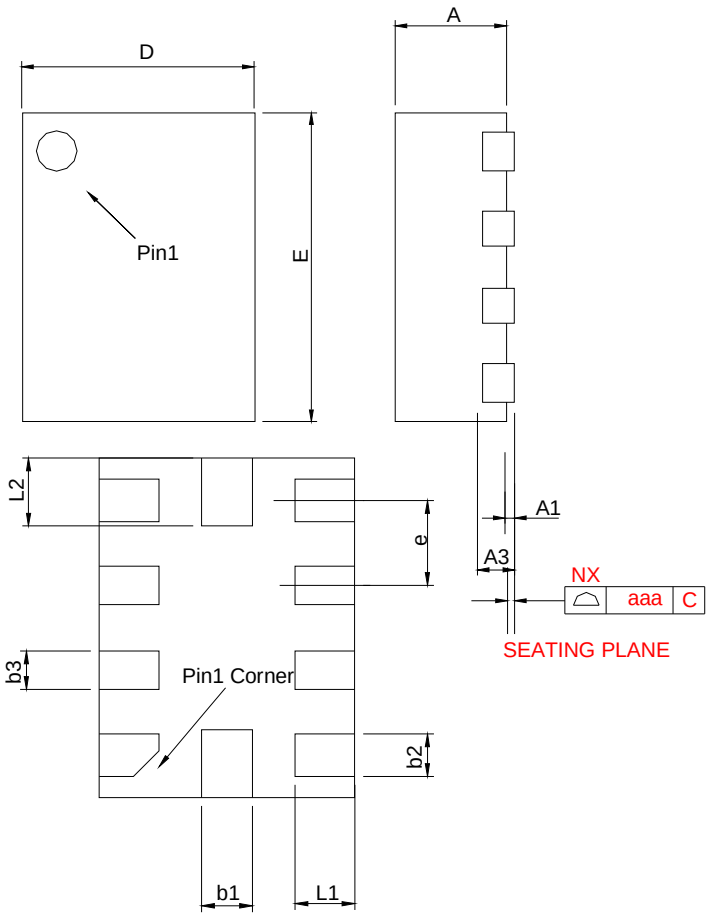
APL6001 / A manufaturing information. Including wafer fab and assembly location.

ANPEC Device	Manufature	Assembly
APL6001/A	TSMC	ASE/ CJE

ANPEC Electronic Corp.
Account manager
Kevin Chang

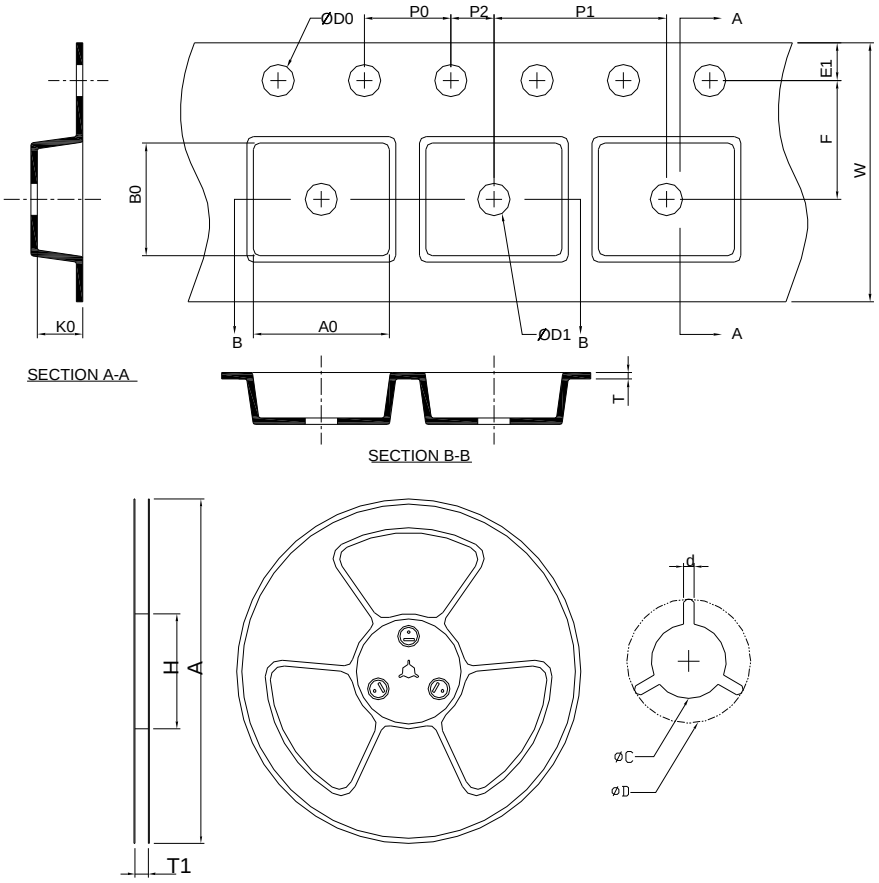
Package Information

VTQFN1.5x2-10



SYMBOL	VTQFN1.5*2-10			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.50	0.60	0.020	0.024
A1	0.00	0.05	0.000	0.002
A3	0.152 REF		0.006 REF	
b1	0.25	0.35	0.010	0.014
b2	0.20	0.30	0.008	0.012
b3	0.17	0.28	0.007	0.011
D	1.40	1.60	0.055	0.063
E	1.90	2.10	0.075	0.083
e	0.50 BSC		0.020 BSC	
L1	0.30	0.40	0.012	0.016
L2	0.35	0.45	0.014	0.018
aaa	0.08		0.003	

Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
VTQFN1.5x2	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	1.0 MIN.	0.6+0.00 -0.40	1.70±0.10	2.20±0.10	0.70±0.10

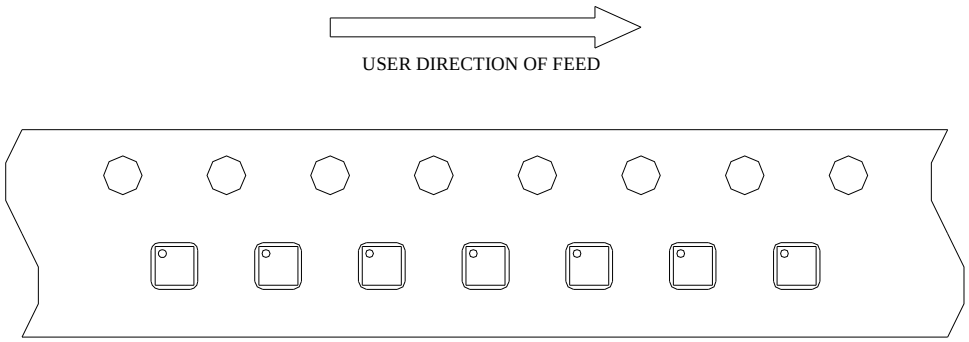
(mm)

Devices Per Unit

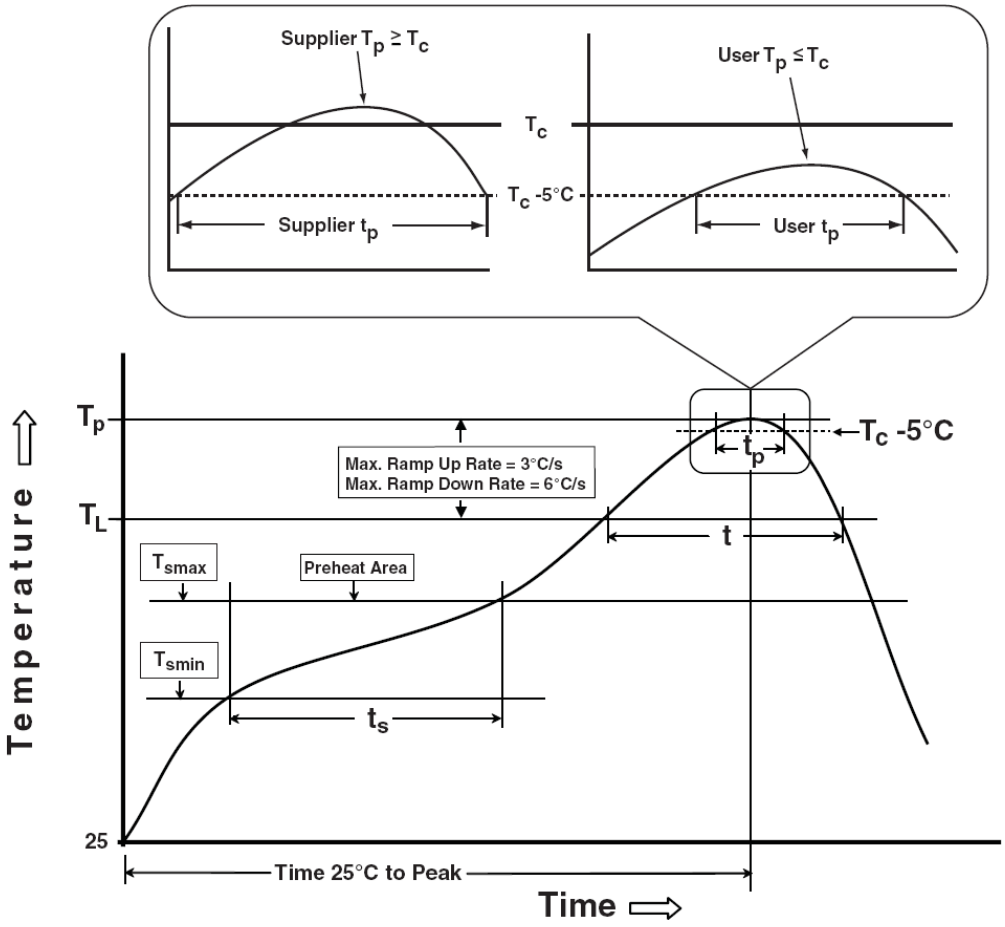
Package Type	Unit	Quantity
VTQFN1.5x2	Tape & Reel	3000

Taping Direction Information

VTQFN1.5x2



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.		

Classification Reflow Profiles (Cont.)

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

Package Thickness	Volume mm^3 <350	Volume mm^3 ³350
<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 @ Tj=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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