APX9360A

Three-Phase Sine-wave Sensor-Less Fan Motor Driver

Features

- **PWM Sine-Wave Driver**
- **Three-Phase Sensor-Less Drive**
- **Adjustable Forced Commutation Frequency (for Start-up)**
- **Built-In External PWM or VSP Speed Control**
- **Built-In Quick Start Function**
- **FG, 1/2FG or RD Output**
- **Power Saving Function**
- **Built-In Lock Protection and AutoRestart Function**
- **Built-in Thermal Protection Circuit**

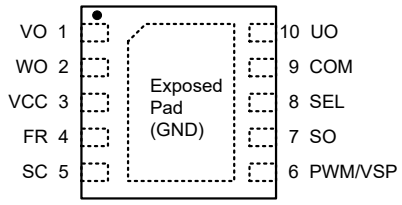
Applications

- **Motor Driver For Silent Fans**
- **Variable Speed Control Fans**

General Description

The APX9360A provides all the circuitry for sensor-less speed control of three-phase brushless DC motor. The Sine-wave Driver method will be better sound quality. The controller functions include start-up circuit, back-EMF commutation control, Pulse Width Modulation (PWM) speed control, voltage speed control, lock protection, and thermal shutdown circuit. The APX9360A is suitable for both game machine and CPU cooler that need silent drivers. It is available in VTDFN3x3-10 package.

Pin Configuration



VTDFN3X3-10
(TOP VIEW)

= Exposed Pad (connected to the ground of power)

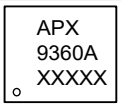
Ordering and Marking Information

APX9360A □□□-□□□

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

Package Code
QF : VTDFN3X3-10
Operating Ambient Temperature Range
I : -40 to 105 °C
Handling Code
TR : Tape & Reel
Assembly Material
G : Green Part

APX9360A QF :



XXXXX - Date Code

Note: ANPEC's green product compliant RoHS and Halogen free.

Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Rating	Unit
V_{CC}	VCC Pin Supply Voltage (VCC to GND)	-0.3 to 7	V
I_{OUT}	UO/VO/WO Pin Output Current	1	A
$V_{UO}/V_{VO}/V_{WO}$	UO/VO/WO Pin Output Voltage	-0.3 to 7	V
$V_{PWM/VSP}$	PWM/VSP Pin Maximum Input Voltage	-0.3 to 7	V
V_{SO}	SO Pin Output Voltage	-0.3 to 7	V
I_{SO}	SO Pin Maximum Output Sink Current	10	mA
V_{FR}	FR Pin Input Voltage	-0.3 to 7	V
T_J	Junction Temperature	-40 to 150	°C
T_{STG}	Storage Temperature	-65 to 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}	Thermal Resistance-Junction to Ambient (Note 2) VTDFN3x3-10	119	°C/W
P_D	Power Dissipation, T_A=25°C VTDFN3x3-10	1.05	W

Note 2: θ_{JA} is measured with the component mounted on a 55mm x 40mm x 1.6mm glass epoxy board (two-layer) in free air.

Recommended Operating Conditions (Note 3)

Symbol	Parameter	Range	Unit
V_{CC}	VCC Pin Supply Voltage Range	1.8 to 6	V
$V_{PWM/VSP}$	PWM/VSP Pin Input Voltage Range	0 to V_{CC}	V
T_A	Ambient Temperature	-40 to 105	°C
I_{OUT}	UO/VO/WO Pin Average Output Current	0 to 400	mA

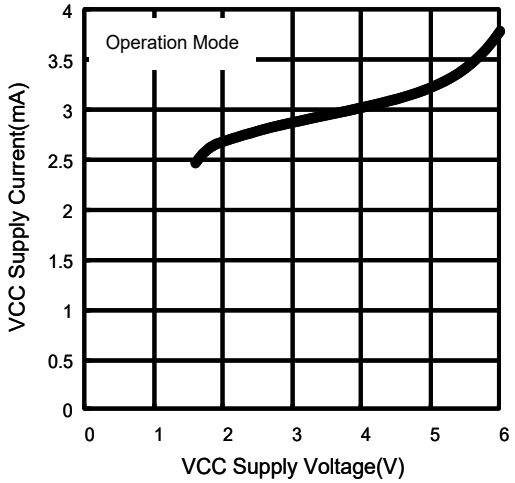
Note 3: Refer to the typical application circuit.

Electrical Characteristics (V_{CC}=5V, T_A=25°C, unless otherwise specified)

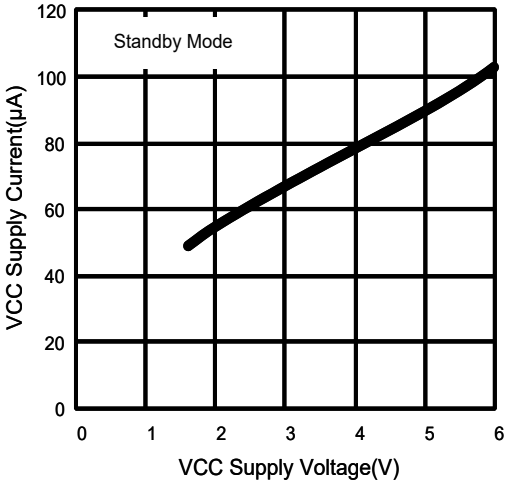
Symbol	Parameter	Test Conditions	APX9360A			Unit
			Min	Typ	Max	
SUPPLY CURRENT						
I_{CC1}	Operating Current	Rotation Mode	-	3	5	mA
I_{CC2}		Standby Mode (PWM=0)	-	100	150	μA
PWM CONTROL						
V_{PWMH}	PWM Input High Level Voltage		2.5	-	V_{CC}+0.3	V
V_{PWML}	PWM Input Low Level Voltage		-0.3	-	0.8	V
I_{PWMH}	PWM High Input Current	PWM=VCC	-	0	-	μA
I_{PWML}	PWM Low Input Current	PWM=GND	-	-10	-	μA
F_{PWM}	PWM Input Frequency		2	-	50	kHz
F_{OUT}	Output Switch Frequency		26	31	36	kHz
OUTPUT DRIVERS						
V_O	Output Driver Saturation Voltage	I_{OUT}=250mA, Upper and Lower total	-	0.25	0.45	V
V_{SO}	FG Pin Low Voltage	I_{SO}=5mA	-	0.1	0.3	V
I_{SO}	FG Pin Leakage Current	V_{SO}=5V	-	<0.1	1	μA
LOCK PROTECTION						
T_{ON}	Lock Detection On Time		0.55	0.7	0.85	sec
T_{OFF}	Lock Detection Off Time		4.25	5	5.75	sec
Oscillator						
V_{SCH}	SC Pin High Level Voltage		1	1.2	1.4	V
V_{SCL}	SC Pin Low Level Voltage		0.5	0.6	0.7	V
I_{SC1}	SC Pin Charge Current	V_{SC}=0V	-	15	-	μA
I_{SC2}	SC Pin Discharge Current	V_{SC}=1.2V	-	15	-	μA
V_{FRH}	FR Pin High Level Voltage		1	1.2	1.4	V
V_{FRL}	FR Pin Low Level Voltage		0.5	0.6	0.7	V
I_{FR1}	FR Pin Charge Current	V_{FR}=0V	-	5	-	μA
I_{FR2}	FR Pin Discharge Current	V_{FR}=1.2V	-	5	-	μA
FR						
V_{FRH}	FR Pin High Level Voltage		2.5	-	Vcc	V
V_{FRL}	FR Pin Low Level Voltage		0	-	0.8	V
Quick Start						
T_{QS}	Quick Start Enable Time		-	10	-	ms
THERMAL SHUTDOWN						
OTS	Over Temperature Shutdown Threshold		-	165	-	°C
	Over Temperature Shutdown Hysteresis		-	30	-	°C

Typical Operating Characteristics

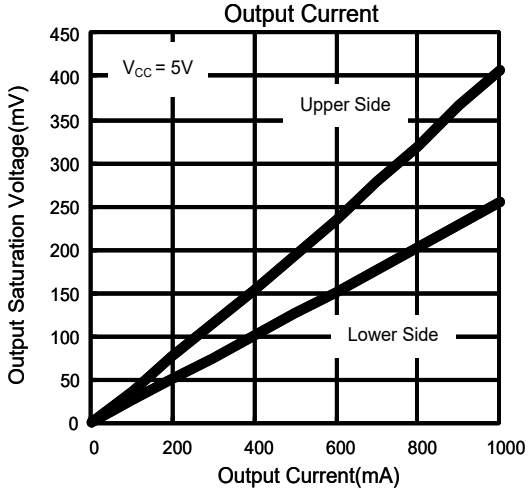
VCC Supply Current vs. VCC Supply Voltage



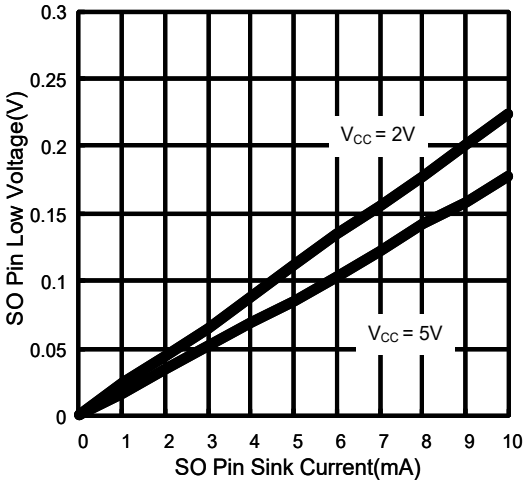
VCC Supply Current vs. VCC Supply Voltage



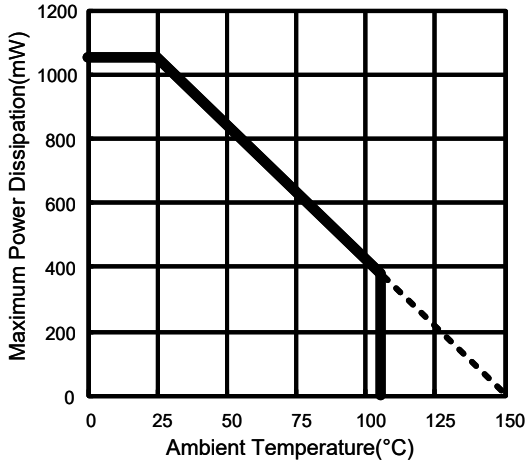
Output Saturation Voltage vs. Output Current



SO Pin Low Voltage vs. Sink Current



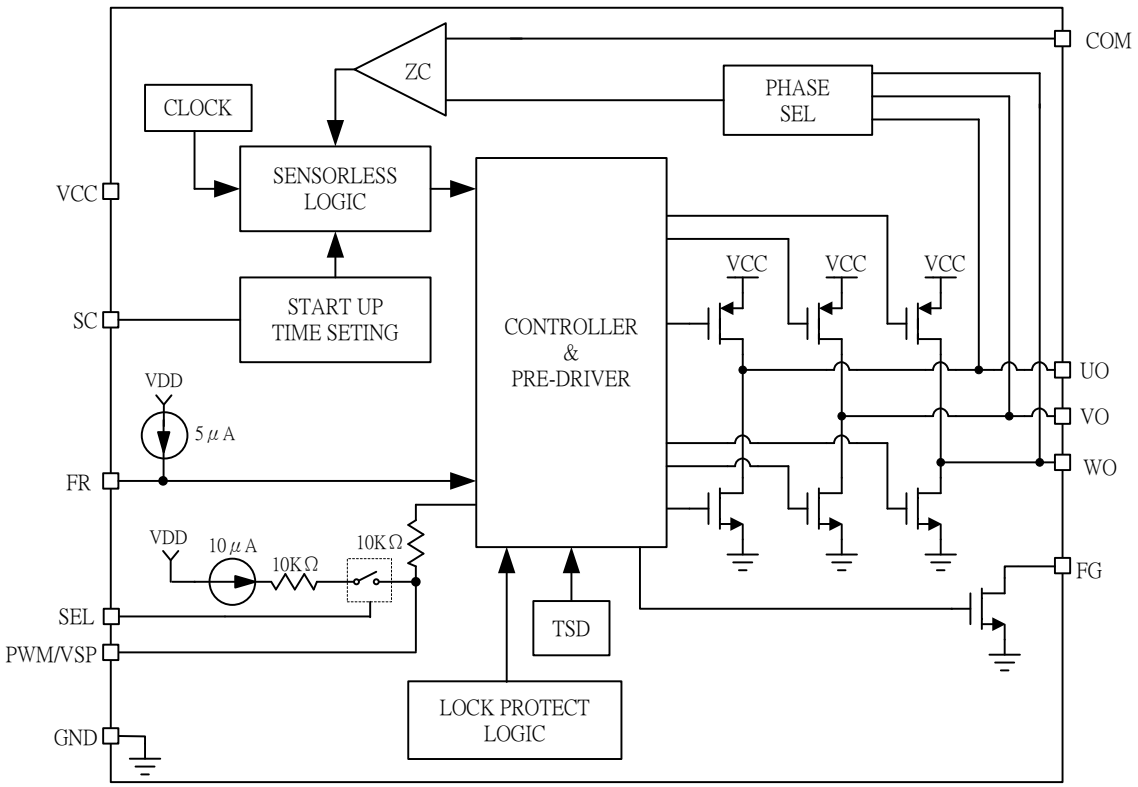
Maximum Power Dissipation vs. Ambient Temperature



Pin Descriptions

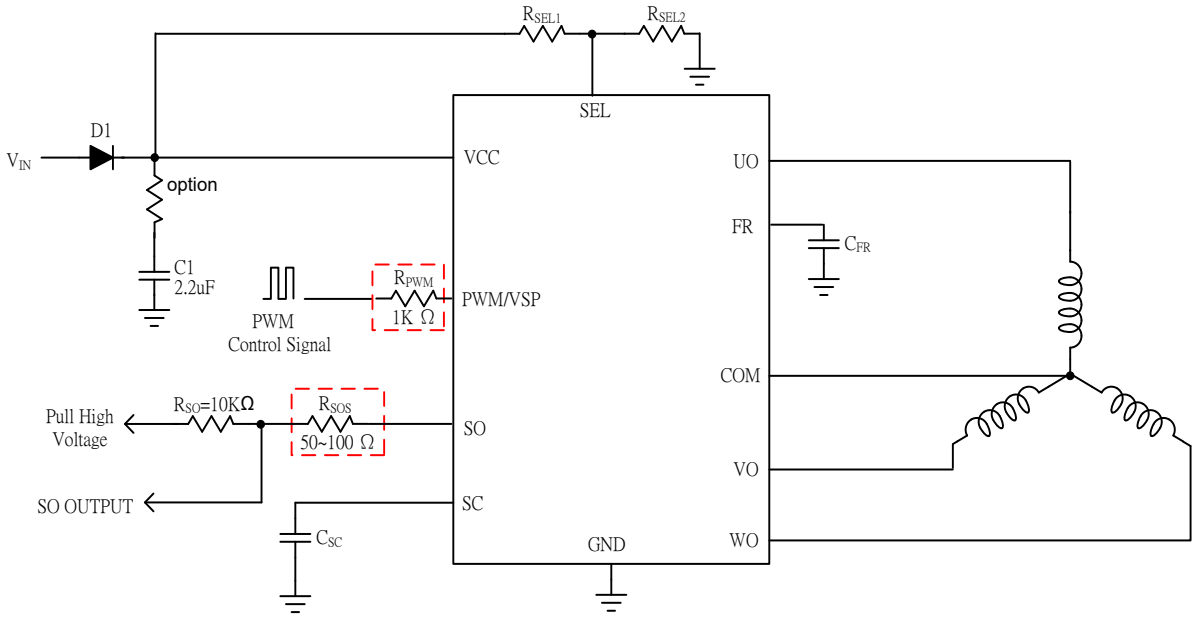
PIN		Function
NO.	NAME	
1	VO	Driver Output Pin. Output signal for driving motor phase V.
2	WO	Driver Output Pin. Output signal for driving motor phase W.
3	VCC	Supply Voltage Input Pin.
4	FR	Motor Spin Direction Control Pin. Fixed High Level Input (FR=VCC): U → V → W Fixed Low Level Input (FR=GND): U → W →V Connect Capacitor to GND: Power on U → W → V for T_{FR} (time of reverse rotation) first.
5	SC	Start-up Commutation Time Setting. Connect a capacitor to GND to set start-up commutation time.
6	PWM/VSP	PWM or VSP Signal Input Pin. Input PWM or Voltage signal to control rotation speed.
7	SO	Rotation Speed Output or Rotation Detection Output. This is an open-drain output.
8	SEL	Mode Setting. Use a voltage divider from VCC to set SEL pin voltage for setting.
9	COM	Motor Neutral Point Input Pin.
10	UO	Driver Output Pin. Output signal for driving motor phase U.
Exposed Pad	GND	Ground Pin.

Block Diagram



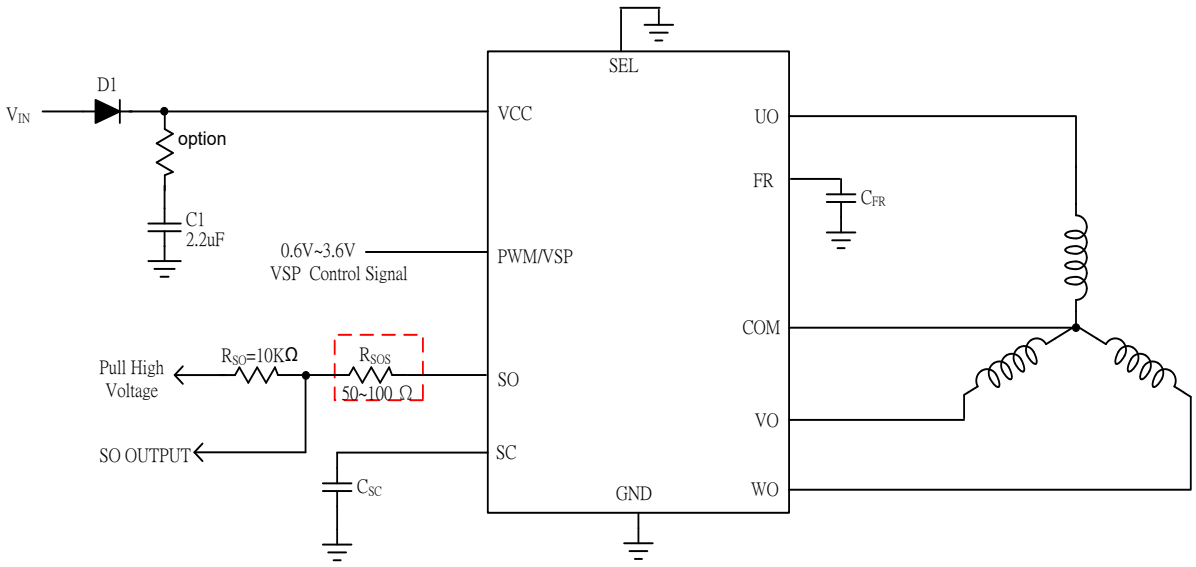
Typical Application Circuit

Circuit1: PWM Speed Control



Note: 1.R_{PWM} and R_{SOS} are optional to protect internal circuit for abnormal voltage stress.
2.C_{FR} is to set the time of reverse rotation after every power on.
3.The capacitance of C_{SC} can be fine tune for different parameter of motor.

Circuit2: VSP Speed Control



Note:1.R_{SOS} is optional to protect internal circuit for abnormal voltage stress.
2.C_{FR} is to set the time of reverse rotation after every power on.
3.The capacitance of C_{SC} can be fine tune for different parameter of motor.

Function Descriptions

Start-Up

APX9360A start mechanism is forcibly start-up mechanism. When BEMF signal isn't detected for constant time at start-up, outputs output logic forcibly signal and makes motor drive.

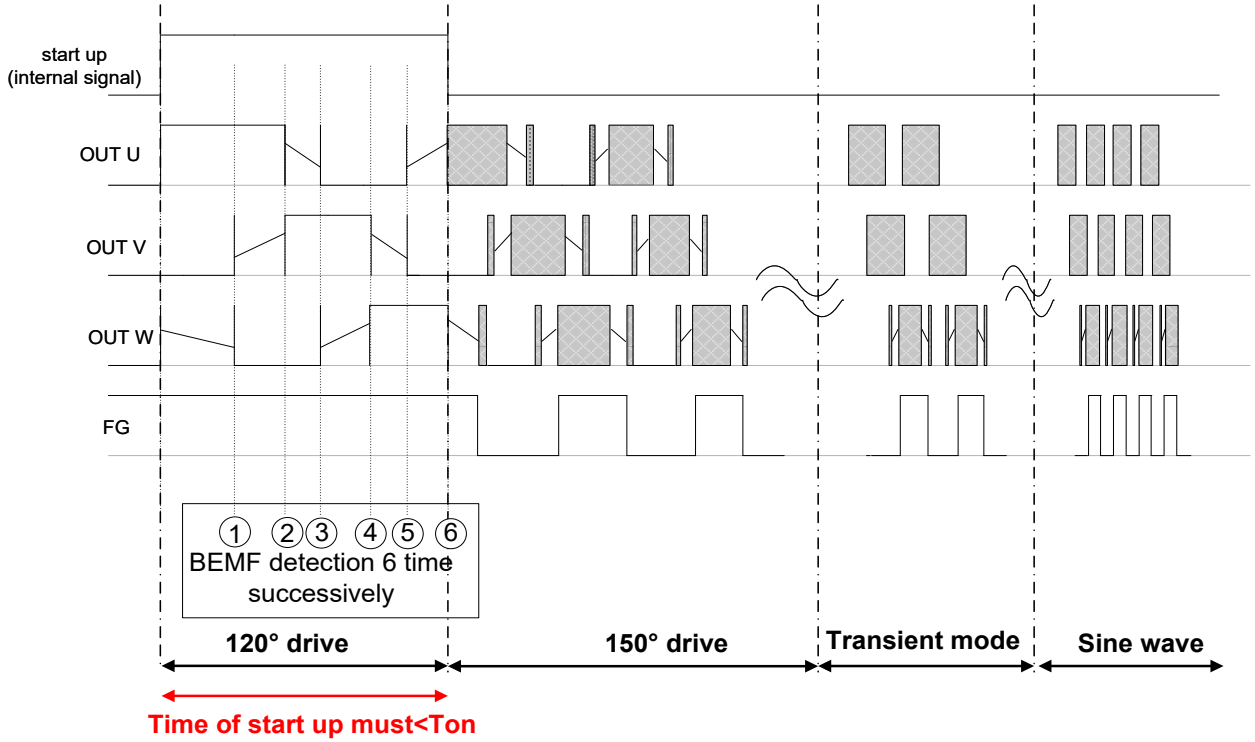


Figure 1: Start-Up Timing Chart

BEMF Zero Crossing

APX9360A has a BEMF detected comparator. However, BEMF characteristic at zero cross point is very flat, if rotor was at this position, the BEMF would not be able to detected. The fan makes drive need adequate BEMF (see Figure 2).

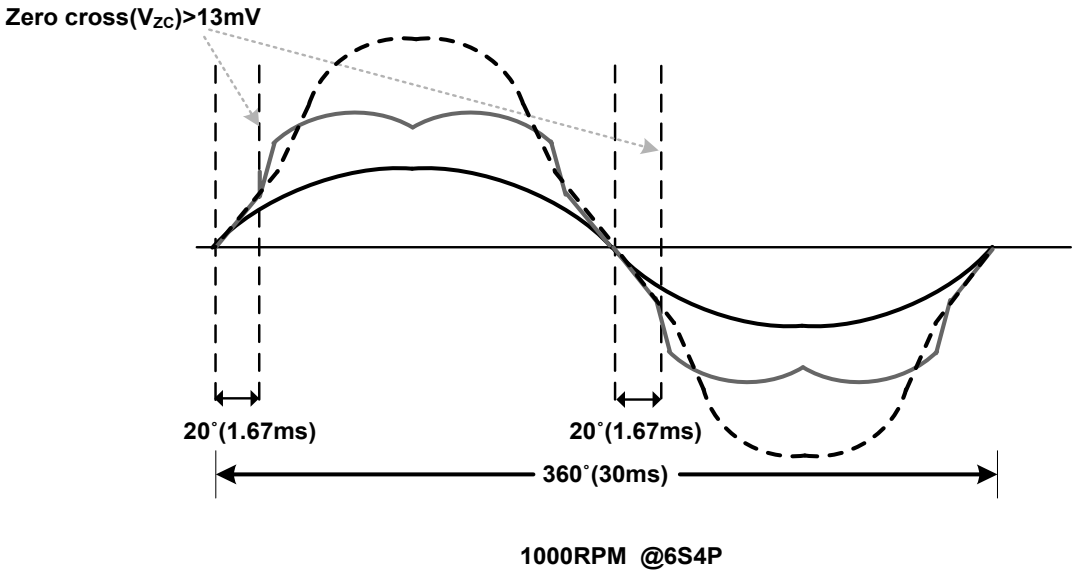


Figure 2: BEMF waveform

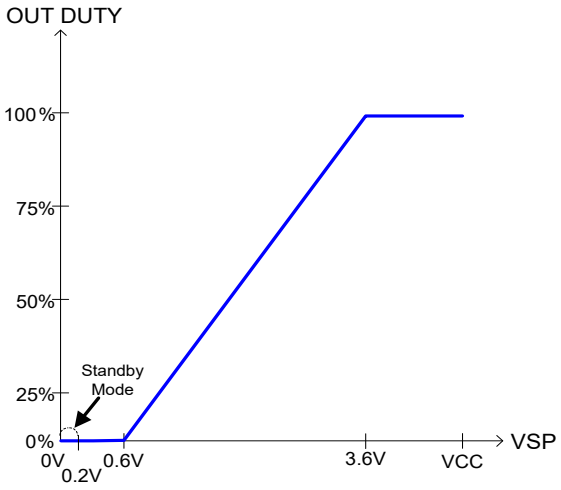
Function Descriptions (Cont.)

PWM Speed Control (fixed output frequency)

It is possible to change rotation speed of the motor by switching output transistor. The on-duty of switching depends on the signal from input of PWM terminal. The output PWM frequency is fixed to 31KHz typically.

VSP Speed Control

The APX9360A also support VSP input voltage speed control. When the SEL pin pulled down to GND, the VSP input pin to control the output duty directly.



Soft Switch (sine-wave output)

This is a soft switch PWM output to make the phase current smoother, which can reduce the noise of motor in switch interval. Using PWM duty control to simulate the idea sine wave output current.

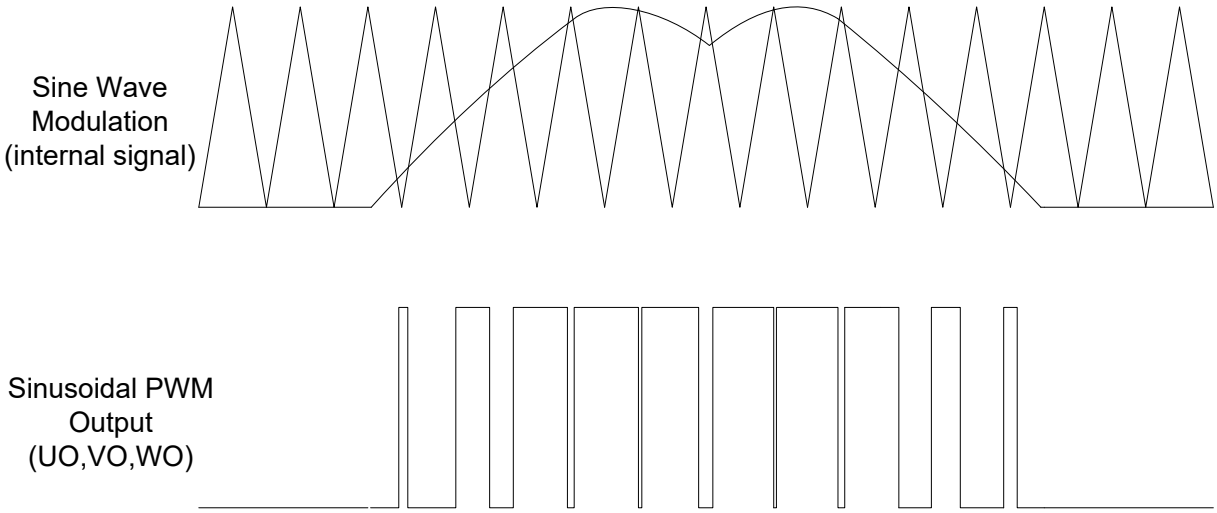


Figure 4: Sine Wave Modulation PWM Output

Function Descriptions (Cont.)

Quick Start and StandbyMode

This IC would enter standby mode when the PWM input keeps low level for more than 10ms (typ.). In standby mode, the supply current is around 100uA and the lock protection function doesn't work, therefore, starting fan is unobstructed when releasing standby mode.

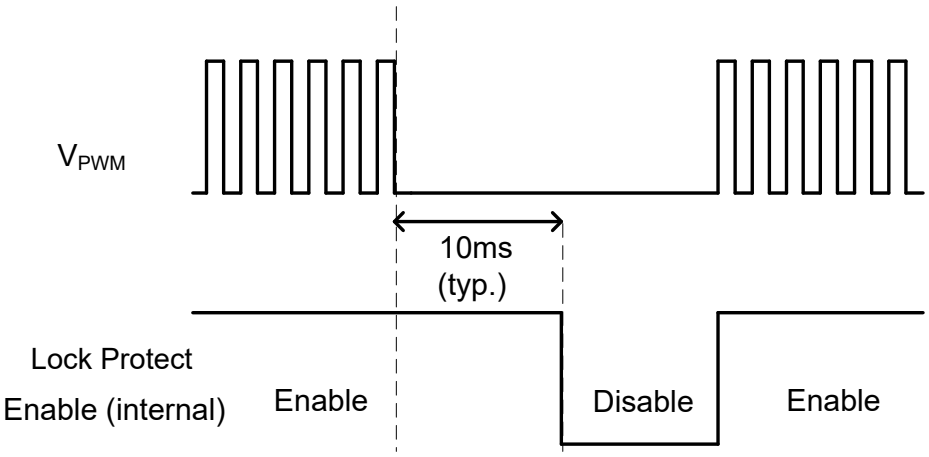


Figure 5: Quick Start waveform

FR Capacitor Control

The APX9360A provide a control pin FR to set the reverse rotation time before normal forward operation when every time of power on. The capacitance determine to time of reverse rotation.

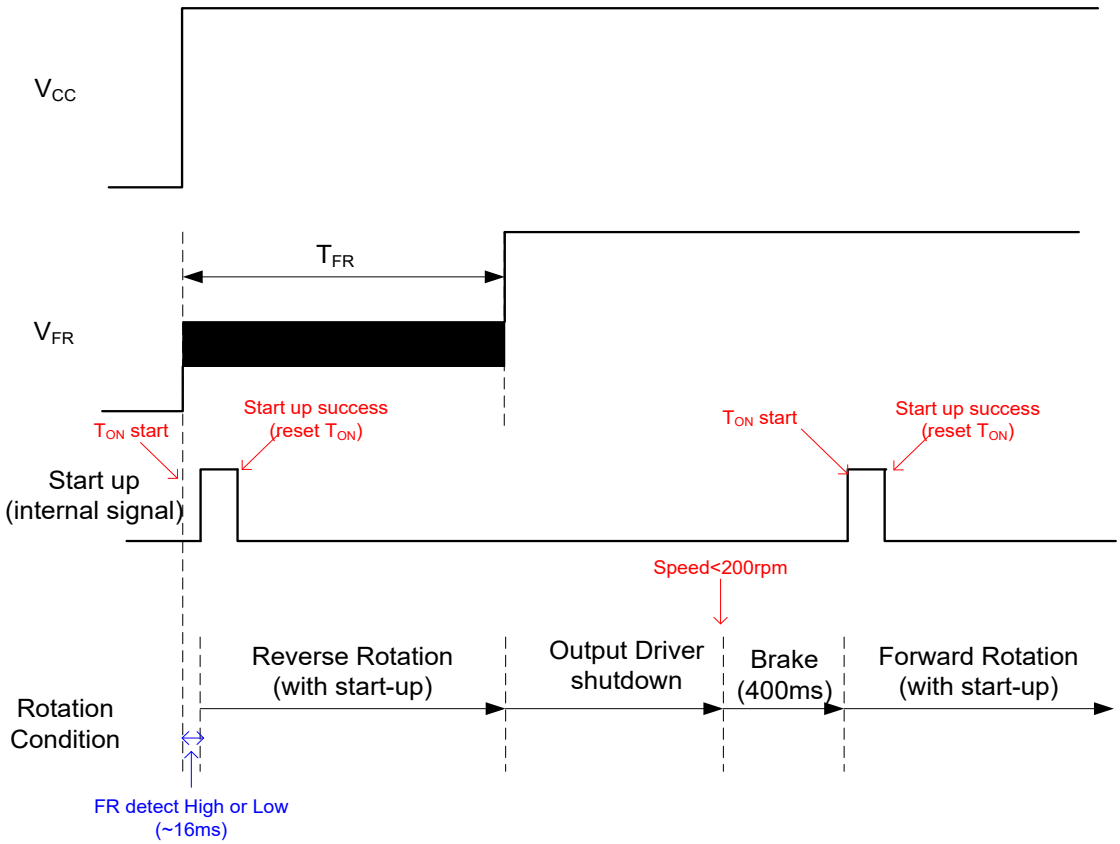


Figure 6: FR Capacitor Control

Function Descriptions (Cont.)

SEL Control

The APX9360A support FG, 1/2FG, or RD Output.

SEL Pin Input Voltage	R_{SEL1}/R_{SEL2}	SO Output	Speed Control
GND	Open/GND	FG	VSP
0.2(V) ~ 0.4*VCC(V)	30KΩ/10KΩ	RD	PWM
0.4*VCC(V) ~ 0.8*VCC(V)	10KΩ/15KΩ	1/2FG	PWM
VCC	VCC/Open	FG	PWM

Table 1: SEL Pin Definition

Lock Protection and Automatic Restart

The APX9360A provides the lock protection and automatic restart functions to prevent the coil burnout while the fan is locked. As the fan is locked, the IC will come into startup operation for 0.7 second. Then, the IC will switch to lock protection mode to turn off output driver for 5 seconds. After lock protection mode, the IC switches to start-up operation again. If the locked condition still remains, the lock-and-restart process will be recurred until the locked condition is released.

Thermal Protection

The APX9360A has thermal protection. When internal junction temperature reaches 165°C, the output devices will be switched off. When the IC's junction temperature cools down 30°C, the thermal sensor will turn on the output devices again, resulting in a pulsed output during continuous thermal protection.

Application Information

Input Protection Diode & Capacitor

It is necessary to add a protection diode (D1) to prevent the damage from the power reverse connection. However, the protection diode will cause a voltage drop on the supply voltage. The current rating of the diode must be larger than the maximum output current. For the noise reduction purpose, a capacitor (C1) is connected between VCC and GND. (see Typical Application Circuit) It's suggested that C1 should be placed as close as possible in the VCC pin.

SC Capacitor

The capacitor connected between SC pin and GND can define the frequency of force commutation. The optimal design of the frequency could make sure the motor start-up in succeed. Its capacitance from 1nF to 10nF is recommended.

$$T_{SC} = \frac{2\times(V_{SCH} - V_{SCL})\times C_{SC}}{I_{SC}} \times 400$$

For example:
C_{SC} =1.0nF
V_{SCL}=0.6V, V_{SCH}=1.2V, I_{SC}= (I_{SC1} + I_{SC2})/2=15uA

The force start up time is 32ms.

FR Capacitor

The capacitor connected between FR pin and GND can define the time of reverse rotation before normal forward rotation when power on. The time TFR is defined by the following equation:

$$T_{FR} = \frac{2\times C_{FR}\times(V_{FRH} - V_{FRL})}{I_{FR}} \times 12000$$

For example:
C_{FR}=10nF, V_{FRH}=1.2V, V_{FRL}=0.6V, I_{FR}=5μA
The reverse rotation time T_{FR}=28.8sec

SO Resistor

The value of the SO resistor could be decided by the following equation:

$$R_{SO} = \frac{V_{CC} - V_{SO}}{I_{SO}}$$

For example:
V_{CC}=5V, I_{SO}=5mA, V_{SO}=0.1V, R_{SO}=0.98kΩ

The value of resistor in the range of 1kΩ to 10kΩ is recommended.

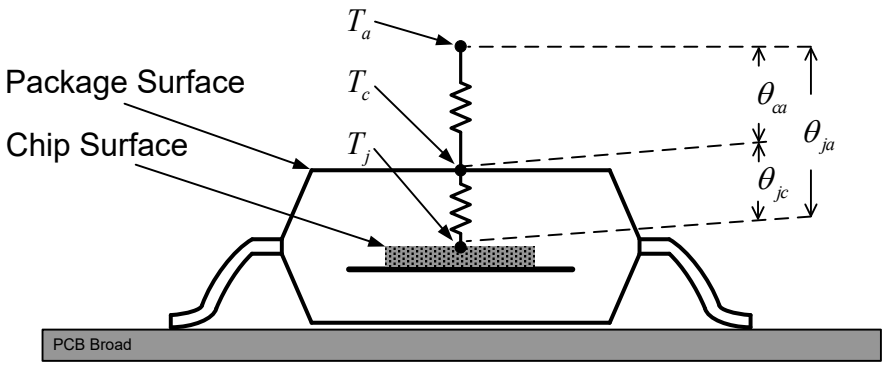
Application Information (Cont.)

Power Dissipation

The power dissipation of IC, it indicates permission consumed power at ambient temperature(T_a=25°C). But it value is related to some conditions of the surrounding, such as the PCB broad size and mounting condition and ambient temperature (T_a). Therefore power dissipation and thermal resistance isn't a fixed value at the same IC package. The power dissipation is determined by IC chip surface permission maximum junction temperature and thermal resistance (θ_{ja}). The below figure is descriptions the thermal resistance from chip surface to ambient temperature and junction temperature (T_j) calculation.

Thermal Resistance and Temperature Symbol Description

symbol	Parameter
T_j	Chip Surface (Junction) Temperature
T_c	Package Surface (Case) Temperature
T_a	Ambient (Air) Temperature
θ_{jc}	Junction to Case Resistance
θ_{ca}	Case to Air Resistance
θ_{ja}	Junction to Air Resistance



$$T_j = \theta_{ja} \times P + T_a(^\circ C)$$

$$\theta_{jc} = \frac{T_j - T_c}{P}(^\circ C/W)$$

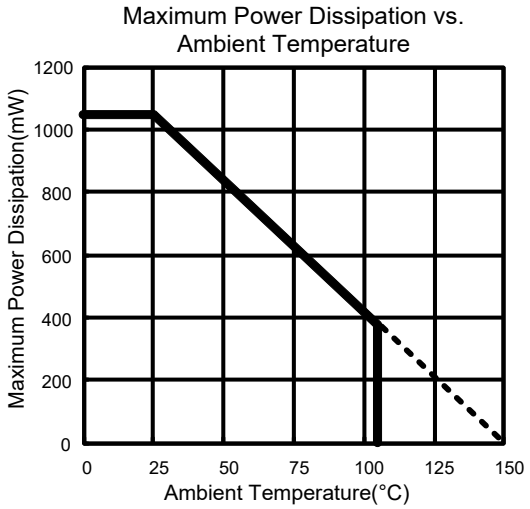
$$\theta_{ca} = \frac{T_c - T_a}{P}(^\circ C/W)$$

$$\theta_{ja} = \frac{T_j - T_a}{P}(^\circ C/W)$$

Note：P is mean the Power(W)

Figure 7. Thermal Resistance Definition Diagram

Application Information (Cont.)

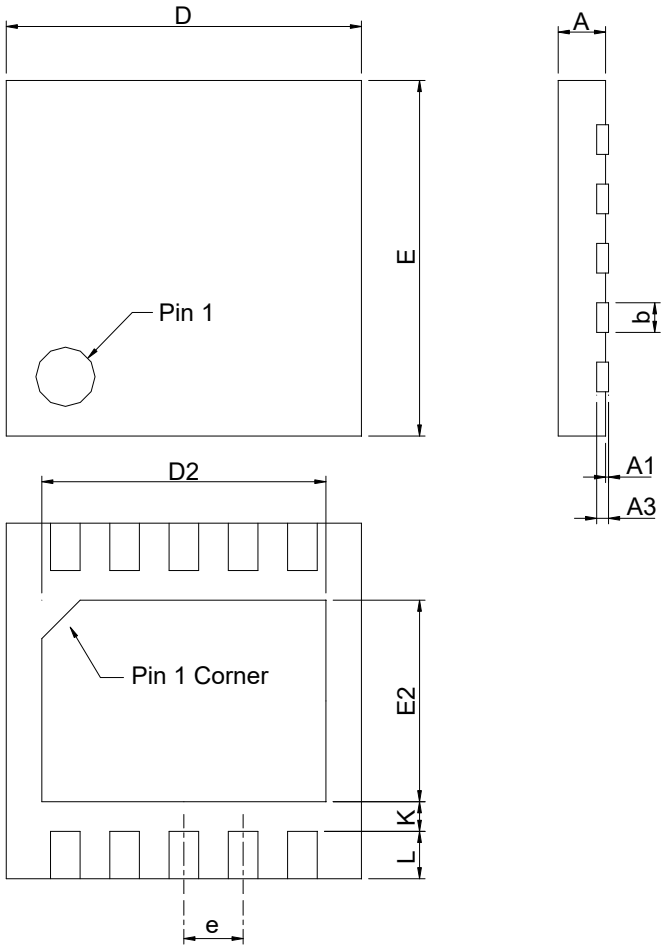


Note: Above Ta = 25°C, derating by 8.4 mW/°C
When glass epoxy board of 55 mm x 40 mm x 1.6 mm is mounted. The Thermal Pad on the bottom of VTDFN3x3-10 package should soldered directly to the PCB's Thermal Pad area that with several thermal vias connect to ground plane, and the PCB is a 2-layer, 10mm square with 2oz cooper thickness.

Figure 8. Thermal derating curve

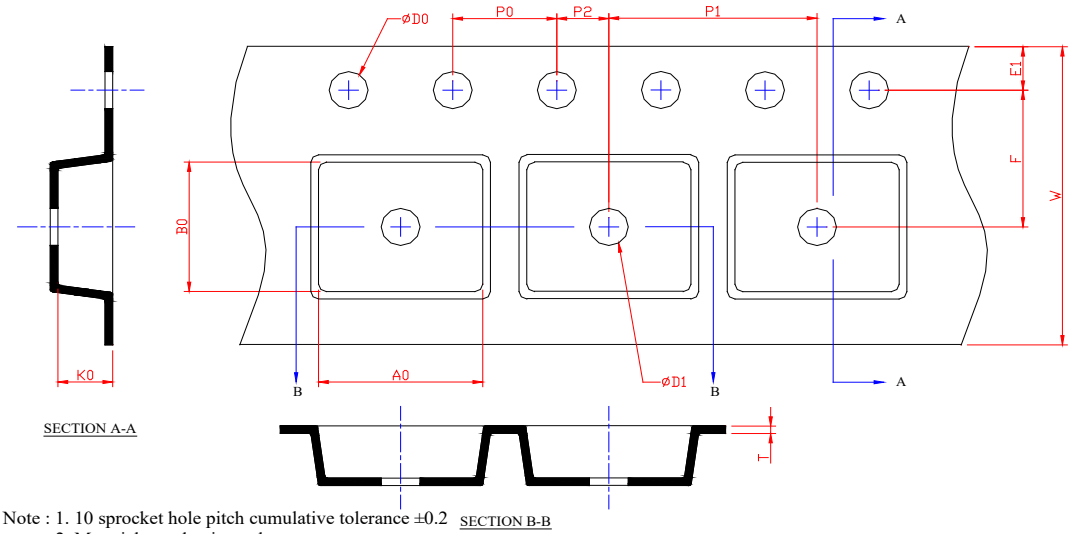
Package Information

VTDFN3x3-10

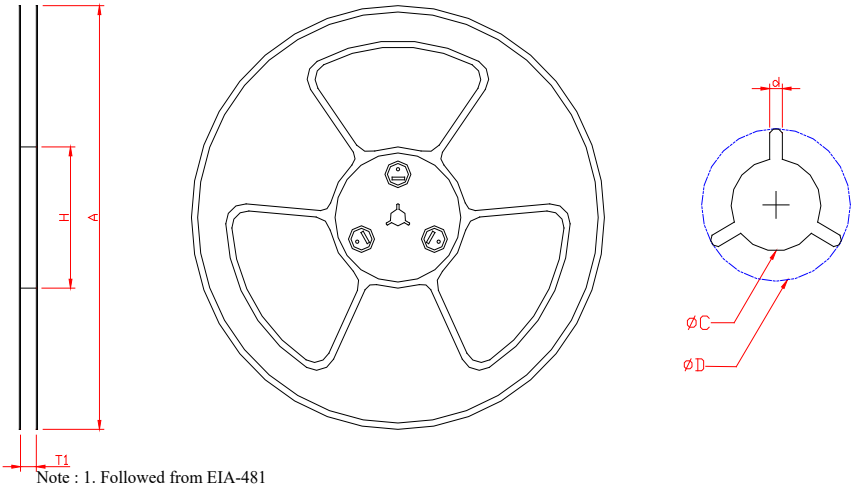


SYMBOL	VTDFN3x3-10			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.50	0.60	0.020	0.024
A1	0.00	0.05	0.000	0.002
A3	0.20 REF		0.008 REF	
b	0.18	0.30	0.007	0.012
D	2.90	3.10	0.114	0.122
D2	2.20	2.70	0.087	0.106
E	2.90	3.10	0.114	0.122
E2	1.40	1.75	0.055	0.069
e	0.50 BSC		0.016 BSC	
L	0.30	0.50	0.012	0.020
K	0.20		0.008	

Carrier Tape & Reel Dimensions



Note : 1. 10 sprocket hole pitch cumulative tolerance ±0.2
2. Material: conductive polystyrene
3. Ao and Bo measured on a plane 0.3mm above the bottom of the pocket
4 Ko measured from a plane on the inside bottom of the pocket to the top surface of the carrier



Note : 1. Followed from EIA-481

Application	A	H	T1	C	d	D	W	E1	F
VTDFN3x3-10	330.0±2.00	50 MIN.	12.4+2.00 -0.00	13.0+0.50 -0.20	1.5MIN.	20.2MIN.	12.0±0.30	1.75±0.10	5.5±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	1.5MIN.	0.6+0.00 -0.40	3.30±0.20	3.30±0.20	0.75±0.20

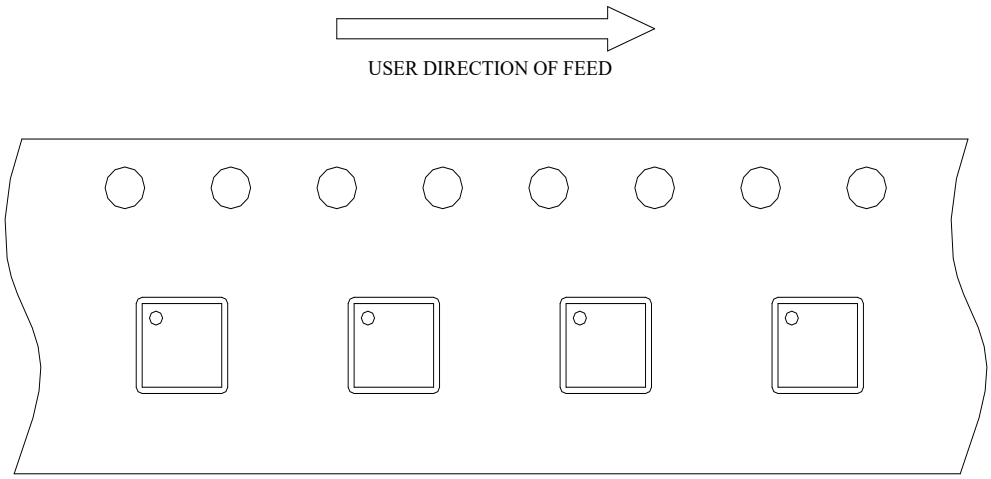
(mm)

Devices Per Unit

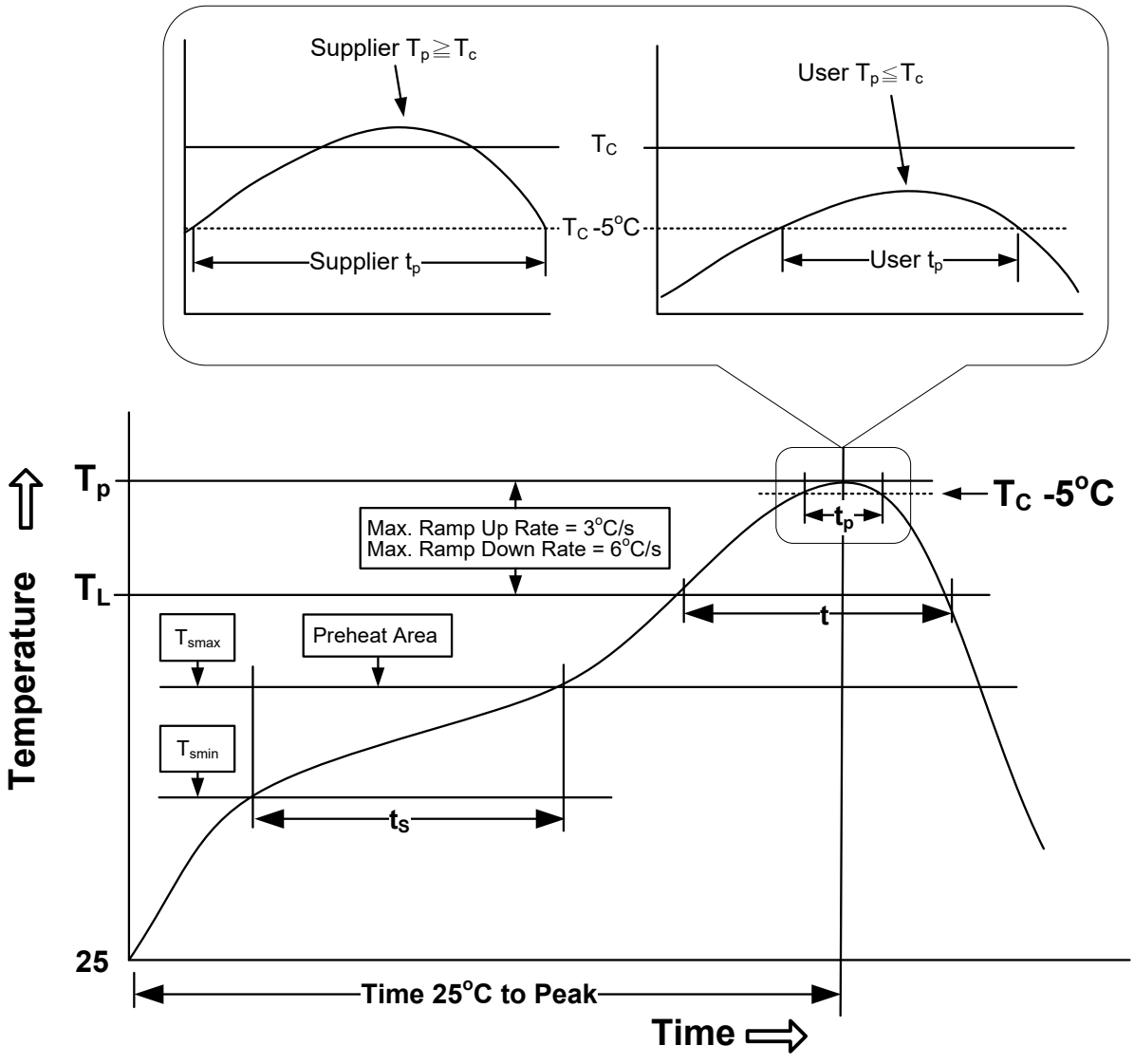
Package type	Packing	Quantity
VTQFN 3*3	Tape & Reel	3000

Taping Direction Information

VTDFN3x3-10



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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