

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

Features

- PWM Sine-Wave Driver
- Three-Phase Sensor-Less Drive
- OTP (2 Banks) For Function Programming
- Adjustable Align Start-up
- Built-In External PWM Speed Control
- Built-In Quick Start Function
- FG, 1/2FG, 1/3FG or 2/3FG Output
- Power Saving Function
- Built-In Lock Protection and Auto Restart Function
- Built-In Adjustable Leading Angle or Auto Leading Angle
- Built-In Adjustable Duty Change Rate
- Built-In Thermal Protection Circuit

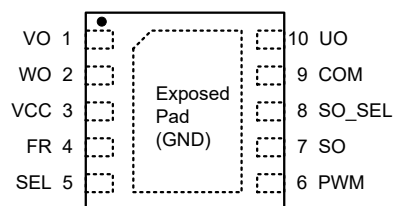
General Description

The APX9351 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, lock protection, and thermal shutdown circuit. Using digital programming (OTP x 2 Bank), it's much easier and adjustable for applications. The APX9351 is suitable for both game machine and CPU cooler that need silent drivers. It is available in XTDFN3x3-10 package.

Applications

- Motor Drivers for Silent Fans
- Variable Speed Control Fans

Pin Configuration



XTDFN3x3-10
(TOP VIEW)

 = Exposed Pad (connected to the ground of power)

Ordering and Marking Information

APX9351-□□□□□-□□□ Assembly Material Handling Code Temperature Range Package Code Source Code	Package Code QH : XTDFN3x3-10 Operating Ambient Temperature Range I : -40 to 105 °C Handling Code TR : Tape & Reel Assembly Material G : Green Part
APX9351-XXX QH : X9351 XXXXX XXX	Second line : Date Code Third line : OTP Source Code
APX9351 QH : X9351 XXXXX	Second line : Date Code Third line : OTP Blank

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

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.

Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Ratings	Unit
V_{CC}	VCC Pin Supply Voltage (VCC to GND)	-0.3 to 7	V
I_{OUT}	UO/VO/WO Pin Output Current	2	A
$V_{UO}/V_{VO}/V_{WO}$	UO/VO/WO Pin Output Voltage	-0.3 to 7	V
V_{PWM}	PWM Pin Maximum Input Voltage	-0.3 to 7	V
	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) XTDFN3x3-10	119	°C/W
P_D	Power Dissipation, $T_A=25^\circ\text{C}$ XTDFN3x3-10	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 Operation Conditions (Note 3)

Symbol	Parameter	Range	Unit
V_{CC}	VCC Pin Supply Voltage Range	2.8 to 6.5	V
V_{PWM}	PWM 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 850	mA

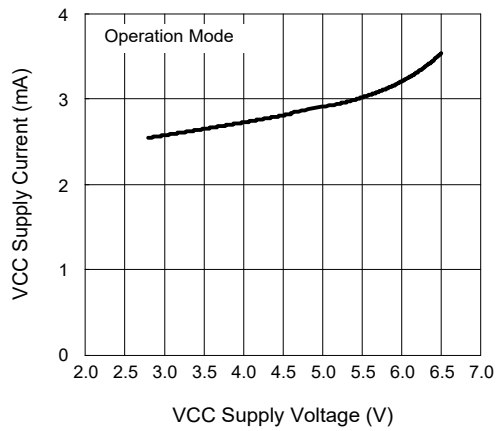
Note 3: Refer to the typical application circuit.

Electrical Characteristics ($V_{CC}=5V$, $T_A=25^{\circ}C$, unless otherwise specified)

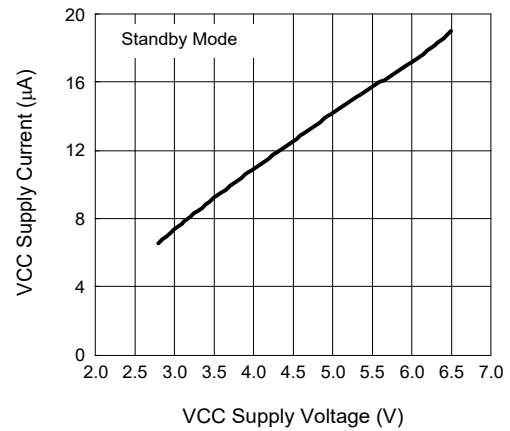
Symbol	Parameter	Test Conditions	APX9351			Unit
			Min.	Typ.	Max.	
SUPPLY CURRENT						
I _{CC1}	Operating Current	Rotation Mode	-	3	5	mA
I _{CC2}		Standby Mode (PWM=0)	-	14	20	μA
PWM CONTROL						
V _{PWMH}	PWM Input High Level Voltage	VCC=5V	1.8	-	5.3	V
V _{PWML}	PWM Input Low Level Voltage	VCC=5V	-0.3	-	0.8	V
V _{PWMH}	PWM Input High Level Voltage	VCC=3.3V	-	1.3	-	V
V _{PWML}	PWM Input Low Level Voltage	VCC=3.3V	-	0.6	-	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		1	-	50	kHz
F _{OUT}	Output Switch Frequency		-	63	-	kHz
T _{DCS}	Duty Change Time for Output Duty 0% to 100%	OTP setting	-	0.5/1/2/4	-	sec
OUTPUT DRIVERS						
V _O	Output Driver Saturation Voltage	I _{OUT} =850mA, T _J =25°C, Upper and Lower total	-	0.425	0.5525	V
V _O	Output Driver Saturation Voltage	I _{OUT} =850mA, T _J =150°C, Upper and Lower total	-	0.6375	0.8075	V
V _{SO}	SO Pin Low Voltage	I _{SO} =5mA	-	0.1	0.3	V
I _{SOL}	SO Pin Leakage Current	V _{SO} =5V	-	<0.1	1	μA
LOCK PROTECTION						
T _{ON}	Lock Detection On Time	Define by SEL	-	1.1~1.7	-	sec
T _{OFF}	Lock Detection Off Time		-	5	-	sec
FR INPUT						
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

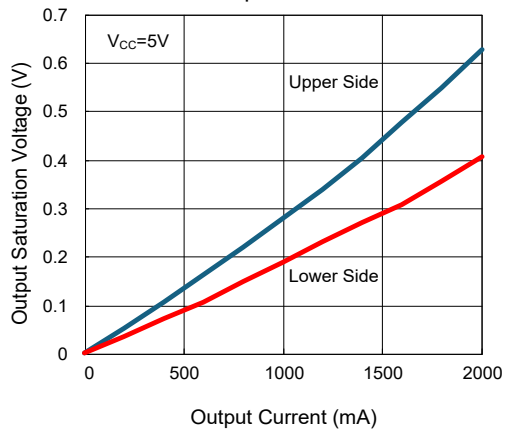
VCC Supply Current vs. VCC Supply Voltage



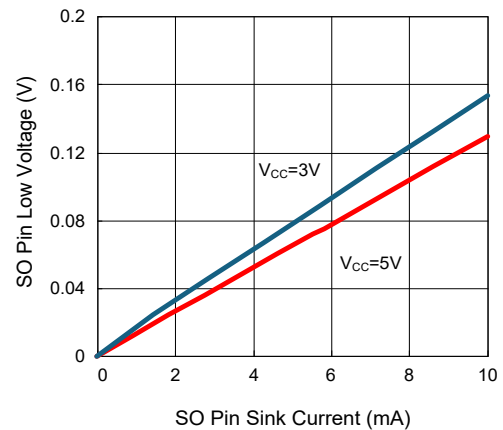
VCC Supply Current vs. VCC Supply Voltage



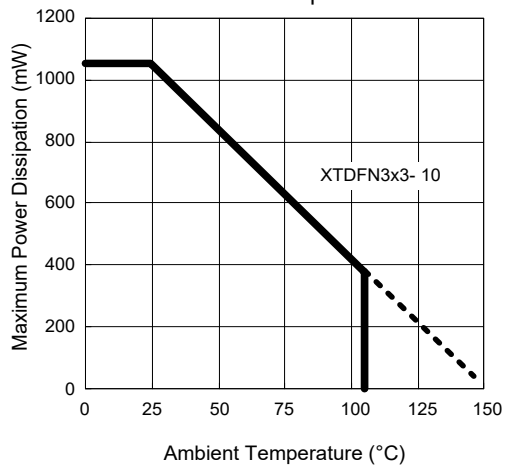
Output Saturation Voltage vs. Output Current



SO Pin Low Voltage vs. Sink Current



Maximum Power Dissipation vs. Ambient Temperature

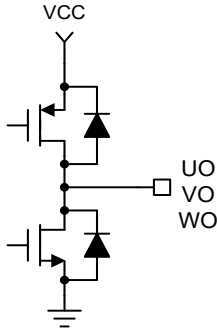


Pin Descriptions

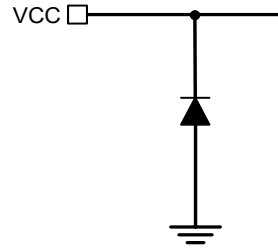
PIN		FUNCTION
NO.	NAME	
1	VO	Driver Output Pin. Output signal for driving motor phase V.
2	WO	Driver Output Pin. Output signal for driving motor phase W.
3	VCC	Supply Voltage Input Pin.
4	FR	Motor Spin Direction Control Pin. Fixed High Level Input (FR=VCC): U → V → W Fixed Low Level Input (FR=GND): U → W → V
5	SEL	Mode Setting. Use a voltage divider from VCC to set SEL pin voltage for setting.
6	PWM	PWM Signal Input Pin. Input PWM signal to control rotation speed.
7	SO	Rotation Speed Output. This is an open-drain output.
8	SO_SEL	SO Setting. Use a voltage divider from VCC to set SO_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.

I/O Equivalent Circuits

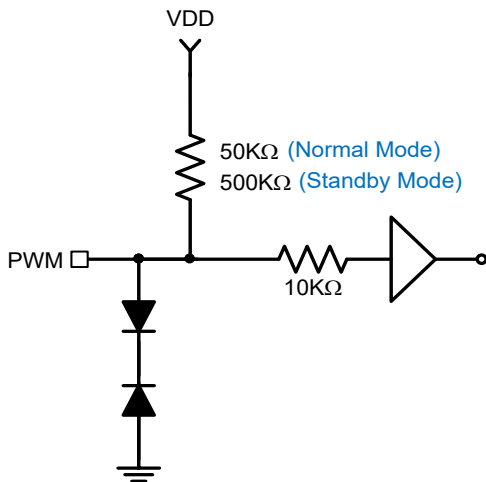
Driver output pin (UO, VO, WO)



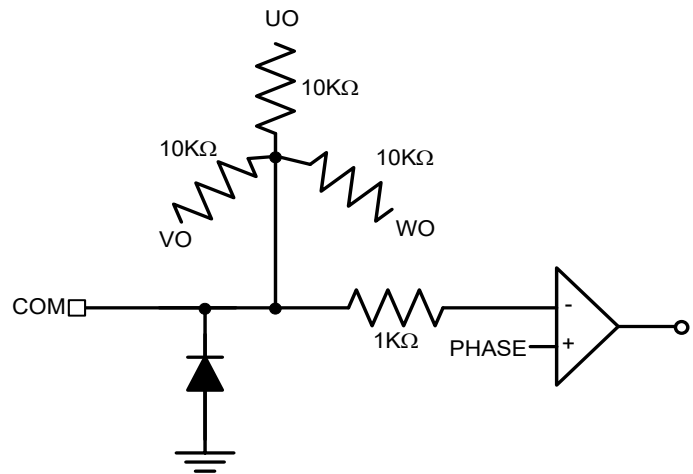
Power supply input pin (VCC, GND)



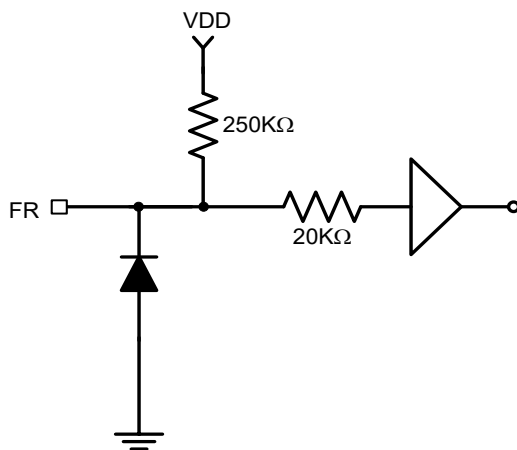
PWM speed control input pin (PWM)



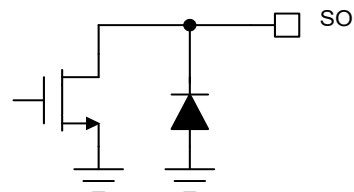
Motor neutral point input pin (COM)



Setting input pin (FR)

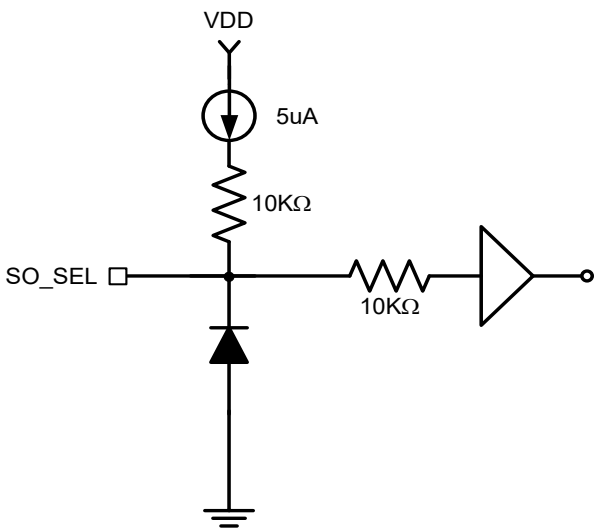


Rotation speed output pin (SO)

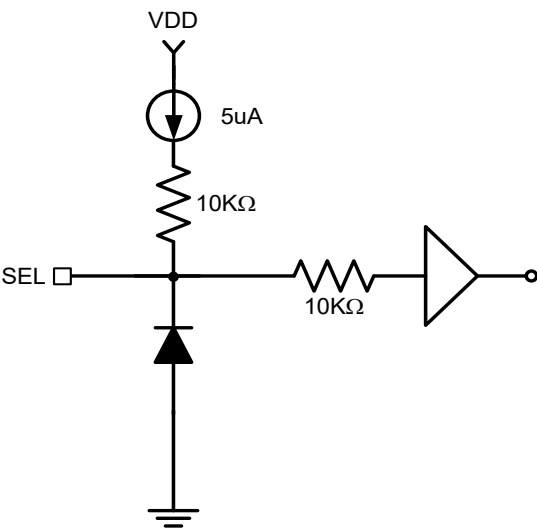


I/O Equivalent Circuits (Cont.)

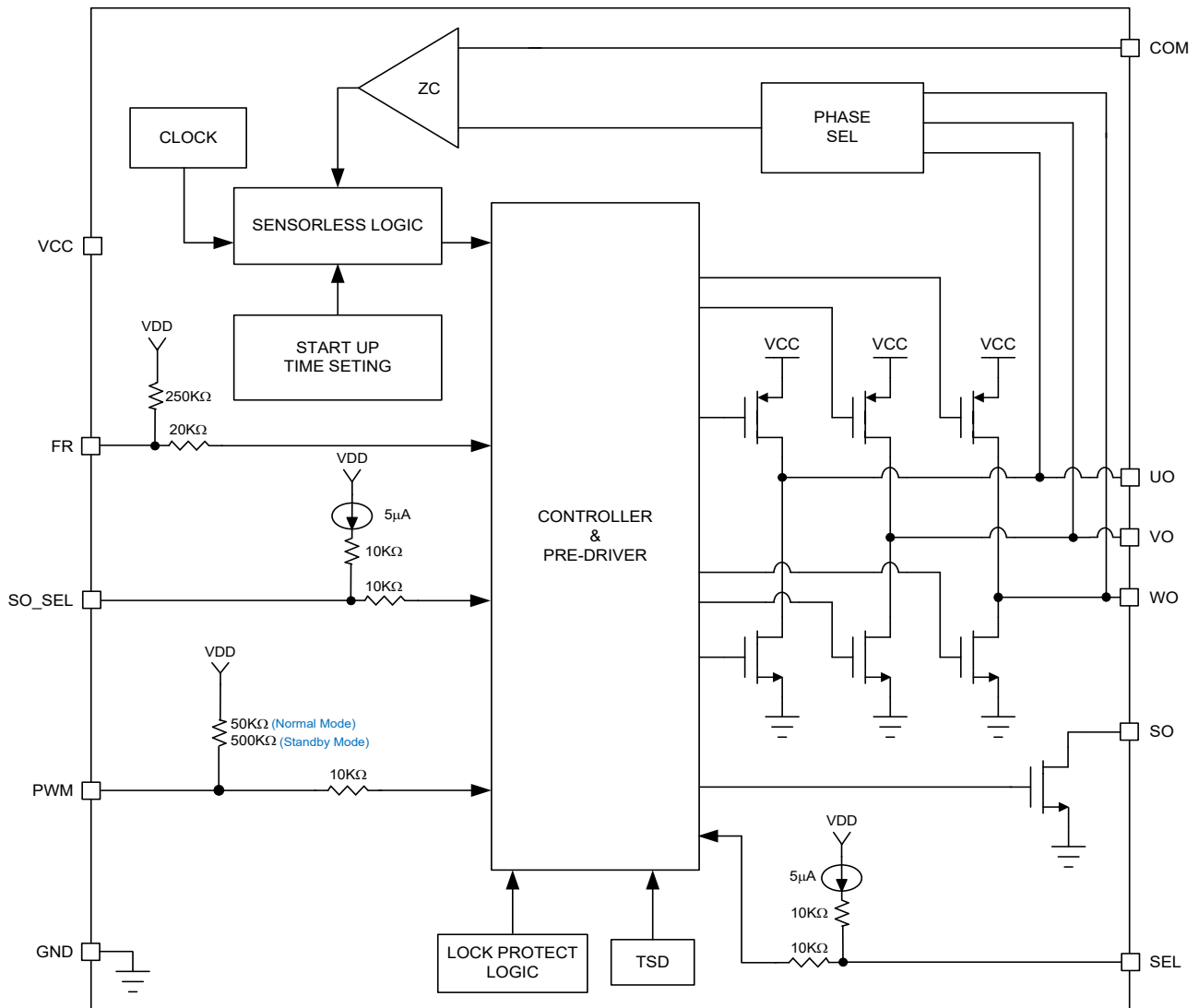
Setting input pin (SO_SEL)



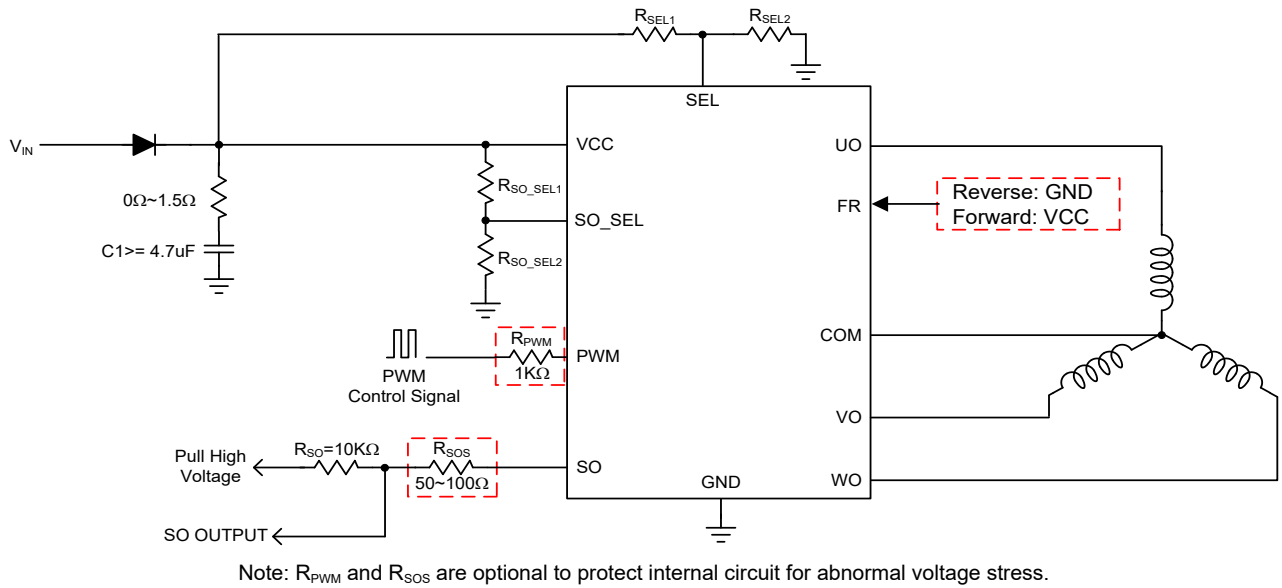
Setting input pin (SEL)



Block Diagram



Typical Application Circuits



Function Descriptions

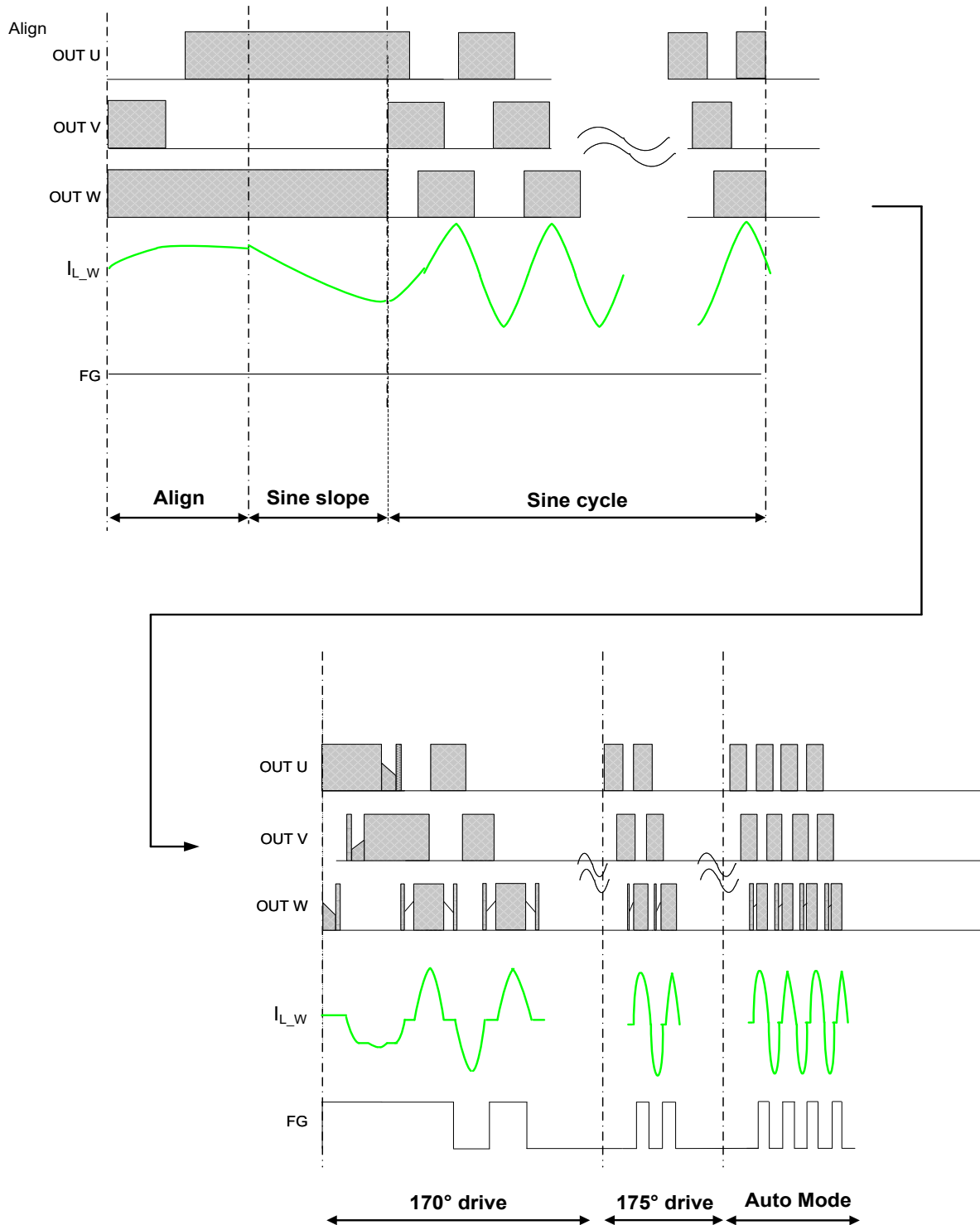
Start-Up

The APX9351 uses a step to start sequence to accelerate the motor up to a point where there is sufficient speed such that the position can be reliably measured.

Align: Aling Duty and Aling Time setting by OTP.

Sine slope: Slope setting by OTP.

Sine cycle: Speed setting by OTP.

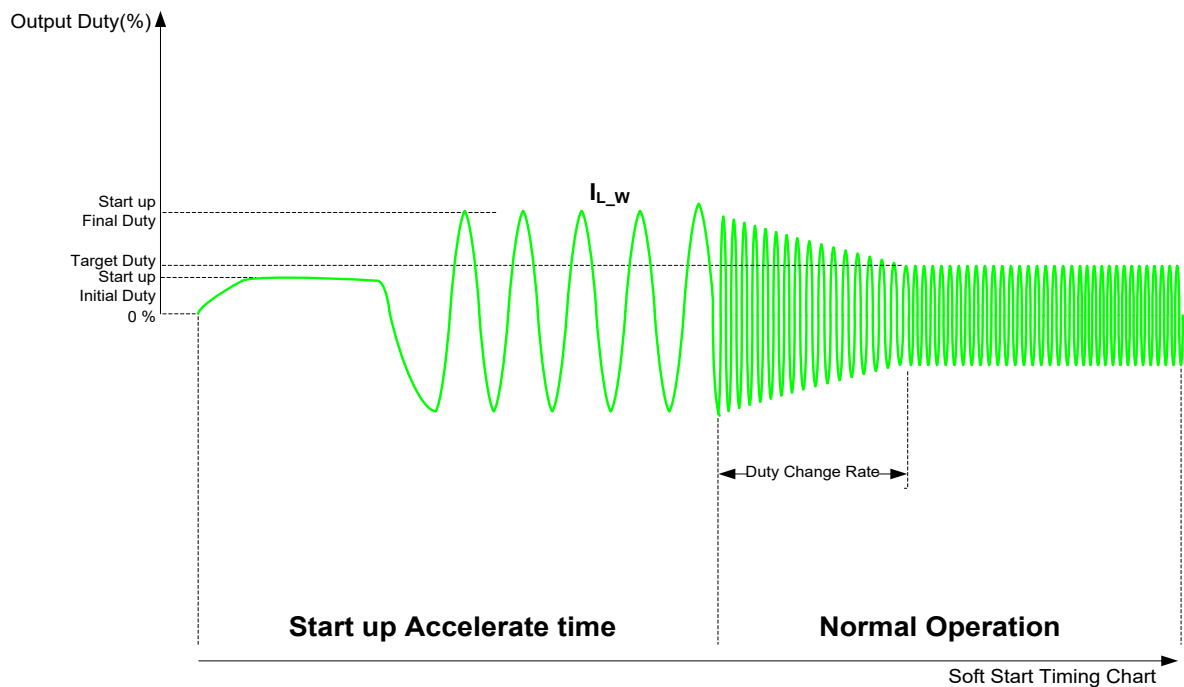
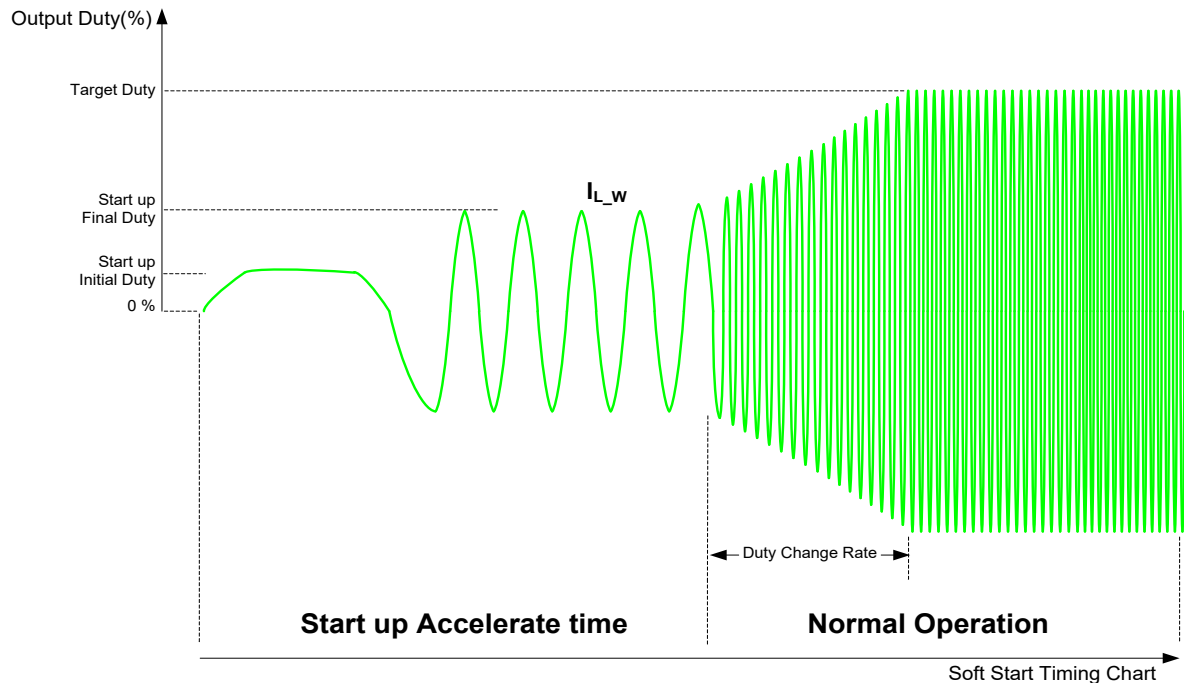


*The picture is for reference only, please refer to the motor.

Function Descriptions (Cont.)

Soft Star

The soft start of APX9351 is divided into two stages. The first is start up accelerate time. In this stage, output duty is from initial duty to final duty. After accelerate time, enter to second stage. The output duty increase or decrease are based on target duty value.



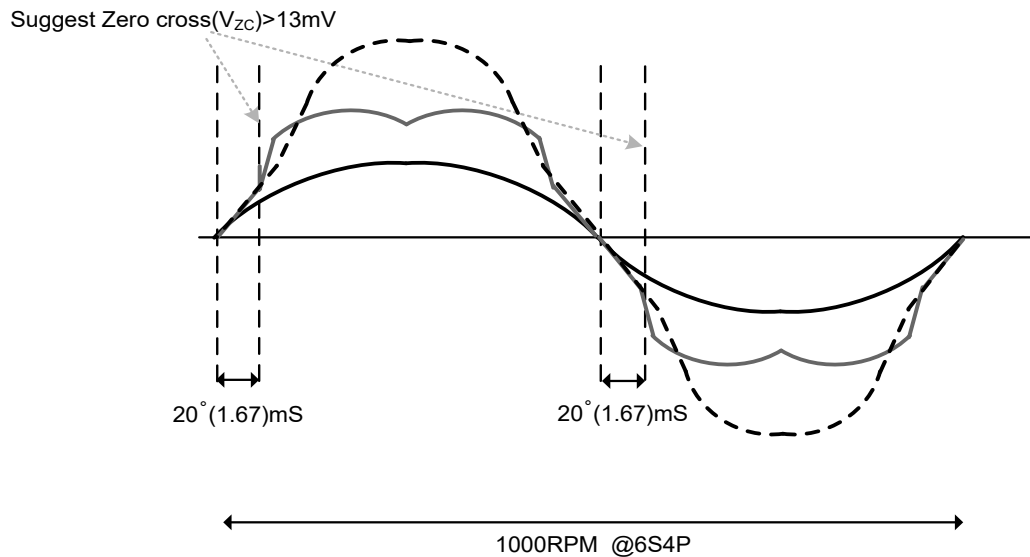
Function Descriptions (Cont.)

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 63KHz typically.

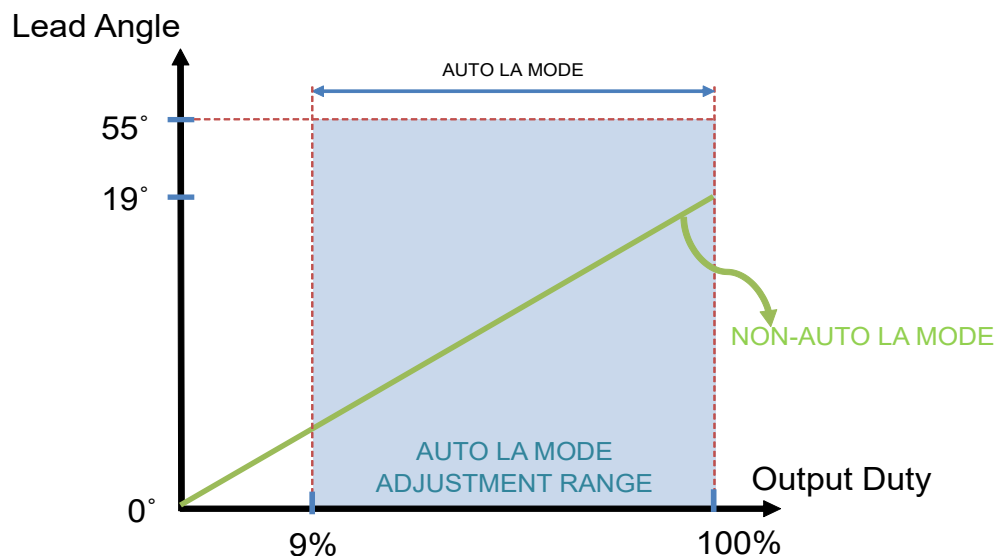
BEMF Zero Crossing

APX9351 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.



Lead Angle

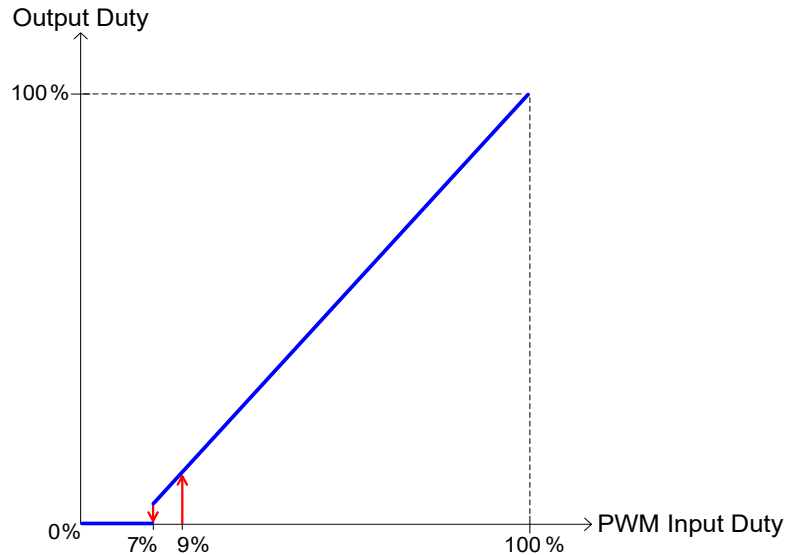
The APX9351 built in lead angle controlled. The LA setting by OTP.



Function Descriptions (Cont.)

Speed Control Curve

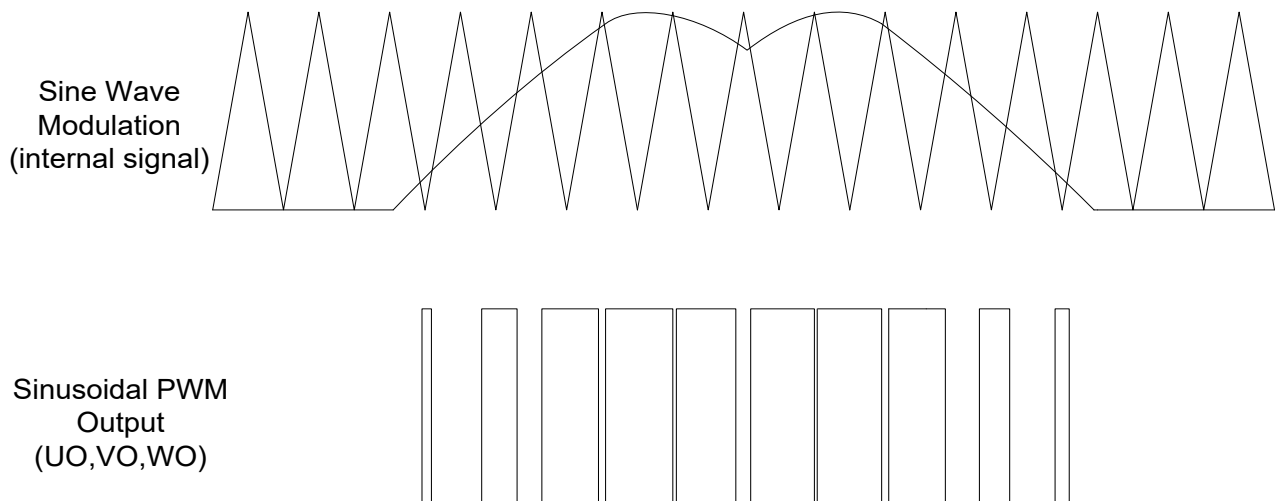
It is possible to change rotation speed of the motor by switching output transistor. The on-duty of switching depends on the signal from input to PWM terminal.



Shutdown Curve

Soft Switch (sine-wave output)

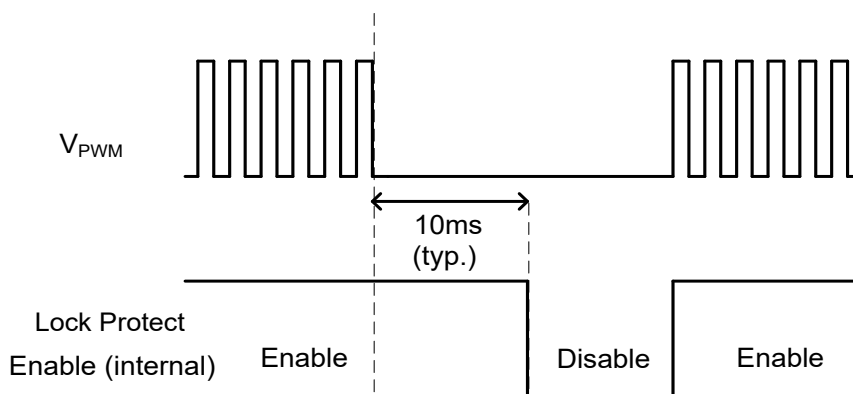
This is a soft switch PWM output to make the phase current smoother, which can reduce the noise of motor in switch interval. Using PWM duty control to simulate the idea sine wave output current.



Function Descriptions (Cont.)

Quick Start and Standby Mode

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 14uA and the lock protection function doesn't work, therefore, starting fan is unobstructed when releasing standby mode.



SO_SEL Control

The APX9351 support FG, 2/3FG, 1/2FG or 1/3FG Output.

SO_SEL Pin Input Voltage	R_{SEL1}/R_{SEL2}	SO Output
GND	Open/GND	1/3FG
$0.2 \cdot V_{CC}(V) \sim 0.55 \cdot V_{CC}(V)$	20K Ω /10K Ω	1/2FG
$0.55 \cdot V_{CC}(V) \sim 0.85 \cdot V_{CC}(V)$	10K Ω /20K Ω	2/3FG
VCC	VCC/Open	FG

SEL Control

SEL Pin Input Voltage	R_{SEL1}/R_{SEL2}	Align Time(S)	Align Duty(%)	SS_Duty(%)	On Time(S)
GND	Open/GND	0.2	15	100	1.1
$0.2 \cdot V_{CC}(V) \sim 0.55 \cdot V_{CC}(V)$	20K Ω /10K Ω	0.2	30	30	1.7
$0.55 \cdot V_{CC}(V) \sim 0.85 \cdot V_{CC}(V)$	10K Ω /20K Ω	0.72	30	50	1.3
VCC	VCC/Open	0.2	30	75	1.1

Lock Protection and Automatic Restart

The APX9351 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 start-up operation for 1.1~1.7 seconds. 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 APX9351 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.

SO Resistor

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

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

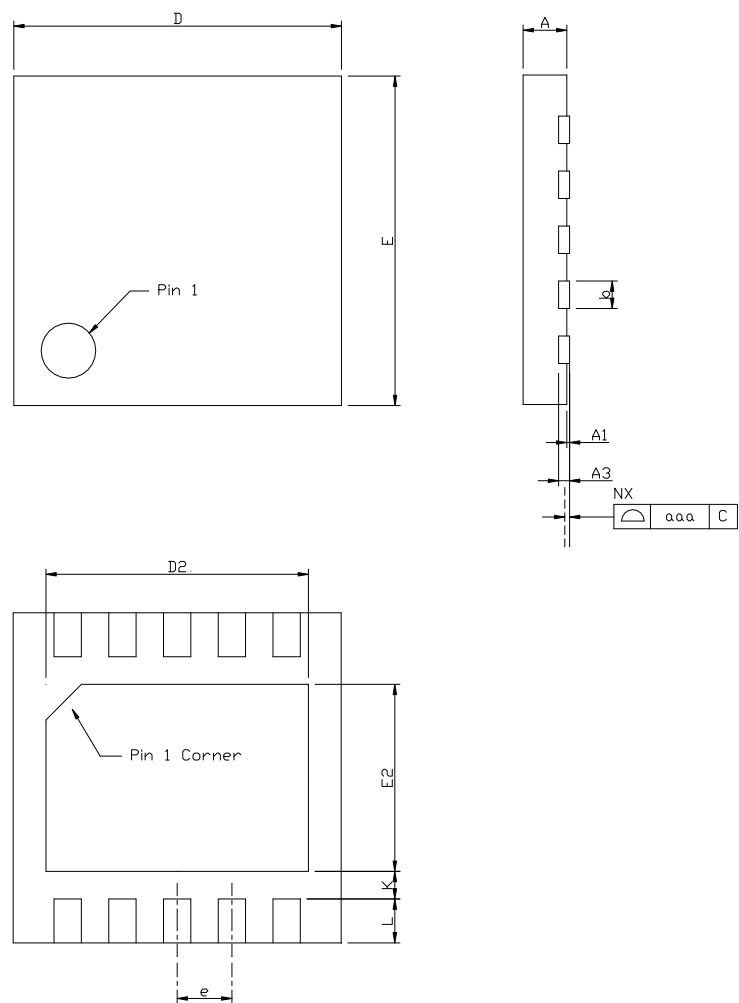
For example:

$V_{CC}=5V$, $I_{SO}=5mA$, $V_{SO}=0.1V$, $R_{SO}=0.98k\Omega$

The value of resistor in the range of $1k\Omega$ to $10k\Omega$ is recommended.

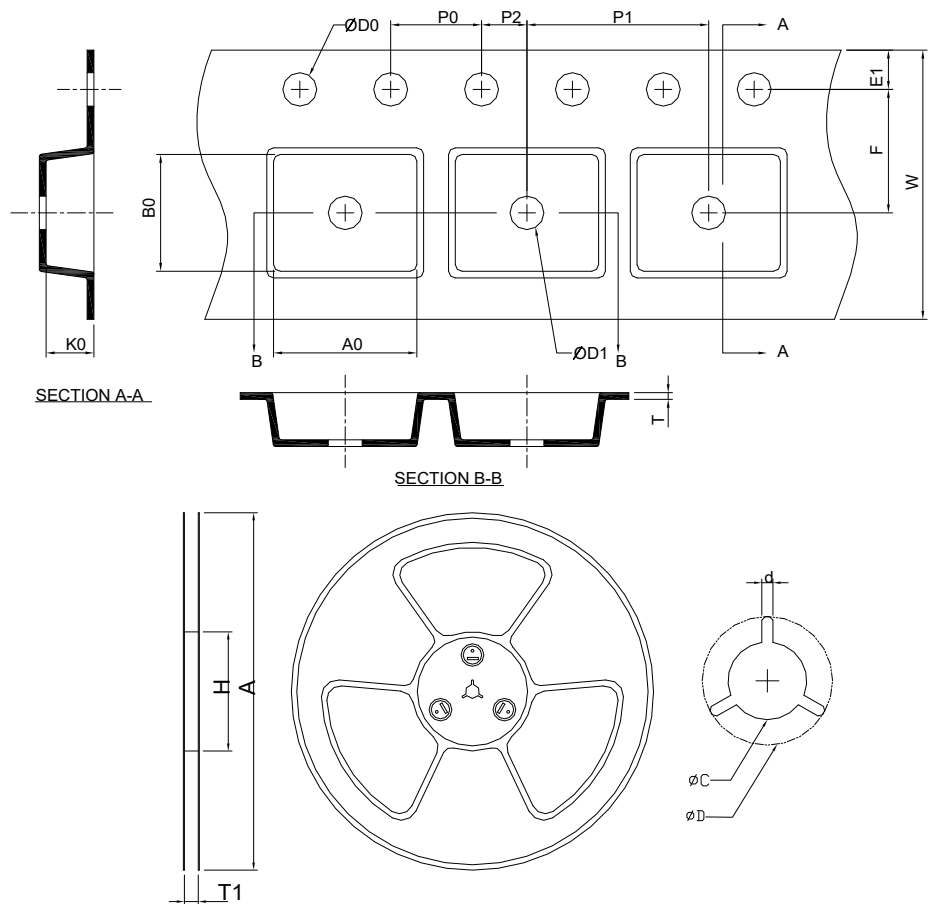
Package Information

XTDFN3x3-10



S Y M B O L	XTDFN3*3-10			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.30	0.40	0.012	0.016
A1	0.00	0.05	0.000	0.002
A3	0.127REF		0.005 REF	
b	0.20	0.30	0.008	0.012
D	2.90	3.10	0.114	0.122
D2	2.40	2.60	0.094	0.102
E	2.90	3.10	0.114	0.122
E2	1.50	1.70	0.059	0.067
e	0.50 BSC		0.020 BSC	
L	0.30	0.50	0.012	0.020
K	0.20		0.008	
Q.Q.Q	0.08		0.003	

Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
XTDFN3x3	330.0±2.00	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	5.5±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	1.5 MIN.	0.6+0.00 -0.40	3.30±0.20	3.30±0.20	0.60±0.10

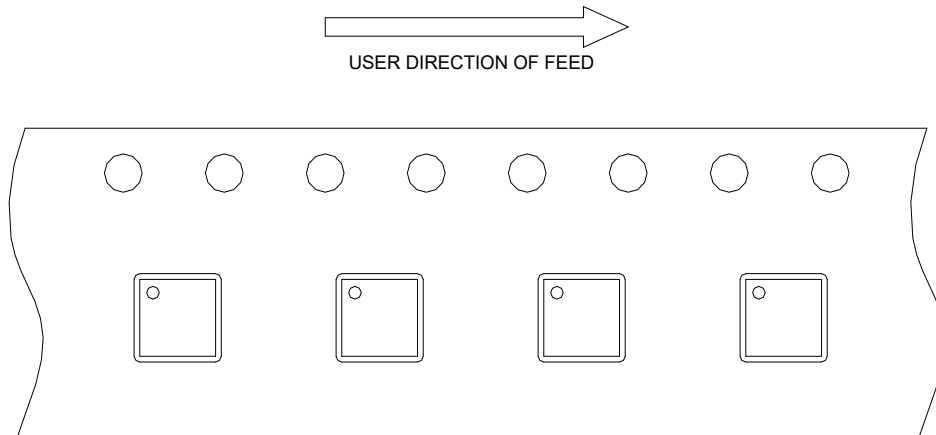
(mm)

Devices Per Unit

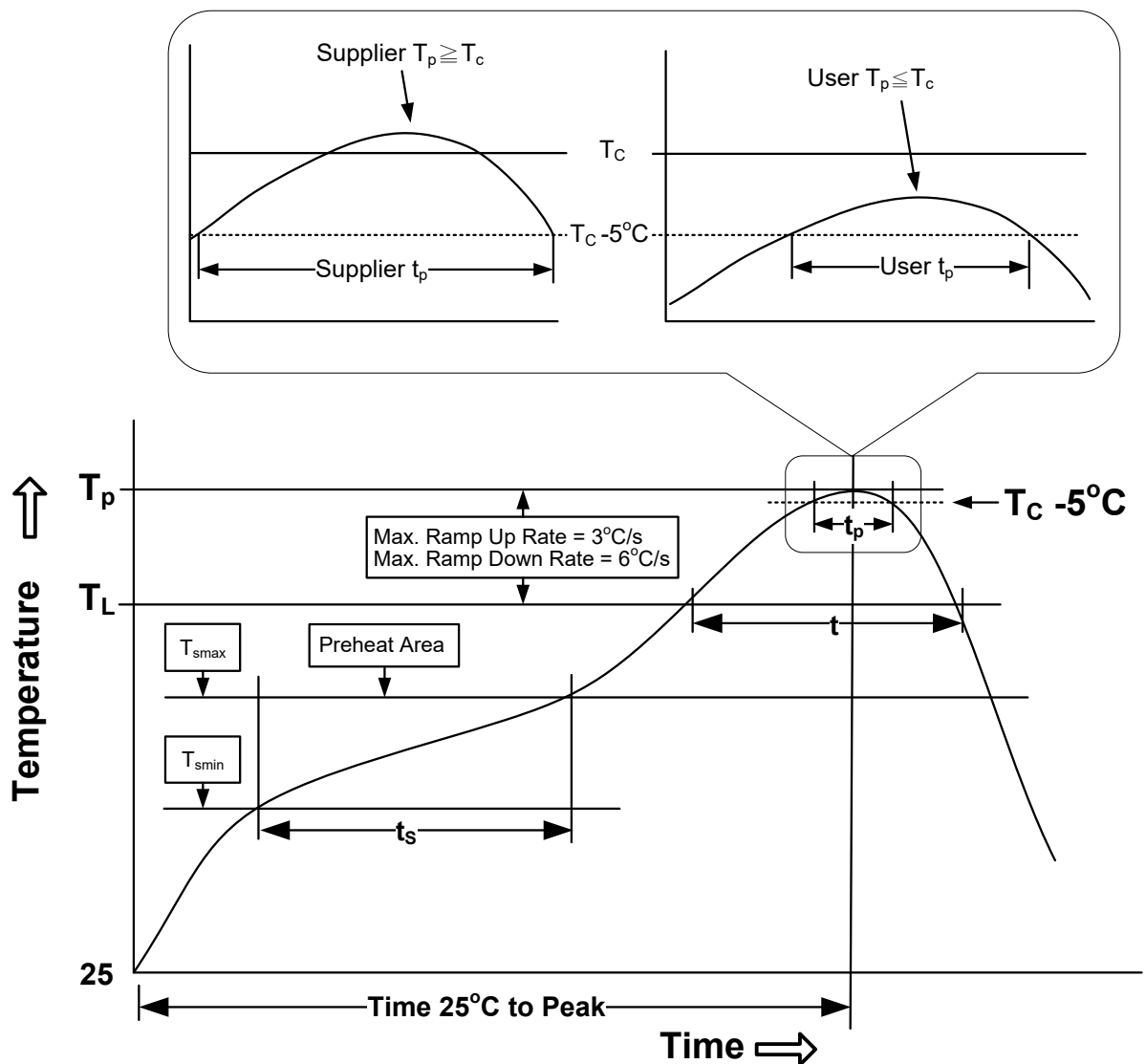
Package Type	Packing	Quantity
XTDFN3x3	Tape & Reel	3000

Taping Direction Information

XTDFN3x3-10



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 9	See Classification Temp in table 10
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.		

Note: ANPEC's green products meet or exceed the lead-free requirements of IPC/JEDEC J-STD-020D for MSL classification at lead-free peak reflow temperature.

Table 9. SnPb Eutectic Process – Classification Temperatures (T_c)

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 10. Pb-free Process – Classification Temperatures (T_c)

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 @ $T_j=125^\circ\text{C}$
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 $\geq 2\text{KV}$
MM	JESD-22, A115	VMM $\geq 200\text{V}$
Latch-Up	JESD-78	10ms, $1_{tr} \geq 100\text{mA}$

Customer Service

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