Three-Phase Full-wave Sine-wave Brushless Motor Driver

Features

- **Three-Phase Full-Wave Sine-Wave Driver**
- **Sensor-Less driver control**
- **PWM Speed Control**
- **Minimum Speed Setting**
- **Power Saving Function**
- **Built-in 5V LDO Regulator**
- **Built-in Current Limit Circuit**
- **Built-in Over Current Protection**
- **Built-in Lock Protection and Auto Restart Function**
- **Soft Start Function**
- **FG, 1/2FG, 1/3FG or RD Output**
- **Built-in Thermal Shutdown Protection**
- **Lead Free and Green Device Available (RoHS Compliant)**

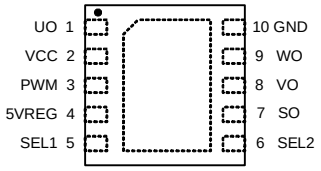
Applications

- **Home Appliance Cooling Fan**
- **Instrumentation Fan**

General Description

The APX9323 is a three-phase full-wave sine-wave brushless motor drive by sensor-less . This IC built-in direct PWM input speed control, current limit and soft start features suitable for the three-phase brushless DC motors. The APX9323 is available in VTDFN3x3-10 package (see Pin Configuration).

Pin Configuration



VTDFN 3X3-10
(TOP VIEW)

= Thermal Pad (connected to the GND plane for better heat dissipation)

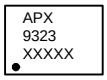
Ordering and Marking Information

APX9323 □□□-□□□

- 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: Halogen and Lead Free Device

APX9323 QF :



XXXXX - Date Code

Note 1: 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/JED
EC 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 inhomogeneous material and total of Br and Cl does not exceed 1500ppm by weight).

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 2)

Symbol	Parameter	Ratings	Unit
V_{CC}	VCC Pin Supply Voltage (VCC to GND)	-0.3 to 18	V
I_{OUT}	UO, VO, WO Pin Maximum Output Peak Current	2.7	A
$V_{UO, VO, WO}$	UO, VO and WO Pins Output Voltage	V_{GND}-0.3 to V_{CC}	V
V_{SEL1}	SEL1 Pin Input Voltage (SEL1 to GND)	-0.3 to 7	V
V_{SEL2}	SEL2 Pin Input Voltage (SEL2 to GND)	-0.3 to 7	V
I_{5VREG}	5VREG Pin Output Source Current	0 to -25	mA
V_{SO}	SO Pin Output Voltage	-0.3 to 18	V
I_{SO}	SO Pin Maximum Output Sink Current	10	mA
V_{PWM}	PWM Pin Input Voltage (PWM to GND)	-0.3 to VCC	V
T_J	Maximum Junction Temperature	150	°C
T_{STG}	Storage Temperature	-65 to 150	°C
T_{SDR}	Maximum Lead Soldering Temperature, 10 Seconds	260	°C

Note 2: 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
θ_{JA}	Thermal Resistance-Junction to Ambient (Note 3) VTDFN3x3-10	119	°C/W
P_D	Power Dissipation, T_A=25°C	1.05	W

Note 3: 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

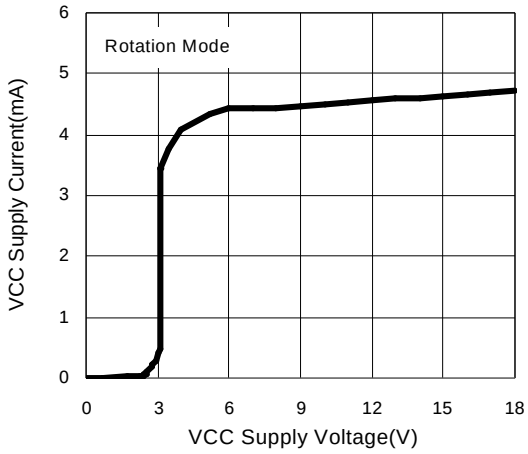
Symbol	Parameter	Range	Unit
V_{CC}	VCC Pin Supply Voltage Range	4.5 to 16	V
V_{SEL1}	SEL1 Pin Input Voltage	0 to V_{5VREG}	V
V_{SEL2}	SEL2 Pin Input Voltage	0 to V_{5VREG}	V
T_A	Ambient Temperature	-40 to 105	°C
T_J	Junction Temperature	-40 to 125	°C

Electrical Characteristics (V_{CC}=12V, T_A=25°C, unless otherwise specified)

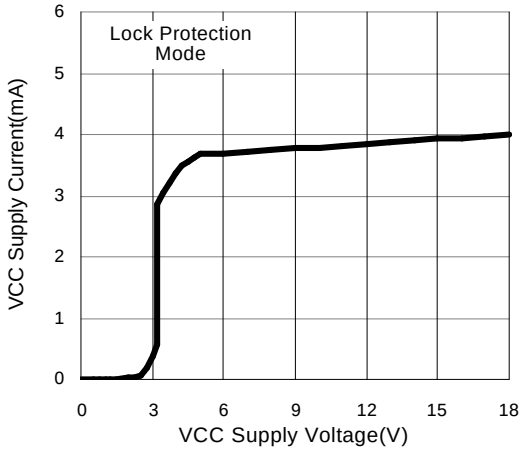
Symbol	Parameter	Test Conditions	APX9323			Unit
			Min	Typ	Max	
SUPPLY CURRENT						
V_{5VREG}	5VREG Pin Output Voltage	I_{5VREG} = -5mA	4.8	5	5.2	V
I_{CC1}	Operating Current	Rotation Mode	3	5	7	mA
I_{CC2}	Operating Current	Lock Protection Mode	2.5	4.5	6.5	mA
I_{CC3}	Standby Mode	PWM = GND(Shutdown mode)	-	150	250	μA
OUTPUT DRIVERS						
V_{OL}	Low-side Output Saturation Voltage	V_{CC}=12V; I_{OUT}=400mA	-	0.08	0.11	V
V_{OH}	High-side Output Saturation Voltage	V_{CC}=12V; I_{OUT}=400mA	-	0.1	0.13	V
V_{SO}	SO Pin Low Voltage	I_{SO}=5mA	-	0.2	0.3	V
I_{SO}	SO Pin Off Leakage Current	V_{SO}=12V	-	0.2	1	μA
ZC Comparator						
V_{ZC}	Floating Node Zero Crossing Hysteresis	VCC=12V	-	140	-	mV
PWM MODE						
V_{PWMH}	High Level Voltage for PWM Mode		2.5	-	5.5	V
V_{PWML}	Low Level Voltage for PWM Mode		0	-	0.8	V
R_{PWM_norl}	PWM pull high R in normal mode		-	18	-	KΩ
R_{PWM_sb}	PWM pull high R in stand by mode		-	80	-	KΩ
F_{PWM}	PWM Input Frequency		1	-	50	KHZ
F_{OUT}	Output Switch Frequency		-	25	-	KHZ
LOCK PROTECTION						
T_{ON}	Lock Protection Detection On Time		-	2.5	-	sec
T_{OFF}	Lock Protection Detection Off Time		-	6.25	-	sec
Soft Start						
T_{SS}	Soft Start Time (D_{OUT}= 0~100%)		-	2.5	-	sec
CURRENT PROTECTION						
I_{LIM}	Current Limit Level of Start up		-	0.4	-	A
	Current Limit Level of Normal Operation		-	1.4	-	A
I_{OCP}	Over Current Protection		-	2.2	-	A
THERMAL PROTECTION						
	Thermal Protection Temperature		-	165	-	°C
	Thermal Protection Hysteresis		-	30	-	°C

Typical Operating Characteristics

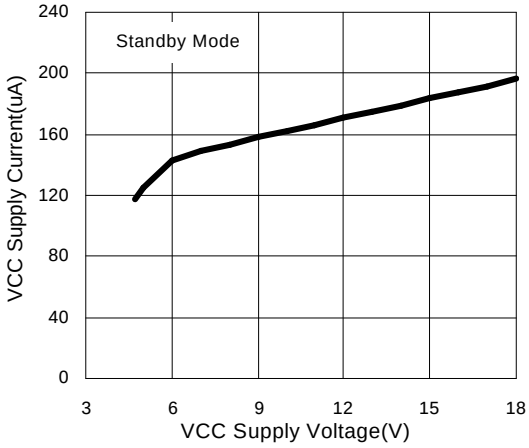
VCC Supply Current vs. VCC Supply Voltage



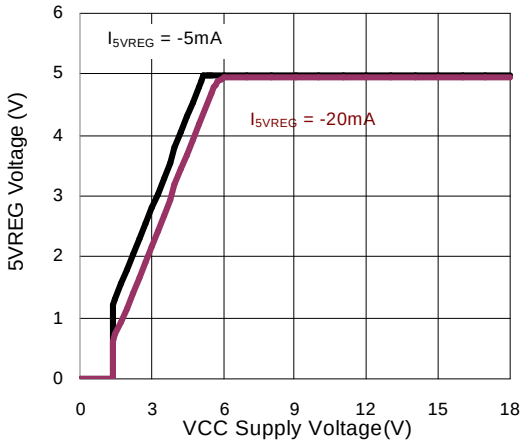
VCC Supply Current vs. VCC Supply Voltage



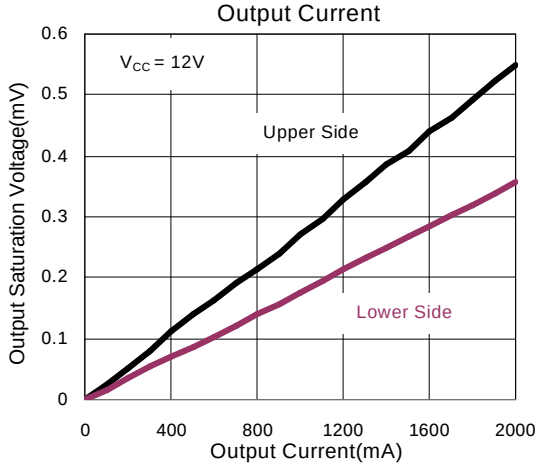
VCC Supply Current vs. VCC Supply Voltage



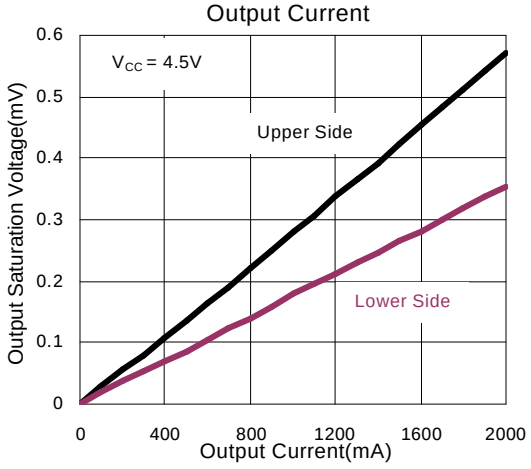
5VREG Voltage vs. VCC Supply Voltage



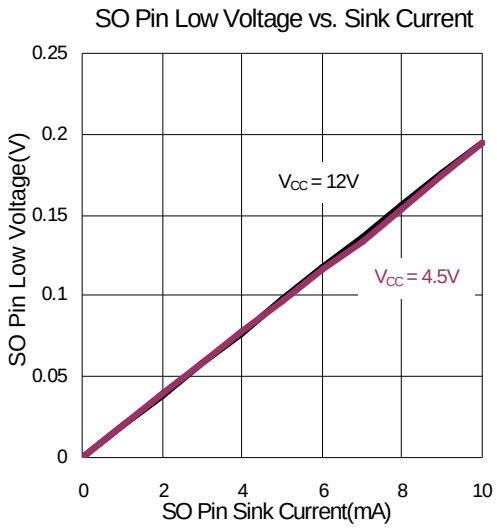
Output Saturation Voltage vs. Output Current

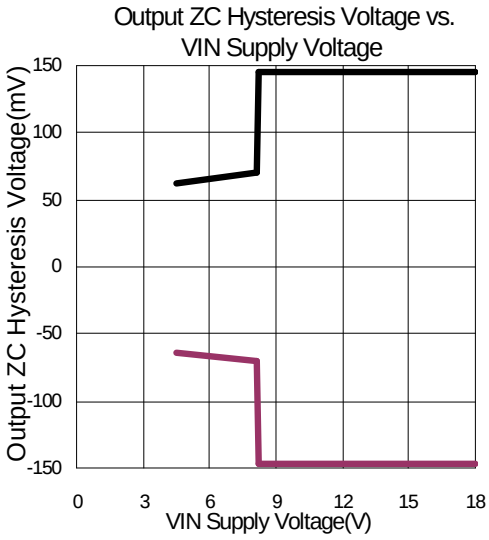


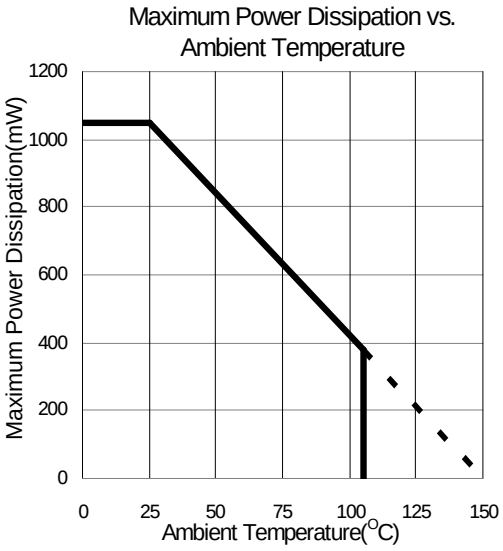
Output Saturation Voltage vs. Output Current



Typical Operating Characteristics (Cont.)





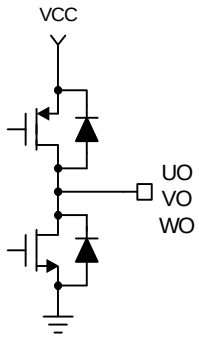


Pin Description

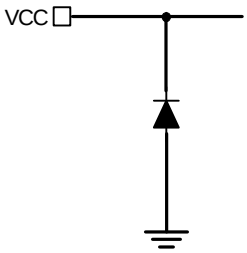
PIN		FUNCTION
NO.	NAME	
1	UO	Driver Output Pin. Output signal for driving motor phase U.
2	VCC	Supply Voltage Input Pin.
3	PWM	PWM Signal Input Terminal. Please let it be floating when not be used.
4	5VREG	5V Regulator Output. This is a 5V constant-voltage output for application circuit biases.
5	SEL1	Mode Setting. Use a voltage divider from 5VREG to set SEL1 pin voltage for setting.
6	SEL2	Mode Setting. Use a voltage divider from 5VREG to set SEL2 pin voltage for setting.
7	SO	Rotation Speed Output or Rotation Detection Output. This is an open-drain output.
8	VO	Driver Output Pin. Output signal for driving motor phase V.
9	WO	Driver Output Pin. Output signal for driving motor phase W.
10	GND	Ground Pin.

I/O Equivalent Circuits

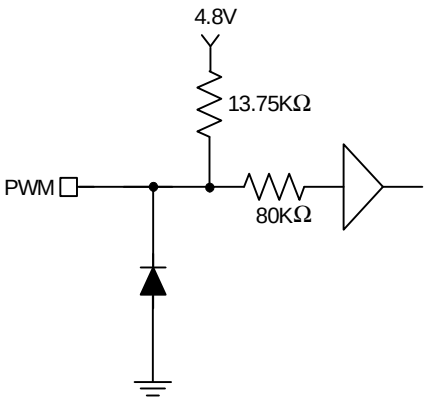
Driver output :pin1 (UO), pin8 (VO), pin9 (WO)



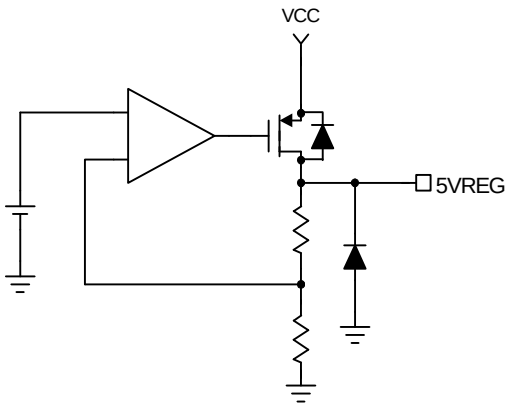
Power supply input :pin2 (VCC)



PWM speed control input :pin3 (PWM)

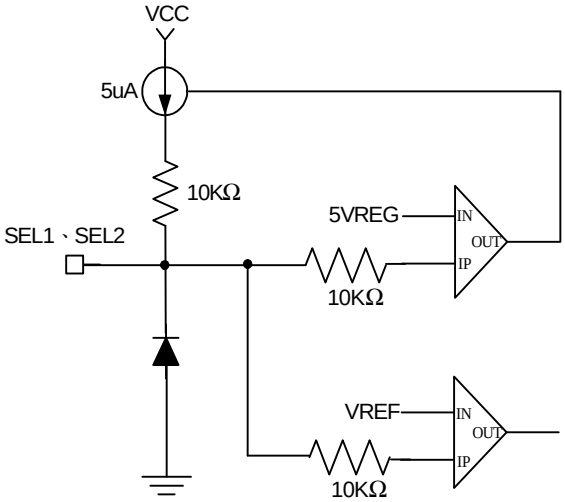


Regulator output : pin4 (5VREG)

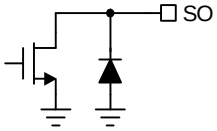


I/O Equivalent Circuits (Cont.)

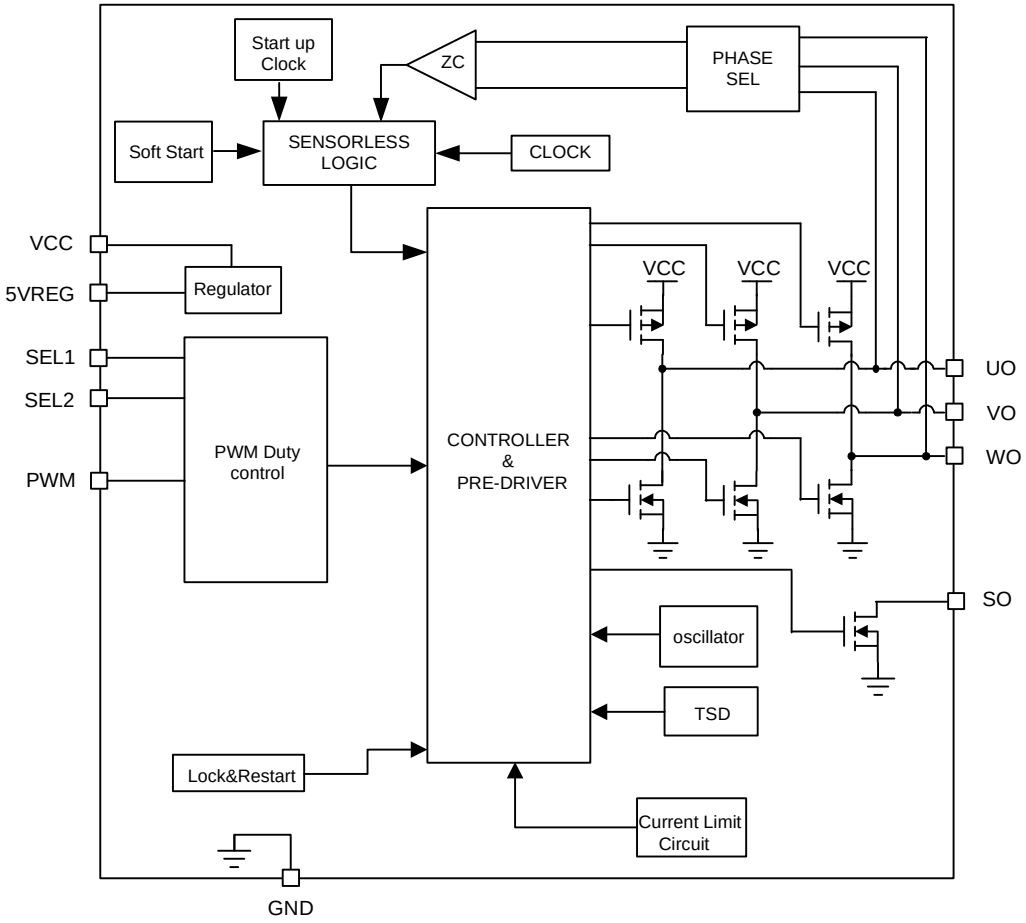
Setting input :pin5 (SEL1), pin6 (SEL2)



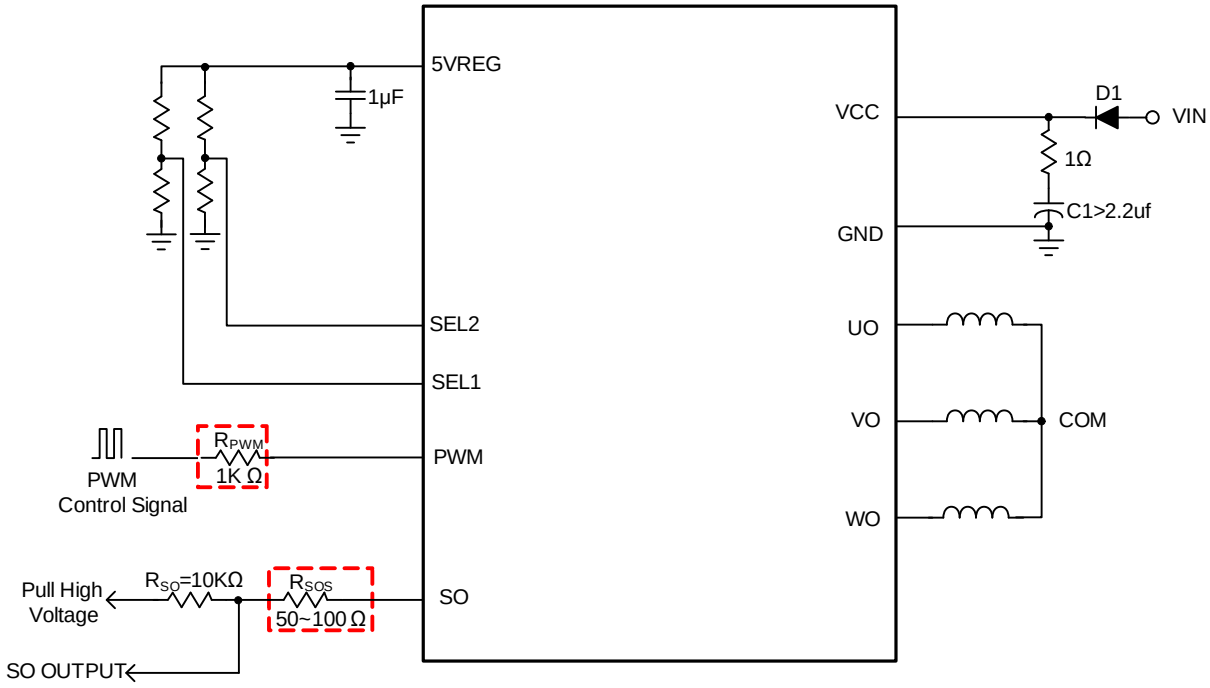
Rotation speed output: pin7 (SO)



Block Diagram



Typical Application Circuit



Note:R_{PWM} and R_{SOS} are optional to protect internal circuit for abnormal voltage stress.

Function Description

SEL1 and SEL2 Control

The APX9323 has two input pin SEL1, SEL2 to control output duty of driver for the rotation speed of motor and SO output.

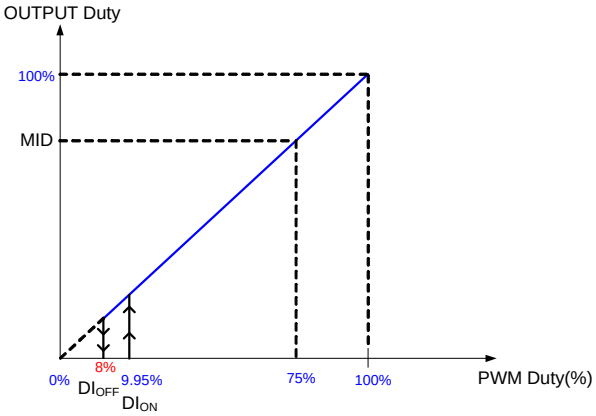


Figure1: Shutdown mode Output Duty Control Curve

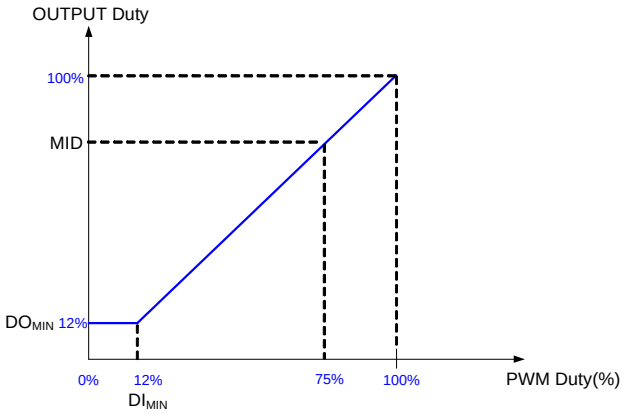


Figure2: Minimum mode Output Duty Control Curve

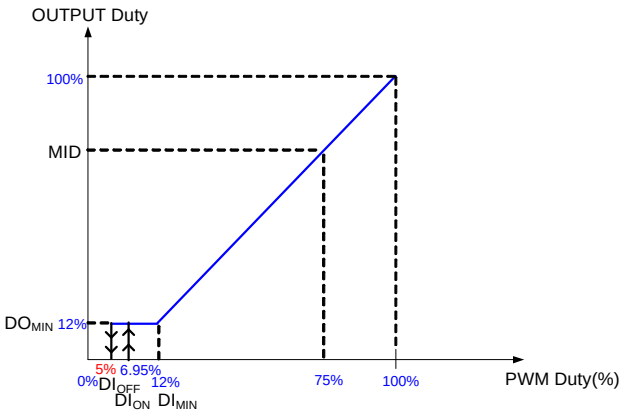


Figure3: Shutdown and Minimum mode Output Duty Control Curve

Function Description (Cont.)

SO	DI_{ON}	DI_{OFF}	DO_{MIN}	DI_{MIN}	MID	V_SEL1	V_SEL2	Note
FG	X	X	12%	12%	75%	0	0	Auto Mode and start up(0~50%)
	6.95%	5%	12%	12%	75%	0	5	Full duty start up and Auto Mode
	9.95%	8%	X	X	75%	1.5	3.5	Non-Auto Mode and start up(0~50%)
	X	X	12%	12%	75%	2.5	1.5	Non-Auto Mode and start up(0~50%)
	9.95%	8%	X	X	75%	3.5	5	Full duty start up and Non-Auto Mode
	9.95%	8%	X	X	75%	5	3.5	Full duty start up and Auto Mode
	9.95%	8%	X	X	75%	5	5	Auto Mode and start up(0~50%)

SO	DI_{ON}	DI_{OFF}	DO_{MIN}	DI_{MIN}	MID	V_SEL1	V_SEL2	Note
1/2FG	X	X	12%	12%	75%	0	1.5	Auto Mode and start up(0~50%)
	9.95%	8%	X	X	75%	0	2.5	Full duty start up and Non-Auto Mode
	6.95%	5%	12%	12%	75%	0	3.5	Full duty start up and Auto Mode
	9.95%	8%	X	X	75%	2.5	0	Non-Auto Mode and start up(0~50%)
	X	X	12%	12%	75%	3.5	0	Non-Auto Mode and start up(0~50%)
	9.95%	8%	X	X	75%	5	0	Auto Mode and start up(0~50%)
	9.95%	8%	X	X	75%	5	2.5	Full duty start up and Auto Mode

SO	DI_{ON}	DI_{OFF}	DO_{MIN}	DI_{MIN}	MID	V_SEL1	V_SEL2	Note
1/3FG	9.95%	8%	X	X	75%	1.5	0	Auto Mode and start up(0~50%)
	X	X	12%	12%	75%	1.5	2.5	Auto Mode and start up(0~50%)
	9.95%	8%	X	X	75%	1.5	5	Full duty start up and Non-Auto Mode
	9.95%	8%	X	X	75%	3.5	1.5	Non-Auto Mode and start up(0~50%)
	9.95%	8%	X	X	75%	5	1.5	Full duty start up and Auto Mode

SO	DI_{ON}	DI_{OFF}	DO_{MIN}	DI_{MIN}	MID	V_SEL1	V_SEL2	Note
RD	9.95%	8%	X	X	75%	1.5	1.5	Full duty start up and Non-Auto Mode
	X	X	12%	12%	75%	2.5	3.5	Auto Mode and start up(0~50%)
	9.95%	8%	X	X	75%	2.5	5	Non-Auto Mode and start up(0~50%)
	9.95%	8%	X	X	75%	3.5	2.5	Full duty start up and Auto Mode
	9.95%	8%	X	X	75%	3.5	3.5	Auto Mode and start up(0~50%)

Table1: SEL1 and SEL2 function table (V_SEL1 and V_SEL2 voltage value when 5VREG = 5V)

*Non-Auto mode Maximum RPM 20000(experimental data)

*Maximum RPM determined by different parameter of motor at Auto mode

Function Description (Cont.)

Lock Protection and Auto Restart

The APX9323 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 2.5 seconds. Then, the IC will switch to lock protection mode to turn off output driver for 6.25 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.

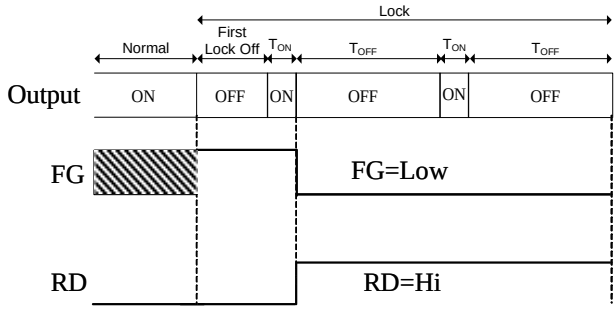


Figure:Lock protection operation

Current Limit and Over Current Protection (OCP)

The APX9323 includes an internal current sense circuits for current limit and over-current protection (OCP). When the total current of three phase over the current limit level, the high side driver will be turned off to stop supplying current to the motor. If the total output current over the OCP current level, the OCP function will be enable to turn-off all of the output driver to prevent output short through condition until pull low PWM pin or re-power on or wait 2.5 seconds.

Thermal Protection

The APX9323 is designed with a thermal protection to protect the IC from the damage of over temperature. When internal junction temperature reaches 165°C, the output devices will be switched off. When the IC's junction temperature cools by 30°C, the thermal sensor will turn the output devices on again resulting in a pulsed output during continuous thermal overload.

Application Information

Input Protection Diode & Capacitor

The IC should be added 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 greater than the maximum output current. For the noise reduction purpose, a capacitor (C1) must connect between VCC and GND. It is the suggestion that C1 should be placed as close as possible to the device VCC pin.

SO Resistor

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

$$R_{SO} = \frac{V_{5VREG} - V_{SO}}{I_{SO}}$$

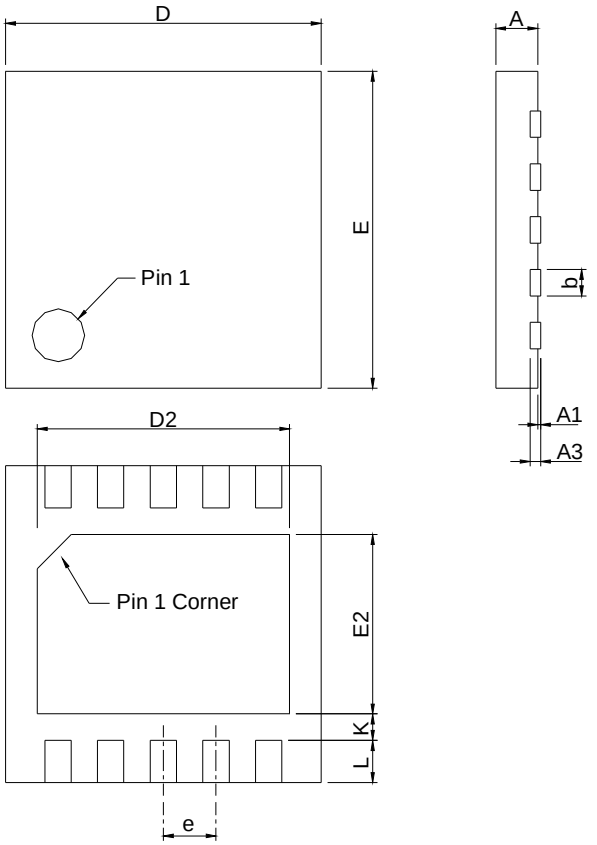
For example:

V_{5VREG} = 5V, I_{SO} = 5mA, V_{SO} = 0.2V, R_{SO} = 0.96kΩ

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

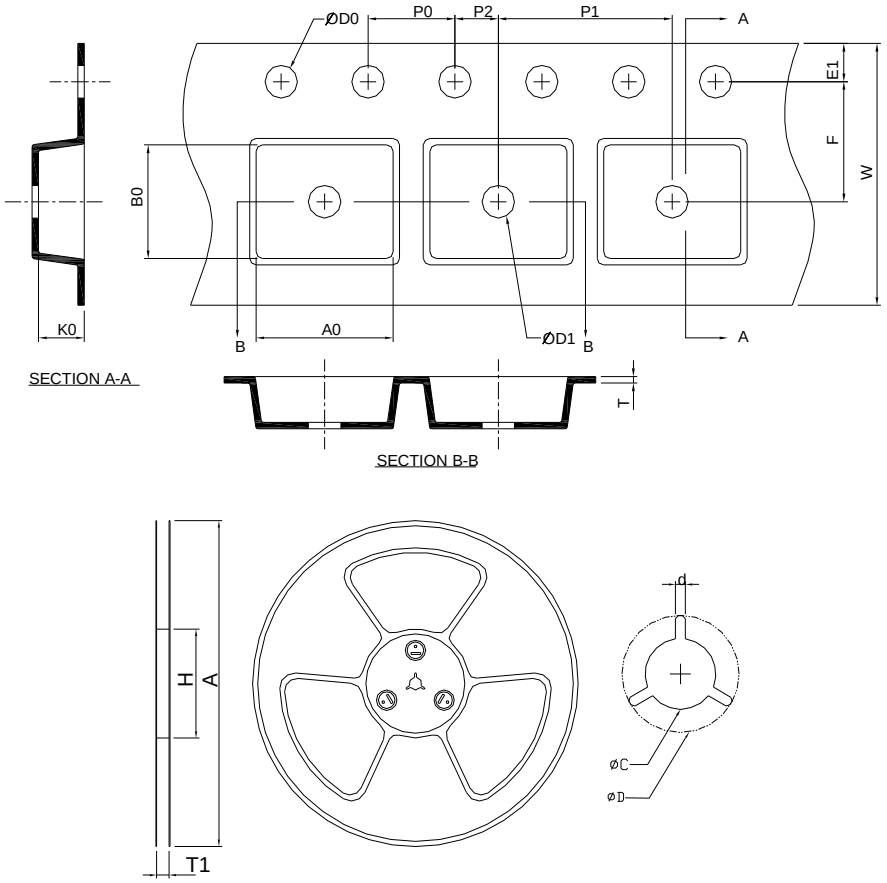
Package Information

VTDFN3x3-10



SYMBOL	VTDFN3*3-10			
	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	
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		0.020 BSC	
L	0.30	0.50	0.012	0.020
K	0.20		0.008	

Carrier Tape & Reel Dimensions



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	1.5 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	0.75±0.20

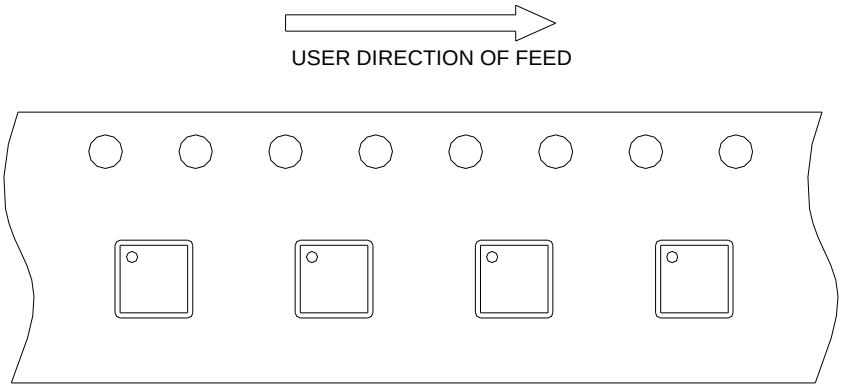
(mm)

Devices Per Unit

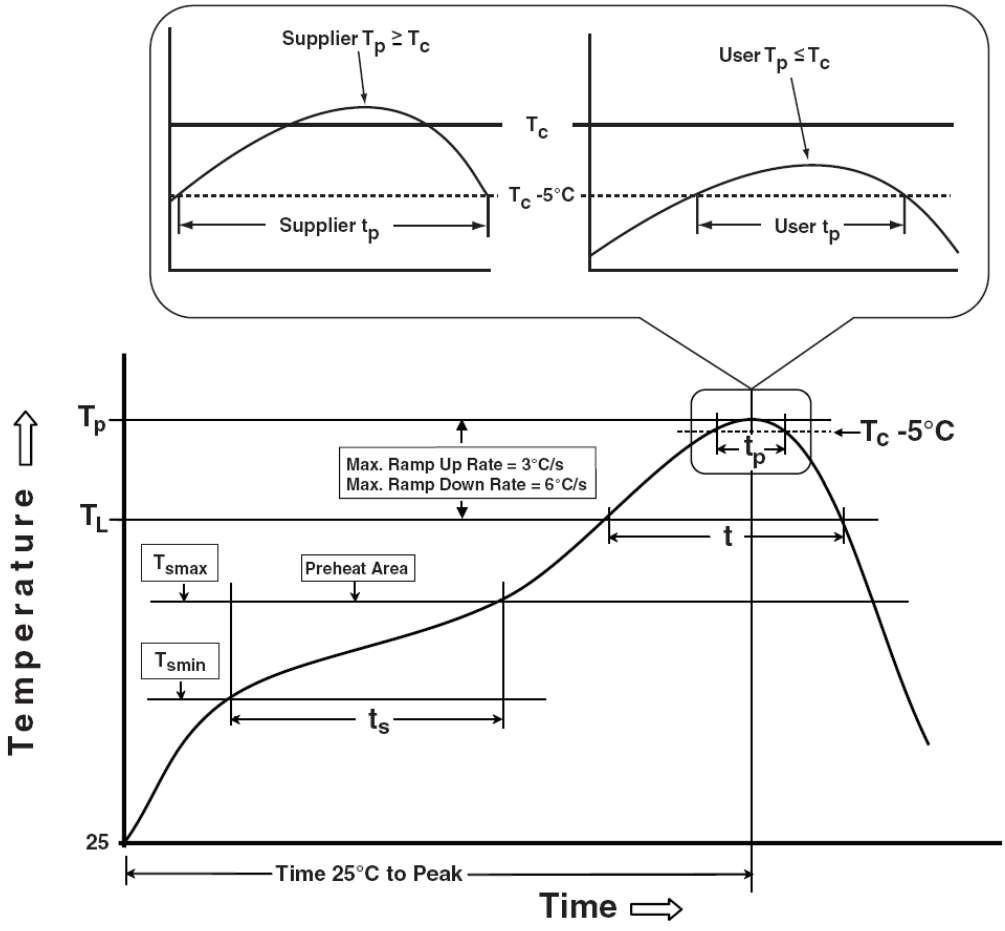
Package Type	Unit	Quantity
VTDFN3x3-10	Tape & Reel	3000

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 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 @ 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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