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

Features

- Three-Phase Full-Wave Sine-Wave Driver
- One-Hall / Sensor-Less driver control
- Open Loop Rpm-Curve Control
- Rotation Direction Selectable
- 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 Output
- Built-in Thermal Shutdown Protection
- QFN4x4-24 Package
- Lead Free and Green Device Available (RoHS Compliant)
- Reset Signal Input
- PWM and SET control OUT Duty

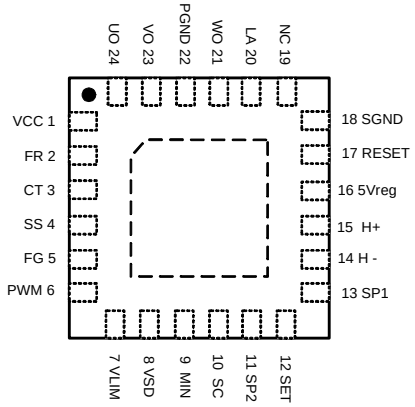
Applications

- Home Appliance Cooling Fan
- Instrumentation Fan

General Description

The APX9322 is a three-phase full-wave sine-wave brushless motor drive by one-hall or sensor-less . This IC built-in linear or direct PWM input speed control, leading angle setting, current limit and soft start features suitable for the three-phase brushless DC motors. The APX9322 is available in QFN4x4-24 package (see Pin Configuration).

Pin Configuration



QFN4x4-24
Top View

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

Ordering and Marking Information

APX9322 □□□-□□□ Assembly Material Handling Code Temperature Range Package Code	Package Code QA : QFN4x4-24 Operating Ambient Temperature Range I : -40 to 90 °C Handling Code TR : Tape & Reel Assembly Material G: Halogen and Lead Free Device
APX9322 APX9322 XXXXX	XXXXX - Date Code

Note1: 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 inhomogeneous material and total of Br and Cl does not exceed 1500ppm by weight).

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Absolute Maximum Ratings (Note 2)

Symbol	Parameter	Ratings	Unit
V_{CC}	VCC Pin Supply Voltage (VCC to SGND)	-0.3 to 18	V
I_{OUT}	UO, VO, WO Pin Maximum Output Peak Current	3.5	A
V_{UO}, V_{VO}, V_{WO}	UO, VO and WO Pins Output Voltage	VPGND-0.3 to VCC	V
V_{LA}	LA Pins Input Voltage (LA to SGND)	-0.3 to 7	V
V_{SET}	SET Pins Input Voltage (SET to SGND)	-0.3 to 7	V
V_{SEL}	SEL Pin Input Voltage (SEL to SGND)	-0.3 to 7	V
I_{5VREG}	5VREG Pin Output Source Current	25	mA
V_{SP1}	SP1 Pin Input Voltage (SP1 to SGND)	-0.3 to 7	V
V_{SP2}	SP2 Pin Input Voltage (SP2 to SGND)	-0.3 to 7	V
V_{MIN}	MIN Pin Input Voltage (MIN to SGND)	-0.3 to 7	V
V_{VSD}	VSD Pin Input Voltage (VSD to SGND)	-0.3 to 7	V
V_{VLIM}	VLIM Pin input Voltage (VLIM to SGND)	-0.3 to 7	V
V_{FG}	FG Pin Output Voltage	-0.3 to 18	V
I_{FG}	FG Pin Maximum Output Sink Current	10	mA
V_{PWM}	PWM Pin Input Voltage (PWM to SGND)	-0.3 to VCC	V
V_{FR}	FR Pin Input Voltage (FR to SGND)	-0.3 to 7	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) QFN4x4-24	50	°C/W
θ_{JC}	Thermal Resistance-Junction to Case (Note 4) QFN4x4-24	20	°C/W
P_D	Power Dissipation, TA=25℃	2.5	W

Note 3: θ_{JA} is measured with the component mounted on a high effective thermal conductivity test board in free air. The exposed pad of QFN4x4-24 is soldered directly on the PCB.

Note 4: The case temperature is measured at the center on the top of the QFN4x4-24 package.

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Recommended Operation Conditions(Note 5)

Symbol	Parameter	Range	Unit
V_{CC}	VCC Pin Supply Voltage Range	6 to 18	V
V_{LA}	LA Pins Input Voltage	0 to V_{5VREG}	V
V_{SET}	SET Pins Input Voltage	0 to V_{5VREG}	V
V_{SEL}	SEL Pin Input Voltage	0 to V_{5VREG}	V
V_{SP1}	SP1 Pin Input Voltage	0 to V_{5VREG}	V
V_{SP2}	SP2 Pin Input Voltage	0 to V_{5VREG}	V
V_{MIN}	MIN Pin Input Voltage Range	0 to V_{5VREG}	V
V_{VSD}	VSD Pin Input Voltage	0 to V_{5VREG}	V
V_{VLIM}	VLIM Pin Input Voltage	0 to V_{5VREG}	V
V_{FR}	FR Pin Input Voltage	0 to V_{5VREG}	V
T_A	Ambient Temperature	-40 to 90	°C
T_J	Junction Temperature	-40 to 125	°C

Note 5: Refer to the typical application circuit

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

Symbol	Parameter	Test Conditions	APX9322			Unit
			Min	Typ	Max	
SUPPLY CURRENT						
V_{5VREG}	5VREG Pin Output Voltage	I_{5VREG} = -25mA	4.8	5	5.2	V
I_{CC1}	Operating Current	Rotation Mode	4	5	6	mA
I_{CC2}	Operating Current	Lock Protection Mode	4	5	6	mA
OUTPUT DRIVERS						
V_{OL}	Low-side Output Saturation Voltage	V_{CC}=12V; I_{OUT}=400mA	-	45	75	mV
V_{OH}	High-side Output Saturation Voltage	V_{CC}=12V; I_{OUT}=400mA	-	70	105	mV
V_{FG}	FG Pin Low Voltage	I_{FG}=5mA	-	0.2	0.3	V
I_{FGL}	FG Pin Off Leakage Current	V_{FG}=12V	-	0.2	1	μA
LOCK PROTECTION						
V_{CTH}	CT Pin High Level Voltage		2.7	3	3.2	V
V_{CTL}	CT Pin Low Level Voltage		0.8	1	1.2	V
I_{CT1}	CT Charge Current	V_{CT}=0.7 V	1.5	2	2.5	μA
I_{CT2}	CT Discharge Current	V_{CT}=3.5V	0.15	0.2	0.25	μA
R_{CT}	CT Charge/Discharge Current Ratio		8	10	12	-
START UP 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	20	40	50	μA
I_{SC2}	SC Pin Discharge Current	V_{SC}=2V	30	45	60	μA

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

Symbol	Parameter	Test Conditions	APX9322			Unit
			Min	Typ	Max	
SOFT START OSCILLATOR						
V_{SSH}	SS Pin High Level Voltage		1	1.2	1.4	V
V_{SSL}	SS Pin Low Level Voltage		0.5	0.6	0.7	V
I_{SS1}	SS Pin Charge Current	V_{SS}=0V	6	10	14	μA
I_{SS2}	SS Pin Discharge Current	V_{SS}=2V	6	10	14	μA
FR						
V_{FRH}	FR Pin High Level Voltage		2.5	-	V_{5VREG}	V
V_{FRL}	FR Pin Low Level Voltage		0	-	1	V
I_{FR}	FR Pin Bias Current	V_{FR}=0V	0.6	1.2	1.8	μA
PWM MODE						
V_{PWMH}	High Level Voltage for PWM Mode		2.5	-	5.5	V
V_{PWMH}	Low Level Voltage for PWM Mode		0	-	1	V
I_{PWM}	PWM Pin Bias Current	V_{PWM}=0V	-	10	20	μA
CURRENT PROTECTION						
I_{LIM}	Current Limit Level	V_{LIM}= 0~1V	-	0	-	A
	Current Limit Level	V_{LIM}= 2.5V	-	1.75	-	A
	Current Limit Level	V_{LIM}= 4~4.5V	-	3.5	-	A
	Current Limit Level	V_{LIM}= 4.5V to V_{5VREG}	-	2.3	-	A
I_{OCP}	Over Current Protection		-	3.6	-	A
HALL SENSITIVITY						
V_{HN}	Hall Input Sensitivity	Zero to peak including offset and hysteresis	-	10	20	mV
THERMAL PROTECTION						
	Thermal Protection Temperature		-	165	-	℃
	Thermal Protection Hysteresis		-	30	-	℃

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Pin Description

PIN		FUNCTION
NO.	NAME	
1	VCC	Supply Voltage Input Pin.
2	FR	Rotation Direction Control. Low Level Input (short to GND): U à W à V (Reverse) High Level Input (short to 5VREG): U à V à W (Forward)
3	CT	Shutdown Time and Restart Time Setting. Connect a capacitor to SGND to set shutdown time and restart time in lock mode.
4	SS	Soft-Start Time Setting. Connect a capacitor to SGND to set soft-start time to reduce the large current at power on and lock-restart mode.
5	FG	Rotation Speed Output.
6	PWM	PWM Signal Input Terminal. Please let it be floating when not be used.
7	VLIM	Current Limit Setting Input Pin.
8	VSD	Shutdown PWM Duty Setting. Use a voltage divider from 5VREG to set VSD pin voltage for setting Shutdown PWM Duty.
9	MIN	Minimum Speed Setting. Use a voltage divider from 5VREG to set MIN pin voltage for setting minimum speed.
10	SC	Start-up Time Setting Input Pin. Connect a capacitor to SGND to set the start-up timing.
11	SP2	Maximum Speed Setting. Use a voltage divider from 5VREG to set MIN pin voltage for setting maximum speed.
12	SET	Speed Setting. External voltage into SET pin to set fan speed.
13	SP1	Minimum PWM Duty Setting. Use a voltage divider from 5VREG to set SP1 pin voltage for setting minimum PWM Duty.
14	H-	Hall Input -. Connect to hell element negative output.
15	H+	Hall Input +. Connect to hell element positive output.
16	5VREG	5V Regulator Output. This is a 5V constant-voltage output for application circuit biases.
17	RESET	Reset Signal Input.
18	SGND	Control Stage GND.
19	NC	NC.
20	LA	Maximum Lead Angle Setting. Use a voltage divider from 5VREG to set VLA pin voltage for the maximum lead angle setting.
21	WO	Driver Output Pin. Output signal for driving motor phase W.
22	PGND	Power Stage GND.
23	VO	Driver Output Pin. Output signal for driving motor phase V.
24	UO	Driver Output Pin. Output signal for driving motor phase U.

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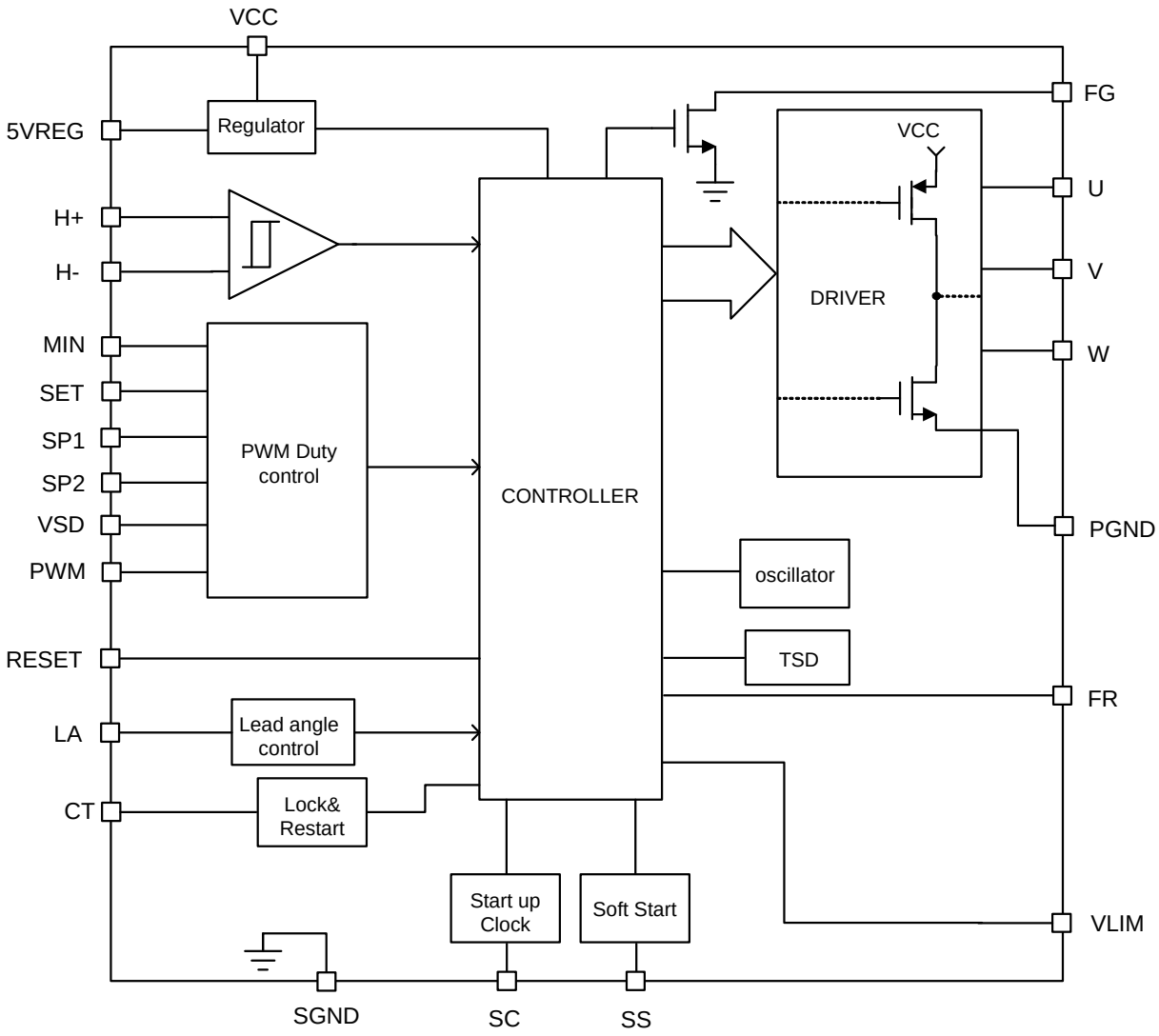
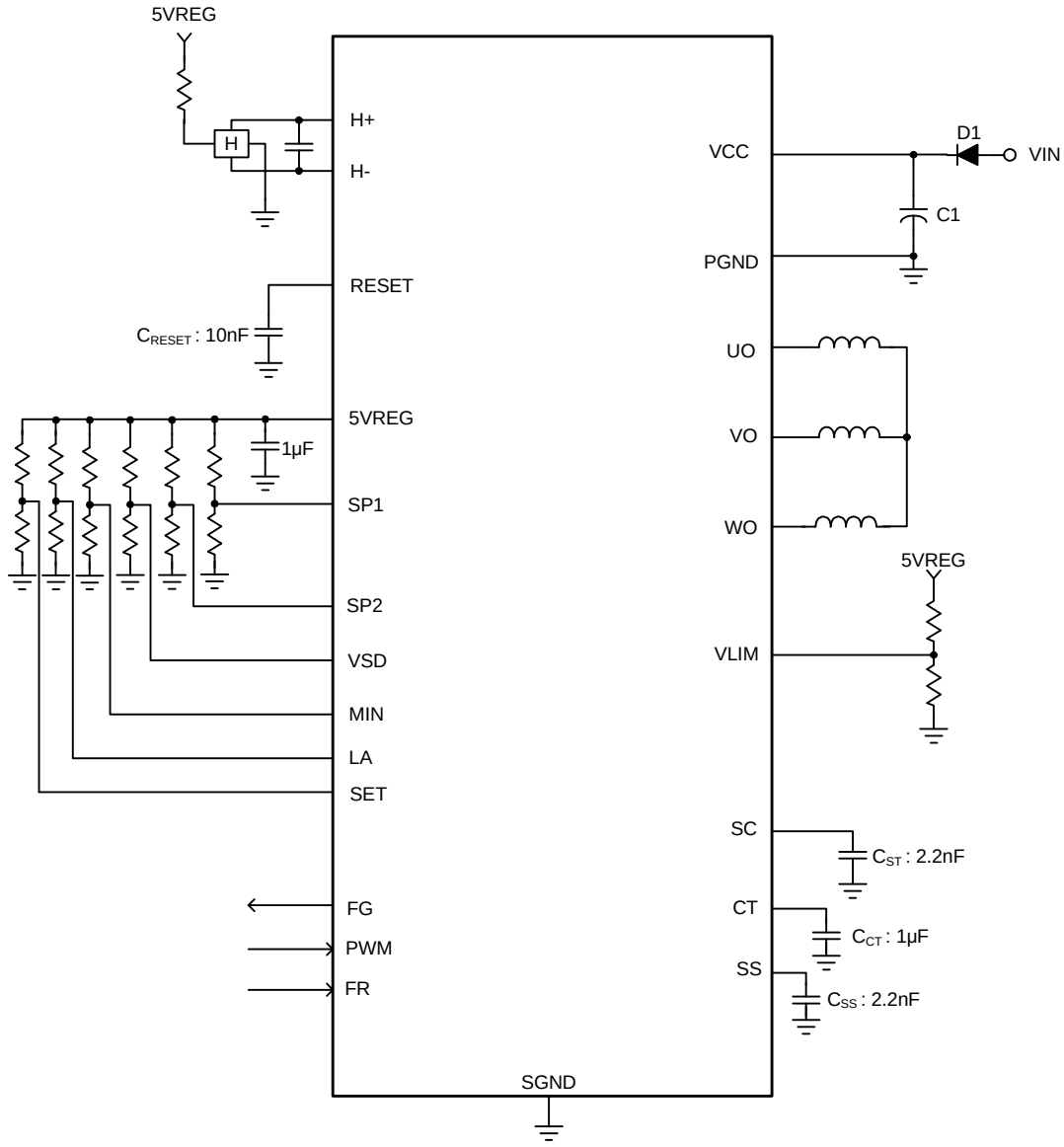
Block Diagram



Typical Application Circuit

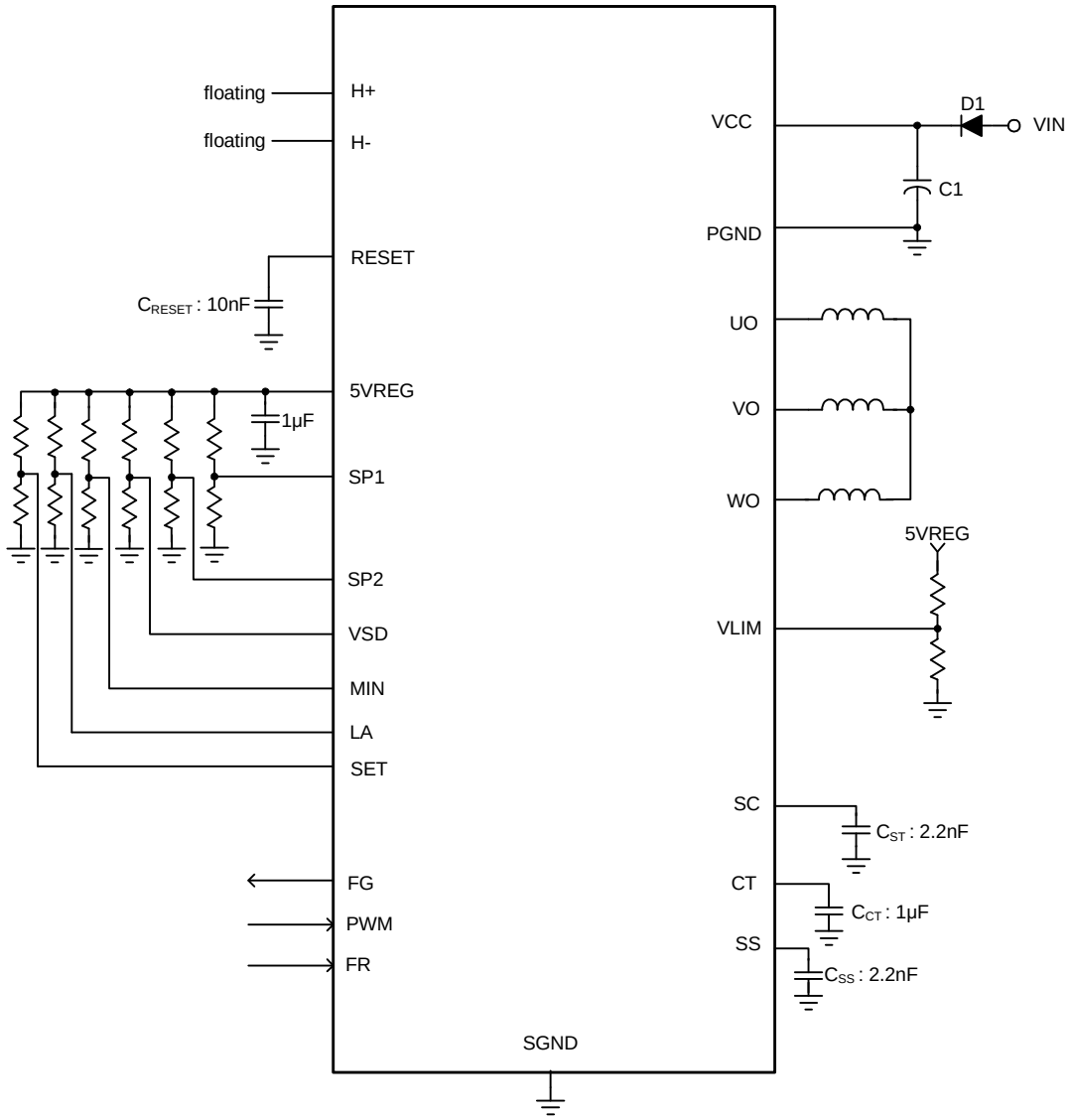
Circuit 1: 1-Hall Input Application



Note: The capacitance of C_{SS}, C_{ST} ,C_{RESET} and C_{CT} can be fine tune for different parameter of motor .

Typical Application Circuit

Circuit 2: Sensor-Less Application



Note: The capacitance of C_{SS}, C_{ST} ,C_{RESET} and C_{CT} can be fine tune for different parameter of motor .

Function Descriptions

Open Loop Rpm-Curve Control

The APX9322 has four input pin SP1, SP2, VSD and MIN to control output duty of driver for the rotation speed of motor.

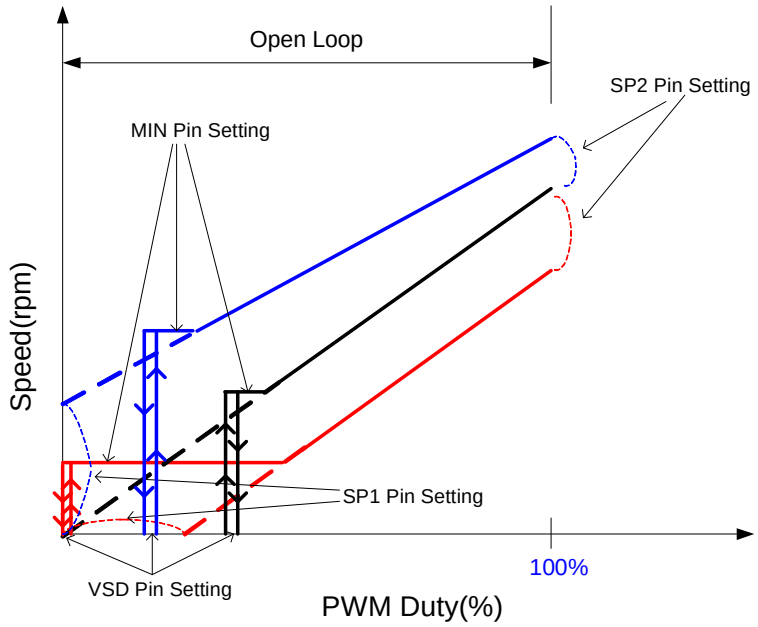


Figure1: Voltage Mode Output Duty Control

PWM and SET Control

The APX9322 also support direct PWM input signal and SET input voltage speed control. When the MIN pin pulled up to V_{5VREG}, the PWM and SET input pin to control the output duty directly.

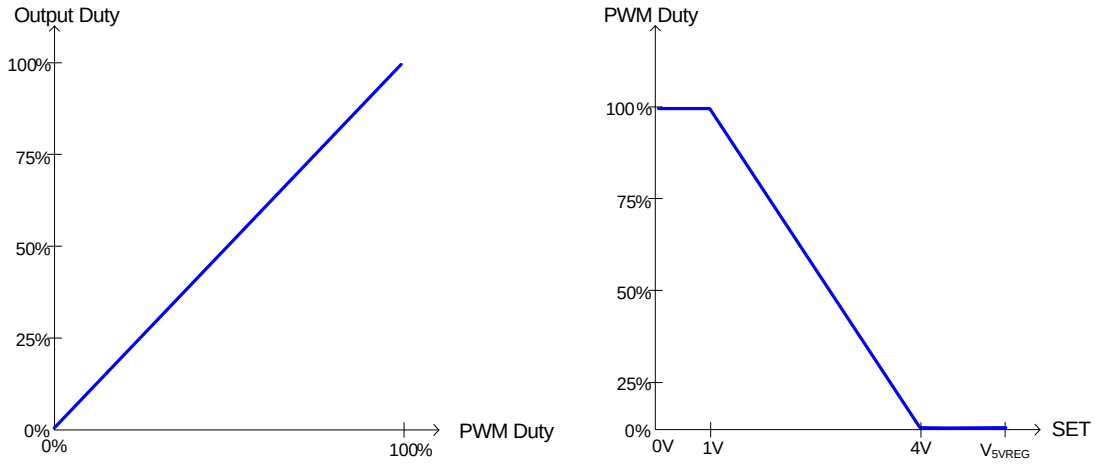


Figure2: Direct PWM Mode and SET Mode Output Duty Control

Function Descriptions (Cont.)

SP1,SP2 And VSD Control

When the MIN pin pulled up to V_{5VREG}, the SP1, SP2 and VSD input pin to control the input duty directly.

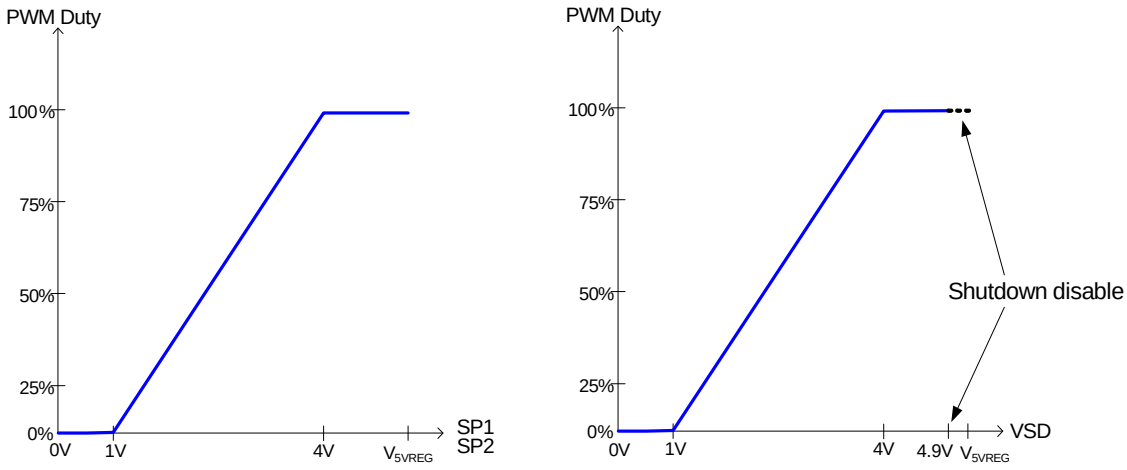


Figure3: SP1, SP2 and VSD Control

Lead Angle Control

The APX9322 built in automatic lead angle controlled by the duty variation of PWM. The maximum lead angle can be adjusted between 0° to 58° in 32 separate steps according to the input voltage of LA pin, which works with 0V to V_{5VREG}. The lead angle control range is 0° to the maximum value set by LA input for PWM duty 0% to 100%.

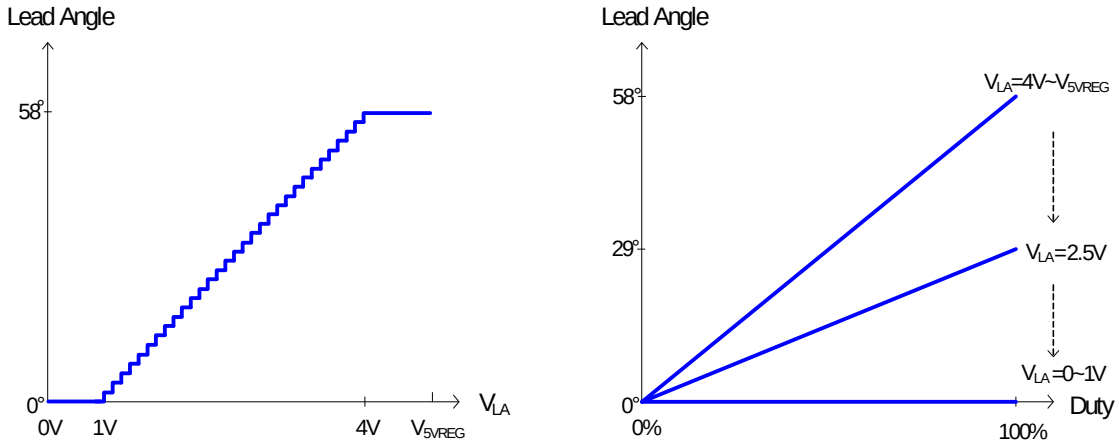


Figure4: Lead Angle Control

Function Descriptions (Cont.)

Forward Rotation Timing Chard (FR=5VREG)

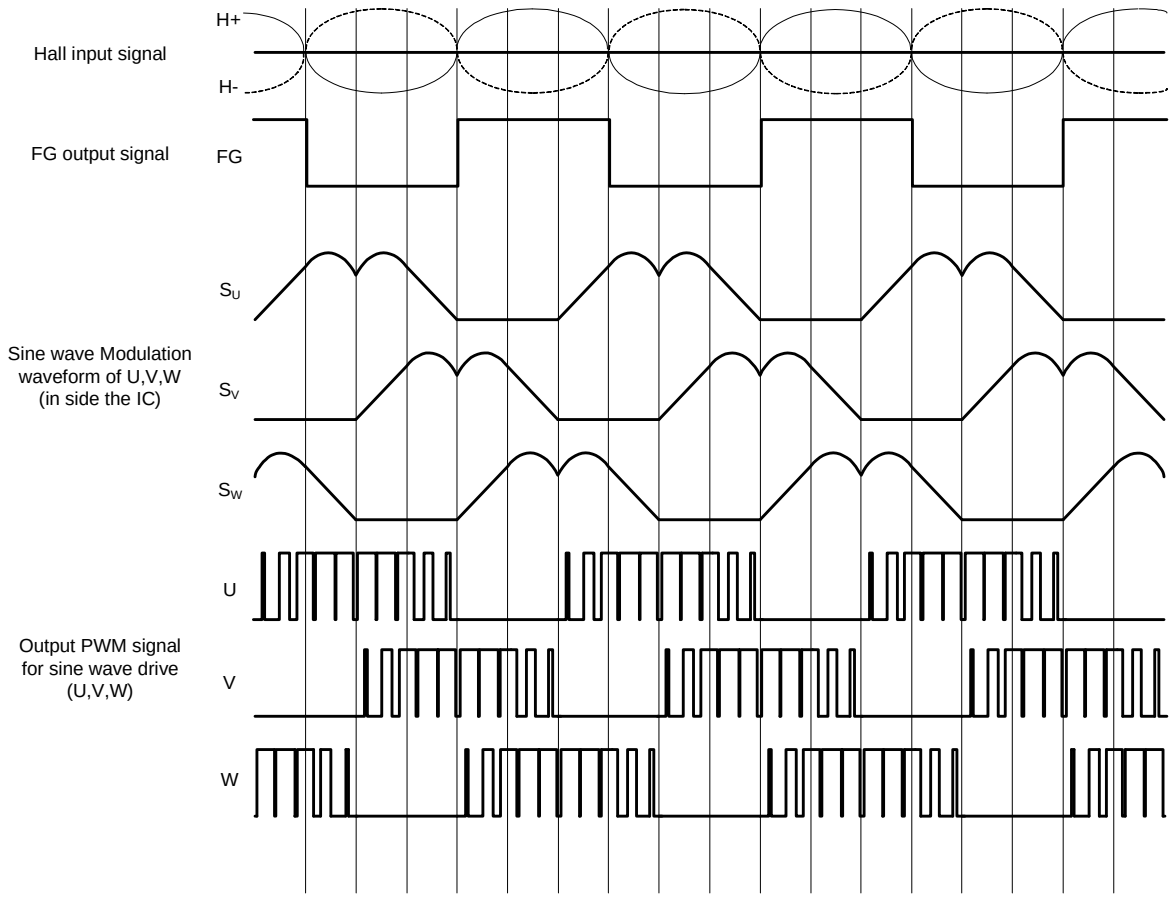


Figure 5: Forward Rotation Input and Output timing chards

Function Descriptions (Cont.)

Reverse Rotation Timing Chard (FR=GND)

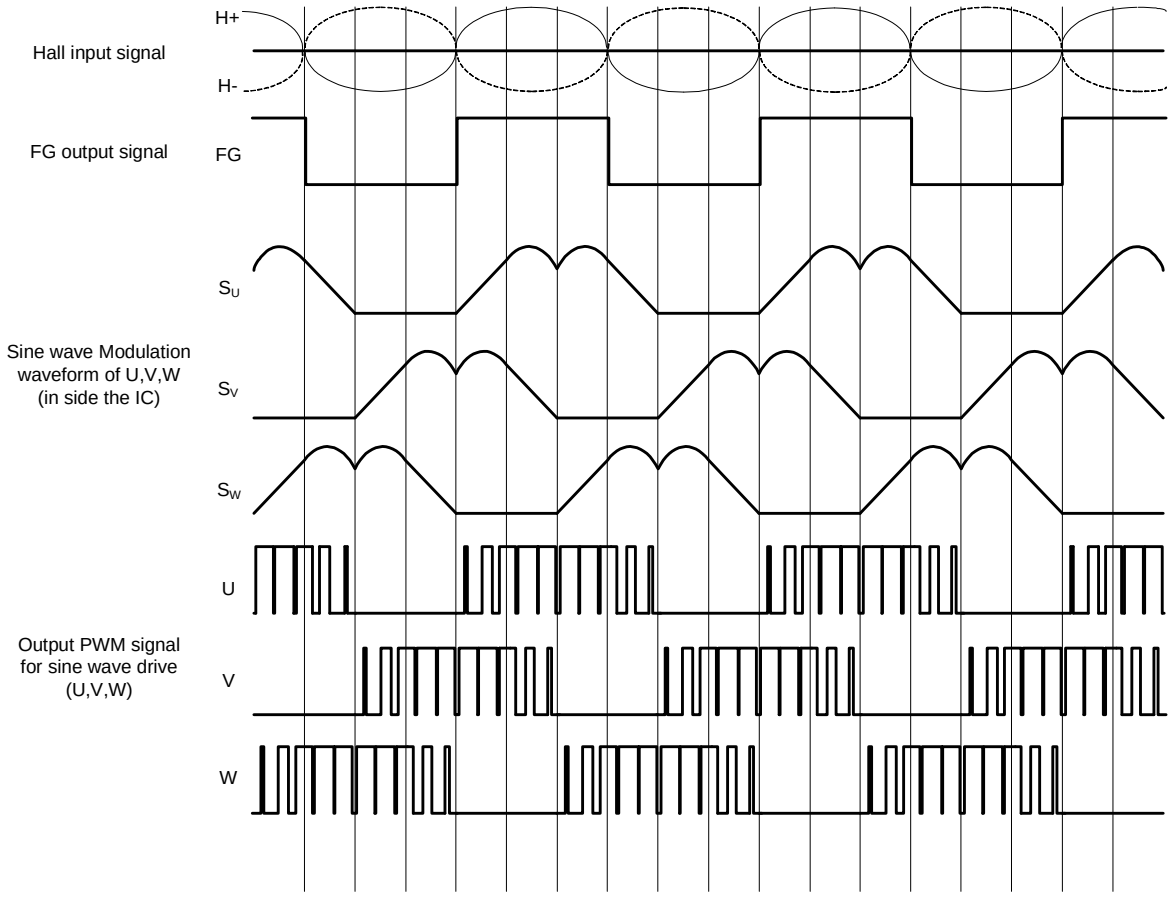


Figure 6: Reverse Rotation Input and Output timing chards

Function Descriptions (Cont.)

Sine Wave Modulation

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.

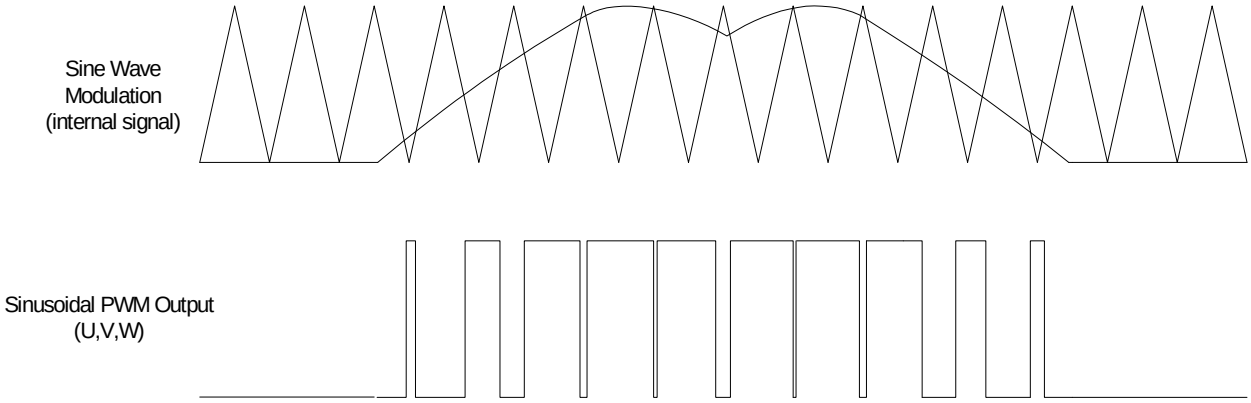


Figure 7: Sine Wave Modulation PWM Output

Lock Protection and Auto Restart

The APX9322 provides the lockup protection and automatic restart functions for preventing the coil burnout while the fan motor is locked. Connecting the capacitor from CT pin to SGND can determine the shut down time and restart time.

Current Limit and Over Current Protection (OCP)

The APX9322 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.

Thermal Protection

The APX9322 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.

SC Capacitor

The SC pin capacitor is used to set the force start up timing (T_{SC}) for sine-wave start up. Adjust the SC capacitor can set the start up timing for different motor or loading of fan motor. T_{SC} would increase in proportion to the capacitor.

EX:

:

C_{SC} =1.0nF >>>> T_{SC} =124ms

C_{SC} =2.2nF >>>> T_{SC} =272ms

:

:

C_{SC} =5nF >>>> T_{SC} =620ms

:

SS Capacitor

The SS capacitor is used to set the output duty change rate for soft start. The time (T_{SS}) is define the time of output duty from 0% to 100%. T_{SS} would increase in proportion to the capacitor.

EX:

:

C_{SS} =1.0nF >>>> T_{SS} =3.72s

C_{SS} =2.2nF >>>> T_{SS} =8.18s

:

:

C_{SS} =5nF >>>> T_{SC} =18.6s

:

CT Capacitor

The capacitor that is connected from CT pin to GND determines the shutdown time and restart time.

Locked Detection Time = $\frac{C_{CT}\times(V_{CTH}-0.2V)}{I_{CT1}}$

Restart Time= $\frac{C_{CT}\times(V_{CTH}-V_{CTL})}{I_{CT1}}$

Shutdown Time= $\frac{C_{CT}\times(V_{CTH}-V_{CTL})}{I_{CT2}}$

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Application Information

CT Capacitor

The capacitor that is connected from CT pin to GND determines the shutdown time and restart time.

Locked Detection Time = $\frac{C_{CT} \times (V_{CTH} - 0.2V)}{I_{CT1}}$

Restart Time= $\frac{C_{CT} \times (V_{CTH} - V_{CTL})}{I_{CT1}}$

Shutdown Time= $\frac{C_{CT} \times (V_{CTH} - V_{CTL})}{I_{CT2}}$

For example:

V_{CC}=12V, C_{CT}=1μF
V_{CTL}=1V, V_{CTH}=3V, I_{CT1}=2μA, I_{CT2}=0.2μA

Locked Detection Time = 1.4s
Restart Time = 1s
Shutdown Time= 10s

The value of C_{CT} must be considered with soft start up result.

RESET Capacitor

The capacitor that is connected from RESET pin to GND determines the Electric Motor Brakes. In the Power ON and Quick Start before.

Braking time = $\frac{C_{RESET} \times V_{RESET}}{I_{RESET}}$

EX:

I_{RESET} = 1.2μA , V_{RESET} = 1.9V , C_{RESET} = 0.22μF

Braking time = 0.348s

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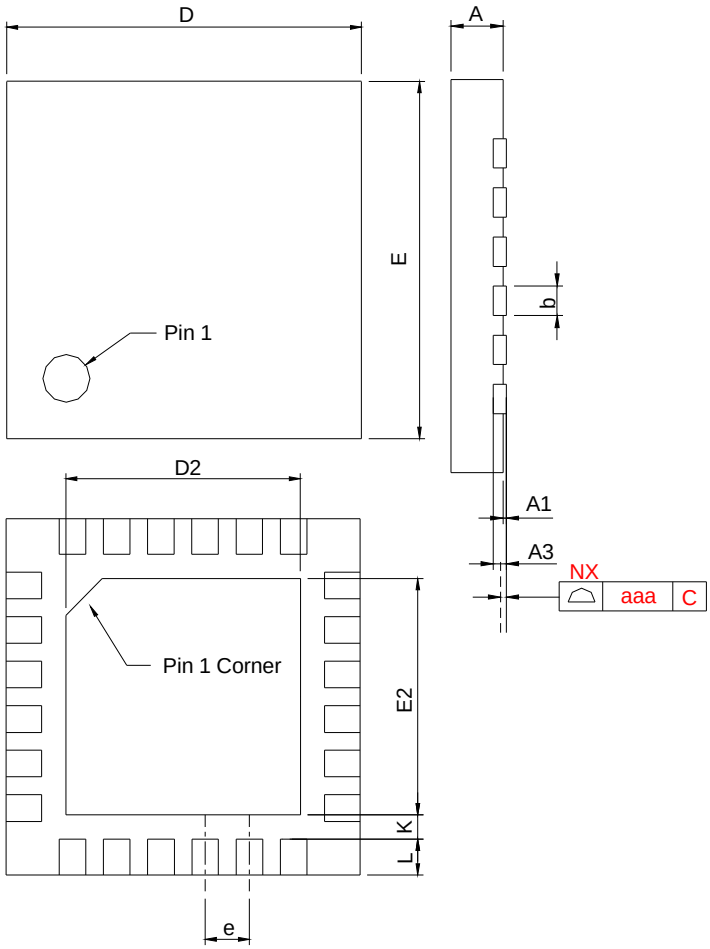
Package Information

QFN4x4-24



SYMBOL	QFN4*4-24			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.80	1.00	0.032	0.039
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	3.90	4.10	0.154	0.161
D2	2.50	2.80	0.098	0.110
E	3.90	4.10	0.154	0.161
E2	2.50	2.80	0.098	0.110
e	0.50 BSC		0.020 BSC	
L	0.35	0.45	0.014	0.018
K	0.20		0.008	
aaa	0.08		0.003	

Note : 1. Followed from JEDEC MO-220 WGGD-6.

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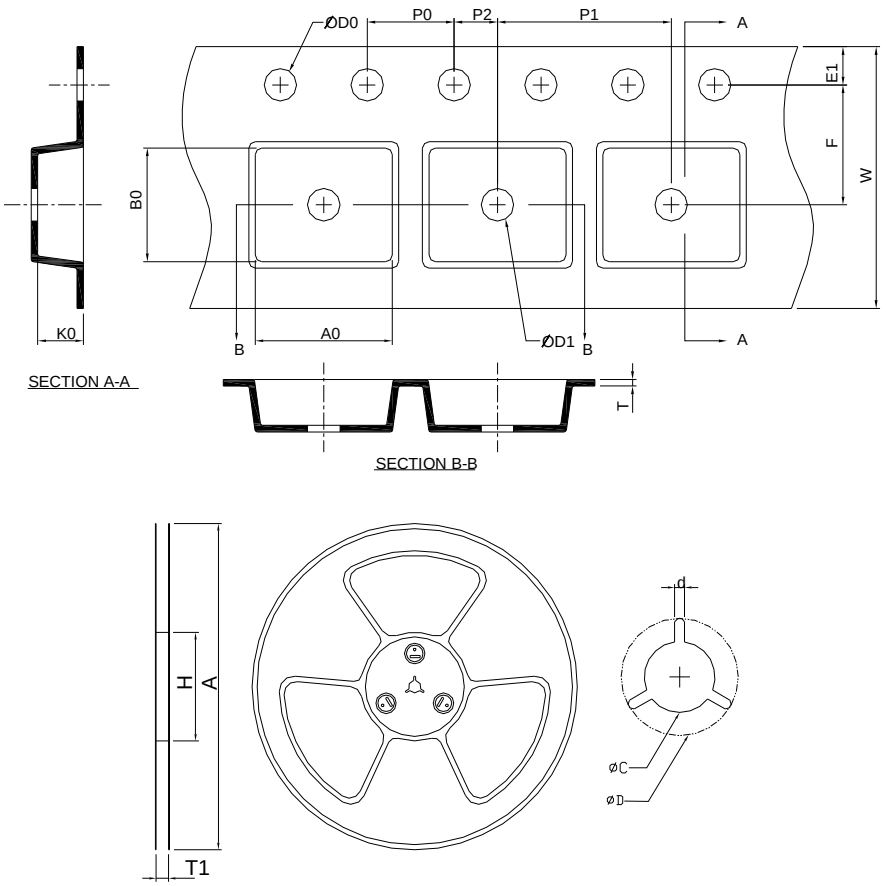
Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
QFN 4x4-24	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	4.30±0.20	4.30±0.20	1.30±0.20

(mm)

Devices Per Unit

Package type	Packing	Quantity
QFN 4*4-24	Tape & Reel	3000

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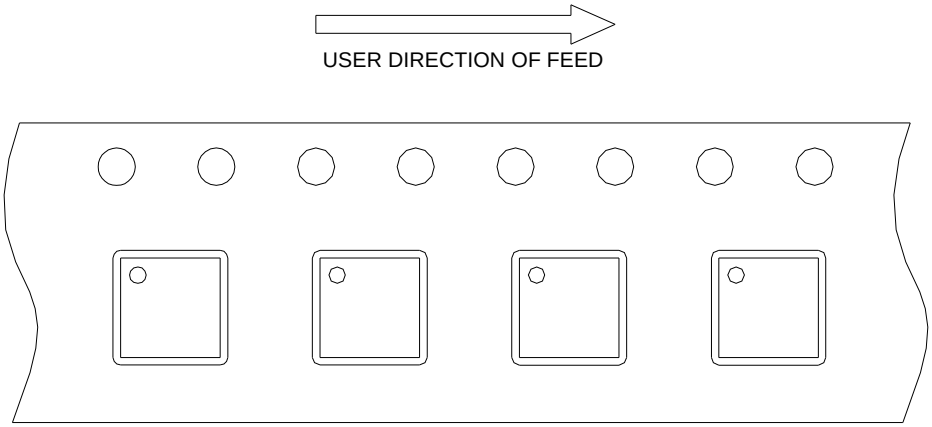
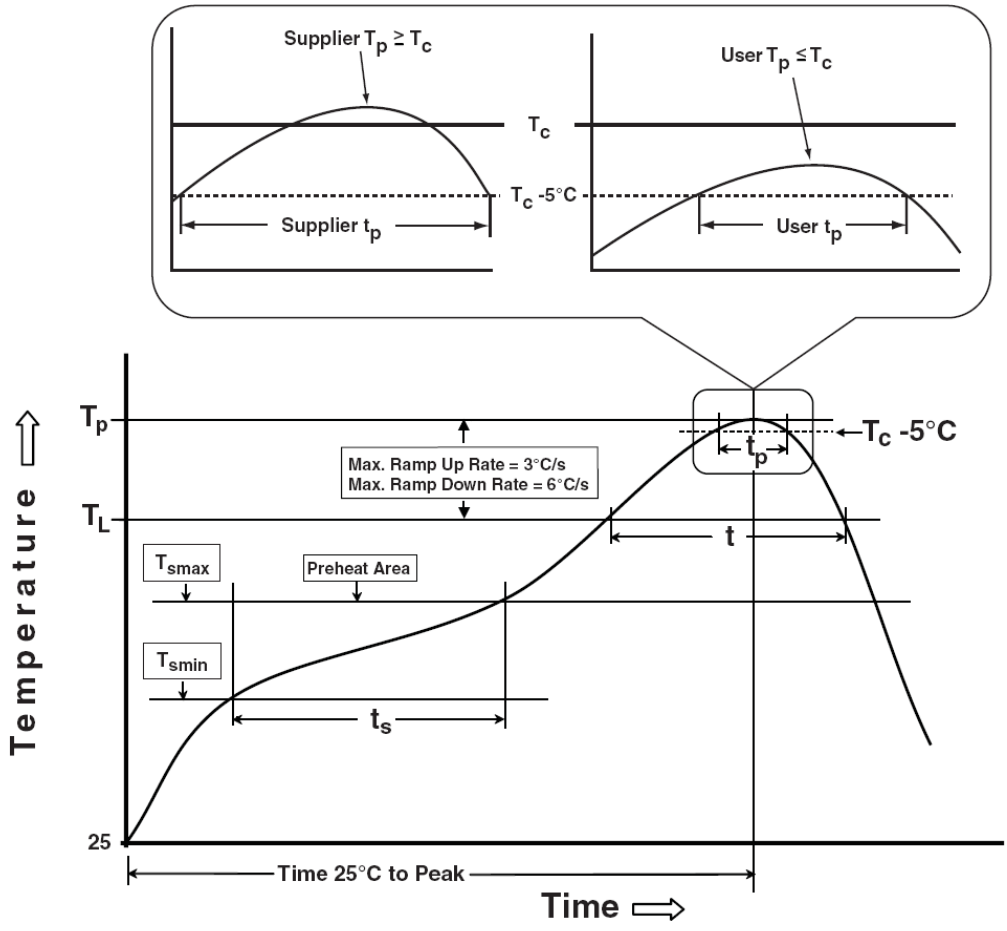
Taping Direction Information

QFN4x4-24



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 @ 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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