

Single-Phase Full-Wave Motor Driver

Features

- Built-in Soft Start Function
- Built-in Adjustable PWM Soft Switching Function
- Built-in Variable Speed Curve Function
- Built-in Adjustable Phase Angle Function
- Built-in Current Limit Circuit
- Built-in Over Voltage Protection(OVP) Function
- Built-in Lock Protection and Auto Restart Function
- Built-In Quick Start Function
- FG / 1/2FG / RD (Rotation Speed Detection) Output
- Built-in Thermal Protection Circuit
- MID, SP1, MIN, SP2, PA and SW are Multi Function
- Lead Free and Green Devices Available (RoHS Compliant)

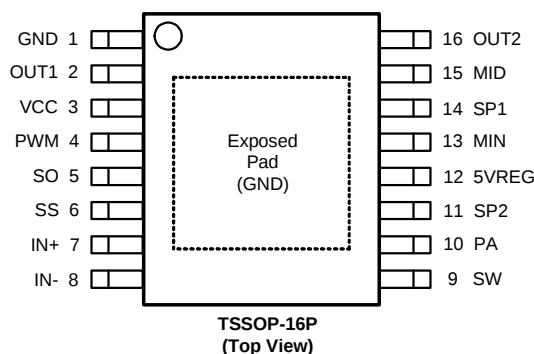
Applications

- Brushless DC Fans
- Brushless DC Motors

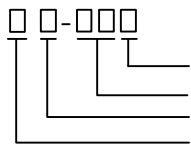
General Description

The APX9222 is a single-phase full-wave motor driver for DC fan motors. It's suitable for variable speed curve applications, and then It is suitable for cooler DC fan that needs silent drivers. In normal operation, the supply current is less than 9mA. The APX9222 is available in TSSOP-16P package.

Pin Configuration



Ordering and Marking Information

APX9222  Assembly Material Handling Code Temperature Range Package Code	Package Code R : TSSOP-16P Operating Ambient Temperature Range I : -40 to 105 °C Handling Code TR : Tape & Reel Assembly Material G : Halogen and Lead Free Device
APX9222 R : APX9222 XXXXX	XXXXXX - 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-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 1)

Symbol	Parameter	Rating	Unit
V _{CC}	VCC Pin Supply Voltage (VCC to GND)	-0.3 to 34	V
V _{OUT}	Output Pin (OUT1, OUT2) Output Voltage	-0.3 to 34	V
I _{OUT}	Output Pin (OUT1, OUT2) Maximum Output Peak Current	1.8	A
V _{PWM}	PWM Pin Input Voltage (For PWM Mode)	-0.3 to 20	V
V _{PWM}	PWM Pin Input Voltage (For VSP Mode)	-0.3 to V _{5VREG}	V
	SO Pin Output Voltage	-0.3 to 34	V
I _{SO}	SO Pin Output Sink Current	10	mA
I _{5VREG}	5VREG Pin Maximum Output Current	15	mA
V _{SP1}	SP1 Pin Input Voltage (SP1 to GND)	0 to 7	V
V _{MIN}	MIN Pin Input Voltage (MIN to GND)	0 to 7	V
V _{MID}	MID Pin Input Voltage (MID to GND)	0 to 7	V
V _{SP2}	SP2 Pin Input Voltage (SP2 to GND)	0 to 7	V
V _{SW}	SW Pin Input Voltage (SW to GND)	0 to 7	V
V _{PA}	PA Pin Input Voltage (PA to GND)	0 to 7	V
V _{SS}	SS Pin Input Voltage (SS to GND)	0 to 7	V
T _J	Maximum Junction Temperature	150	°C
T _{STG}	Storage Temperature	-65 to 150	°C
T _{SOR}	Maximum Lead Soldering Temperature, 10 Seconds	260	°C

Note 1: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device.

Thermal Characteristics

Symbol	Parameter	Typical Value	Unit
R _{TH,JA}	Thermal Resistance-Junction to Ambient TSSOP-16P	83	°C/W
P _D	Power Dissipation, T _A = 25 °C TSSOP-16P	1.5	W

Note 2: The maximum allowable power dissipation at any T_A (ambient temperature) is calculated using: $P_D = (T_J - T_A) / R_{TH,JA}$; T_J = 150°C. Exceeding the maximum allowable power dissipation will result in excessive die temperature.

Recommended Operation Conditions

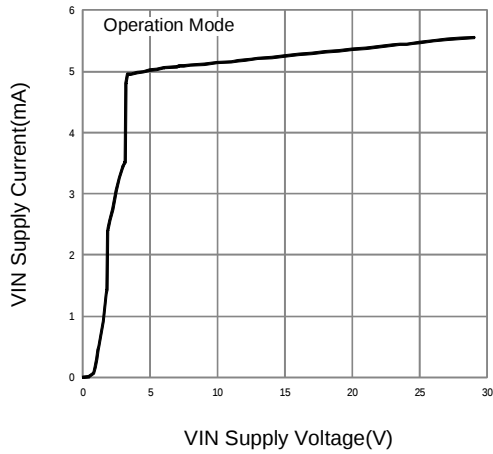
Symbol	Parameter	Range	Unit
V _{CC}	VCC Supply Voltage	4 to 29	V
V _{SP1}	SP1 Pin Input Voltage (SP1 to GND)	0 to V _{5VREG}	V
V _{MIN}	MIN Pin Input Voltage (MIN to GND)	0 to V _{5VREG}	V
V _{MID}	MID Pin Input Voltage (MID to GND)	0 to V _{5VREG}	V
V _{SP2}	SP2 Pin Input Voltage (SP2 to GND)	0 to V _{5VREG}	V
V _{SW}	SW Pin Input Voltage (SW to GND)	0 to V _{5VREG}	V
V _{PA}	PA Pin Input Voltage (PA to GND)	0 to V _{5VREG}	V
V _{SS}	SS Pin Input Voltage (SS to GND)	0 to V _{5VREG}	V
V _{ICM}	Common-Mode Hall Input Voltage Range	0.4 to V _{5VREG} -1.2	V
T _A	Operating Ambient Temperature	-40 to 105	°C
T _J	Junction Temperature	-40 to 125	°C

Electrical Characteristics ($T_A = 25^{\circ}\text{C}$, $V_{CC} = 24\text{V}$, unless otherwise specified)

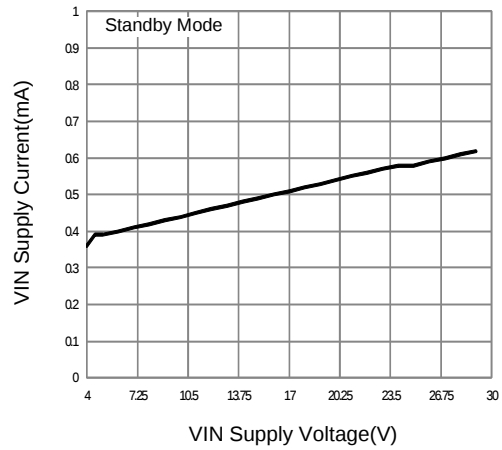
Symbol	Parameter	Test Condition	APX9222			Unit
			Min.	Typ.	Max.	
SUPPLY CURRENT						
I _{CC}	Operation Mode	V _{CC} = 12V (No Load)	-	6	9	mA
I _{CC2}	Standby Mode	PWM = GND and FG Output	-	-	1	mA
V _{5VREG}	5VREG Pin Output Voltage	I _{5VREG} = 10mA	4.8	5	5.2	V
OUTPUT DRIVERS						
V _O	Output Driver Saturation Voltage	I _{OUT} = 300mA, Upper and Lower total	-	0.15	0.225	V
V _{SO}	SO Pin Low Voltage	I _{SO} = 5mA	-	0.15	0.25	V
I _{SOL}	SO Pin Off Leakage Current	V _{SO} = 12V	-	<0.1	1	μA
V _{SOT}	SO Pin Current Limit Trigger Level	IN- > IN+	1	-	1.5	V
HALL SENSITIVITY						
V _{HYS}	Hall Input Hysteresis Voltage		-	±8	±15	mV
PWM CONTROL						
V _{PWMH}	Pulse Mode PWM Input High Level Voltage		2	-	5	V
V _{PWML}	Pulse Mode PWM Input Low Level Voltage		-0.3	-	0.8	V
F _{PWM}	PWM Input Frequency		0.5	-	50	KHz
F _{OUT}	Output PWM Switch Frequency		28	33	38	KHz
R _{PWM_PU}	PWM Internal pull-up Resistor		-	16	-	KΩ
V _{PWM_PU}	PWM Internal pull-up Voltage		-	4.8	-	V
LOCK PROTECTION						
T _{LDT1}	Lock Protection Detection Time	OUTPUT Duty>20%	-	0.2	-	sec
T _{LDT2}	Lock Protection Detection Time	OUTPUT Duty<20%, Define by C _{SS}	-	0.5~2	-	sec
T _{ON}	Lock Protection Detection On Time	Define by V _{SS} and C _{SS}	-	0.6 ~ 3.8	-	sec
T _{OFF}	Lock Protection Detection Off Time	Define by C _{SS}	-	3.5 ~ 14	-	sec
T _{QS}	Quick Start Enable Time		-	66.5	-	ms
Soft Start						
T _{SS1}	Soft Start Time	For Start up, Define by V _{SS} .	-	0.48 ~ 11.4	-	sec
I _{SS2}	SS pin Discharge current	V _{SS} = 2V	-	10	-	mA
V _{SS2H}	SS Pin High Level Voltage		1.8	2	2.2	V
V _{SS2L}	SS Pin Low Level Voltage		0.05	0.15	0.25	V
D _{SS}	Soft Start Initial Duty		-	5	-	%
CURRENT PROTECTION						
I _{LIM1}	Current Limit Level of Start up		-	0.75	-	A
I _{LIM2}	Current Limit Level of Normal Operation		-	1.5	-	A
VOLTAGE PROTECTION OF VCC						
V _{OVP}	Over Voltage Protection Level		31	-	34	V
THERMAL PROTECTION						
	Over-Thermal Protection Temperature		-	170	-	°C
	Over Thermal Protection Hysteresis		-	30	-	°C
	Thermal Protection release time		-	4	-	sec

Typical Operation Characteristics

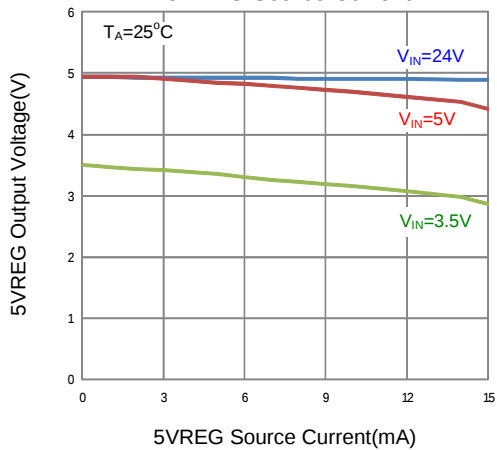
VIN Supply Current vs. VIN Supply Voltage



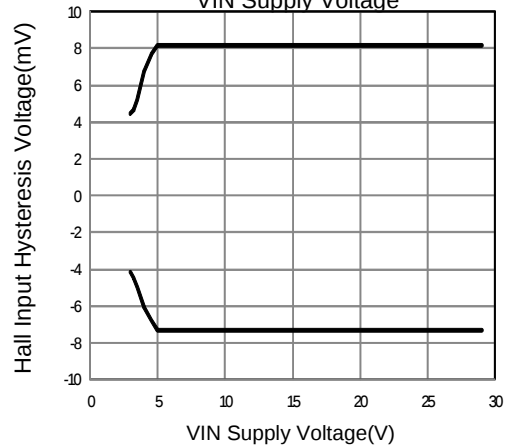
VIN Supply Current vs. VIN Supply Voltage



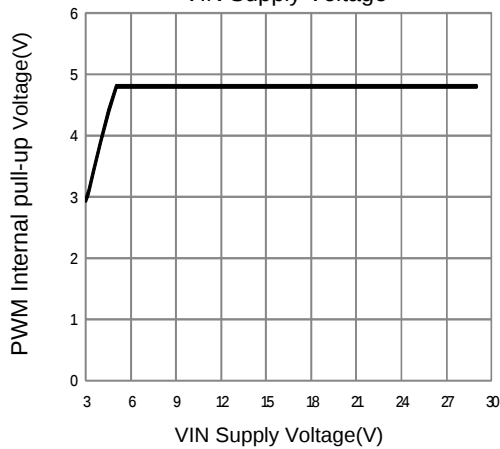
5VREG Output Voltage vs. 5VREG Source Current



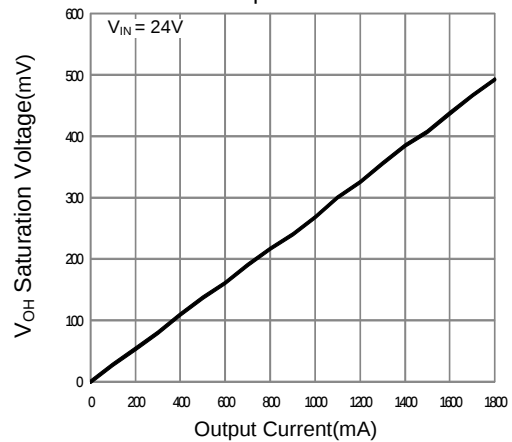
Hall Input Hysteresis Voltage vs. VIN Supply Voltage



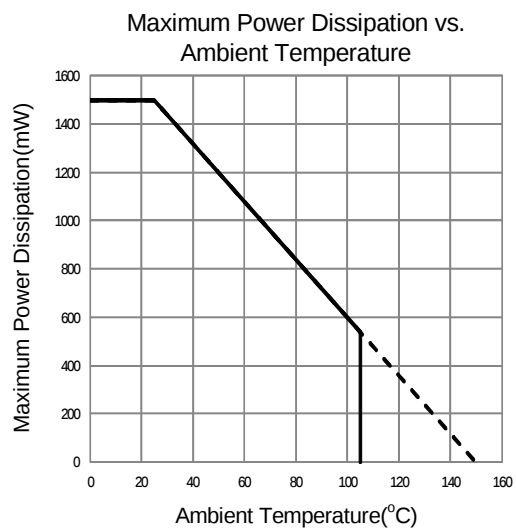
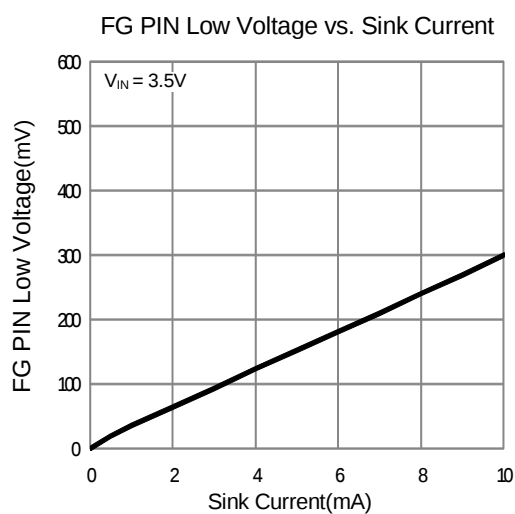
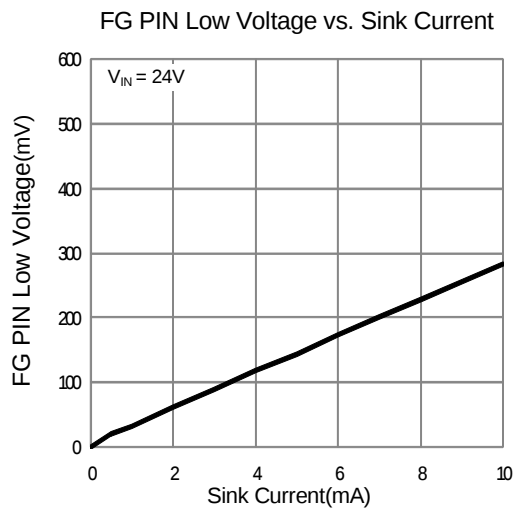
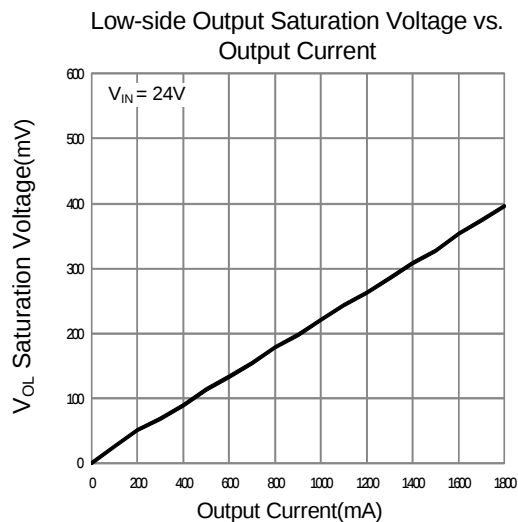
PWM Internal pull-up Voltage vs. VIN Supply Voltage



High-side Output Saturation Voltage vs. Output Current



Typical Operation Characteristics (Cont.)

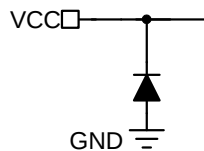


Pin Description

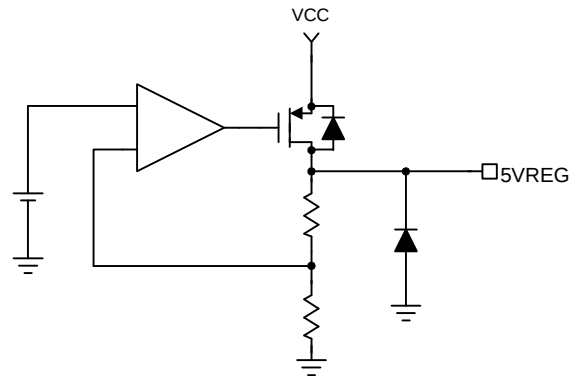
PIN		Function
NO.	NAME	
1	GND	Ground of the IC.
2	OUT1	H-bridge output connection. The output stage is a H-bridge formed by four transistors and four-protection diode for switching applications.
3	VCC	Supply Voltage Input.
4	PWM	PWM Signal or DC Voltage Input Terminal
5	SO	FG / 1/2FG / RD(Rotation Speed Detection) Output. This is an open-drain output.
6	SS	Soft Start Time Setting.
7	IN+	Hall Input +. Connect to hall element positive output.
8	IN-	Hall Input -. Connect to hall element negative output.
9	SW	Soft Switching Term Setting and Decision SP2 pin is Output Duty or Phase Angle High Setting.
10	PA	Phase Angle Setting or Auto Leading Angle Mode Select.
11	SP2	Output Duty (DO_{SP2}) For Turning Point (DI_{SP2}) or Phase Angle High Setting.
12	5VREG	5V Regulator Output.
13	MIN	Minimum Output Duty Setting and Off Side Dead Time Degree Setting.
14	SP1	Input Duty Setting For Turning Point (DI_{SP1}) and Speed Curve Type Select (Shut Down or Minimum Speed Curve).
15	MID	Output Duty Setting (DO_{MID}) For Turning Point (DI_{MID}) and Speed Control Type Select (Direct PWM Mode or VSP Mode).
16	OUT2	H-bridge output connection. The output stage is a H-bridge formed by four transistors and four-protection diode for switching applications.

I / O Equivalent Circuits

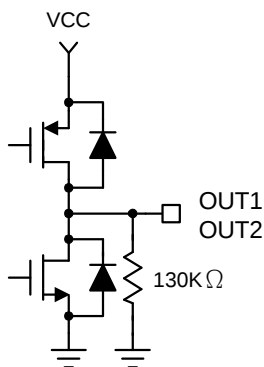
(1) Power supply input pin (VCC, GND)



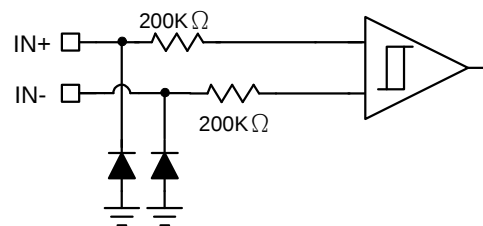
(2) Regulator output pin (5VREG)



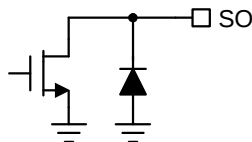
(3) Driver output pin (OUT1, OUT2)



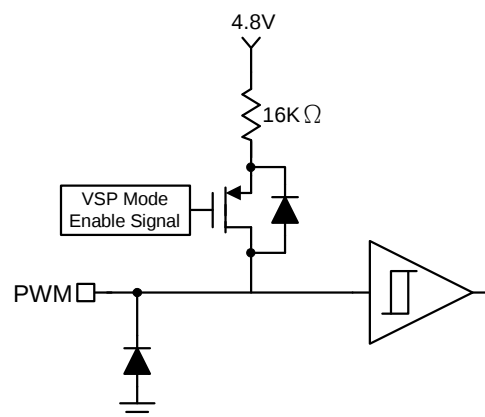
(4) Hall signal input pin (IN+, IN-)



(5) Rotation speed detection output pin (SO)

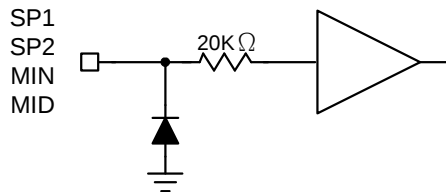


(6) PWM speed control input pin (PWM)

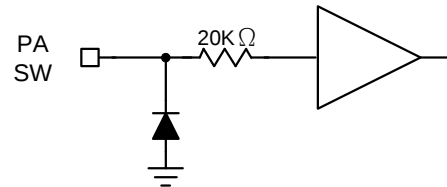


I / O Equivalent Circuits (Cont.)

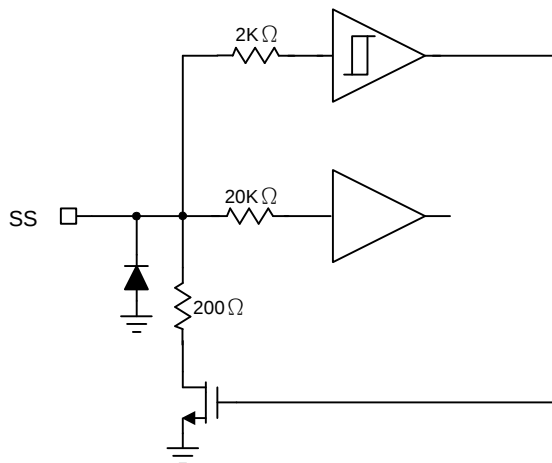
(7) Input and output duty setting input pin (SP1, SP2, MIN, MID)



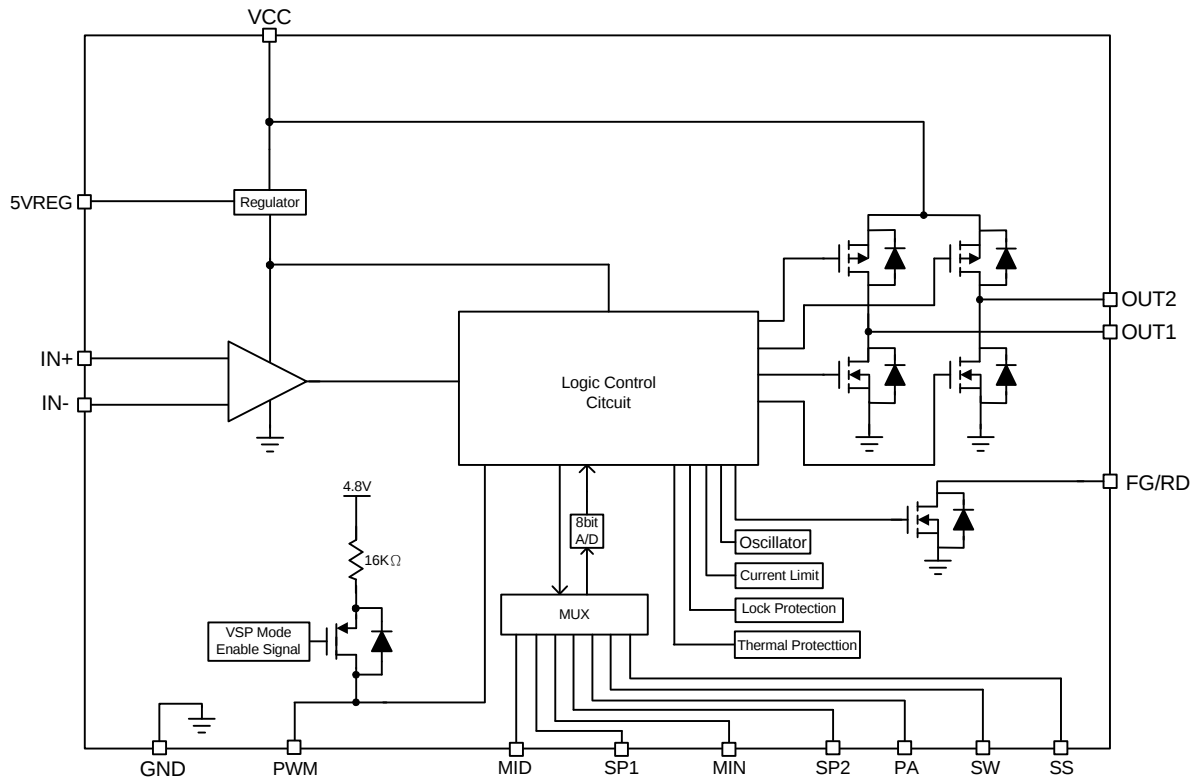
(8) Phase Angle and Soft Switch angle setting pin (SW, PA)



(9) Soft Start time setting pin (SS)

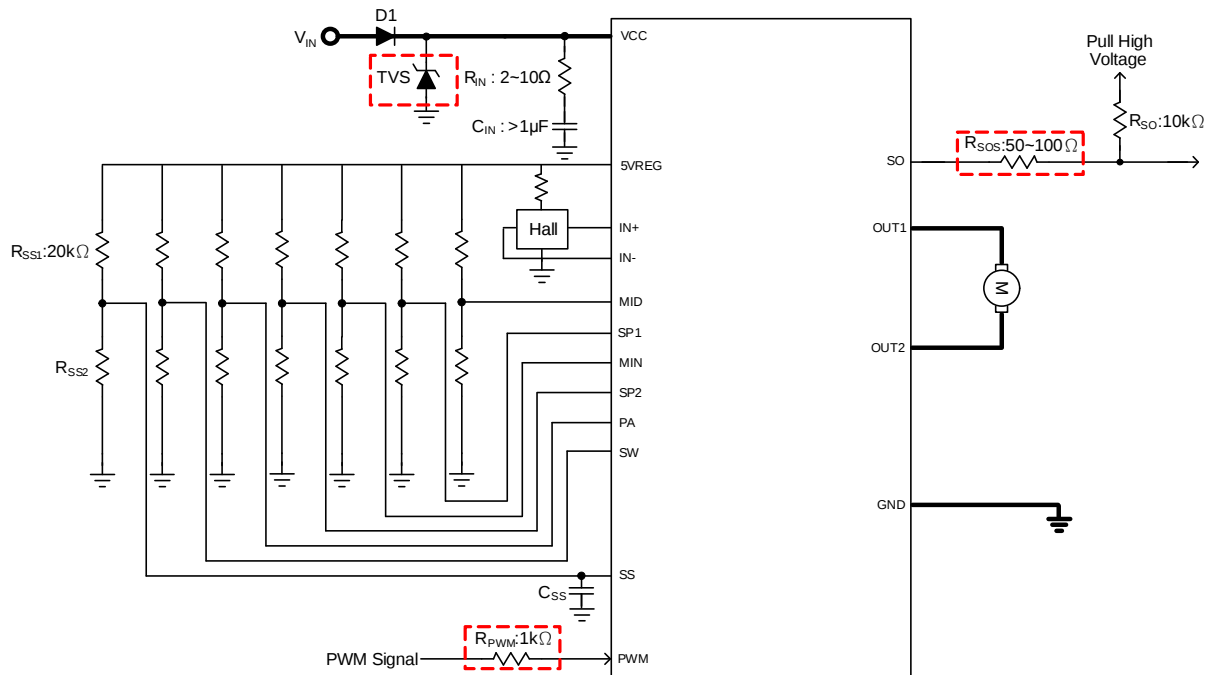


Block Diagram



Typical Application Circuit

(1) Direct PWM Mode Speed Control



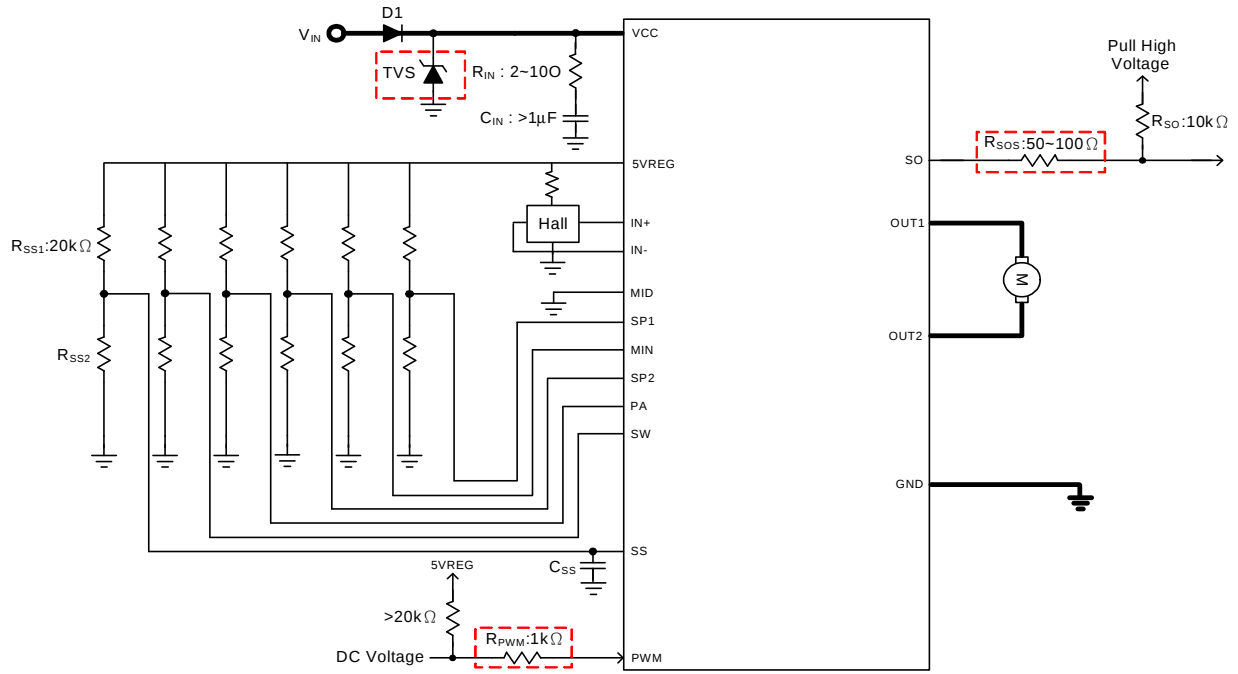
Note: R_{PWM} and R_{SOS} are optional to protect internal circuit for abnormal voltage stress.

Note: The C_{IN} value is adjusted by motor characteristic and it type must select X7R(50V).

Note: The TVS is option to avoid VCC peaking caused IC damage.

Typical Application Circuit (Cont.)

(2)VSP Mode Input Speed Control



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

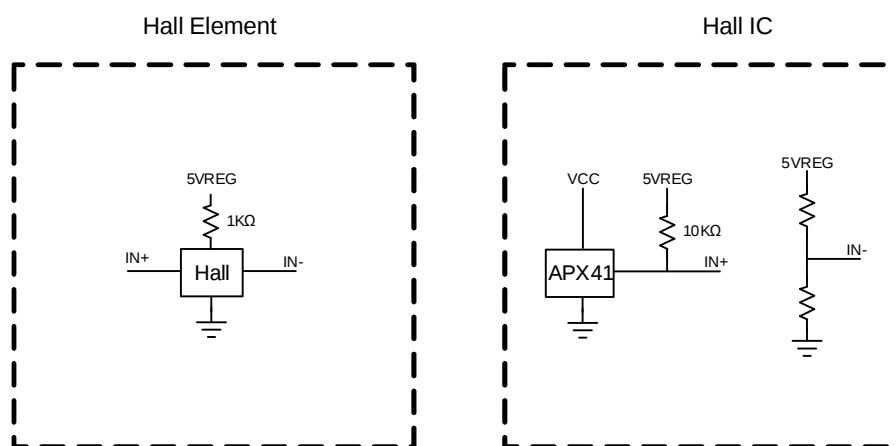
Note: The C_{IN} value is adjusted by motor characteristic and it type must select X7R(50V).

Note: The TVS is option to avoid VCC peaking caused IC damage.

Function Description

Hall Element and Hall IC

The APX9222 hall signal input pin offers two types of Hall element and Hall IC application, the circuit design will be more flexible.



HALL Input Circuits

Multi Function

The APX9222 has multi function of some pins. It's in order to reduce the number of IC Pin. The SP1, MIN, SP2 and MID pin primary function is speed control curve setting. The PA pin primary function is phase angle adjustable. The SW pin primary function is setting off side soft switching degree. All of above pin, the secondary function set up following to table1.

Secondary Function Setting Reference Table

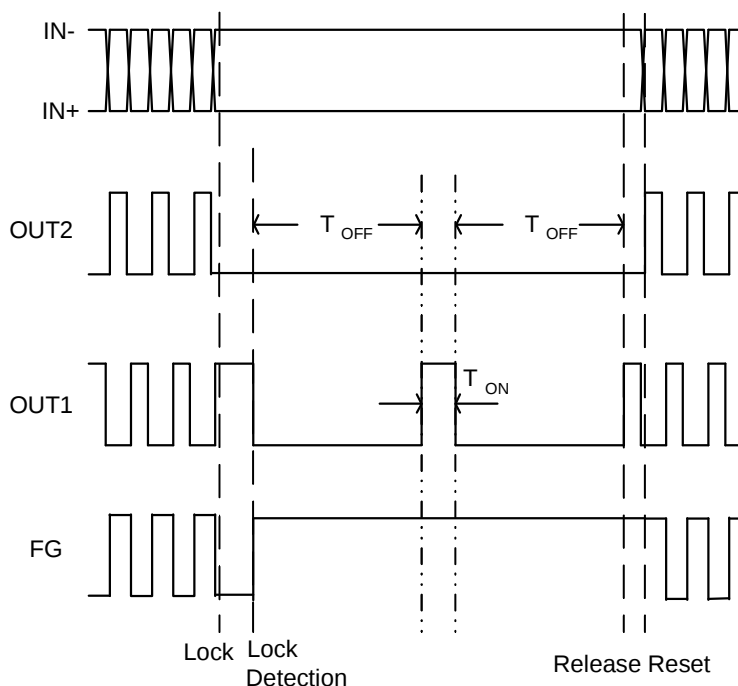
	<0.15V	0.5~2.45V	2.55~4.5V	>4.85V
SP1	Shutdown Mode	Shutdown Mode	Minimum Speed Mode	Minimum Speed Mode
MID	VSP Mode and SO(FG)	SO(1/2FG)	SO(FG)	SO(FG)
MIN	Dead Time of OFF Side(Auto)	Dead Time of OFF Side(Auto)	Dead Time of OFF Side(Fix 15°)	Dead Time of OFF Side(Fix 15°)
SP2	1.SO(RD Signal)	1.PWM_IN=100% PWM_OUT=DO _{SP2}	1.PWM_IN=DI _{SP2} PWM_OUT=100%	1.PWM_IN= DI _{SP2} PWM_OUT=100%
	2. V _{SW} = GND, the SP2 change to PAH feature.	2. V _{SW} = GND, the SP2 change to PAH feature.	2. V _{SW} = GND, the SP2 change to PAH feature.	2. V _{SW} = GND, the SP2 change to PAH feature.
	3. V _{SW} = GND and V _{PA} = 5VREG, the SP2 change to set up Auto LA _(Max.) (°) angle	3. V _{SW} = GND and V _{PA} = 5VREG, the SP2 change to set up Auto LA _(Max.) (°) angle	3. V _{SW} = GND and V _{PA} = 5VREG, the SP2 change to set up Auto LA _(Max.) (°) angle	3. V _{SW} = GND and V _{PA} = 5VREG, the SP2 change to set up Auto LA _(Max.) (°) angle
PA	V _{SW} = GND, the PA pin change to PAL Feature.	V _{SW} = GND, the PA pin change to PAL Feature.	V _{SW} = GND, the PA pin change to PAL Feature.	Auto LA
SW	SP2 Pin Change to PAH Feature and SW fix 22.5°	N/A	N/A	N/A

Note : The MIN pin voltage recommended region is <0.15V, 0.63~4.37V and >4.85V.

Function Description

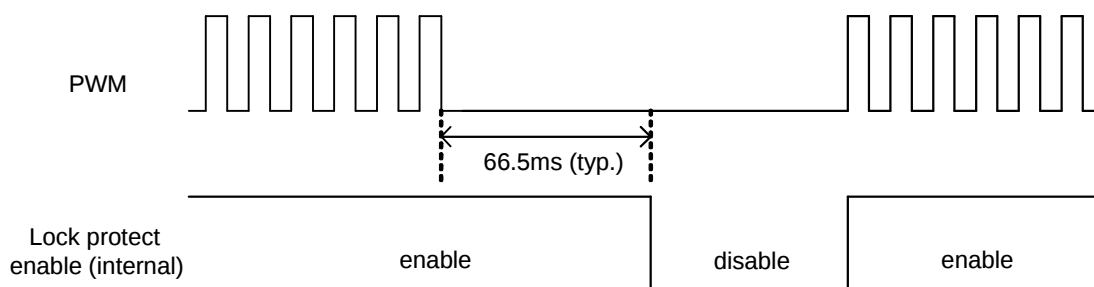
Lockup Protection and Automatic Restart

The APX9222 provides the lockup protection and automatic restart functions for preventing the coil burn-out in the fan is locked. This IC has an internal counter to determine the shutdown time (T_{OFF}) and restart time (T_{ON}). During shutdown time, the output drivers keep turning off and then enter the restart time. During the restart time, one output is high and the other is low, which makes a torque for fan rotation. The shutdown time is the restart time seven times. The restart time is related to the soft start time. If the locked condition is not removed, the shutdown restart process will be recurred until the locked condition is released.



Quick Start and Standby Mode

This IC would enter standby mode when the PWM input keeps low level for then 66.5ms (typ.). In standby mode, it will shutdown amplifier and FG. In standby mode, the lock protection function doesn't work, therefore, starting fan is unobstructed when releasing standby mode.



Function Description (Cont.)

Soft-Start Function

The APX9222 provides the soft-start function to avoid peak current at power-on and lock-restart moments. The soft start time(T_{SS1}) is define by SS pin input voltage at start up moment. At start up, the output initial duty is 5%. After the hall signal cross eight times, the output duty will trace to target duty. The T_{SS1} can set up voltage range following the figure and table.

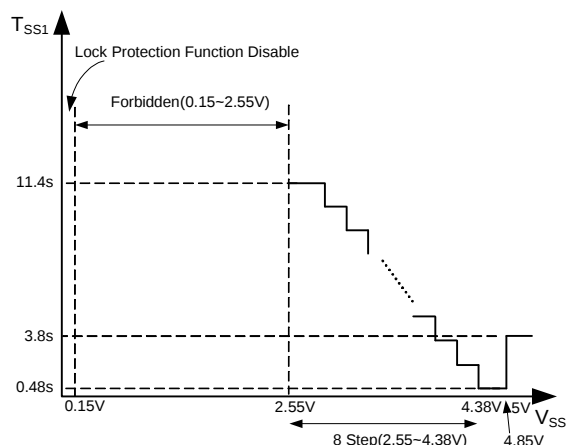
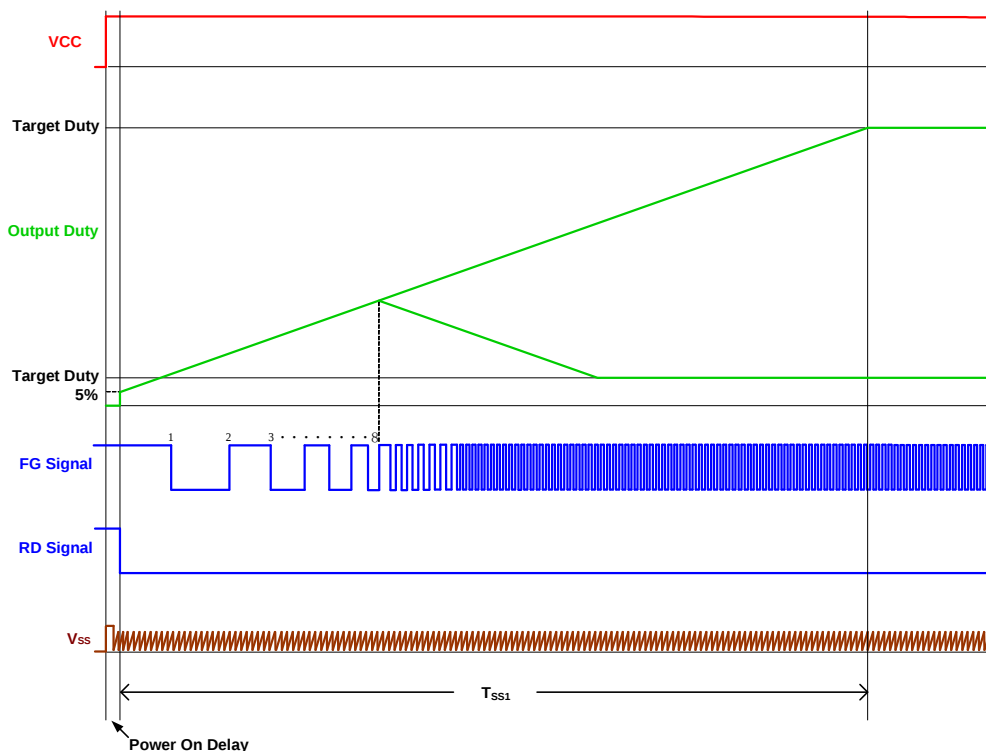


Table2. V_{SS} Voltage Setting Table		
Step	V_{SS} (V)	T_{SS1} (s)
	>4.85	3.8
8	4.38	0.48
7	4.14	0.95
6	3.89	1.9
5	3.64	3.8
4	3.39	5.7
3	3.14	7.6
2	2.88	9.5
1	2.63	11.4

SS1 Voltage Setting Range

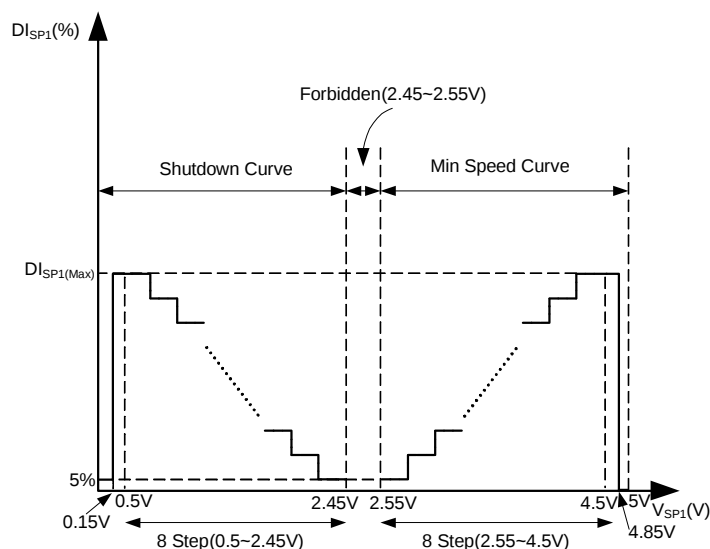


Soft Start Timing Chart

Function Description (Cont.)

Speed Control Pin Setting Description

The SP1 pin contain of multi function by input voltage setting. In this pin, the input duty setting for turning point (DI_{SP1}) is primary function. The secondary function is setting speed control curve with shutdown or minimum speed. It can set up voltage range following the figure and table.



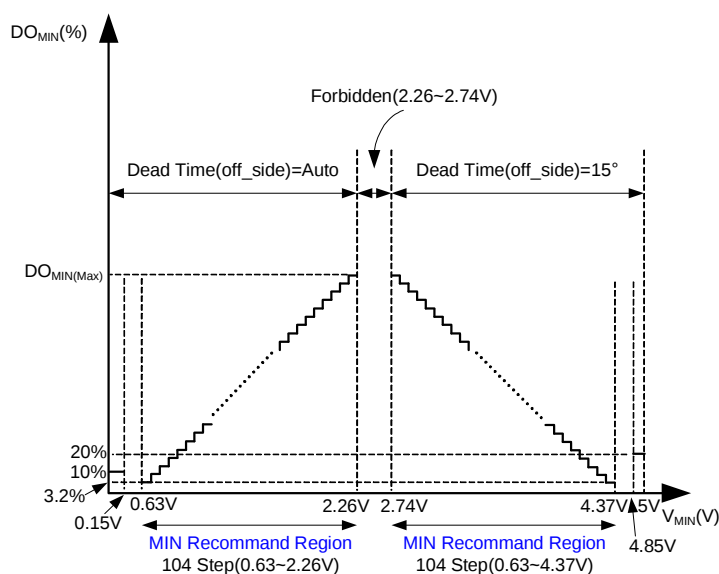
SP1 Voltage Setting Range

SP1 Input Voltage Setting Table

Step	V _{SP1} (V)	DI _{SP1} (%)	Secondary Function
	>4.85	0	Minimum Speed Curve
16	4.38	33	
15	4.14	29	
14	3.89	25	
13	3.64	21	
12	3.39	17	
11	3.14	13	
10	2.88	9	
9	2.63	5	
Forbidden			
8	2.38	5	ShutDown Curve
7	2.13	9	
6	1.88	13	
5	1.63	17	
4	1.38	21	
3	1.13	25	
2	0.88	29	
1	0.63	33	
	<0.15	5	

Function Description (Cont.)

The MIN pin contain of multi function by input voltage setting. In this pin, the minimum output duty setting is primary function and the secondary function is setting dead time (off side) degree. The dead time (off side) degree divided into two types. The first type of dead time is fixed 15°. The second type of dead time is auto adjust. It can set up voltage range following the figure and table.



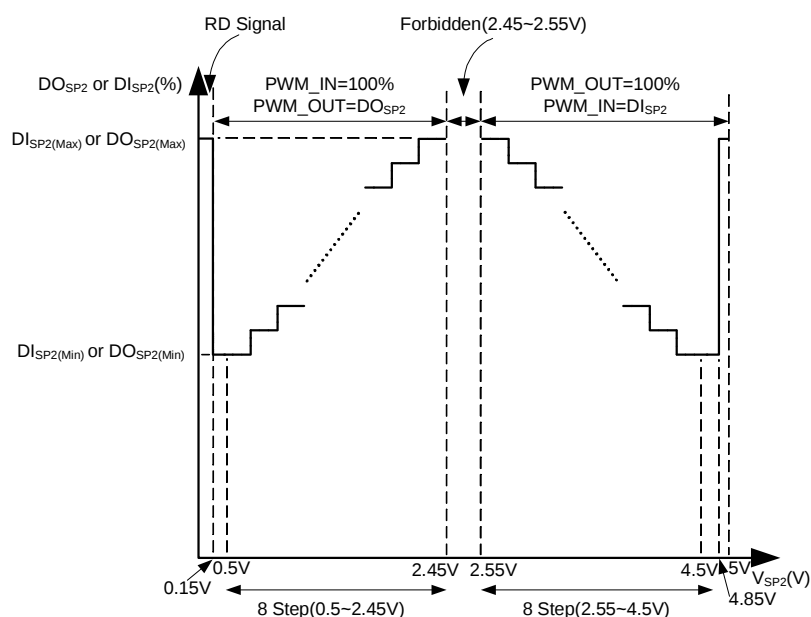
MIN Voltage Setting Range

MIN Input Voltage Setting Table

Step	V _{MIN} (V)	DO _{MIN} (%)	Secondary Function
	>4.85	20	Dead Time(off_side) = Fix 15°
247	4.37	3.2	
143	2.74	43.92	
Forbidden			
112	2.26	43.92	Dead Time(off_side) = Auto
8	0.63	3.2	
	<0.15	10	

Function Description (Cont.)

The SP2 pin is setting up when the PWM input duty is 100%, the output duty can set up not equaling to 100%. Or, when the PWM output duty is 100%, the input duty also can set up not equaling to 100%. If SP2 connect to GND, the FG signal is change to RD signal. It can set up voltage range following the figure and table.



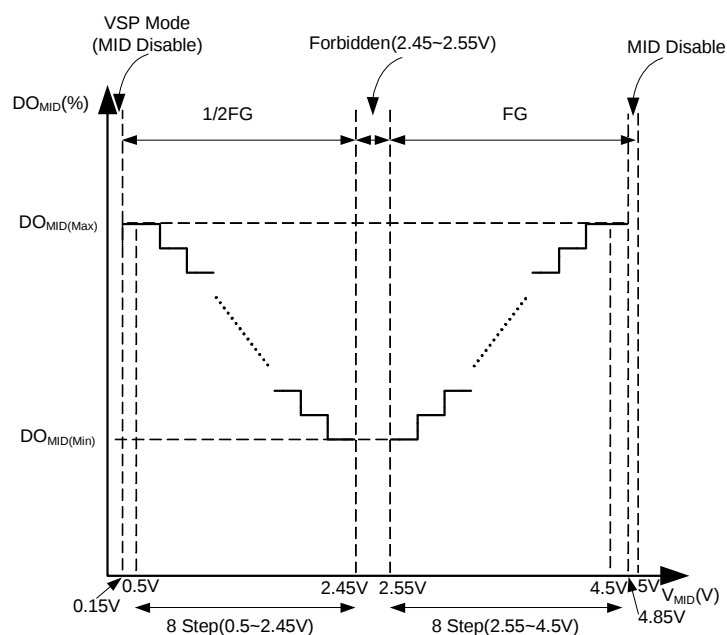
SP2 Voltage Setting Range

SP2 Input Voltage Setting Table

Step	V _{SP2} (V)	DI _{SP2} or DO _{SP2} (%)	Secondary Function
	>4.85	100	PWM_IN=DI _{SP2} PWM_OUT=100%
16	4.38	83.9	
15	4.14	86.2	
14	3.89	88.5	
13	3.64	90.8	
12	3.39	93.1	
11	3.14	95.4	
10	2.88	97.7	
9	2.63	100	
Forbidden			
8	2.38	100	PWM_IN= 100% PWM_OUT=DO _{SP2}
7	2.13	97.7	
6	1.88	95.4	
5	1.63	93.1	
4	1.38	90.8	
3	1.13	88.5	
2	0.88	86.2	
1	0.63	83.9	
	<0.15	100	

Function Description (Cont.)

The MID pin contain of multi function by input voltage setting. In this pin, the output duty set up (DO_{MID}) for turning point (PWM_IN=75%) is primary function and the secondary function is setting PWM pin Input signal type (direct PWM signal input or DC voltage input) and the RPM signal is FG or 1/2FG. The MID pin can set up voltage range following the figure and table.



MID Voltage Setting Range

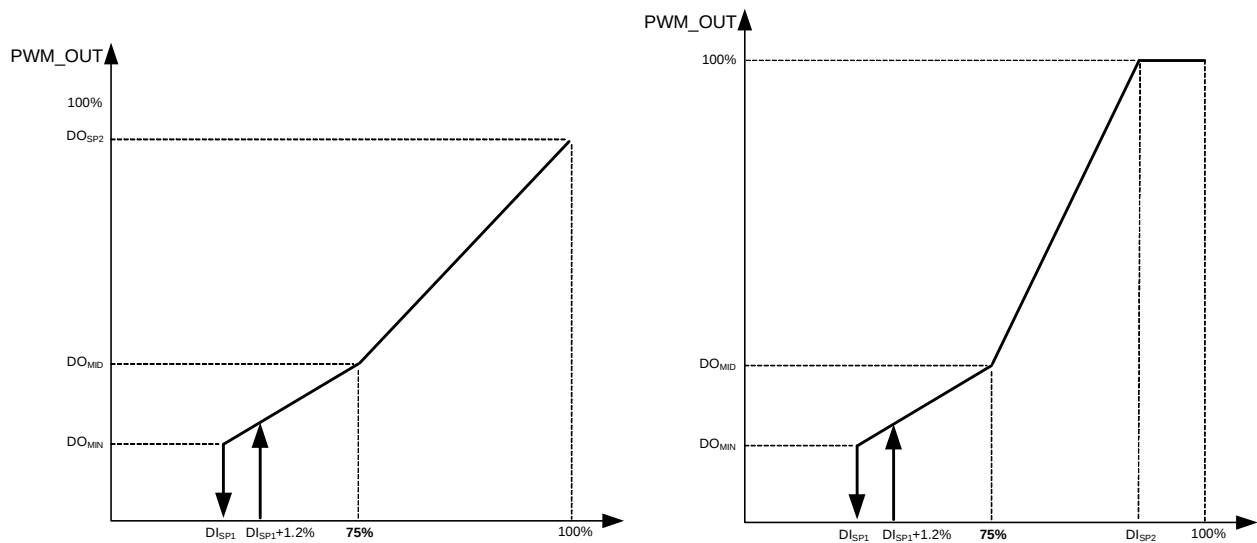
MID Input Voltage Setting Table

Step	V _{MID} (V)	DO _{MID} (%)	Secondary Function
	>4.85	Disable	MID Disable
16	4.38	75	FG OUTPUT
15	4.14	70	
14	3.89	65	
13	3.64	60	
12	3.39	55	
11	3.14	50	
10	2.88	45	
9	2.63	40	
Forbidden			
8	2.38	40	1/2FG OUTPUT
7	2.13	45	
6	1.88	50	
5	1.63	55	
4	1.38	60	
3	1.13	65	
2	0.88	70	
1	0.63	75	
	<0.15	Disable	

Function Description (Cont.)

Speed Control Curve

The APX9222 has two types PWM speed control curve, it select by SP1 pin voltage setting. The first type of PWM speed control curve is shutdown mode. When PWM input duty is less than DI_{SP1} the output will close, until PWM input duty is rising more than the $DI_{SP1} + 1.2\%$ the output will startup. In addition, when the PWM input duty is 100%, the output duty can set up not equaling to 100%. Or, when the PWM output duty is 100%, the input duty also can set up not equaling to 100%.



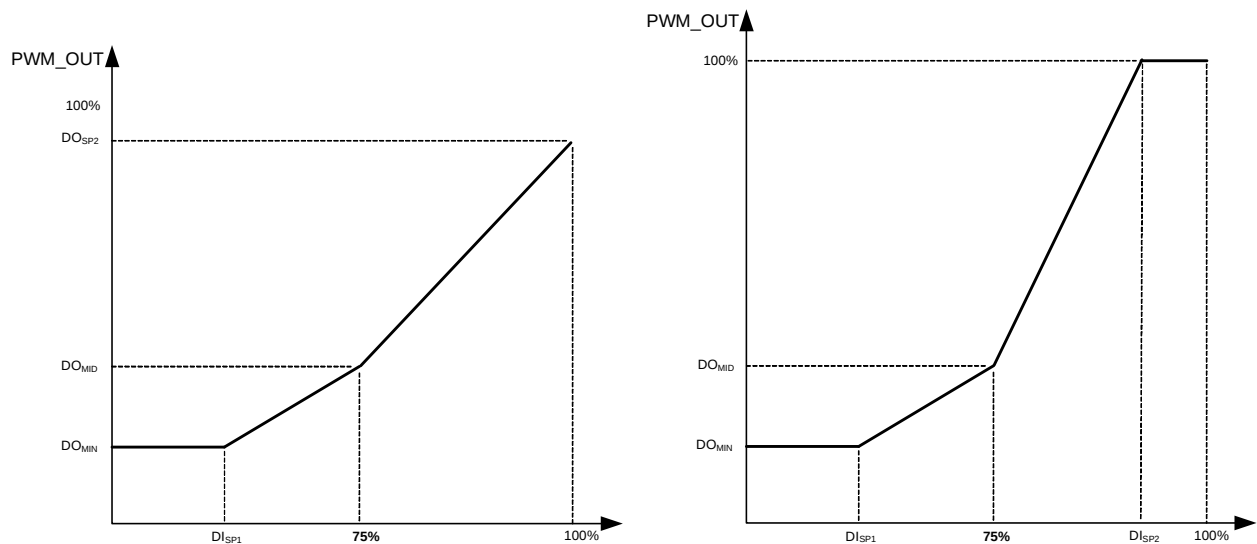
Shutdown Mode Speed Curve

Note : The DO_{MIN} , DO_{MID} , DO_{SP2} , DI_{SP1} , DI_{SP2} duty can set up range following the above description.

Note : The DO_{MIN} don't less than 3%.

Function Description (Cont.)

The second type of PWM speed control curve is minimum speed mode. When PWM input duty is less than DI_{SP1} the output duty will keep minimum output duty. In addition, when the PWM input duty is 100%, the output duty can set up not equaling to 100%. Or, when the PWM output duty is 100%, the input duty also can set up not equaling to 100%.



Minimum Speed Mode Speed Curve

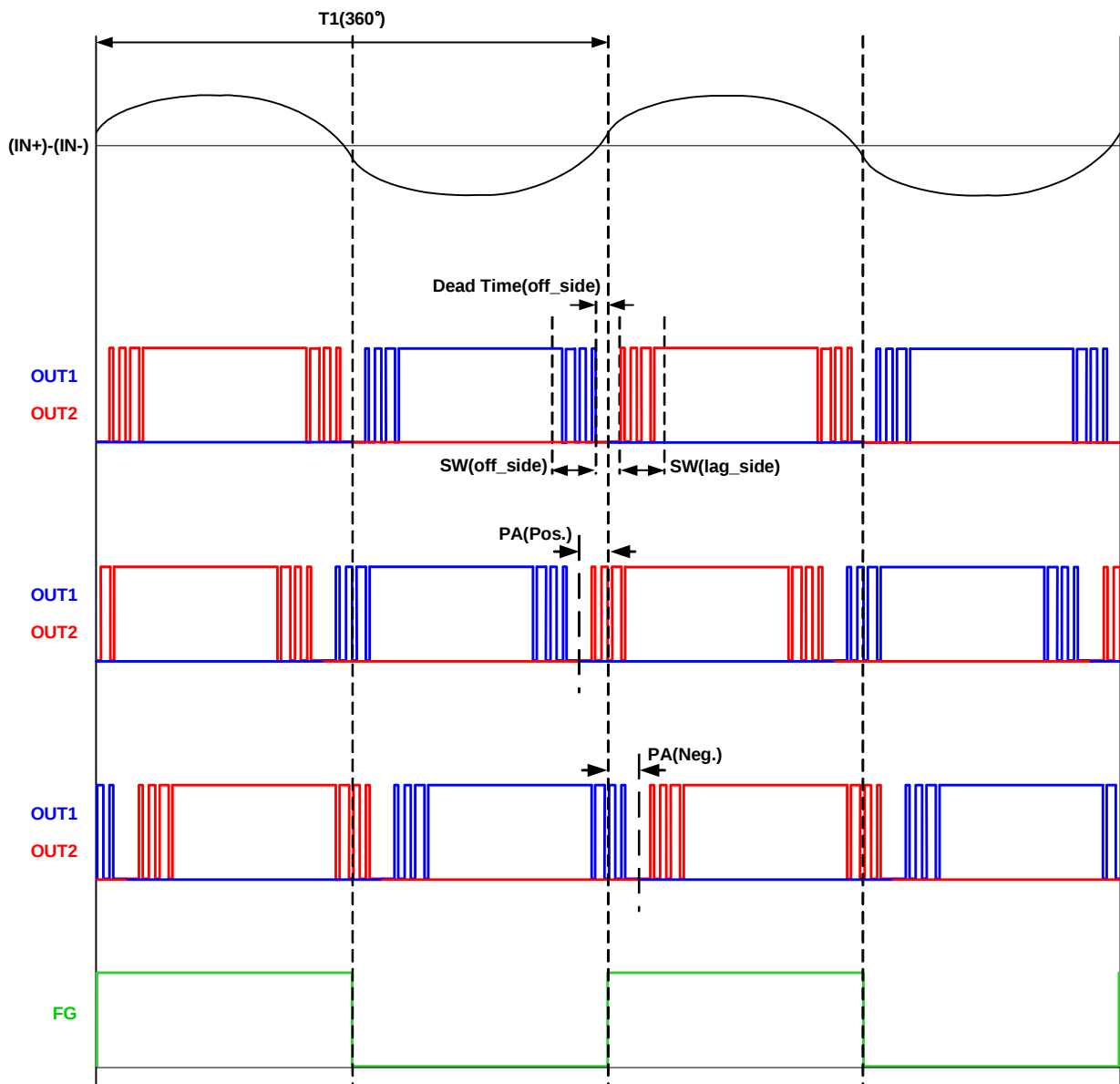
Note : The DO_{MIN} , DO_{MID} , DO_{SP2} , DI_{SP1} , DI_{SP2} duty can set up range following the above description.

Note : The DO_{MIN} don't less than 3%.

Function Description (Cont.)

SW, PA and Dead Time Schematic Diagram

The SW, PA and dead time are following figure to define the behavior.

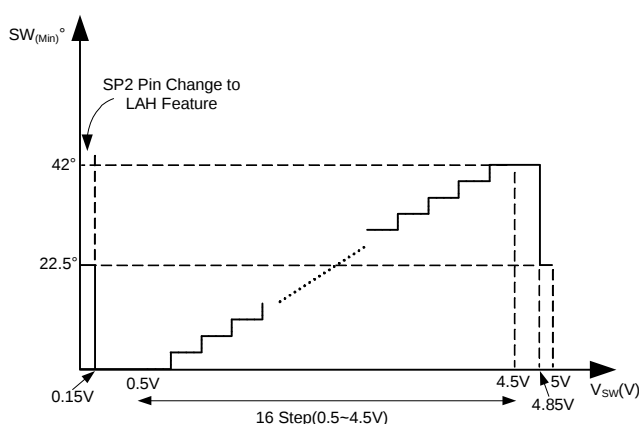


SW, PA and Dead Time Schematic Diagram

Function Description (Cont.)

PWM Soft-Switch Function

The APX9222 built in PWM soft-switch output control circuit to improve the vibration and noise of fan motor operation. At start-up operation, the APX9222 drive the output driver by square wave to force the fan motor start to rotate. After several square wave outputs, the internal PWM soft-switch control circuit will be enable to drive fan motor to improve vibration and noise. The SW pin contain of multi function by input voltage setting. In this pin, the primary function is setting off side soft switching degree at PWM output duty equal to 100% and the secondary function is selecting SP2 pin feature. In addition, with the output duty drop the soft switch degree increases. It can set up voltage range and soft switching degree with output duty relation following the figure and table.



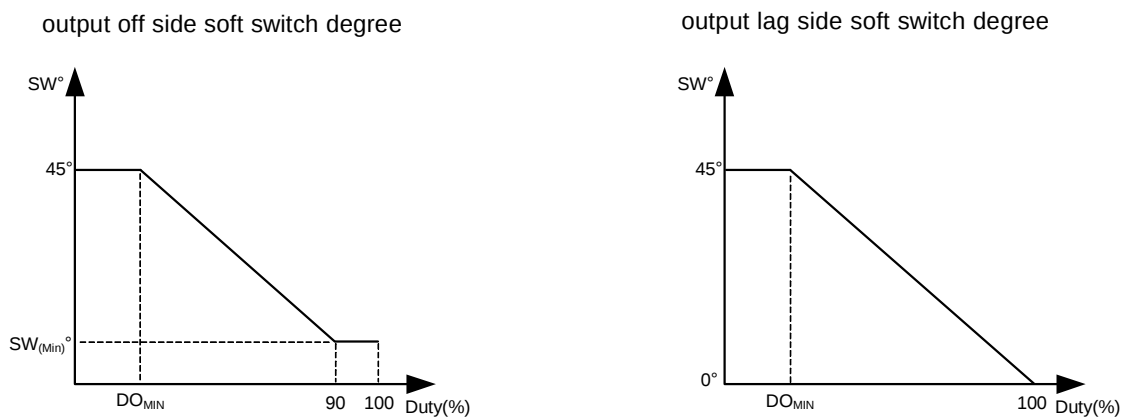
Soft Switching Voltage Setting Range

Soft Switching Setting Range

Step	V _{sw} (V)	SW _(Min.) (°)
	>4.85	22.5
16	4.38	42
15	4.14	39.2
14	3.89	36.4
13	3.64	33.6
12	3.39	30.8
11	3.14	28
10	2.88	25.1
9	2.63	22.3
8	2.38	19.5
7	2.13	16.7
6	1.88	13.9
5	1.63	11.1
4	1.38	8.3
3	1.13	5.4
2	0.88	2.6
1	0.63	0
	<0.15	22.5

Function Description (Cont.)

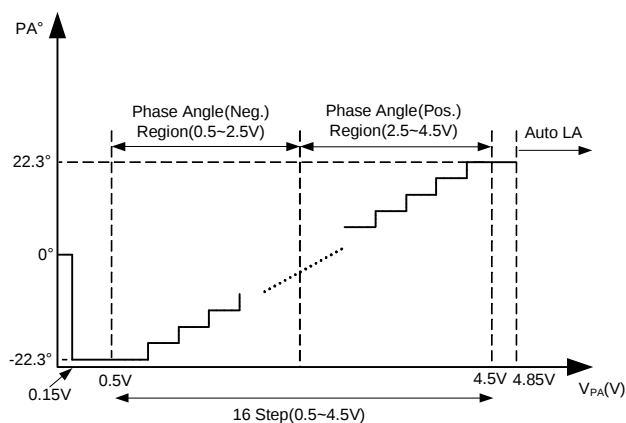
PWM Soft-Switch Function (Cont.)



Soft Switching degree with output duty relation

Phase Angle

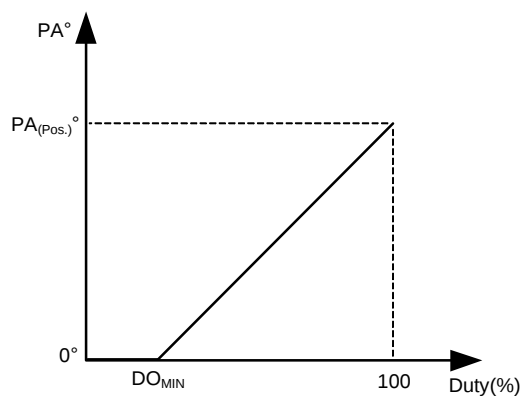
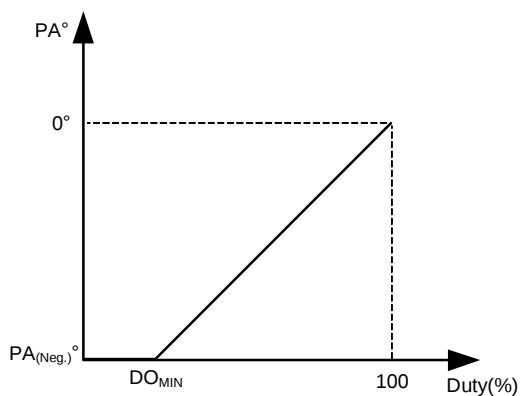
The PA pin contain of multi function by input voltage setting. In this pin, the primary function is setting PA(Phase angle) angle. The secondary function is auto LA feature. It can set up voltage range and phase angle with output duty relation following the figure and table.



Phase Angle Voltage Setting Range

Function Description (Cont.)

Phase Angle (Cont.)



Phase Angle degree with output duty relation

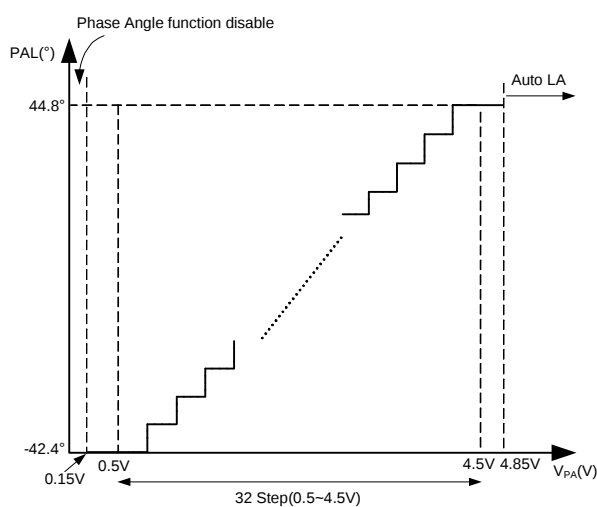
Phase Angle Setting Range

Step	$V_{PA}(V)$	$PA(^{\circ})$
	>4.85	Auto LA
16	4.38	22.5
15	4.14	19.7
14	3.89	16.9
13	3.64	14.1
12	3.39	11.3
11	3.14	8.4
10	2.88	5.6
9	2.63	2.8
8	2.38	-2.8
7	2.13	-5.6
6	1.88	-8.4
5	1.63	-11.3
4	1.38	-14.1
3	1.13	-16.9
2	0.88	-19.7
1	0.63	-22.5
	<0.15	0

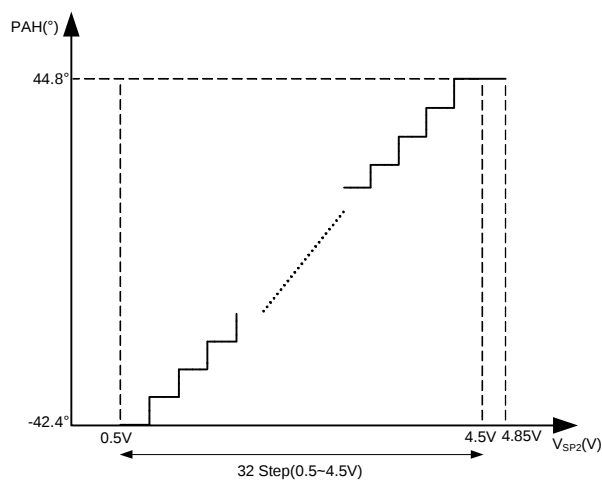
Function Description (Cont.)

Phase Angle High and Phase Angle Low

When the SW pin is connecting to GND, the SP2 pin will change to PAH feature. In this setting, the PA pin is setting phase angle low degree at output duty equal to minimum output duty and the SP2 pin is setting phase angle high degree at output duty equal to 100%. In addition, the PA(Phase Angle Low) and SP2(Phase Angle High) pin can set up phase angle degree is from -42.4° to 44.8° but the PA pin setting up degree can't exceed SP2 set up degree. With the output duty drop the phase angle high degree decreases to phase angle low degree. The PA and SP2 pin can set up voltage range and phase angle degree with output duty relation following the figure and table.



Phase Angle Low Voltage Setting Range



Phase Angle High Voltage Setting Range

Phase Angle Low Setting Range

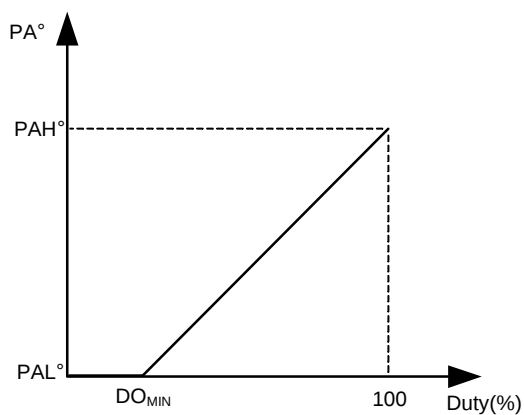
Step	V_{PA} (V)	PAL ($^{\circ}$)	Step	V_{PA} (V)	PAL ($^{\circ}$)
16	2.44	-0.2		>4.85	Auto LA
15	2.31	-3	32	4.44	44.8
14	2.19	-5.8	31	4.31	42
13	2.06	-8.6	30	4.19	39.2
12	1.94	-11.4	29	4.06	36.4
11	1.81	-14.2	28	3.94	33.6
10	1.69	-17.1	27	3.81	30.8
9	1.56	-19.9	26	3.69	28
8	1.44	-22.7	25	3.56	25.1
7	1.31	-25.5	24	3.44	22.3
6	1.19	-28.3	23	3.31	19.5
5	1.06	-31.1	22	3.19	16.7
4	0.94	-33.9	21	3.06	13.9
3	0.81	-36.7	20	2.94	11.1
2	0.69	-39.6	19	2.81	8.3
1	0.56	-42.4	18	2.69	5.5
	<0.15	Phase angle adjust disable	17	2.56	2.6

Function Description (Cont.)

Phase Angle High and Phase Angle Low (Cont.)

Phase Angle High Setting Range

Step	V _{SP2} (V)	PAH(°)	Step	V _{SP2} (V)	PAH(°)
16	2.44	-0.2		>4.85	44.8
15	2.31	-3	32	4.44	44.8
14	2.19	-5.8	31	4.31	42
13	2.06	-8.6	30	4.19	39.2
12	1.94	-11.4	29	4.06	36.4
11	1.81	-14.2	28	3.94	33.6
10	1.69	-17.1	27	3.81	30.8
9	1.56	-19.9	26	3.69	28
8	1.44	-22.7	25	3.56	25.1
7	1.31	-25.5	24	3.44	22.3
6	1.19	-28.3	23	3.31	19.5
5	1.06	-31.1	22	3.19	16.7
4	0.94	-33.9	21	3.06	13.9
3	0.81	-36.7	20	2.94	11.1
2	0.69	-39.6	19	2.81	8.3
1	0.56	-42.4	18	2.69	5.5
	<0.15	-42.4	17	2.56	2.6

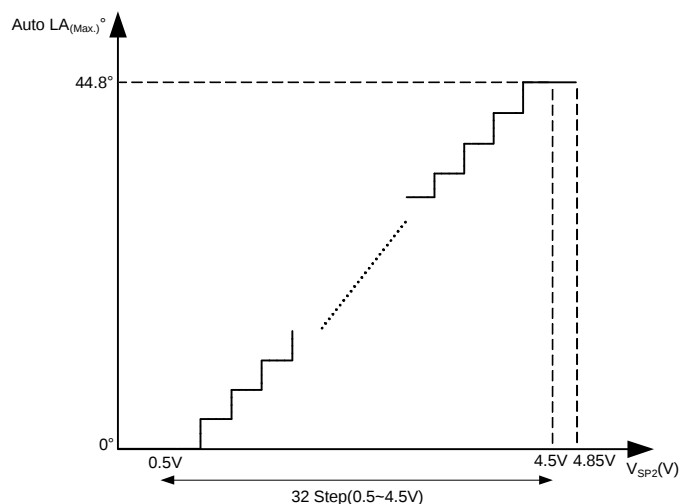


Phase Angle degree with output duty relation

Function Description (Cont.)

Auto Lead Angle

If the PA pin connect to 5VREG, the PA feature become to auto lead angle feature. In addition, if the SW pin connect to GND, the SP2 pin become to set up auto lead angle maximum leading degree. Following the figure and table set up auto lead angle maximum lead angle.



Auto Lead Angle Maximum Lead Angle Voltage Setting Range

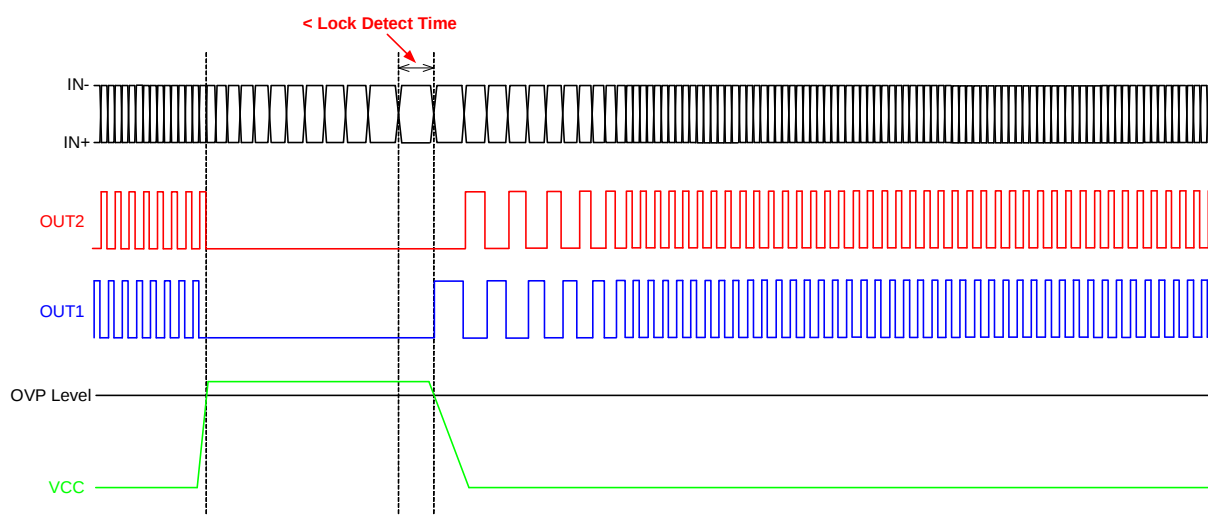
Auto Lead Angle Maximum Lead Degree Setting Range

Step	V _{SP2} (V)	Auto LA _(Max.) (°)	Step	V _{SP2} (V)	Auto LA _(Max.) (°)
16	2.44	22.3	32	>4.85	44.8
15	2.31	20.9	31	4.44	44.8
14	2.19	19.5	30	4.31	43.4
13	2.06	18.1	29	4.19	42
12	1.94	16.7	28	4.06	40.6
11	1.81	15.3	27	3.94	39.2
10	1.69	13.9	26	3.81	37.8
9	1.56	12.5	25	3.69	36.4
8	1.44	11.1	24	3.56	35
7	1.31	9.7	23	3.44	33.6
6	1.19	8.3	22	3.31	32.2
5	1.06	6.9	21	3.19	30.8
4	0.94	5.5	20	3.06	29.4
3	0.81	4.0	19	2.94	28
2	0.69	2.6	18	2.81	26.5
1	0.56	1.3	17	2.69	25.1
	<0.15	0		2.56	23.7

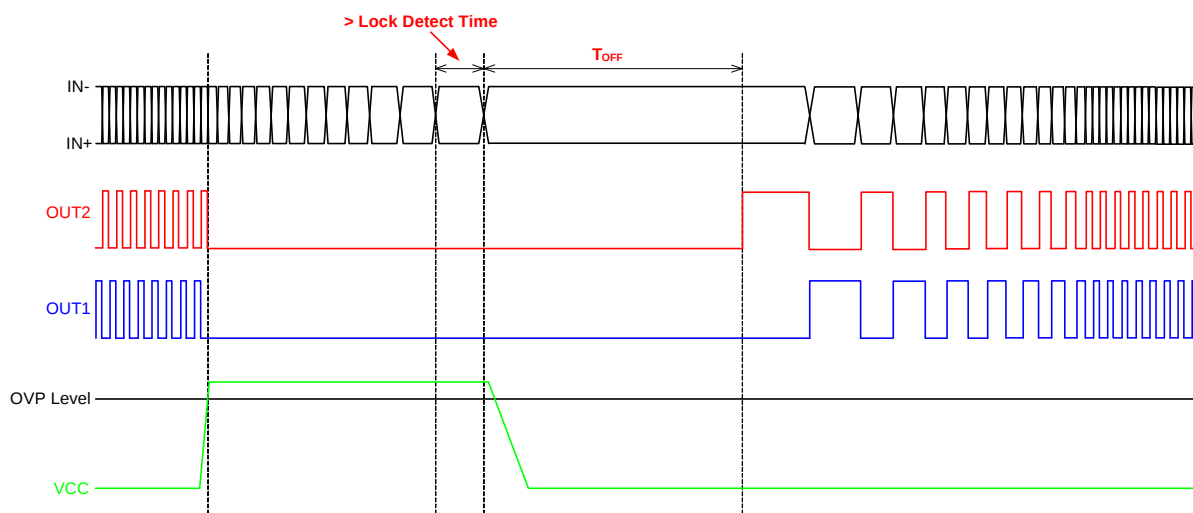
Function Description (Cont.)

Over Voltage Protection(OVP)

The APX9222 provides over voltage protection(OVP) function to avoid VCC peaking caused the IC damage. When the VCC over than OVP level, the output will turn off. Until the VCC under than OVP level, the output will turn on. In addition, if the VCC over than OVP level for a long time causing the fan to stop. The IC will enter lock protection mode. At this moment, if the VCC under than OVP level, the output isn't starting up immediately. Must waiting the T_{OFF} time, the output will start up.



OVP Without Fan Stopping

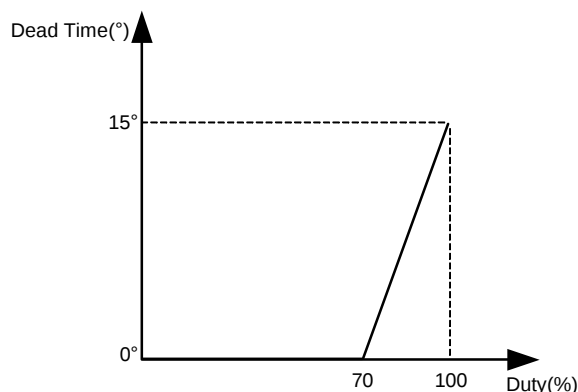


OVP With Fan Stopping

Function Description (Cont.)

Dead Time

The APX9222 dead time(off side) degree divided into two types. The first type of dead time is fixed 15° at output duty equal to 100%. With the output duty drop the dead time(off side) degree decreases. It's with output duty relation following the figure18. The second type of dead time (off side) is auto adjustment. It detect the coil current to decide the dead time decrease or increase in motor commutation .



Dead Time(off side) degree with output duty relation

Current Limit

The APX9222 includes an internal current sense circuits for current limit. When the total current of output over the current limit level (1.5A), the high side driver will be turned off to stop supplying current to the motor until $I_{OUT} < 1.5A$ or re-power on. At Start up, the current limit level will decrease to 0.75A.

SO Output

The SO pin is an open-drain output, connecting a pull up resistor to a high level voltage for the speed detection function. During the Lock Mode, the SO will always high (switch off). Open the terminal when not in use.

Thermal Protection

The APX9222 has thermal protection. When internal junction temperature reaches 170°C, the output devices will be switched off. When the IC's junction temperature cools by 30°C and wait 4 second, the thermal sensor will turn the output devices on again, resulting in a pulsed output during continuous thermal protection.

Truth Table

Input		Output				Mode
IN-	IN+	OUT1	OUT2	FG	RD	
H	L	H	L	L	L	Operation Mode(PWM H)
L	H	L	H	OFF	L	
H	L	OFF	L	L	L	Operation Mode(PWM L)
L	H	L	OFF	OFF	L	
H	L	L	L	OFF	OFF	Lock Mode
L	H	L	L	OFF	OFF	

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 (C_{IN}) must connect between VCC and GND. It is the suggestion that C_{IN} should be placed as close as possible to the device VCC pin.

SS Capacitor

The C_{SS} capacitor is used to set the output duty change rate for T_{SS2} time. The time (T_{SS2}) defines the time of output duty from 0% to 100%. Following the table to set T_{SS2} time.

T_{SS2} time Setting reference table

				1nF	2.2nF	4.7nF	10nF
$R_{SS1}(\Omega)$	$R_{SS2}(\Omega)$	$R_{total}(\Omega)$	$V_{SS}(DC)$	$T_{SS2}(s)$			
20K	22K	42K	2.62	1.1	2.3	4.7	10.1
20K	27K	47K	2.87	1	2.2	4.3	9.2
20K	33K	53K	3.11	0.9	1.9	3.9	8.4
20K	43K	63K	3.41	0.8	1.8	3.7	7.9
20K	51K	71K	3.59	0.8	1.7	3.5	7.6
20K	68K	88K	3.86	0.8	1.6	3.4	7.3
20K	100K	120K	4.16	0.8	1.6	3.4	7.2
20K	150K	170K	4.41	0.7	1.6	3.3	7

Application Information

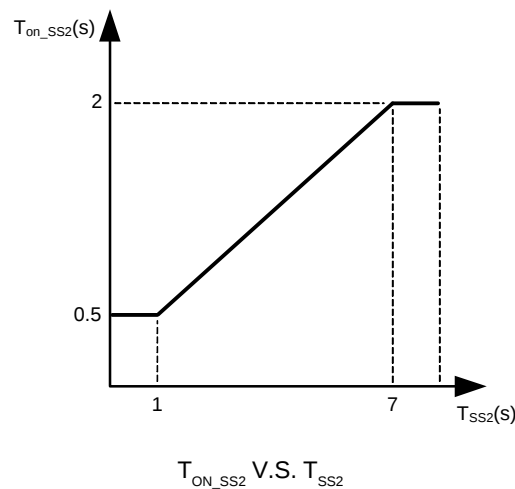
Shutdown Time(T_{OFF}) and Restart Time(T_{ON})

The shutdown time (T_{OFF}) and restart time (T_{ON}) are related to soft start time. In addition, the restart time (T_{ON}) is combines with T_{ON_SS1} and T_{ON_SS2} . Following the formula and figure to calculate shutdown time and restart time.

$$\text{Restart Time Of } T_{ON_SS1} = T_{SS1} \times \frac{D_{SS} - 20}{D_{SS} - 100} (\text{s})$$

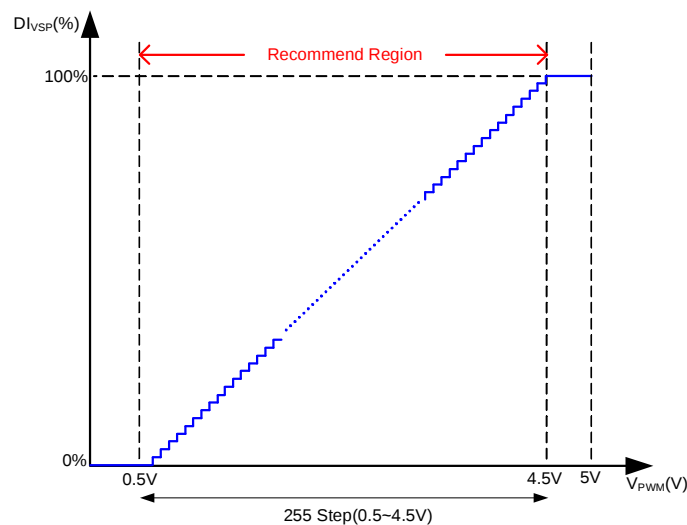
Restart Time Of T_{ON_SS2} reference the figure.

$$\text{Shutdown Time} = T_{ON_SS2} \times 7 (\text{s})$$



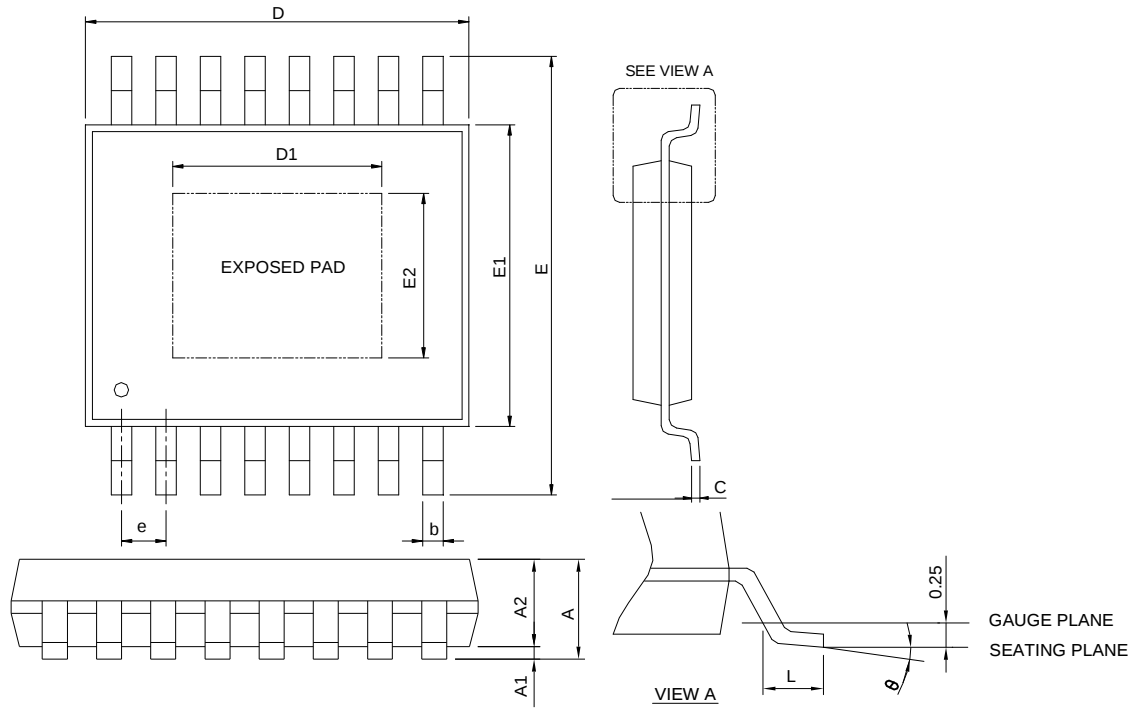
VSP Mode

In this mode, the speed control signal is DC voltage. When the DC voltage input to PWM pin, the IC internal circuit will transfer to input duty to control speed curve. In VSP mode, the DC voltage value is more and more high representative the input duty more high. It can set up range following figure.



Package Information

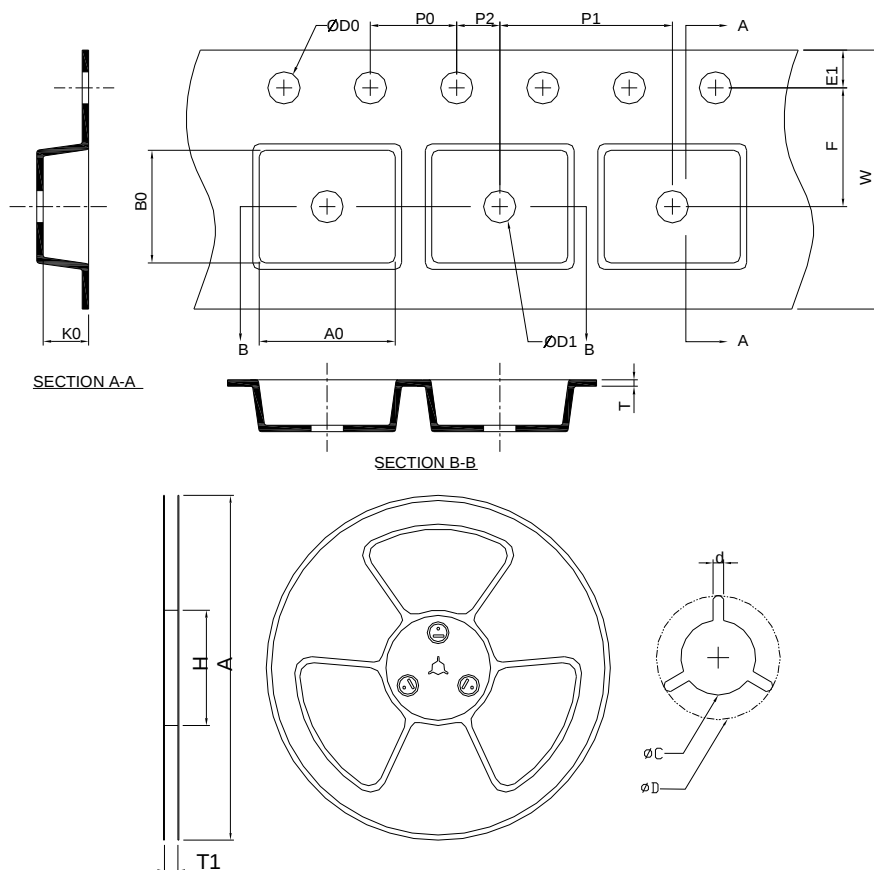
TSSOP-16P



SYMBOL	TSSOP-16P			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A		1.20		0.047
A1	0.05	0.15	0.002	0.006
A2	0.80	1.05	0.031	0.041
b	0.19	0.30	0.007	0.012
c	0.09	0.20	0.004	0.008
D	4.90	5.10	0.193	0.201
D1	2.00	3.50	0.079	0.138
E	6.20	6.60	0.244	0.260
E1	4.30	4.50	0.169	0.177
E2	2.50	3.50	0.098	0.138
e	0.65 BSC		0.026 BSC	
L	0.45	0.75	0.018	0.030
θ	0°	8°	0°	8°

- Note : 1. Follow from JEDEC MO-153 AB.
 2. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusion or gate burrs shall not exceed 6 mil per side.
 3. Dimension "E1" does not include inter-lead flash or protrusions. Inter-lead flash and protrusions shall not exceed 10 mil per side.

Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
TSSOP-16P	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	5.50±0.05
	P0	P1	P2	D0	D1	T	A0	B0	K0
	4.00±0.10	8.00±0.10	2.00±0.05	1.5+0.10 -0.00	1.5 MIN.	0.6+0.00 -0.40	6.80±0.20	5.40±0.20	1.60±0.20

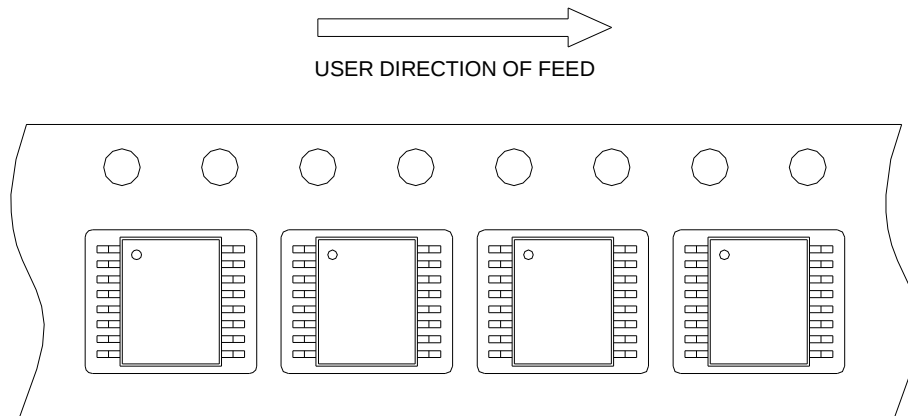
(mm)

Devices Per Unit

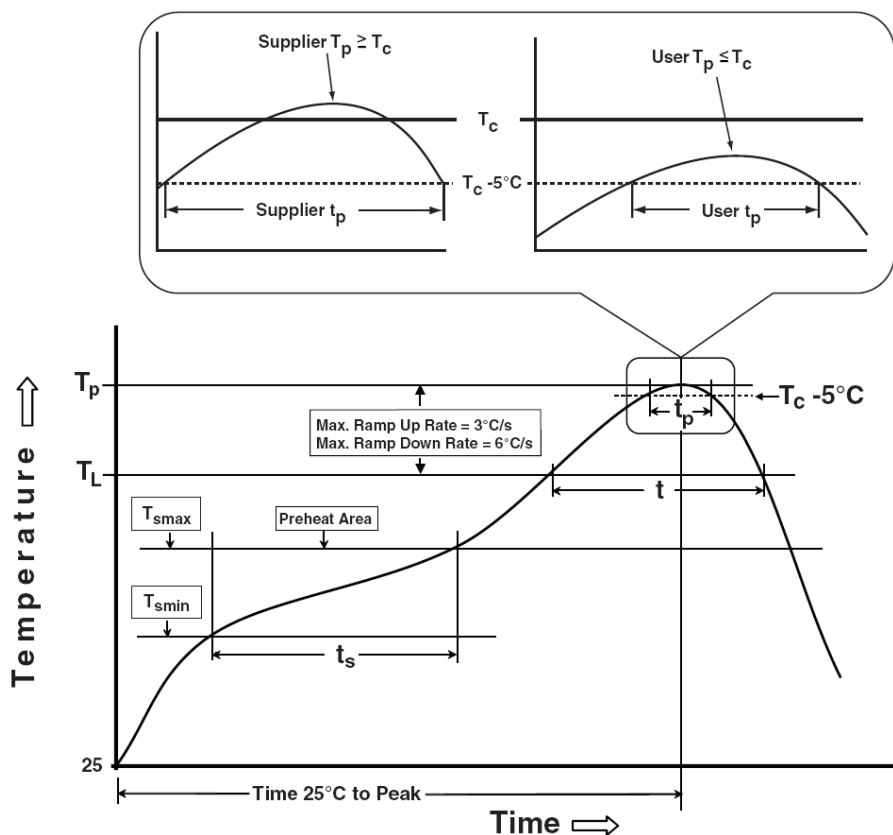
Package Type	Unit	Quantity
TSSOP-16P	Tape & Reel	2500

Taping Direction Information

TSSOP-16P



Classification Profile



Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Preheat & Soak		
Temperature min (T_{smin})	100 °C	150 °C
Temperature max (T_{smax})	150 °C	200 °C
Time (T_{smin} to T_{smax}) (t_s)	60-120 seconds	60-120 seconds
Average ramp-up rate (T_{smax} to T_p)	3 °C/second max.	3°C/second max.
Liquidous temperature (T_L)	183 °C	217 °C
Time at liquidous (t_L)	60-150 seconds	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 ≥ 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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