

Single-Phase Full-Wave Motor Driver for Fan Motor

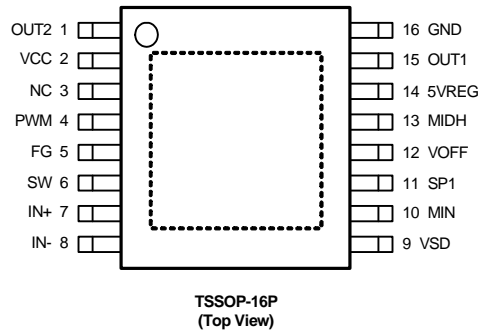
Features

- **Single Phase Full Wave Fan Driver**
- **Built-in Variable Speed Curve Function. It can compensate motors whose Speed curve is not linear.**
- **Current Limit Circuit**
- **Built-in LOCK Protection and Auto-restart Function**
- **Built-in Adjustable PWM Soft Switching and Dead Time Function**
- **Low Standby Current**
- **FG(Rotation Speed Detection)Output**
- **Built-in Thermal Protection Circuit**
- **HBM/MM ESD level sustain up to 4KV/400V**
- **TSSOP-16P Package**
- **Lead Free and Green Device Available (RoHS Compliant)**

General Description


The APX9202A 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. When PWM is at low level in a short time, the supply current is less than 30uA. In normal operation, the supply current is less than 8mA. The APX9202A is available in TSSOP-16P package.

Pin Configuration

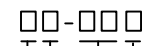




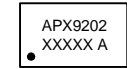


Applications

- **Motor Drivers For Silent Fan Motors**

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

Ordering and Marking Information

<p>APX9202A </p> <p style="margin-left: 100px;">  Assembly Material  Handling Code  Temperature Range  Package Code </p>	<p>Package Code R: TSSOP - 16P</p> <p>Operating Ambient Temperature Range I : -40 to 110 °C</p> <p>Handling Code TR : Tape & Reel</p> <p>Assembly Material G: Halogen and Lead Free Device</p>
<p>APX9202A R : </p>	<p style="text-align: center;">XXXXXX - Date Code</p>

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-020D 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 in homogeneous 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	Ratings	Unit
V_{CC}	VCC Pin Supply Voltage (VCC to GND)	-0.3 to 20	V
I_{OUT}	V_{OUT1}, V_{OUT2} Pin Maximum Output Peak Current	1.2	A
V_{OUT1}, V_{OUT2}	V_{OUT1}, V_{OUT2} Pins Output Voltage(OUT1 to GND, OUT2 to GND)	-0.3 to 20	V
V_{PWM}	PWM Pin Input Voltage (PWM to GND)	-0.3 to 20	V
V_{VSD}	VSD Pin Input Voltage (VSD to GND)	-0.3 to 7	V
V_{MIN}	MIN Pin Input Voltage (MIN to GND)	-0.3 to 7	V
V_{SP1}	SP1 Pin Input Voltage (SP1 to GND)	-0.3 to 7	V
V_{MIDH}	MIDH Pin input Voltage (MIDH to GND)	-0.3 to 7	V
V_{SW}	SW Pin Input Voltage (SW to GND)	-0.3 to 7	V
V_{VOFF}	VOFF Pin Input Voltage (VOFF to GND)	-0.3 to 7	V
V_{FG}	FG Pin Output Voltage (FG to GND)	-0.3 to 20	V
I_{FG}	FG Pin Maximum Output Sink Current	10	mA
I_{5VREG}	5VREG Pin Maximum Output Current	20	mA
T_J	Maximum Junction Temperature	-40 to 150	°C
T_{STG}	Storage Temperature	-55 to 150	°C
T_{SDR}	Maximum Lead Soldering Temperature, 10 Seconds	260	°C

Note 1: 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 2) TSSOP-16P	83	°C/W
P_D	Power Dissipation, $T_A=25^\circ\text{C}$	1.5	W

Note 2: Mounted on a board (60x38x1.6mm, Glass epoxy). The Thermal Pad on the bottom of TSSOP-16P package should soldered directly to the PCB's Thermal Pad area that with several thermal vias connect to ground plan, and the PCB is a 2-layer 10mm square area with 2oz cooper thickness.

Recommended Operating Conditions (Note3)

Symbol	Parameter	Range	Unit
V_{CC}	VCC Pin Supply Voltage	3 to 15	V
V_{VSD}	VSD Pin Input Voltage	0 to $V_{5VREG}-0.2$ or V_{5VREG}	V
V_{MIN}	MIN Pin Input Voltage	0 to V_{5VREG}	V
V_{SP1}	SP1 Pin Input Voltage Range	0 to V_{5VREG}	V
V_{MIDH}	MIDH Pin input Voltage Range	0 to V_{5VREG}	V
V_{SW}	SW Pin Input Voltage Range	0 to V_{5VREG}	V
V_{VOFF}	VOFF Pin Input Voltage Range	0 to V_{5VREG}	V
V_{ICM}	Common-Mode Hall Input Voltage Range	0.2 to $V_{5VREG}-1.5$	V
T_A	Ambient Temperature	-40 to 110	°C
T_J	Junction Temperature	-40 to 125	°C

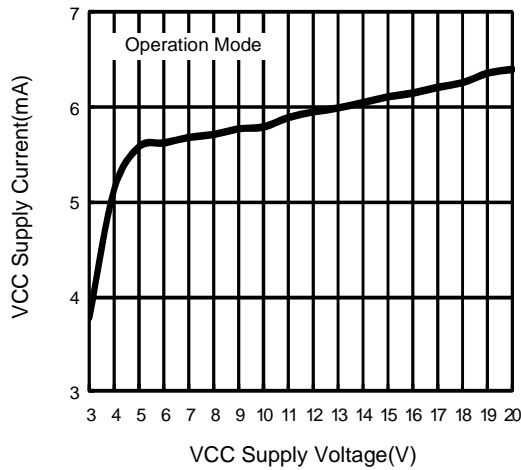
Note 3: Refer to the typical application circuit

Electrical Characteristics ($V_{CC} = 12V$, $T_A = 25^\circ C$, unless otherwise specified)

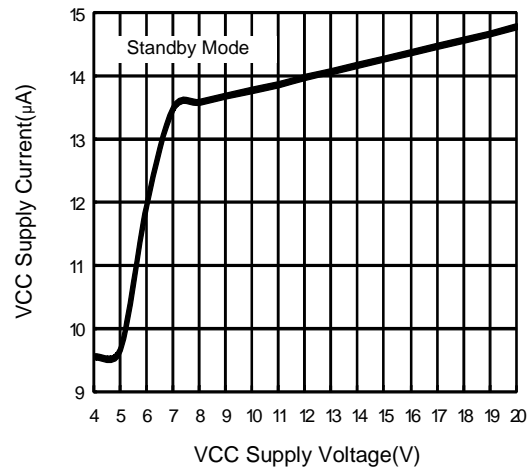
Symbol	Parameter	Test Conditions	APX9202A			Unit
			Min	Typ	Max	
SUPPLY CURRENT						
V_{5VREG}	5VREG Pin Output Voltage	$I_{5VREG} = 5mA$	4.8	5	5.2	V
I_{CC1}	Rotation Mode		-	6	8	mA
I_{CC2}	Standby Mode	PWM= GND	-	15	30	uA
OUTPUT DRIVERS						
V_{OL}	Low-side Output Saturation Voltage	$I_{OUT}=300mA$	-	0.1	0.2	V
V_{OH}	High-side Output Saturation Voltage	$I_{OUT}=300mA$	-	0.12	0.25	V
V_{FG}	FG Pin Low Voltage	$I_{FG}=5mA$	-	0.1	0.2	V
I_{FGL}	FG Pin Off Leakage Current	$V_{FG}=12V$	-	-	1	μA
HALL SENSITIVITY						
VHYS	Input Hysteresis Voltage		-	± 8	± 15	mV
LOCK PROTECTION						
T_{ON}	Lock Protection Detection On Time		0.35	0.5	0.65	Sec
T_{OFF}	Lock Protection Detection Off Time		3.5	5	6.5	Sec
PWM CONTROL						
V_{PWML}	PWM Input Low Level Voltage		-0.3	-	0.8	V
V_{PWHM}	PWM Input High Level Voltage		2	-	V_{CC}	V
F_{PWM}	PWM Input Frequency		200	-	50K	Hz
I_{PWML}	PWM Low Input Current	$V_{PWM}=0V$	-	-10	-20	μA
T_{QS}	Quick Start Enable Time		-	60	-	ms
SW&OFF ANGLE CONTROL						
I_{SW}	SW PIN Internal Pull-high Current		17	20	23	μA
θ_{SW1}	Soft Switch Angle Correction	$V_{SW}=0V$	-	0	-	$^\circ$
θ_{SW2}		$V_{SW}=1/2 * V_{5VREG}$	42	45	48	$^\circ$
θ_{SW3}		$V_{SW}=V_{5VREG}$	-	90	-	$^\circ$
θ_{OFF1}	OFF Angle Correction	$V_{OFF}=0V$	0	1.5	4.5	$^\circ$
θ_{OFF2}		$V_{OFF}=1/2 * V_{5VREG}$	19.5	22.5	25.5	$^\circ$
θ_{OFF3}		$V_{OFF}=V_{5VREG}$	0	3	6	$^\circ$
CURRENT PROTECTION						
I_{LIM}	Current Limit Level		-	1.1	-	A
THERMAL PROTECTION						
	Over-Thermal Protection Temperature		-	165	-	$^\circ C$
	Over-Thermal Protection Hysteresis		-	30	-	$^\circ C$

Typical Operating Characteristics

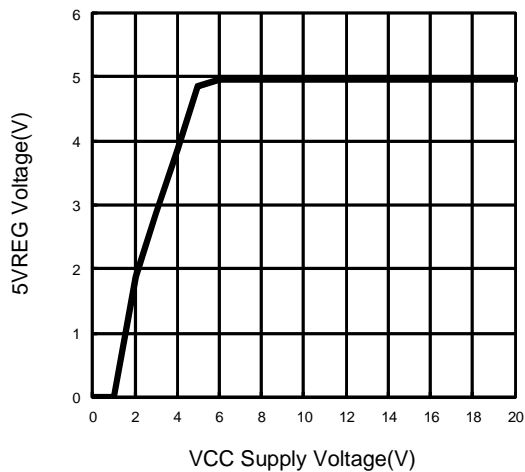
VCC Supply Current vs. VCC Supply Voltage



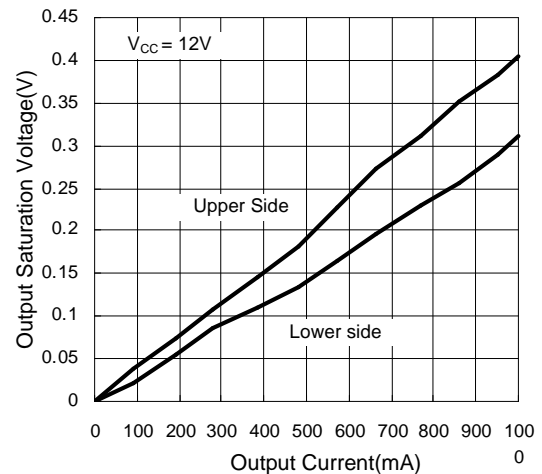
VCC Supply Current vs. VCC Supply Voltage



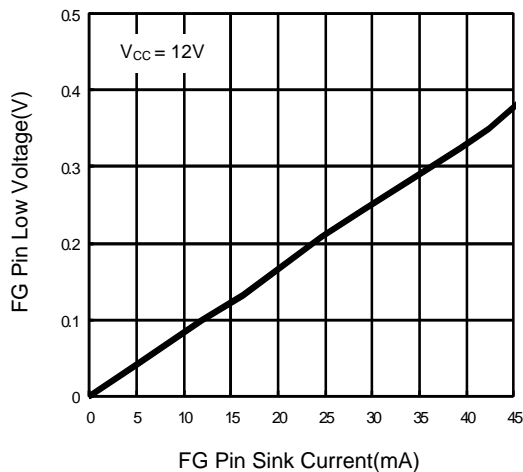
5VREG vs. VCC Supply Voltage



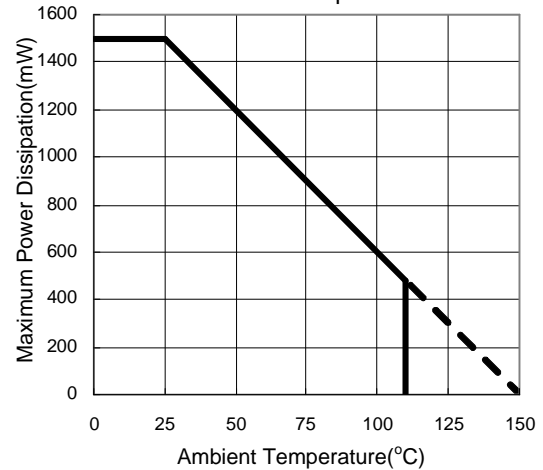
Output Saturation Voltage vs. Output Current



FG Pin Low Voltage vs. Sink Current



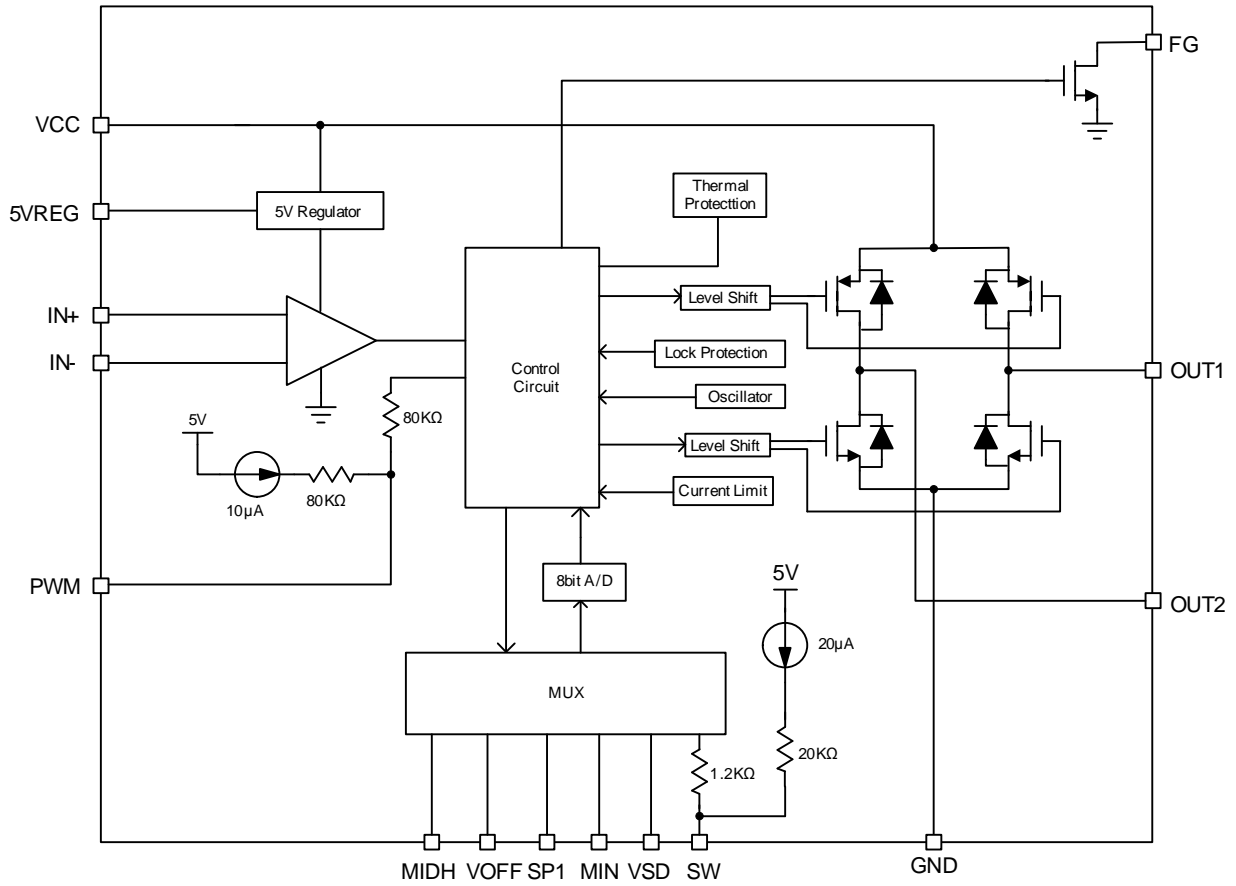
Maximum Power Dissipation vs. Ambient Temperature



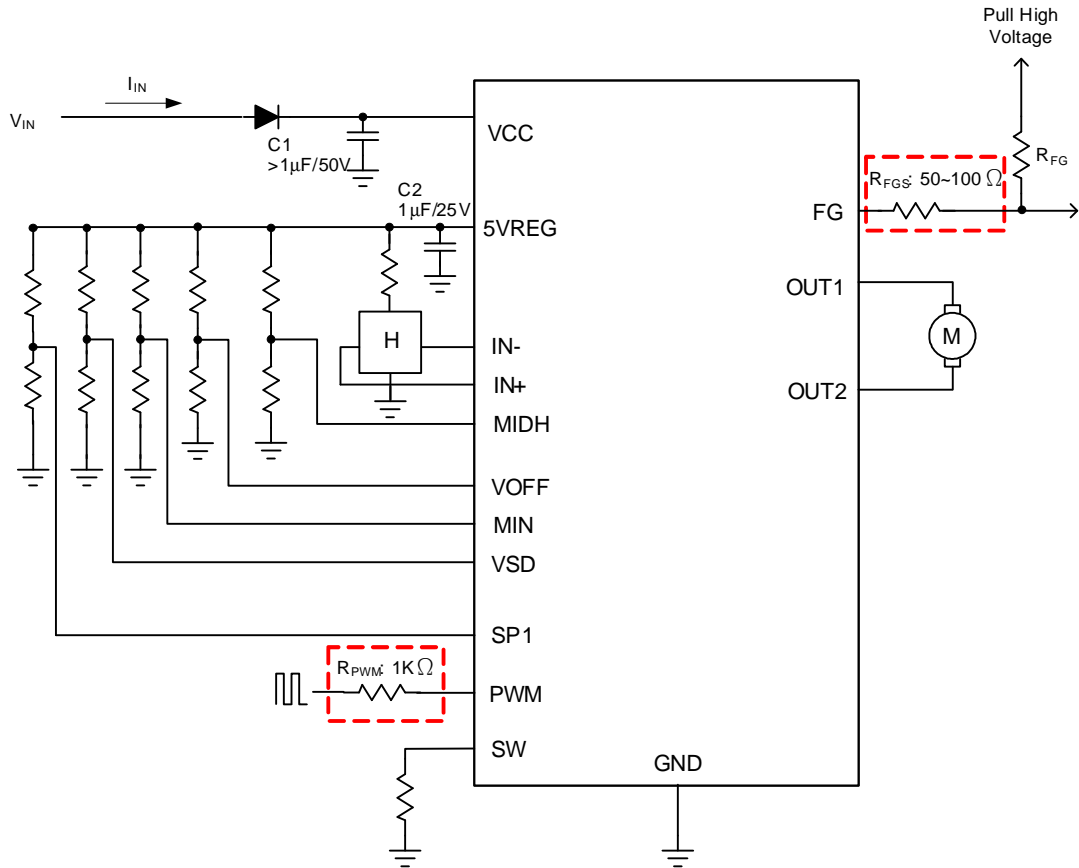
Pin Descriptions

PIN		FUNCTION
NO.	NAME	
1	OUT2	H-bridge Output Connection.
2	VCC	Supply Voltage Input Pin.
3	NC	No connection
4	PWM	PWM Signal Input Terminal.
5	FG	Rotation Speed output. This is an open-drain output.
6	SW	Soft Switching Angle Setting.
7	IN+	Hall Input +. Connect to hall element positive output.
8	IN-	Hall Input -. Connect to hall element negative output.
9	VSD	Output Duty Shutdown Setting.
10	MIN	Minimum Output Duty Setting.
11	SP1	Input Duty Setting For Turning Point (D_{ISP1}).
12	VOFF	OFF Angle Setting.
13	MIDH	Output Duty Setting (DO_{MIDH}) For Turning Point (DI_{MIDH}).
14	5VREG	5V Regulator Output.
15	OUT1	H-bridge Output Connection.
16	GND	Power GND.

Block Diagram



Typical Application Circuit



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

Function Description

MIN and MIDH Output Duty Control (SP1&VSD are not in use)

The APX9202A has four input pins MIN MIDH SP1 VSD to control speed curve of fan motor when the APX9202A works in rotation mode. The input of MIN pin sets the minimum output duty (DO_{MIN}) at the beginning, and MIDH sets the output duty (DO_{MIDH}) for turning point (DI_{MIDH}). SP1 sets the turning point (DI_{SP1}) for that Output duty maintains MIN output duty setting until DI_{SP1} . VSD sets the output shutdown function. Output duty is shut down when PWM input duty smaller than the VSD Shutdown Duty (DI_{VSD}) Setting.

In this case, we only use MIN and MIDH to control the output speed curve. First, the input of MIN pin sets the minimum output duty at the PWM 0% duty, and then the speed curve keeps linear slope to DI_{MIDH} . Then the speed curve change to another slope till PWM full duty.

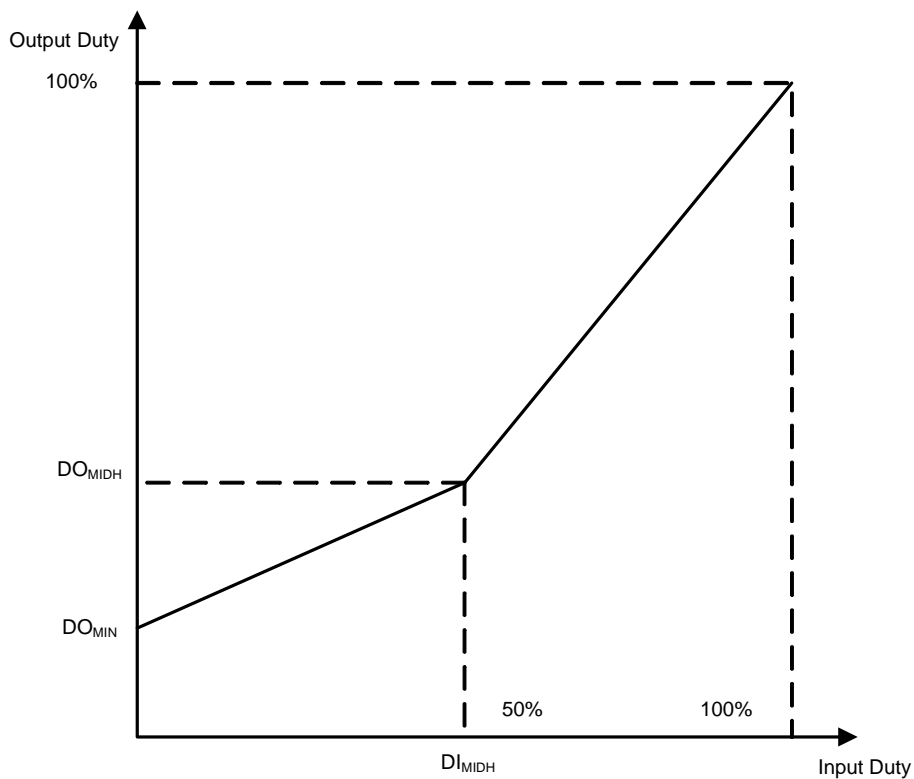


Figure1: MIN and MIDH Output Duty Control

ALL Duty Setting are approximated by below formulas:

$$DO_{MIN} (\%) = 100\% \times \frac{V_{MIN}}{V_{5VREG}} \quad . \quad DO_{MIDH} (\%) = 100\% \times \frac{V_{MIDH}}{V_{5VREG}}$$

Note1: SP1 connect to GND and VSD connect to 5VREG.

Note2: DI_{MIDH} is fixed at 50%.

Note3: DO_{MIN} can't be larger than DO_{MIDH} .

Function Description (Cont.)

MIN, MIDH, and SP1 Output Duty Control (VSD is not in use)

In this case, we use MIN, MIDH and SP1 to control the output speed curve. The input of MIN pin sets the minimum output duty (DO_{MIN}) at the PWM 0% duty, and besides the speed keeps constant until DI_{SP1} . Then the speed curve keeps linear slope to DI_{MIDH} . Finally, the speed curve change to another slope till PWM full duty.

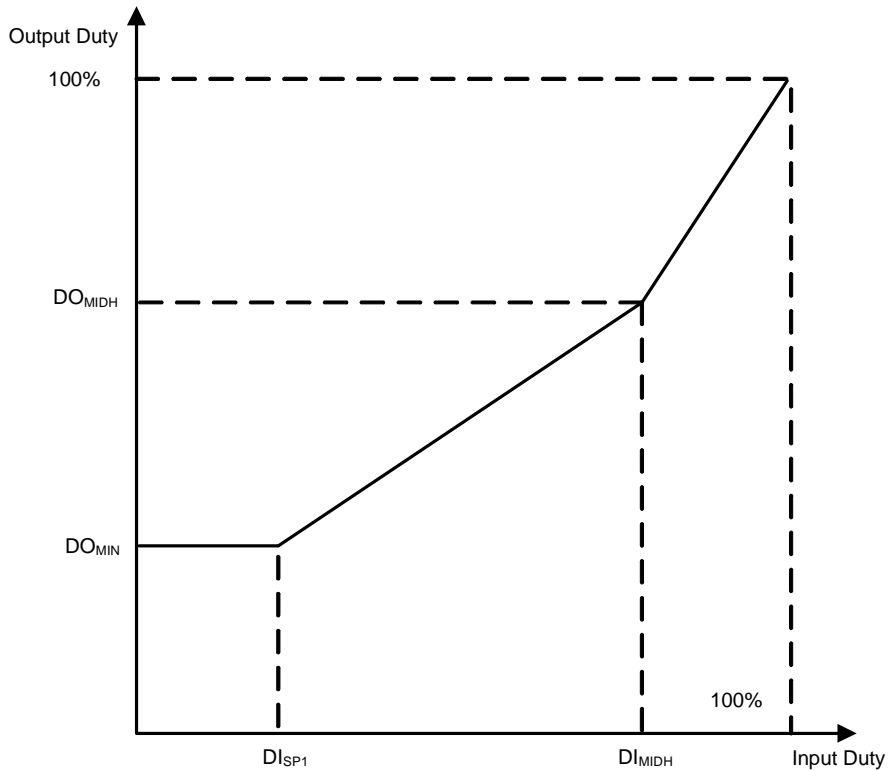


Figure2: MIN, MIDH, and SP1 Output Duty Control

ALL Duty Setting are approximated by below formulas:

$$DO_{MIN} (\%) = 100\% \times \frac{V_{MIN}}{V_{5VREG}} \quad . \quad DO_{MIDH} (\%) = 100\% \times \frac{V_{MIDH}}{V_{5VREG}} \quad . \quad DI_{SP1} (\%) = 100\% \times \frac{V_{SP1}}{V_{5VREG}}$$

Note1: In this case, DI_{MIDH} is not fixed, and the formula is presented below.

$$DI_{MIDH} = (100\% - DI_{SP1})/2 + DI_{SP1}$$

Note2: VSD pin connects to 5VREG.

Note3: DO_{MIN} can't be larger than DO_{MIDH} .

Function Description (Cont.)

MIN, MIDH, SP1 and VSD Output Duty Control

In this case, we use MIN, MIDH, SP1 and VSD to control the output speed curve. The application is just like previous **MIN, MIDH and SP1 Output Duty Control** in addition to VSD shutdown function. The output duty is shut down when PWM input duty lower than DI_{VSD} .

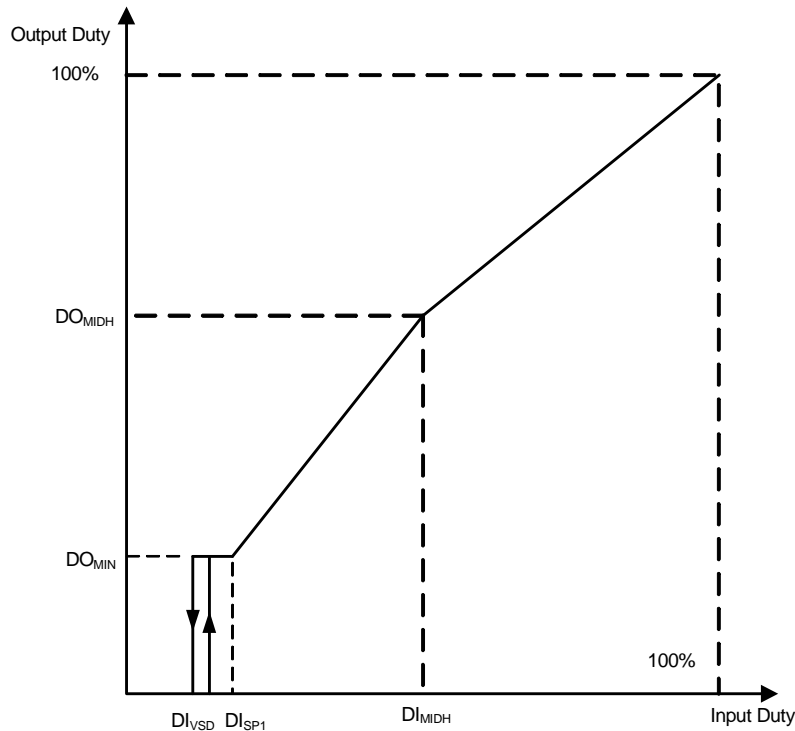


Figure3: MIN, MIDH, and VSD Output Duty Control

ALL Duty Setting are approximated by below formulas:

$$DO_{MIN} (\%) = 100\% \times \frac{V_{MIN}}{V_{5VREG}} \quad . \quad DO_{MIDH} (\%) = 100\% \times \frac{V_{MIDH}}{V_{5VREG}} \quad . \quad DI_{VSD} (\%) = 100\% \times \frac{V_{VSD}}{V_{5VREG}}$$

$$DI_{SP1} (\%) = 100\% \times \frac{V_{SP1}}{V_{5VREG}}$$

Note1: In this case, DI_{MIDH} is not fixed, and the formula is presented below.

$$DI_{MIDH} = (100\% - DI_{SP1})/2 + DI_{SP1}$$

Note2: DI_{VSD} has about 1% to 2% duty hysteresis.

Note3: DO_{MIN} can't be larger than DO_{MIDH} .

Function Description (Cont.)

SP1, MIDH, and VSD Output Duty Control (MIN is not in use)

In this case, we use SP1, MIDH and VSD to control the output speed curve. If VSD Shutdown function is disable, whatever the input duty is given, the output is be shut down($DO_{MIN} = 0\%$) until DI_{SP1} . Therefore the point of this application is that minimum output duty is be set to zero. In addition, DI_{MIDH} is not fixed and VSD Shutdown Function is added.

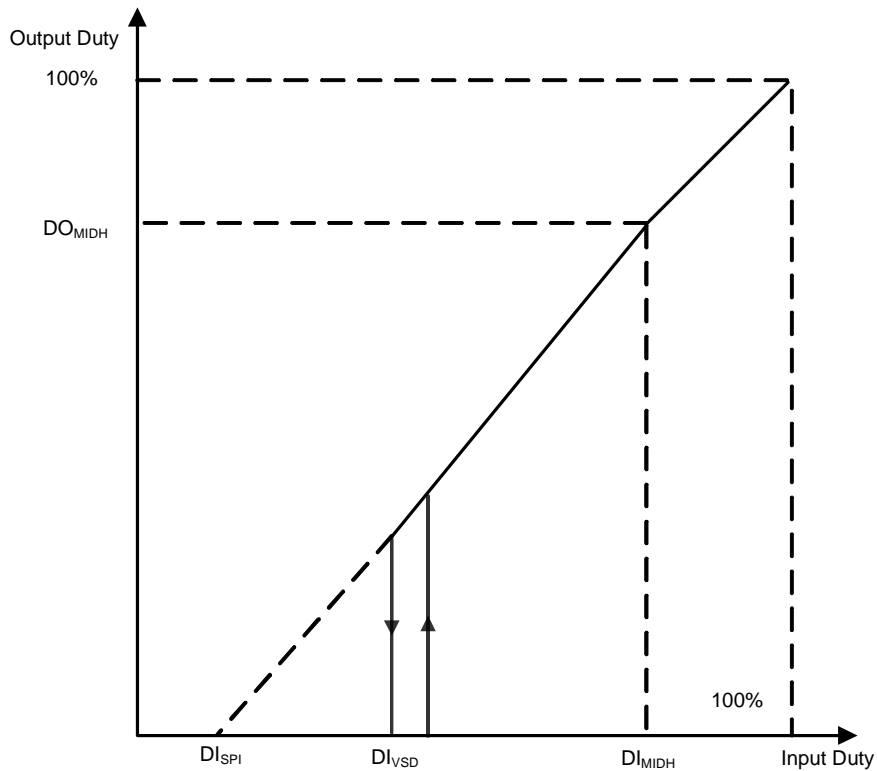


Figure4: SP1, MIDH, and VSD Output Duty Control

ALL Duty Setting are approximated by below formulas:

$$DI_{SP1} (\%) = 100\% \times \frac{V_{SP1}}{V_{5VREG}} \cdot DO_{MIDH} (\%) = 100\% \times \frac{V_{MIDH}}{V_{5VREG}} \cdot DI_{VSD} (\%) = 100\% \times \frac{V_{VSD}}{V_{5VREG}}$$

Note1: In this case, DI_{MIDH} is not fixed, and the formula is presented below.

$$DI_{MIDH} = (100\% - DI_{SP1})/2 + DI_{SP1}$$

Note2: MIN pin connects to GND.

Note3: DI_{VSD} has about 1% to 2% duty hysteresis.

Note4: DO_{MIN} can't be larger than DO_{MIDH} .

Function Description (Cont.)

Lock Protection and Auto Restart

The APX9202A 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 for 5 seconds 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 restart time has 0.5 second. If the locked condition is not removed, the shutdown restart process will be recurred until the locked condition is released (see Figure 5 Lockup/Auto Restart Waveform).

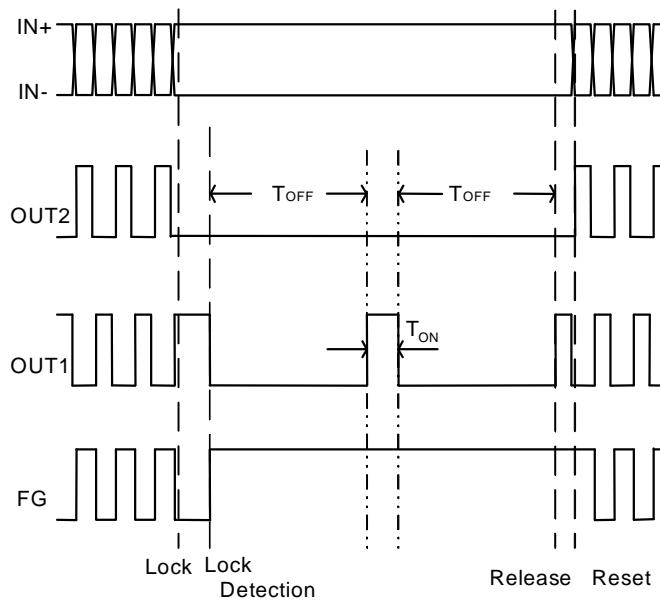


Figure 5: Lockup /Auto Restart Waveform

Function Description (Cont.)

Quick Start and Standby Mode

This IC would enter standby mode when the time of PWM low level over T_{OS} , it will shut down amplifier, FG and 5VREG when the frequency of hall signals lower than 5Hz(typ.). Thus, the supply current is around 15uA. In standby mode, the lock protection function doesn't work. therefore, starting fan is unobstructed when releasing standby mode.

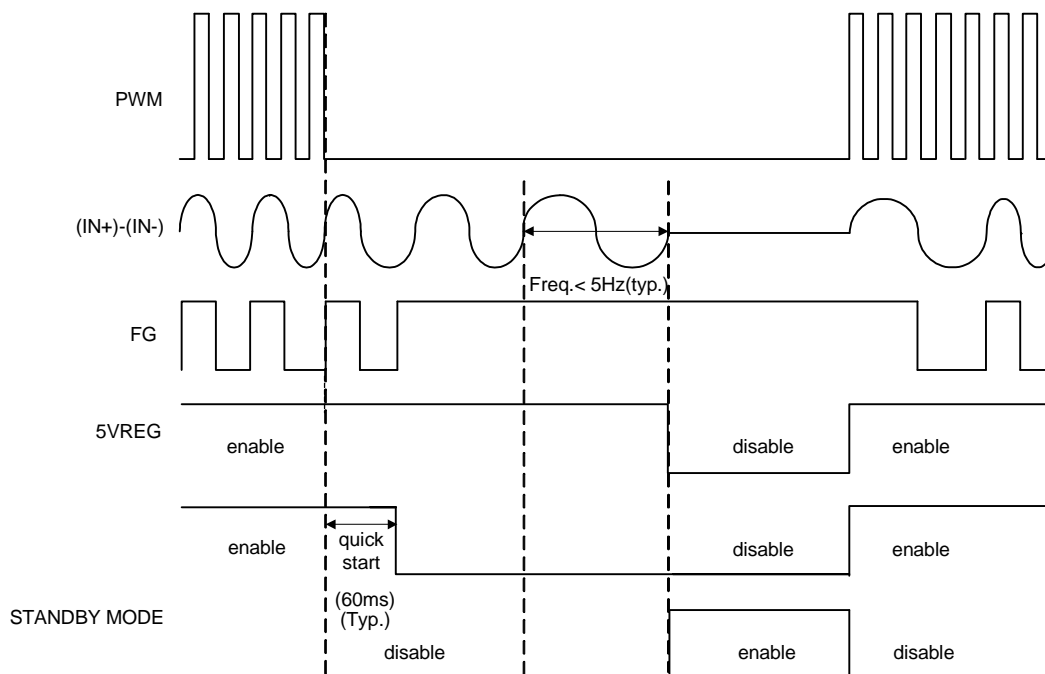


Figure 6: Quick Start Waveform

Function Description (Cont.)

Soft Switching angle & OFF angle Control

Soft switching angle (θ_{SW}) and OFF angle (θ_{OFF}) are performed to control the output current change rate and the regenerate current when conducting phase switches.

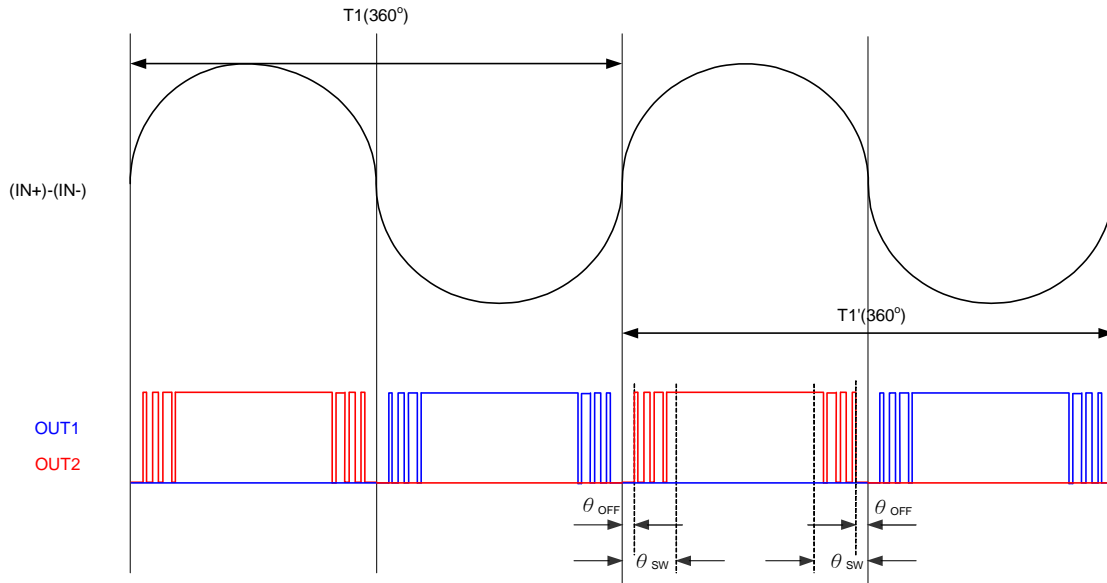


Figure 7: Soft Switching and OFF time define

The soft switching angle (θ_{SW}) is determined by the time of prior hall signal (360°) and the voltage of SW pin. In soft switching after conducting phase switch, the output PWM duty changes gradually from 0% to 100% of the output PWM duty determined by SW voltage for 64 steps in maximum. In soft switching before conducting phase switch, the output PWM duty changes gradually from 100% to 0% of the output PWM duty determined by SW voltage in maximum.

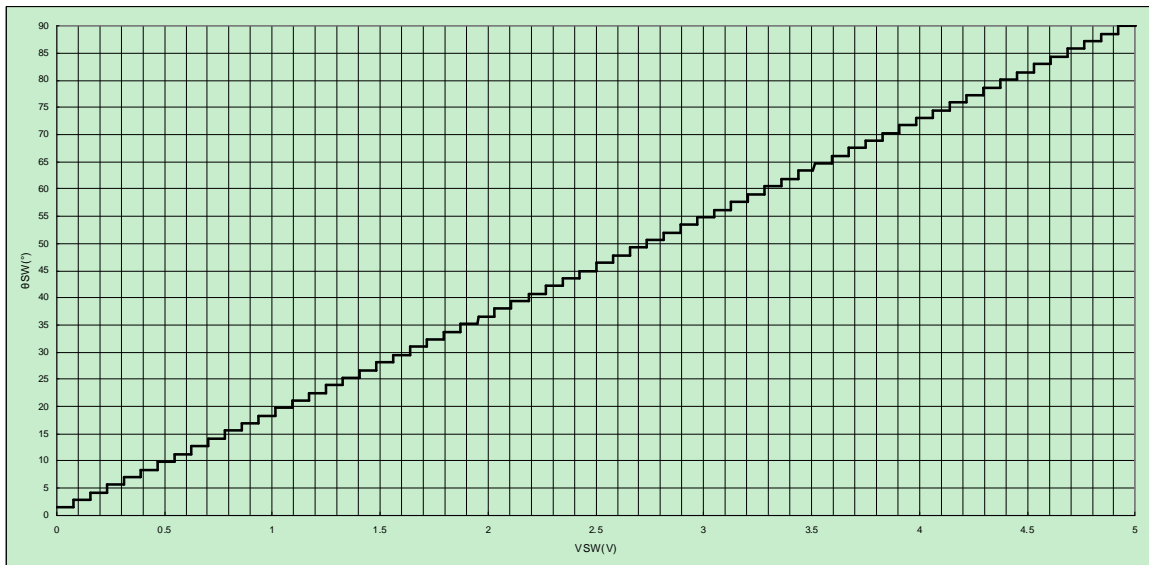


Figure 8: SW angle VS. SW Voltage

Function Description (Cont.)

Use the equation and table below to find out the R_{sw} needed.

$R_{sw} = \frac{V_{sw}}{20mA} (\Omega)$. The recommended voltages V_{sw} are the midpoint to avoid the edge vibration, and the value of internal current source is 20uA.

Step	$V_{sw}(V)$	$\theta_{sw} (^{\circ})$	Step	$V_{sw}(V)$	$\theta_{sw} (^{\circ})$	Step	$V_{sw}(V)$	$\theta_{sw} (^{\circ})$	Step	$V_{sw}(V)$	$\theta_{sw} (^{\circ})$
1	0	1.4	17	1.3	23.9	33	2.54	46.4	49	3.79	68.9
2	0.11	2.8	18	1.37	25.3	34	2.62	47.8	50	3.87	70.3
3	0.19	4.2	19	1.45	26.7	35	2.7	49.2	51	3.95	71.7
4	0.27	5.6	20	1.52	28.1	36	2.77	50.6	52	4.02	73.1
5	0.35	7	21	1.6	29.5	37	2.85	52	53	4.1	74.5
6	0.43	8.4	22	1.68	30.9	38	2.93	53.4	54	4.18	75.9
7	0.51	9.8	23	1.76	32.3	39	3.01	54.8	55	4.26	77.3
8	0.59	11.2	24	1.84	33.7	40	3.09	56.2	56	4.34	78.7
9	0.66	12.7	25	1.91	35.2	41	3.16	57.6	57	4.41	80.1
10	0.74	14.1	26	1.99	36.6	42	3.24	59.1	58	4.49	81.5
11	0.82	15.5	27	2.07	38	43	3.32	60.5	59	4.57	83
12	0.9	16.9	28	2.15	39.4	44	3.4	61.9	60	4.65	84.4
13	0.98	18.3	29	2.23	40.8	45	3.48	63.3	61	4.73	85.8
14	1.05	19.7	30	2.3	42.2	46	3.55	64.7	62	4.8	87.2
15	1.13	21.1	31	2.38	43.6	47	3.63	66.1	63	4.88	88.6
16	1.21	22.5	32	2.46	45	48	3.71	67.5	64	5	90

The OFF angle (θ_{OFF}) before and after phase change is determined by the time of prior hall signal (360°) and the voltage of OFF pin. The OFF angle determined by OFF pin voltage for 32 steps of 45°. The OFF angle overlap the soft switching angle, output will have without soft switching when the OFF angle larger than soft switching.

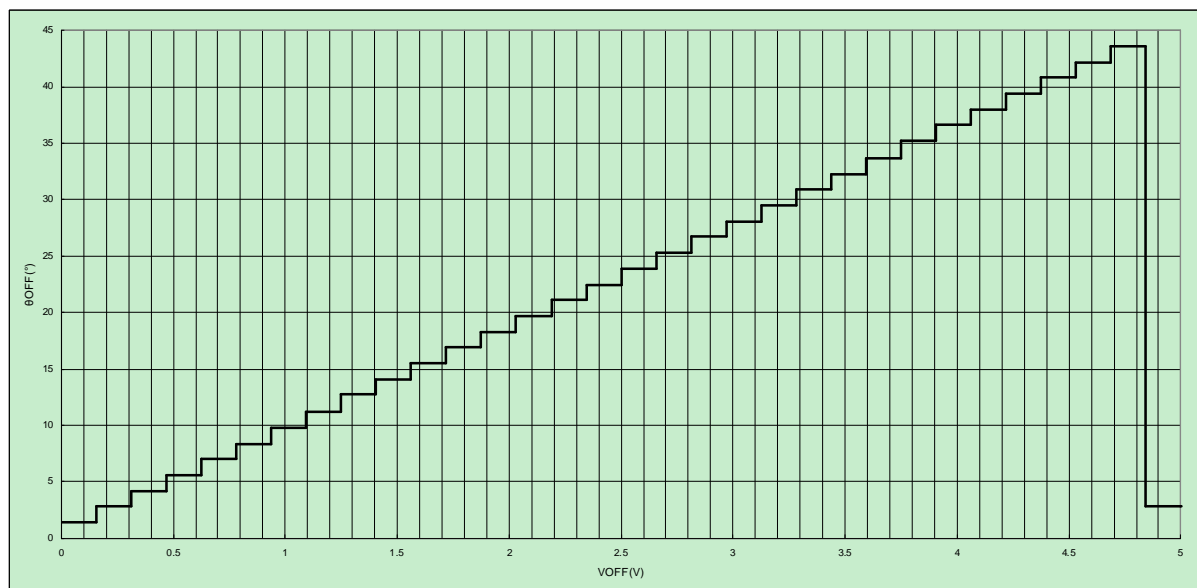


Figure 9: OFF angle VS. OFF Voltage

Function Description (Cont.)

Use a voltage divider from 5VREG to define the off angle, and the recommended voltages V_{OFF} in the below table are the midpoint of every step setting to avoid the edge vibration.

Step	$V_{OFF}(V)$	$\theta_{OFF}(^{\circ})$	Step	$V_{OFF}(V)$	$\theta_{OFF}(^{\circ})$	Step	$V_{OFF}(V)$	$\theta_{OFF}(^{\circ})$	Step	$V_{OFF}(V)$	$\theta_{OFF}(^{\circ})$
1	0	1.4	9	1.33	12.7	17	2.58	23.9	25	3.82	35.2
2	0.23	2.8	10	1.48	14.1	18	2.73	25.3	26	3.98	36.6
3	0.39	4.2	11	1.64	15.5	19	2.89	26.7	27	4.14	38
4	0.55	5.6	12	1.8	16.9	20	3.05	28.1	28	4.3	39.4
5	0.7	7	13	1.95	18.3	21	3.2	29.5	29	4.45	40.8
6	0.86	8.4	14	2.11	19.7	22	3.36	30.9	30	4.61	42.2
7	1.02	9.8	15	2.27	21.1	23	3.52	32.3	31	4.77	43.6
8	1.17	11.2	16	2.42	22.5	24	3.67	33.7	32	V_{5VREG}	2.8

Function Description (Cont.)

FG Output

The FG 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 FG will always high (switch off) (See Truth Table). Open the terminal when not in use.

Current Limit

The APX9202A includes an internal current sense circuits for current limit. When the total current of output over the current limit level (1.1A) , the high side driver will be turned off to stop supplying current to the motor until $I_{OUT} < 1.1A$ or re-power on.

Thermal Protection

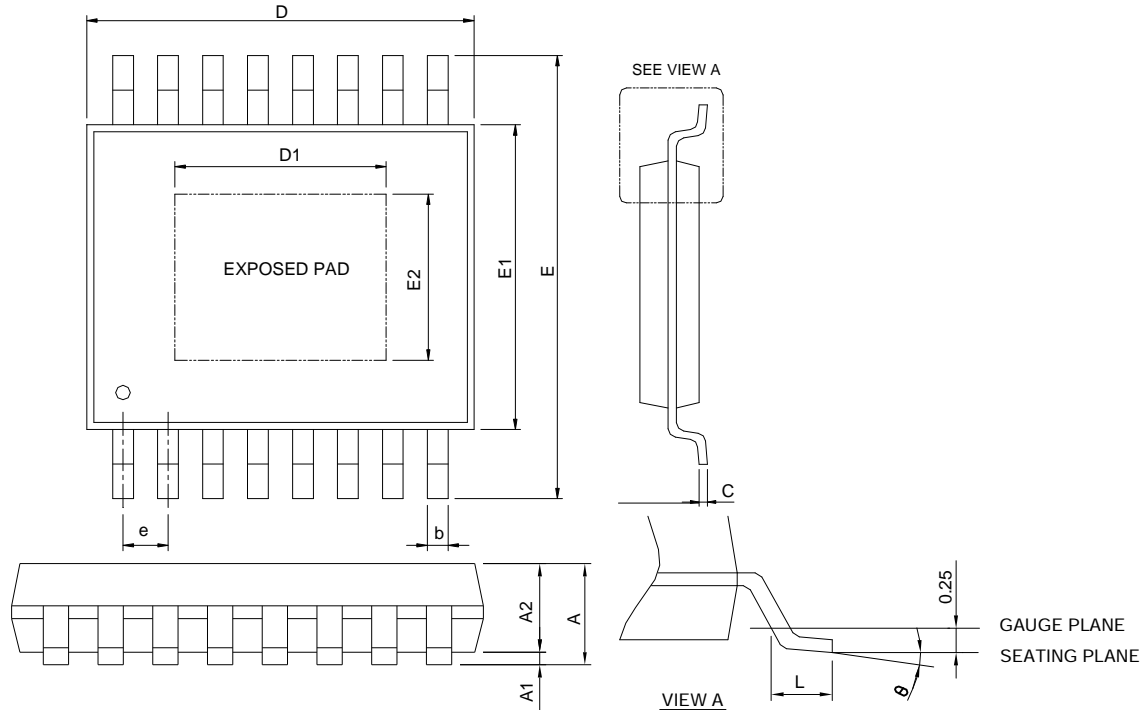
The APX9202A has thermal protection. When internal junction temperature reaches 165°C, the output devices will be switched off. When the IC's junction temperature cools by 30°C, the thermal sensor will turn the output devices on again, resulting in a pulsed output during continuous thermal protection.

Truth Table

INPUT		OUTPUT			Mode
IN-	IN+	OUT1	OUT2	FG	
H	L	H	L	L	Rotation(Drive) (PWM ON)
L	H	L	H	OFF	
H	L	OFF	L	L	Rotation(Regeneration) (PWM OFF)
L	H	L	OFF	OFF	
H	L	L	L	OFF	Lock Mode
L	H	L	L	OFF	

Package Information

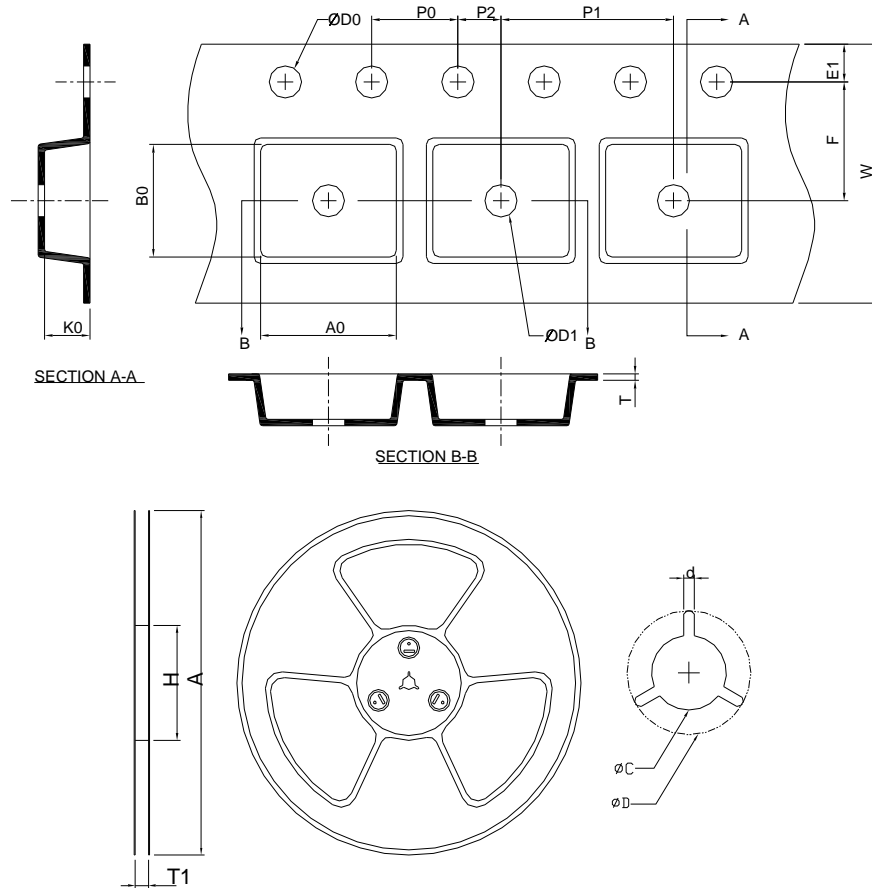
TSSOP-16P



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

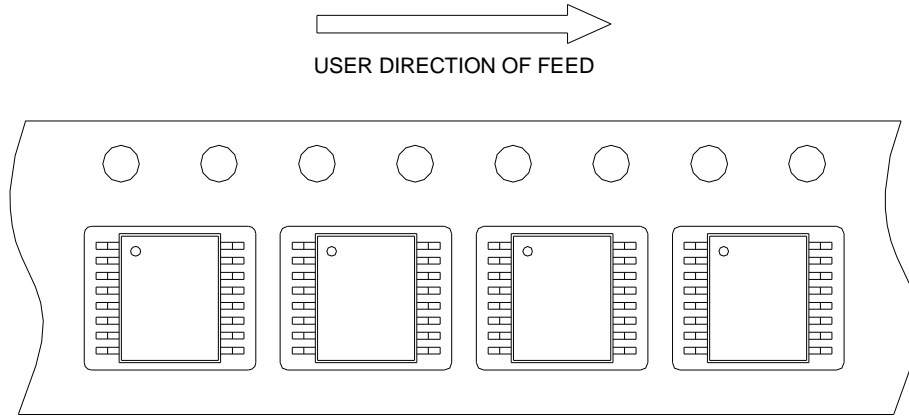
(mm)

Devices Per Unit

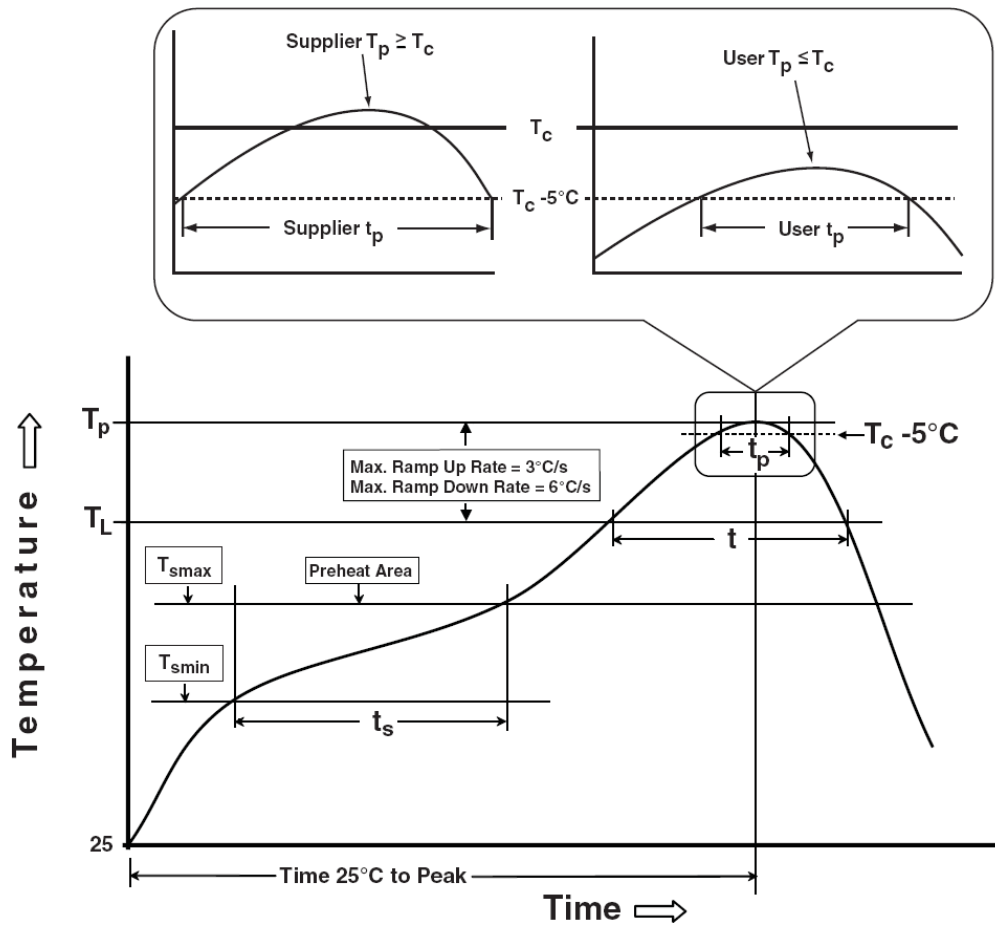
Package Type	Unit	Quantity
TSSOP- 16P	Tape & Reel	2500

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.		

Table 1. 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 2. 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 ≥ 2KV
MM	JESD-22, A115	VMM ≥ 200V
Latch-Up	JESD 78	10ms, $1_{tr} \geq 100\text{mA}$

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