

Single-Phase Full-Wave Motor Driver

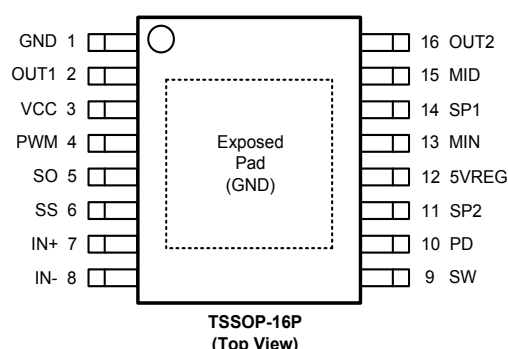
Features

- Built-in Soft Start Function
- Built-in Adjustable PWM Soft Switching Function
- Built-in Variable Speed Curve Function
- Built-in Leading Angle and Phase Delay Function
- Built-in Current Limit Circuit
- 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, PD and SW are Multi Function
- Lead Free and Green Devices Available (RoHS Compliant)

General Description

The APX9230 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 APX9230 is available in TSSOP- 16P package.

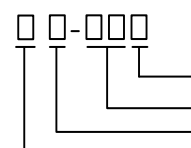
Pin Configuration



Applications

- Brushless DC Fans
- Brushless DC Motors

Ordering and Marking Information

APX9230  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
APX9230 R : APX9230 XXXXX	XXXXX - 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 20	V
V_{OUT}	Output Pin (OUT1, OUT2) Output Voltage	-0.3 to 20	V
I_{OUT}	Output Pin (OUT1, OUT2) Maximum Output Peak Current	3	A
V_{PWM}	PWM Pin Input Voltage	-0.3 to 20	V
	SO Pin Output Voltage	-0.3 to 20	V
I_{SO}	SO Pin Output Sink Current	10	mA
I_{5VREG}	5VREG Pin Maximum Output Current	20	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_{PD}	PD Pin Input Voltage (PD 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
$R_{TH,JC}$	Thermal Resistance-Junction to Case TSSOP-16P	20	°C/W
P_D	Power Dissipation, $T_A = 25^{\circ}\text{C}$ TSSOP-16P	1.5	W

Note 2 : Mounted on a board (65x50x1.6 mm, 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.

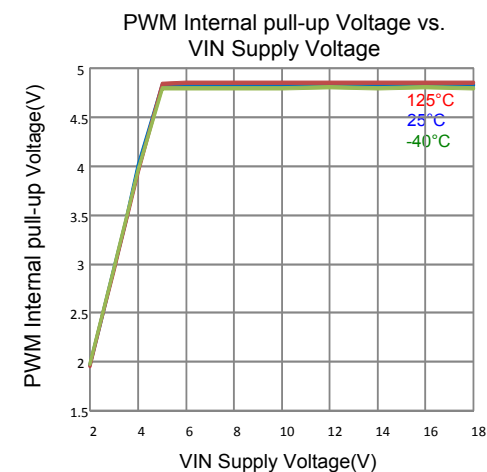
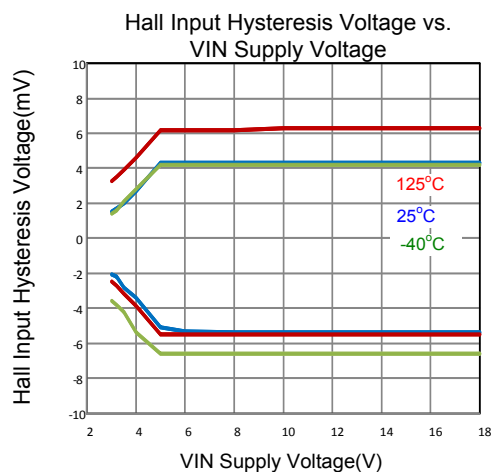
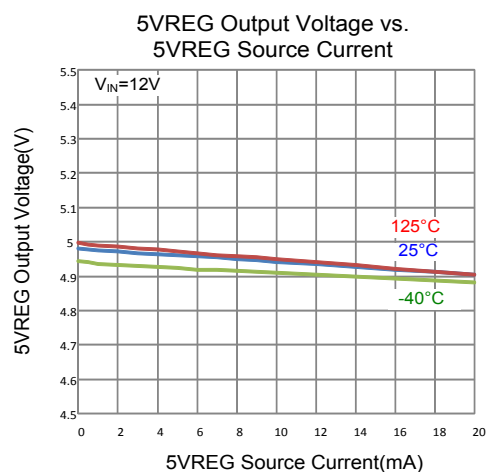
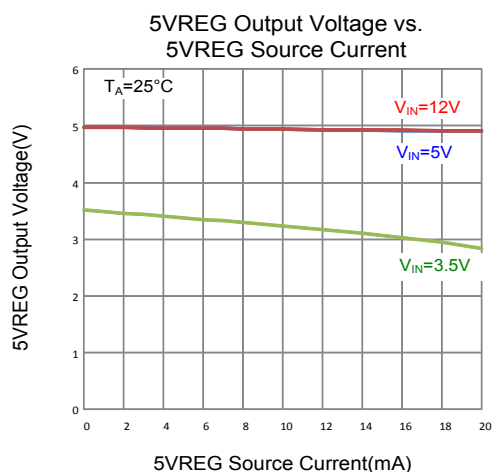
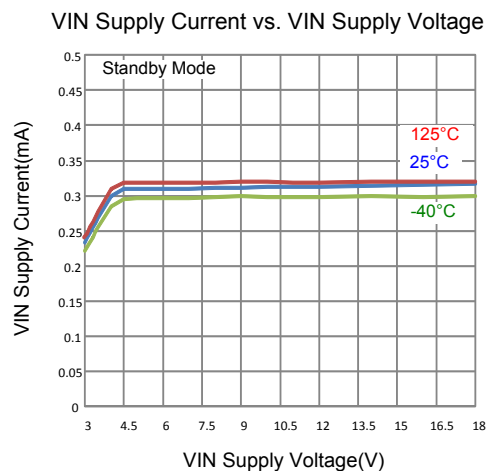
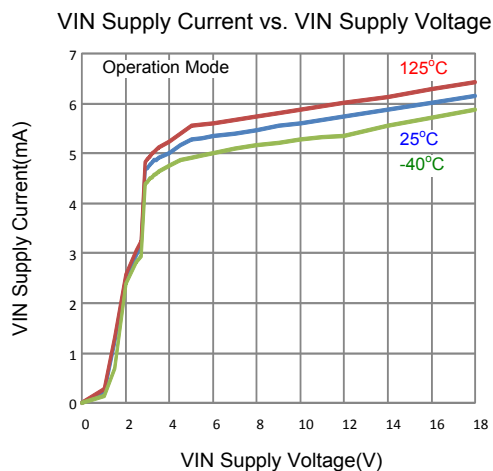
Recommended Operation Conditions

Symbol	Parameter	Range	Unit
V_{CC}	VCC Supply Voltage	3.3 to 18	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_{PD}	PD Pin Input Voltage (PD 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

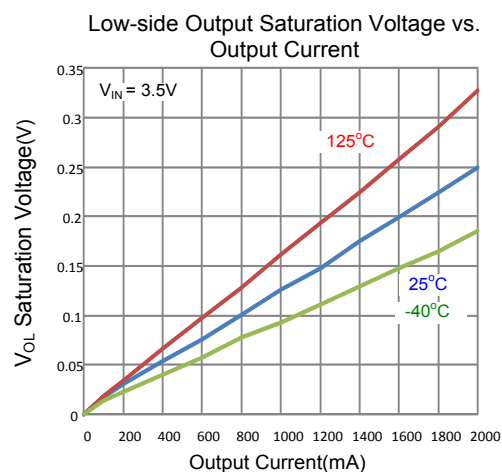
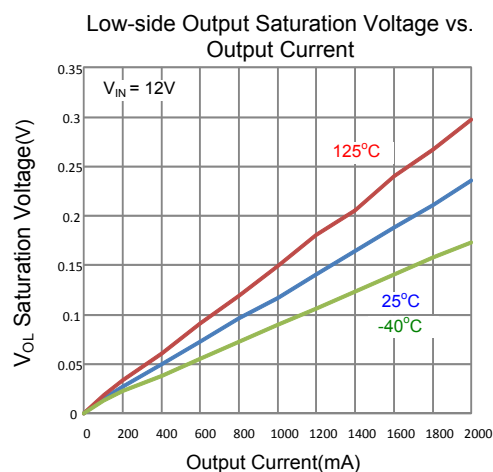
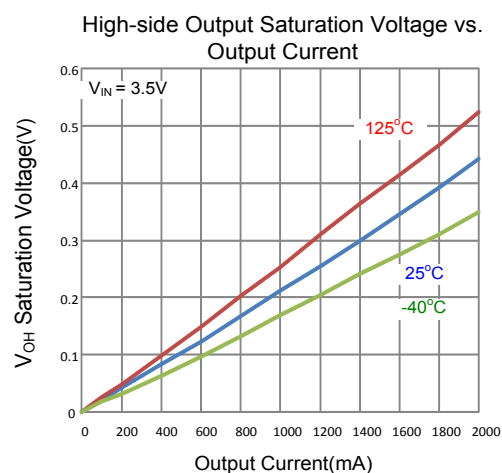
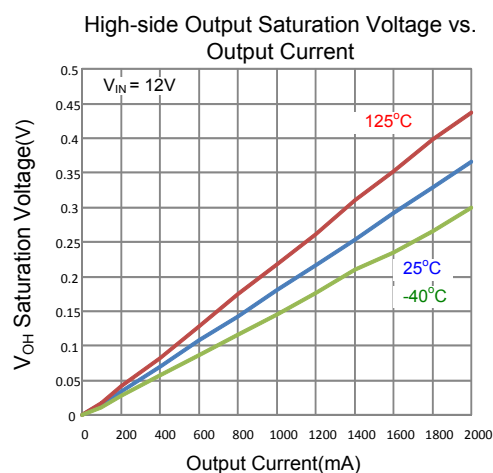
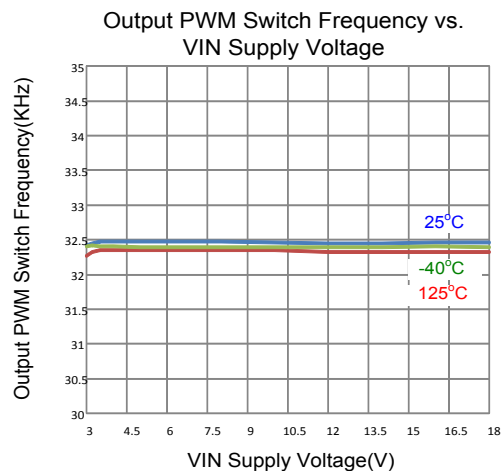
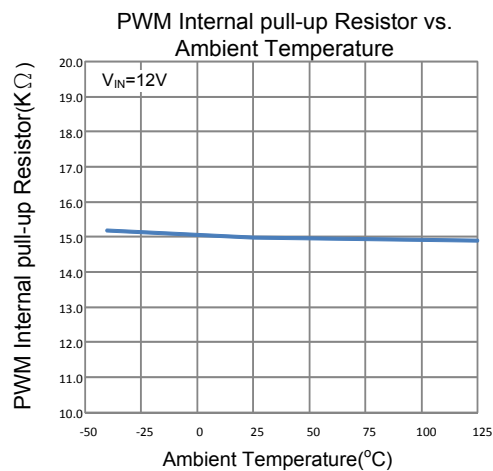
Electrical Characteristics (T_A = 25°C, V_{CC} = 12V, unless otherwise specified)

Symbol	Parameter	Test Condition	APX9230			Unit
			Min.	Typ.	Max.	
SUPPLY CURRENT						
I _{CC}	Operation Mode	V _{CC} = 12V (No Load)	-	6	9	mA
I _{CC1}	Lock Mode	V _{CC} = 12V (No Load)	-	6	9	mA
I _{CC2}	Standby Mode	PWM = GND and FG Output	-	-	500	μA
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} = 500mA, Upper and Lower total	-	0.17	0.25	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		-	18	-	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 (D _{OUT} = 5~40%)	For Start up, Define by V _{SS} .	-	0.18~4.2	-	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		-	1.3	-	A
I _{LIM2}	Current Limit Level of Normal Operation		-	2.5	-	A
THERMAL PROTECTION						
	Over-Thermal Protection Temperature		-	170	-	°C
	Over -Thermal Protection Hysteresis		-	30	-	°C
	Thermal Protection release time		-	4	-	sec

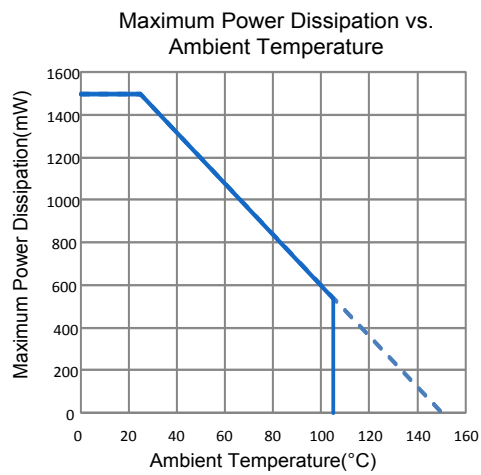
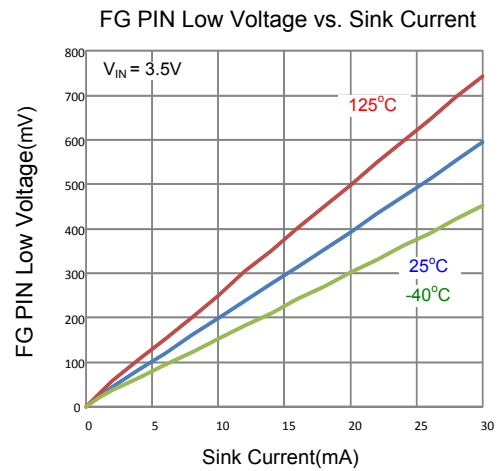
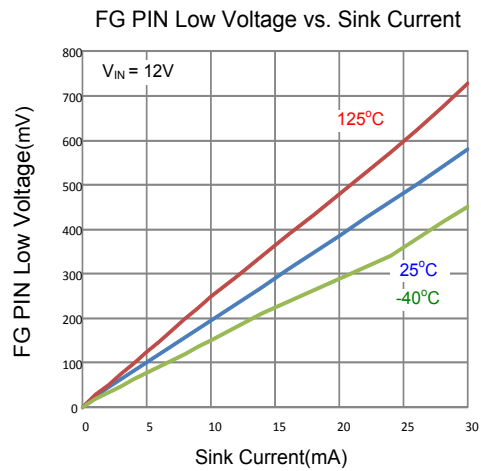
Typical Operating Characteristics



Typical Operating Characteristics (Cont.)



Typical Operating Characteristics (Cont.)

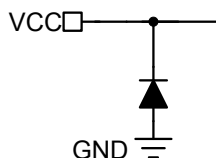


Pin Description

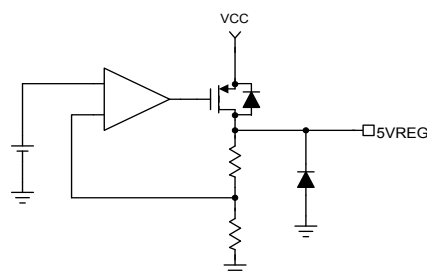
PIN		Function
NO.	NAME	
1	GND	Ground of the IC.
2	OUT1	H-bridge output connection. The output stage is a H-bridge formed by four transistors and four-protection diode for switching applications.
3	VCC	Supply Voltage Input.
4	PWM	PWM Signal or DC Voltage Input Terminal
5	SO	FG / 1/2FG / RD(Rotation Speed 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 Lead Angle High Setting.
10	PD	Lead Angle Low Setting or Auto Lead Angle Mode Select.
11	SP2	Output Duty (DO_{SP2}) for Input PWM_100%, Turning Point (DI_{SP2}) For Output Duty_100% or Lead 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

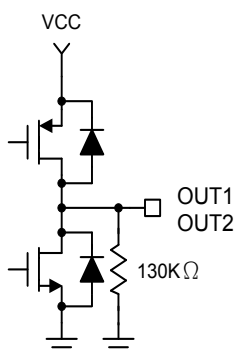
(1) Power supply input pin (VCC, GND)



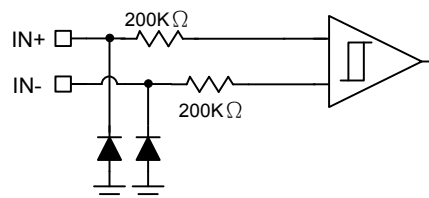
(2) Regulator output pin (5VREG)



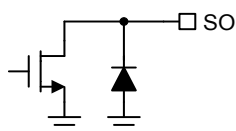
(3) Driver output pin (OUT1, OUT2)



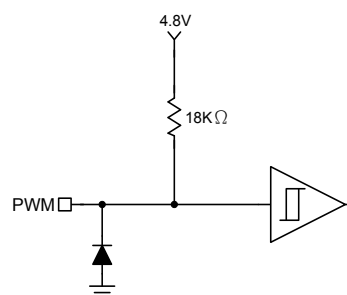
(4) Hall signal input pin (IN+, IN-)



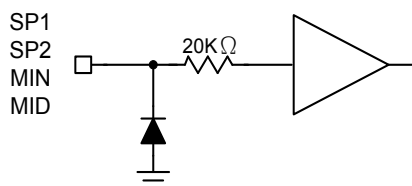
(5) Rotation speed detection output pin (SO)



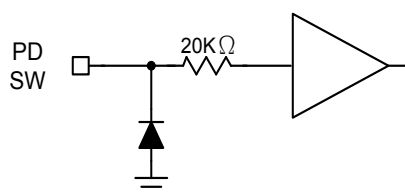
(6) PWM speed control input pin (PWM)



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

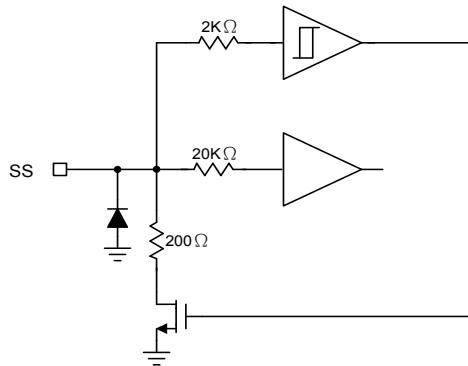


(8) Phase Delay and Soft Switch angle setting pin (SW, PD)

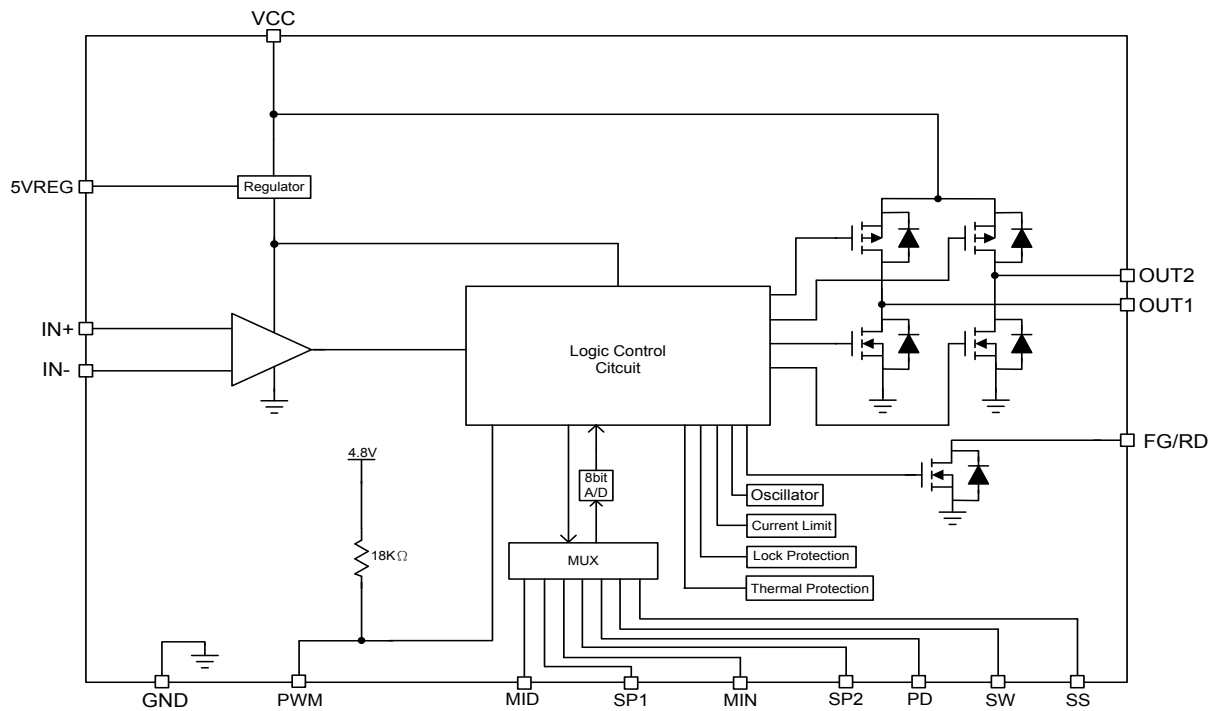


I/O Equivalent Circuits (Cont.)

(9) Soft Start time setting pin (SS)

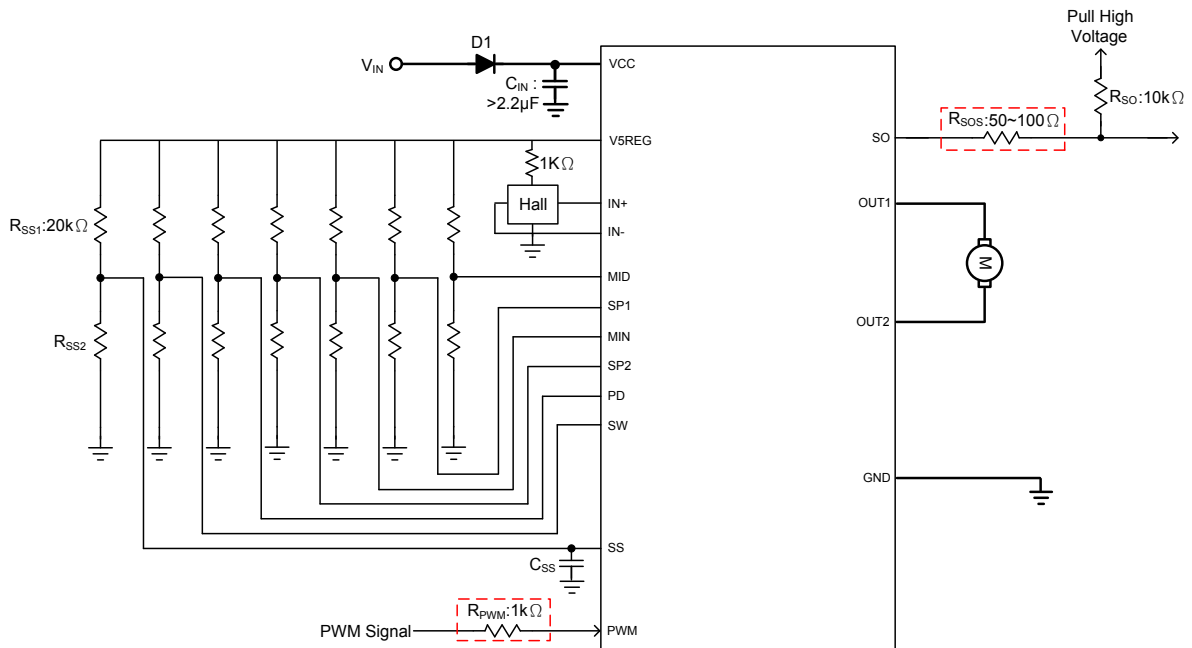


Block Diagram



Typical Application Circuit

(1) Direct PWM Mode Speed Control

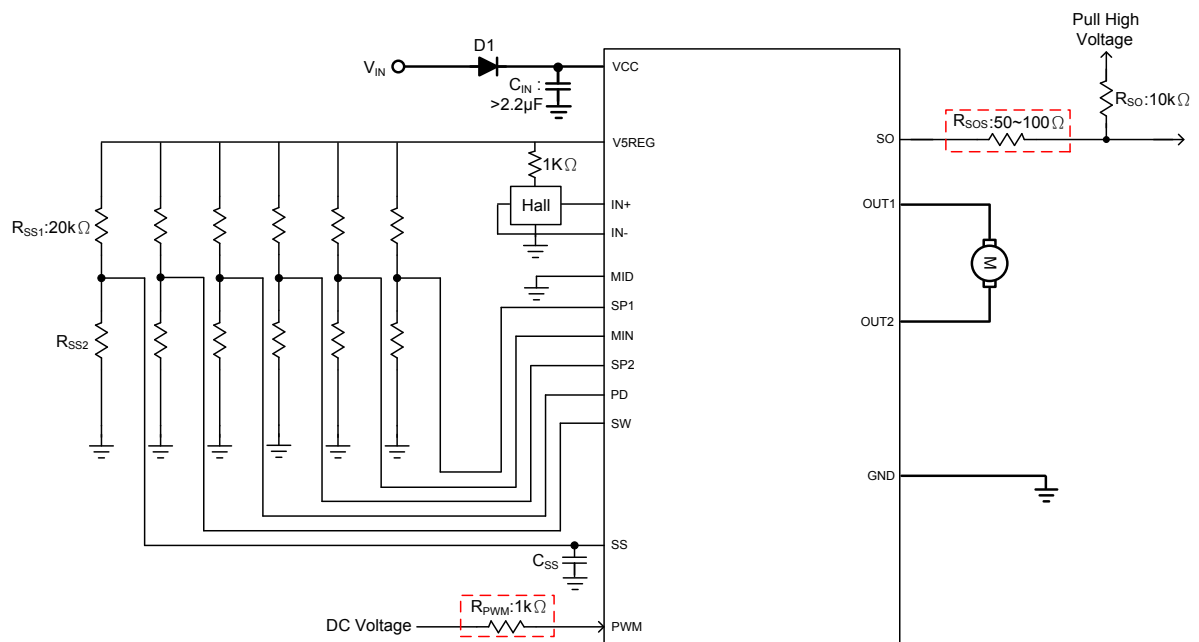


Note: R_{PWM} and R_{SOS} are optional to protect internal circuit for abnormal voltage stress.

Note: The C_{IN} value is adjusted by motor characteristic

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.

Function Description

Multi Function

The APX9230 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 PD pin primary function is phase delay setting. The SW pin primary function is setting off side soft switching degree. All of above pin, the secondary function set up following to table1.

Table1. Secondary Function Setting Reference Table

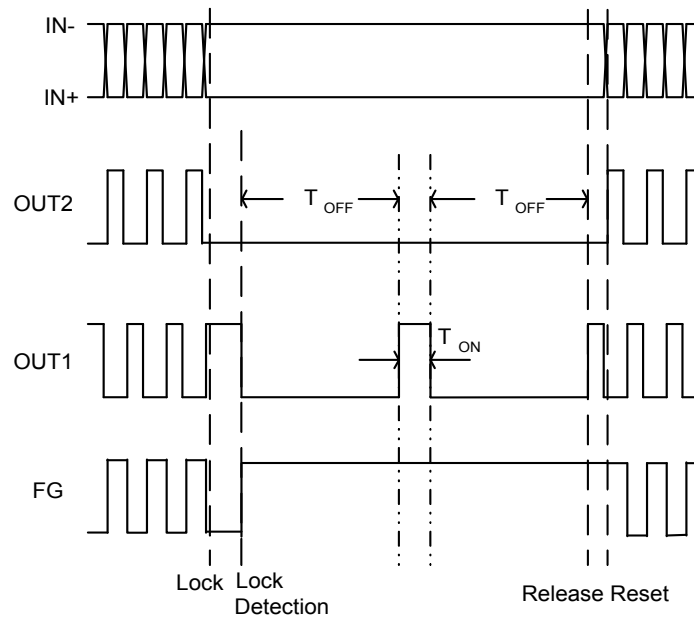
	<0.15V	0.5~2.45V	2.55~4.5V	>4.85V
SP1	Shutdown Mode	Shutdown Mode	Min Speed Mode	Min Speed Mode
MID	VSP Mode and SO(FG)	SO(1/2FG)	SO(FG)	SO(FG)
MIN	Dead Time of OFF Side(Auto)	Dead Time of OFF Side(Auto)	Dead Time of OFF Side(Fix 15°)	Dead Time of OFF Side(Fix 15°)
SP2	1.SO(RD Signal)	1.PWM_IN=100% PWM_OUT=DO _{SP2}	PWM_IN=DI _{SP2} PWM_OUT=100%	PWM_IN=DI _{SP2} PWM_OUT=100%
	2. If the SW pin connect to GND, the SP2 pin become to LAH Feature.	2. If the SW pin connect to GND, the SP2 pin become to LAH Feature.	2. If the SW pin connect to GND, the SP2 pin become to LAH Feature.	2. If the SW pin connect to GND, the SP2 pin become to LAH Feature.
	3. If the SW pin connect to GND and the PD pin connect to 5VREG, the SP2 pin become to auto lead angle maximum lead angle.	3. If the SW pin connect to GND and the PD pin connect to 5VREG, the SP2 pin become to auto lead angle maximum lead angle.	3. If the SW pin connect to GND and the PD pin connect to 5VREG, the SP2 pin become to auto lead angle maximum lead angle.	3. If the SW pin connect to GND and the PD pin connect to 5VREG, the SP2 pin become to auto lead angle maximum lead angle.
PD	If the SW pin connect to GND, the PD pin become to LAL Feature.	If the SW pin connect to GND, the PD pin become to LAL Feature.	If the SW pin connect to GND, the PD pin become to LAL Feature.	Auto LA (MIN>2.55V)
SW	SP2 Pin Change to LAH 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

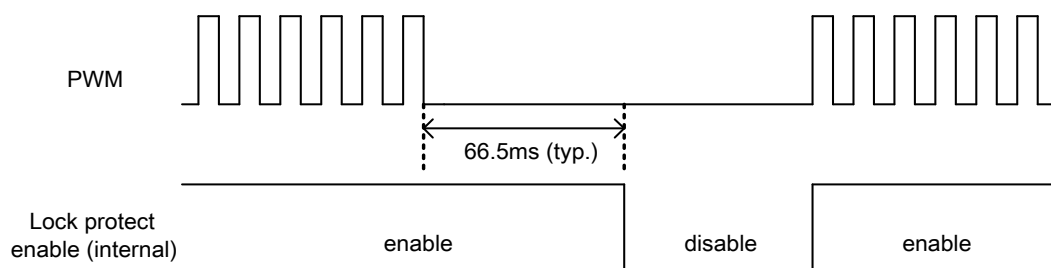
Lockup Protection and Automatic Restart

The APX9230 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 APX9230 provides the soft-start function to avoid peak current at power-on and lock-restart moments. The soft start time combine with T_{SS1} and T_{SS2} . The T_{SS1} is define by SS pin input voltage at start up and the T_{SS2} is define by C_{SS} capacitor. At the soft start time, the output initial duty is 5% and the T_{SS1} is output duty from 5 to 40%. When the output duty is arrived at 40%, the output duty change rate will transform T_{SS1} into T_{SS2} . The T_{SS1} can set up voltage range following the figure and table.

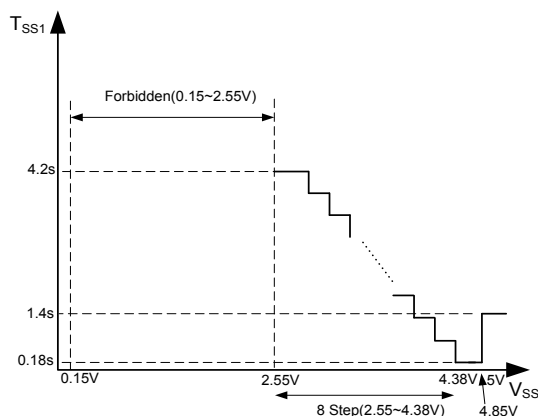


Figure 1: SS1 Voltage Setting Range

Step	V_{SS} (V)	T_{SS1} (s)
	>4.85	1.4
8	4.38	0.18
7	4.14	0.35
6	3.89	0.7
5	3.64	1.4
4	3.39	2.1
3	3.14	2.8
2	2.88	3.5
1	2.63	4.2

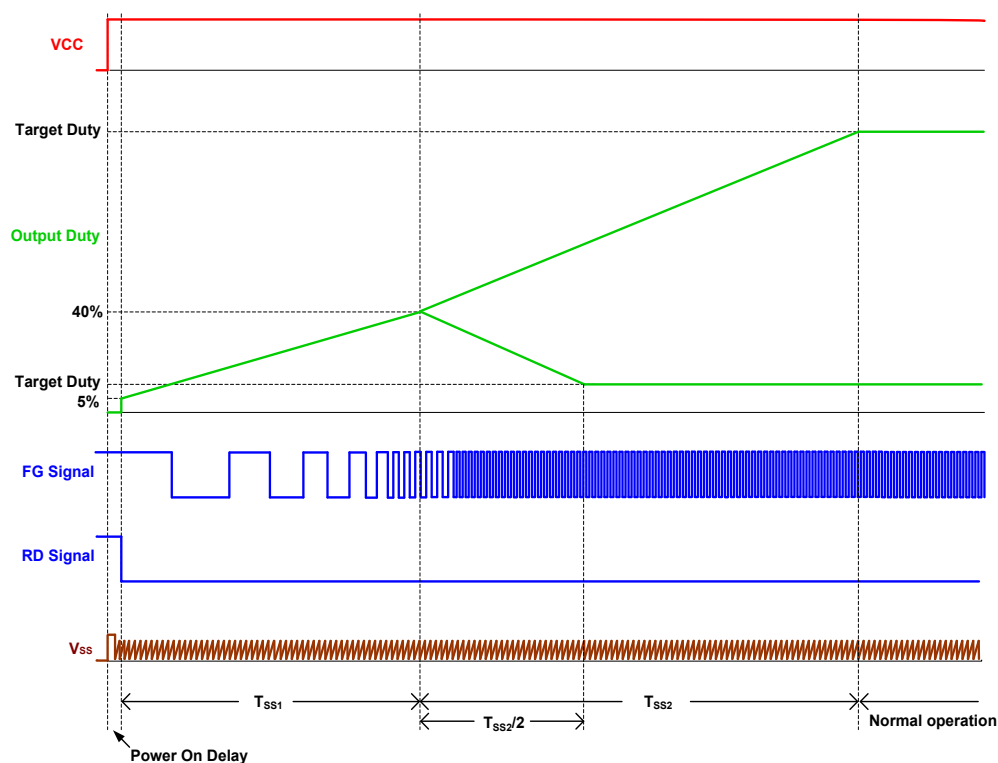


Figure 2: Soft Start Timing Char

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.

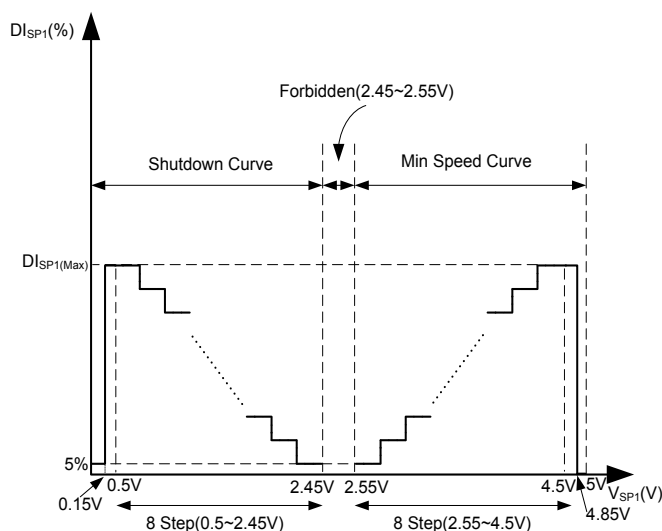


Figure 3: SP1 Voltage Setting Range

Table3. 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.

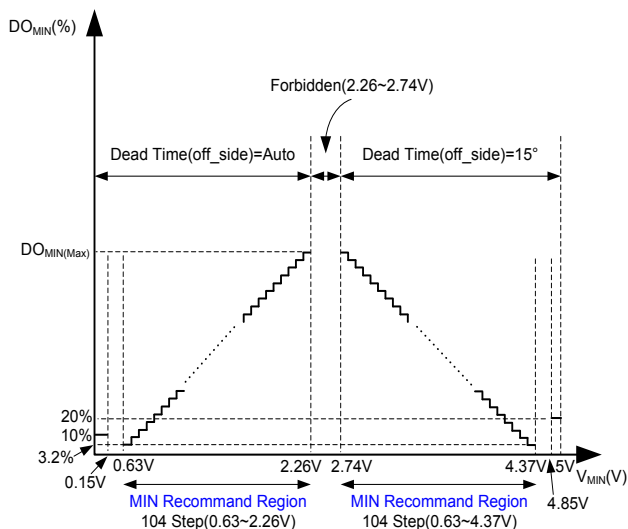


Figure 4: MIN Voltage Setting Range

Table4. 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.

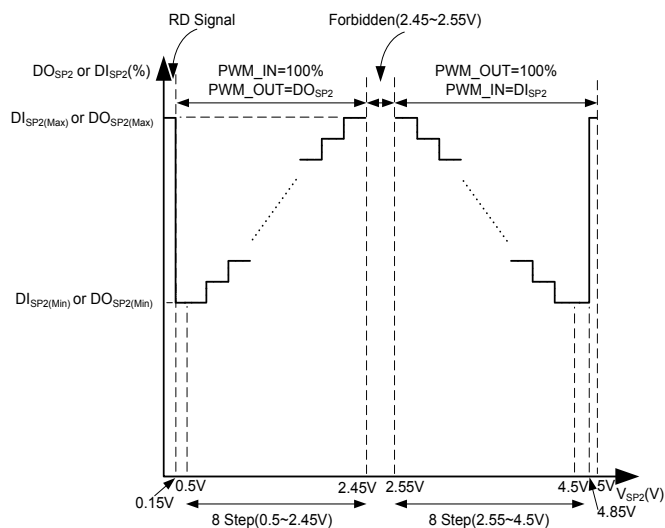


Figure 5: SP2 Voltage Setting Range

Table5. 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.

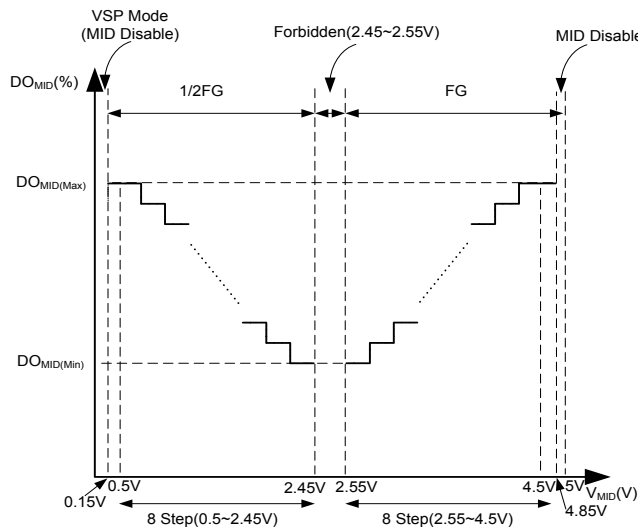


Figure 6: MID Voltage Setting Range

Table6. 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	VSP Mode(MID Disable)

Function Description (Cont.)

Speed Control Curve

The APX9230 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%.

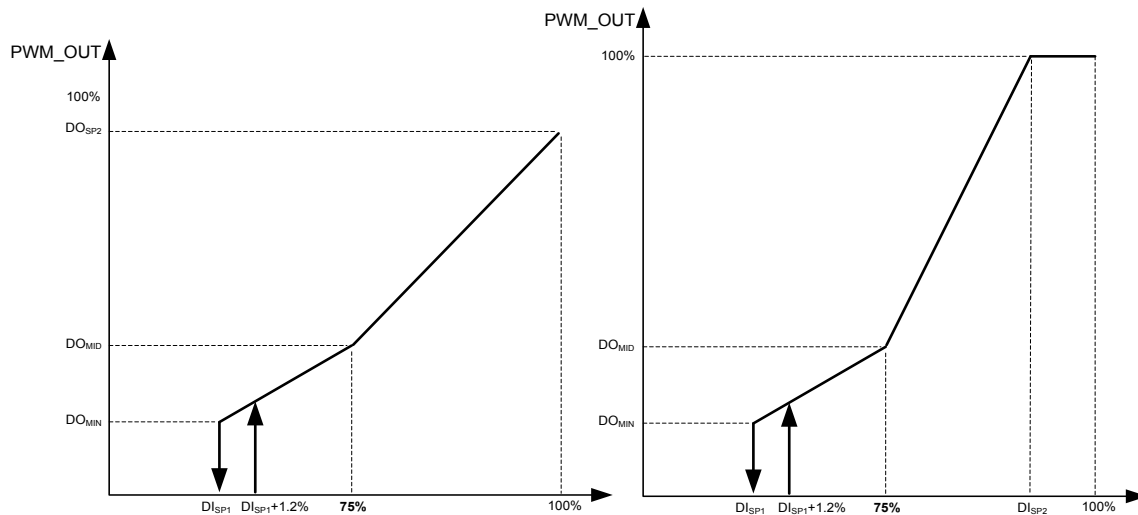


Figure 7: Shutdown Mode Speed Curve

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%.

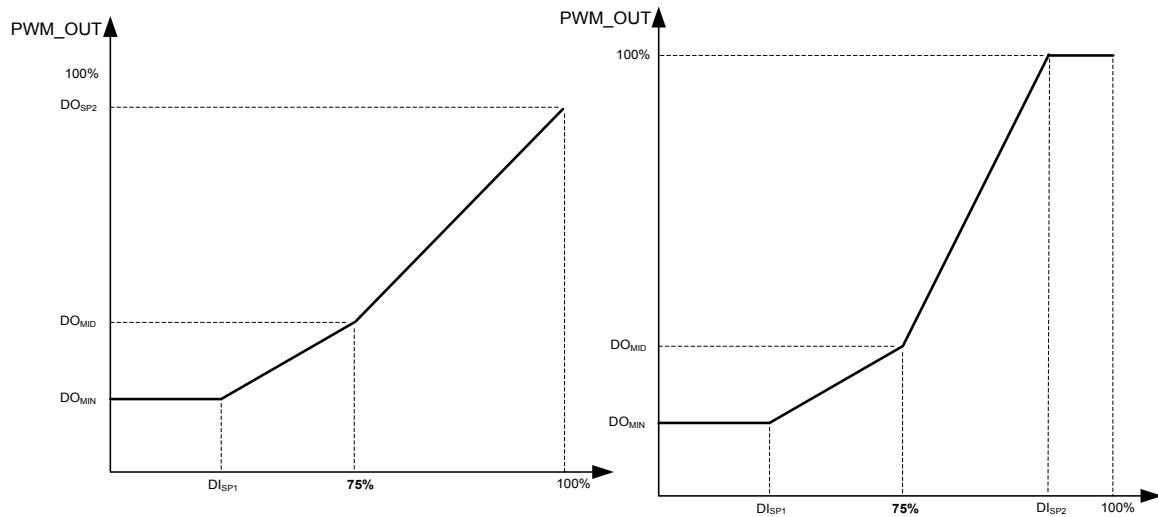


Figure 8: Minimum Speed Mode Speed Curve

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, LA and Dead Time Schematic Diagram

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

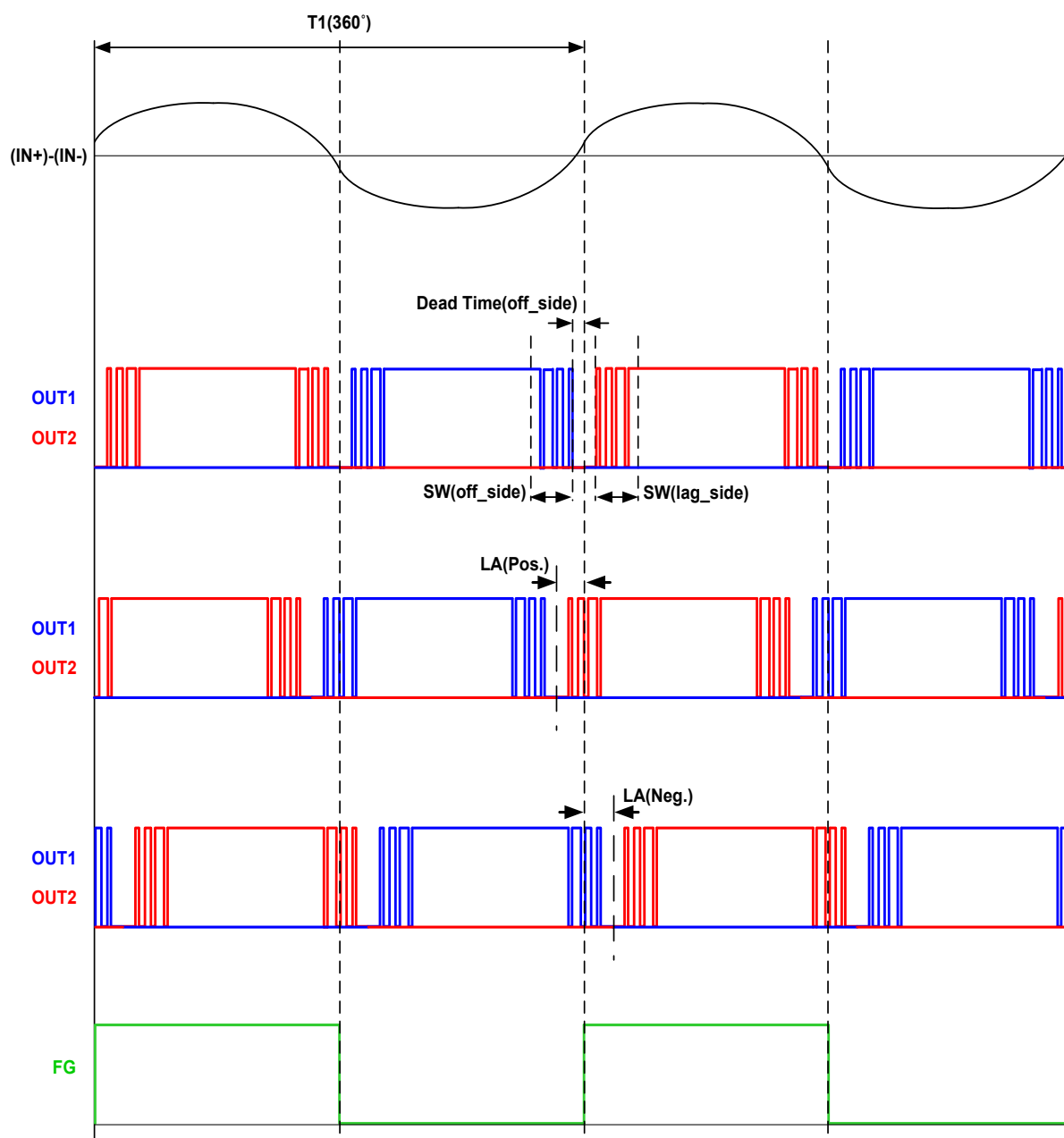


Figure 9: SW, LA and Dead Time Schematic Diagram

Function Description (Cont.)

PWM Soft-Switch Function

The APX9230 built in PWM soft-switch output control circuit to improve the vibration and noise of fan motor operation. At start-up operation, the APX9230 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.

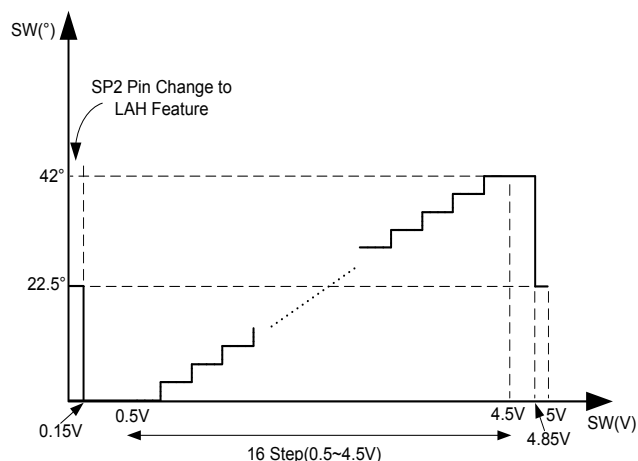


Figure 10: Soft Switching Voltage Setting Range

Table7. Soft Switching Setting Range

Step	V_{SW} (V)	$SW(^{\circ})$
	>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.)

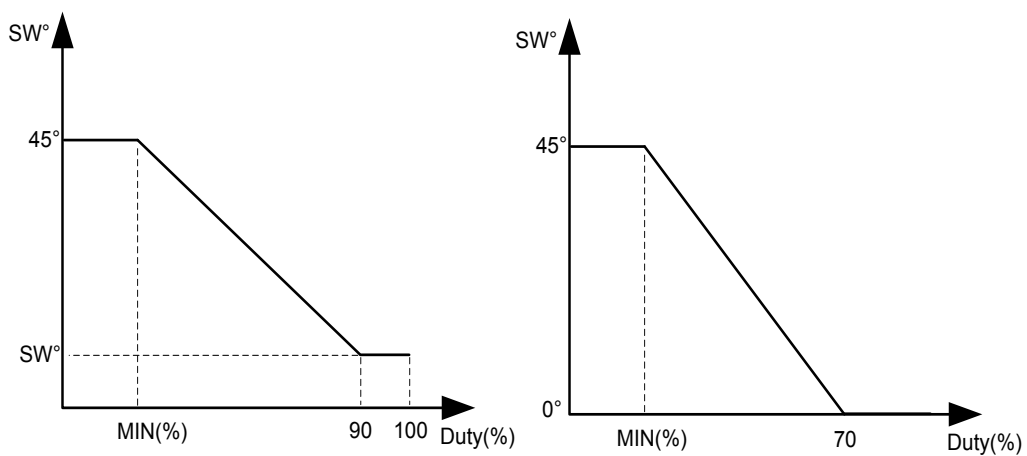


Figure 11: Soft Switching degree with output duty relation

Function Description (Cont.)

Phase Delay

The PD(Phase Delay) pin contain of multi function by input voltage setting. In this pin, the primary function is setting PD (Phase Delay) pin degree at output duty equal to minimum output duty and the secondary function is auto lead angle feature. In addition, with the output duty drop the Output phase delay decreases to the V_{PD} set up degree. It can set up voltage range and phase delay degree with output duty relation following the figure and table.

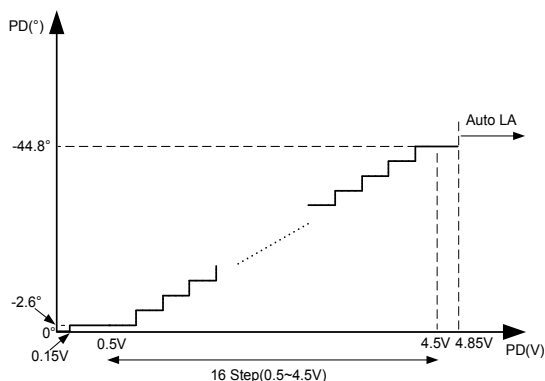


Figure 12: Phase Delay Voltage Setting Range

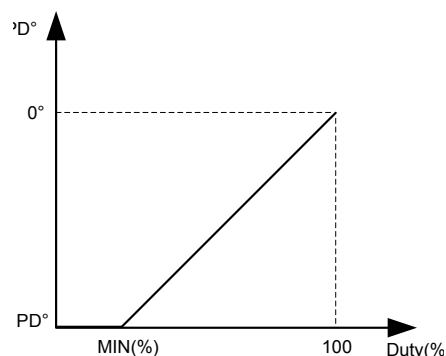


Figure 13: Phase Delay degree with output duty relation

Table8. Phase Delay Setting Range

Step	V_{PD} (V)	PD(°)
	>4.85	Auto LA
16	4.38	-44.8
15	4.14	-42
14	3.89	-39.2
13	3.64	-36.4
12	3.39	-33.6
11	3.14	-30.8
10	2.88	-28
9	2.63	-25.1
8	2.38	-22.3
7	2.13	-19.5
6	1.88	-16.7
5	1.63	-13.9
4	1.38	-11.1
3	1.13	-8.3
2	0.88	-5.4
1	0.63	-2.6
	<0.15	0

Function Description (Cont.)

Lead Angle High and Lead Angle Low

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

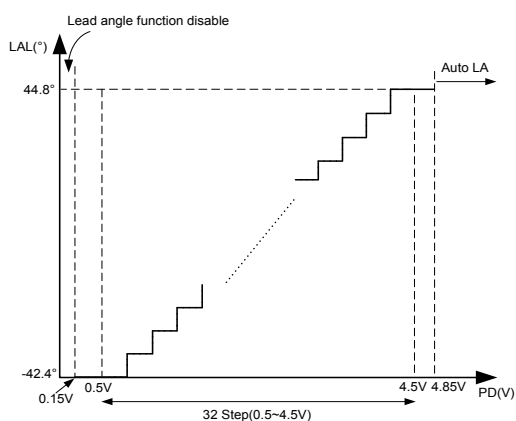


Figure 14: Lead Angle Low Voltage Setting Range

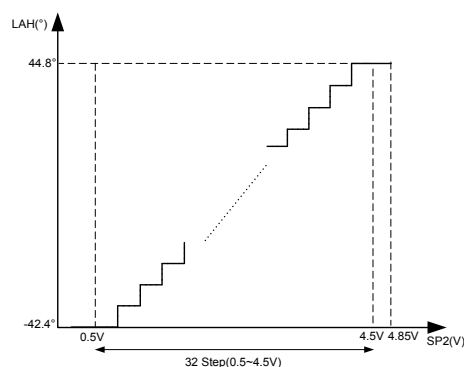


Figure 15: Lead Angle High Voltage Setting Range

Table9. Lead Angle Low Setting Range

Step	V_{PD} (V)	LAL($^{\circ}$)	Step	V_{PD} (V)	LAL($^{\circ}$)
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	lead angle disable	17	2.56	2.6

Function Description (Cont.)

Lead Angle High and Lead Angle Low (Cont.)

Table10. Lead Angle High Setting Range

Step	V _{SP2} (V)	LAH(°)	Step	V _{SP2} (V)	LAH(°)
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

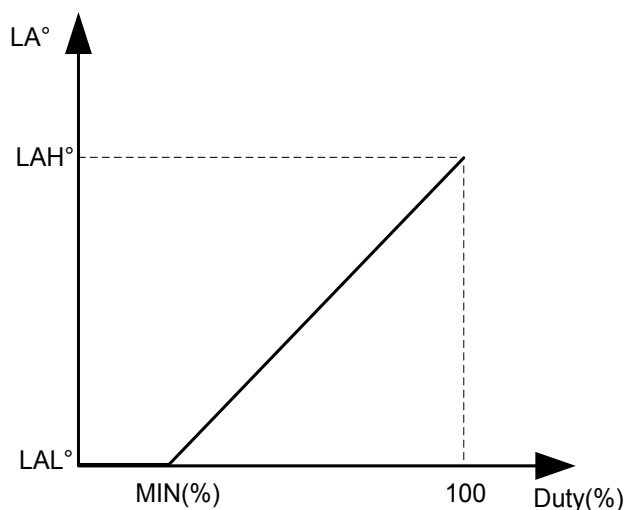


Figure 16: Lead Angle degree with output duty relation

Function Description (Cont.)

Auto Lead Angle

If the PD pin connect to 5VREG, the PD 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.

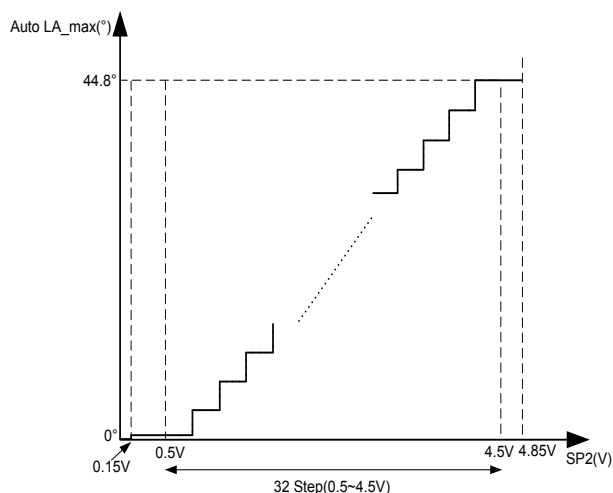


Figure 17: Auto Lead Angle Maximum Lead Angle Voltage Setting Range

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

Function Description (Cont.)

Dead Time

The APX9230 dead time(off side) degree divided into two types. The first type of dead time is fixed 15o 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 adjust. It detect the coil current to decide the dead time decrease or increase in motor commutation .

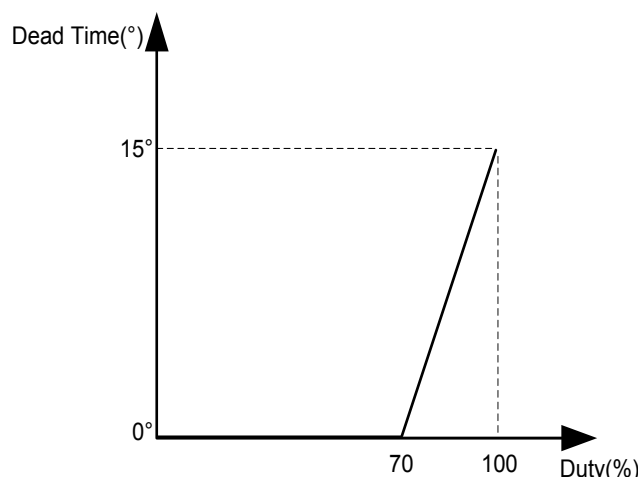


Figure 18: Dead Time(off side) degree with output duty relation

Current Limit

The APX9230 includes an internal current sense circuits for current limit. When the total current of output over the current limit level (2.5A), the high side driver will be turned off to stop supplying current to the motor until $I_{OUT} < 2.5A$ or re-power on. At Start up, the current limit level will decrease to 1.3A.

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 APX9230 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}) is defines the time of output duty from 0% to 100%. Following the table12. to set T_{SS2} time.

Table12. 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 figure20 to calculate shutdown time and restart time.

$$\text{Restart Time Of } T_{ON_SS1} = T_{SS1} \times \frac{D_{SS} - 20}{D_{SS} - 40} (s)$$

Restart Time Of T_{ON_SS2} reference the figure 20.

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

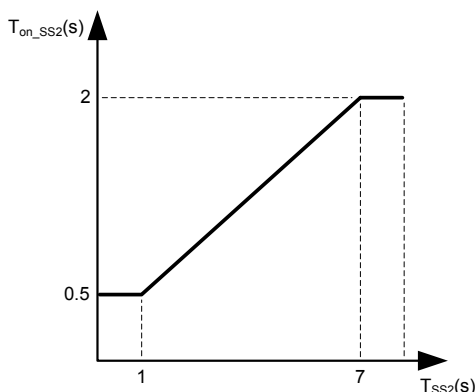
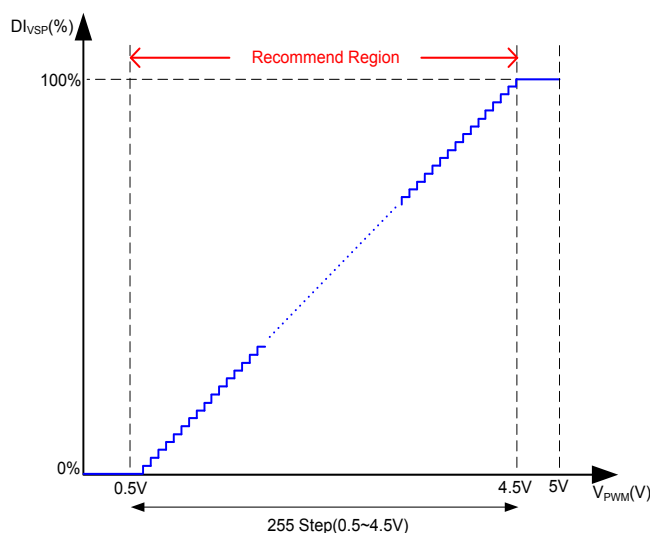


Figure20: T_{ON_SS2} V.S. T_{SS2}

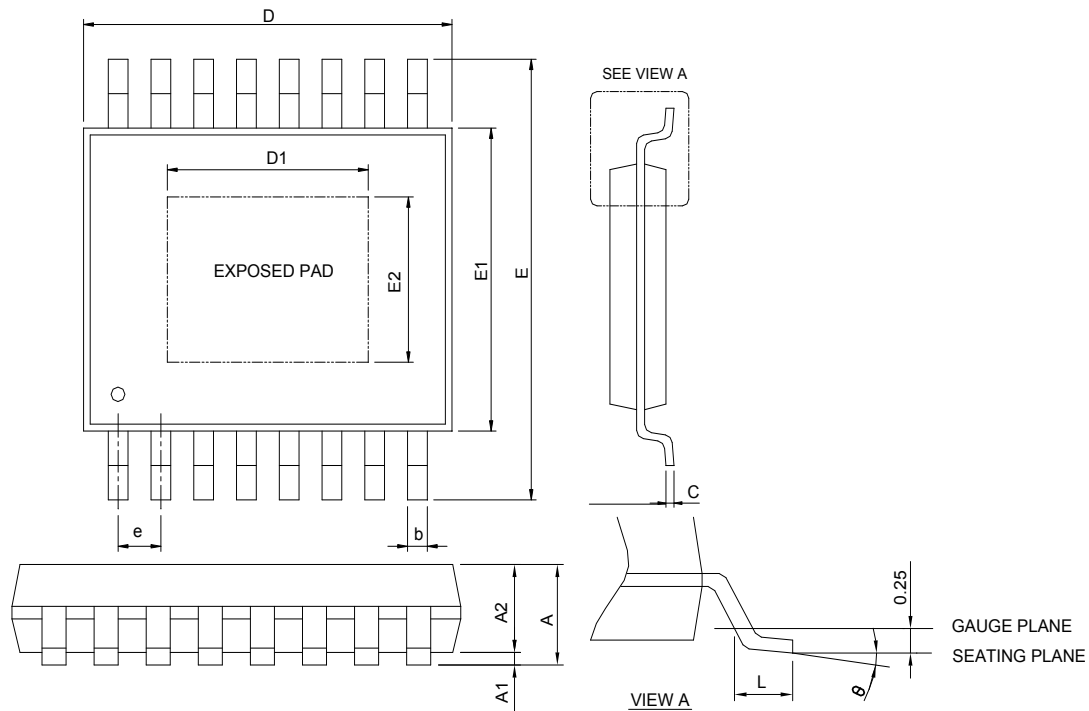
VSP Mode

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

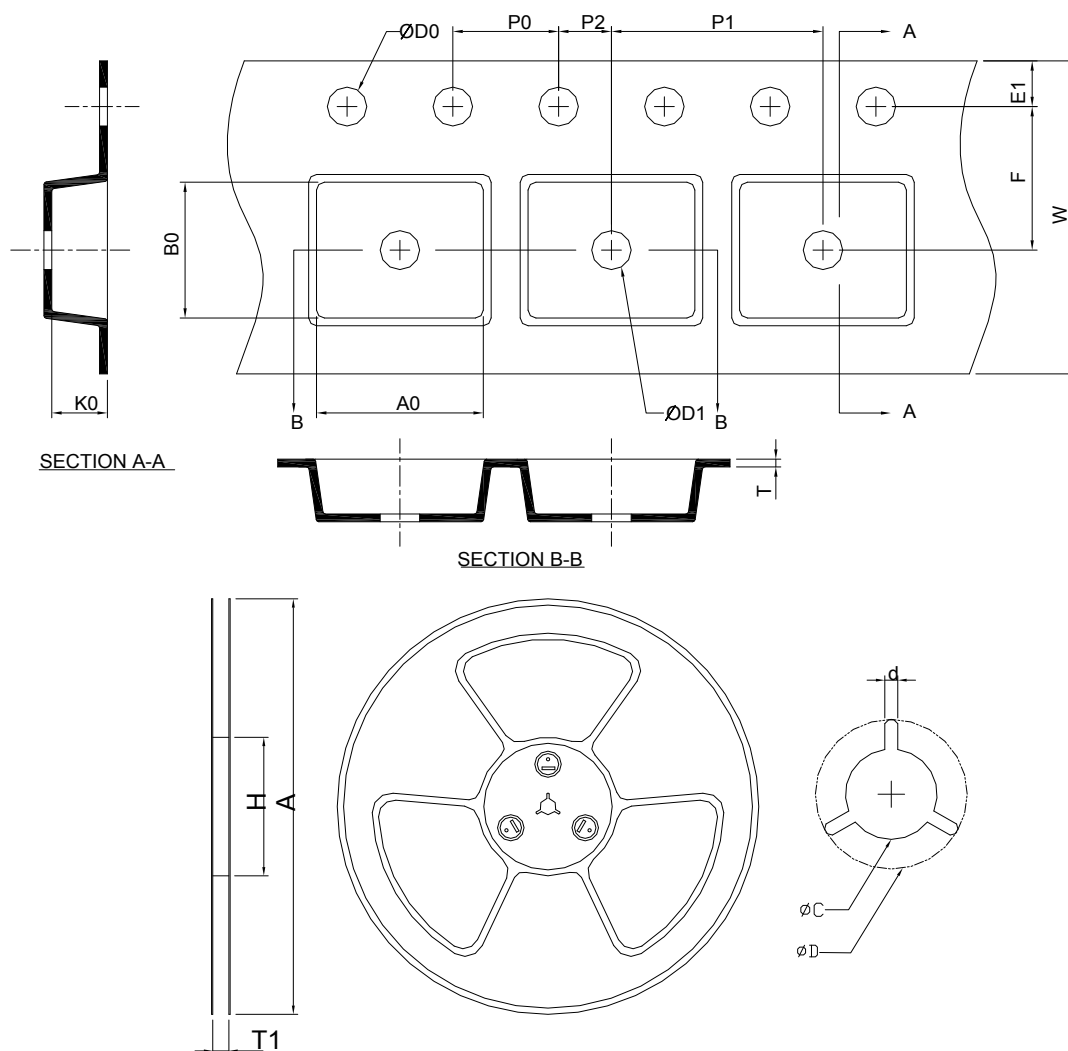
TSSOP-16P



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	6.9±0.20	5.40±0.20	1.60±0.20

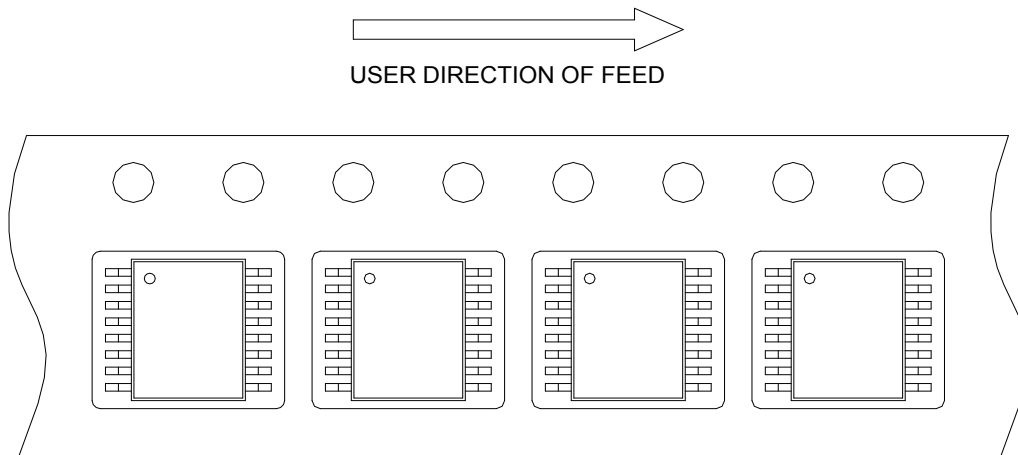
(mm)

Devices Per Unit

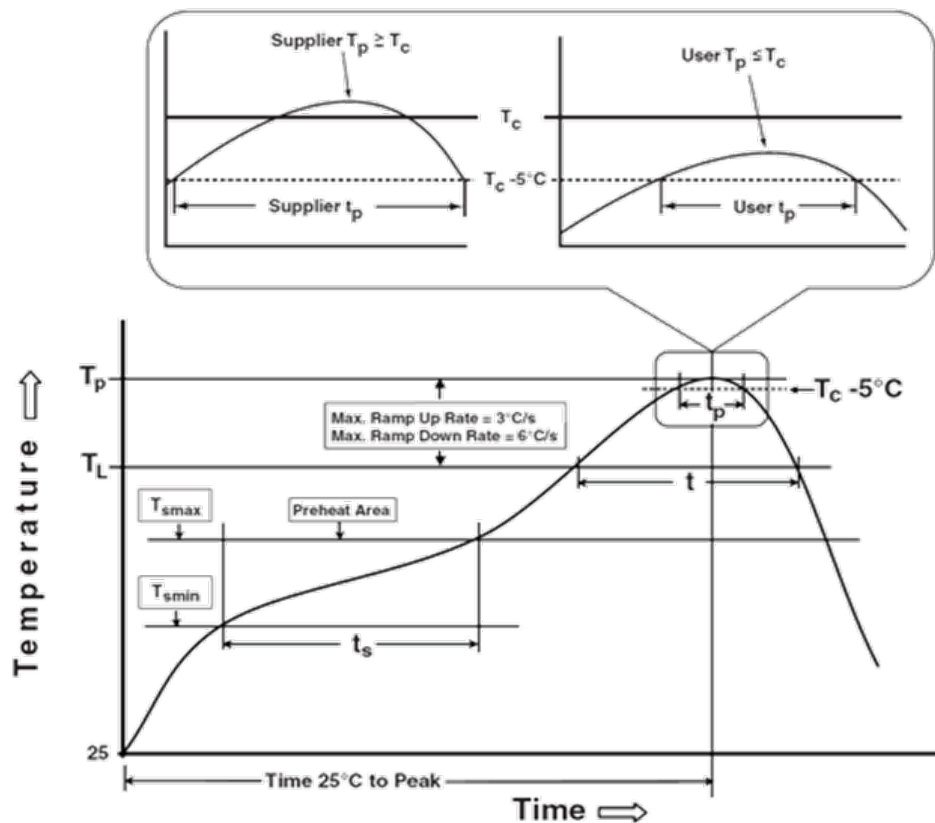
Application	Unit	Quantity
TSSOP-16P	Tape & Reel	2500

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°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, I_{tr} ≥ 100mA

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