APX9710

Single-Phase Full-Wave Motor Driver with Built-in Hall Sensor

Features

- **On-chip Hall Sensor**
- **OTP (2 banks) for function programming**
- **High Sensitivity Hall Effect Sensor IC: ±15G (Typ.)**
- **Speed Controllable by PWM Input signal**
- **FG/RD Output**
- **Built-in Speed Curve setting**
- **Built-in Phase-shift Angle setting (LA)**
- **Built-in PWM Soft-Switch setting (SW)**
- **Built-in Auto-Off control**
- **Built-in Soft Start & Duty change slope setting**
- **Built-in Current Limit level setting**
- **Built-in Lock Protection and Auto Restart Function**

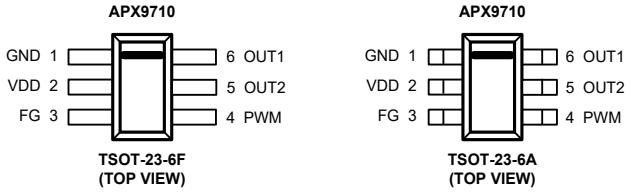
Applications

- **Brushless DC Fans**
- **Brushless DC Motors**

General Description

The APX9710 is an integrated Hall Effect Sensor IC designed for electric commutation of single-phase DC brushless motor applications. The device cat set speed curve, signal output type (FG/RD), soft start, current limit, lock protection and the parameters of output phase change. Using digital programming (OTP x 2 Bank), it's much easier and adjustable for applications. It is also with thermal shutdown protection function. The APX9710 is available in low cost TSOT-23-6 packages.

Pin Configuration



Ordering and Marking Information

APX9710 - □□□□□□ - □□□ Assembly Material Handling Code Temperature Range Package Code Source Code	Package Code CE : TSOT-23-6F CT : TSOT-23-6A Operating Ambient Temperature Range I : -40 to 105 ℃ Handling Code TR : Tape & Reel Assembly Material G : Green Part
APX9710 - XXX CE/CT : X10X XXX	1st line: The last X is referred as Date Code 2nd line: OTP Source Code
APX9710 CE/CT : X10X	1st line: The last X is referred as Date Code 2nd line: OTP Blank

Note: ANPEC's green product compliant RoHS and Halogen free.

Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Rating	Unit
V_{DD}	VDD Pin Supply Voltage (VDD 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 Current	1	A
V_{PWM}	PWM Pin Input Voltage	-0.3 to 20	V
I_{FG}	FG Pin Output Sink Current	10	mA
	FG Pin Output Voltage	-0.3 to 20	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 beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Thermal Characteristics

Symbol	Parameter	Typical Value	Unit
$R_{TH,JA}$	Thermal Resistance-Junction to Ambient (Note2) TSOT-23-6F TSOT-23-6A	156.25	°C/W
P_D	Power Dissipation, T_A=25°C TSOT-23-6F TSOT-23-6A	800	mW

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_{DD}	VDD Supply Voltage	3.5 to 16	V
V_{PWM}	PWM Pin Input Voltage	0 to V_{DD}	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_{DD}=12V, unless otherwise noted)

Symbol	Parameter	Test Condition	APX9710			Unit
			Min.	Typ.	Max.	
SUPPLY VOLTAGE						
I_{DD1}	VDD Supply Current	V_{DD}=12V, no load	-	5	7	mA
I_{DD2}	VDD Standby Current	V_{DD}=12V, PWM=0V in SD mode	-	600	800	μA
OUTPUTDRIVERS						
V_O	Output Driver Saturation Voltage	I_{OUT}=400mA, Upper and Lower total	-	0.35	0.525	V
V_{FG}	FG Pin Low Voltage	I_{FG}=5mA	-	0.1	0.3	V
I_{FGL}	FG Pin Off Leakage Current	V_{FG}=12V	-	<0.1	1	μA
PWM CONTROL						
V_{PWMH}	Pulse Mode PWM Input High Level Voltage		2	-	VDD	V
V_{PWML}	Pulse Mode PWM Input Low Level Voltage		-0.3	-	0.8	V
I_{PWML}	PWM Low Input Current	V_{PWM}=0V	-150	-250	-350	μA
F_{PWM}	PWM Input Frequency		0.5	-	50	kHz
F_{OUT}	Output PWM Switch Frequency	OTP setting	-	32/64	-	kHz
DI_{SP1}	PWM Input Duty Threshold for SD or MIN	Duty falling, OTP setting	5	-	50	%
	PWM Input Duty Hysteresis of SD	Duty falling, SD mode	-	1.6	-	%
DO_{MID}	Output Duty in middle between SP1 and SP2	OTP setting	0	-	100	%
DI_{SP2}	PWM Input Duty Threshold for 100% output	Duty rising, OTP setting	75	-	100	%
DO_{SP2}	Output Duty for PWM=100%	PWM=100%, OTP setting	75	-	100	%
T_{DCH}	Duty Change Time for output duty 0% to 100%	OTP setting	-	0/2	-	sec
T_{DCL}	Duty Change Time for output duty 100% to 0%	OTP setting	-	2/4	-	sec
SOFT START						
T_{DCSS}	Duty Change Time for Soft Start (0% to 100%)	OTP setting	-	0/3/6/8	-	sec
D_{ST}	Start up Initial Duty	OTP setting	-	30/50/70/100	-	%
LOCK PROTECTION						
T_{ON}	Lock Detection On Time	OTP setting	-	0.7/1	-	sec
T_{OFF}	Lock Detection Off Time	OTP setting	-	0(disable)/7	-	sec
T_{QS}	Quick Start Enable Time	PWM low to disable lock mode	-	66.5	-	ms
CURRENT LIMIT						
I_{LIM}	Current Limit Trigger Level	OTP setting	-	450/650/800/900	-	mA
THERMAL PROTECTION						
OTS	Over Temperature Shutdown Threshold		-	170	-	°C
	Over Temperature Shutdown Hysteresis		-	30	-	°C
	Over Temperature Shutdown Release Time		-	4	-	sec

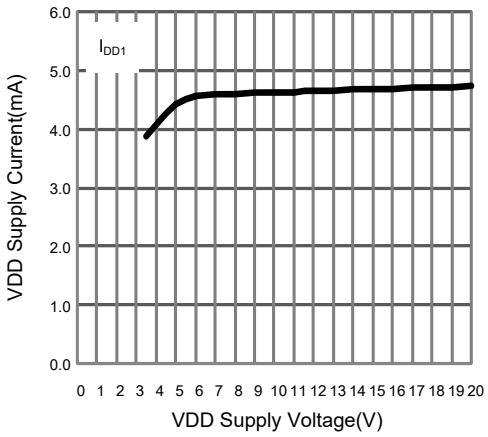
Magnetic Characteristics (T_A=25°C, V_{DD}=12V, unless otherwise noted)

Symbol	Parameter	Test Condition	APX9710			Unit
			Min.	Typ.	Max.	
Bop	Magnetic Operation Point		5	15	30	Gauss
Brp	Magnetic Release Point		-30	-15	-5	Gauss
Bhys	Magnetic Hysteresis		-	30	-	Gauss

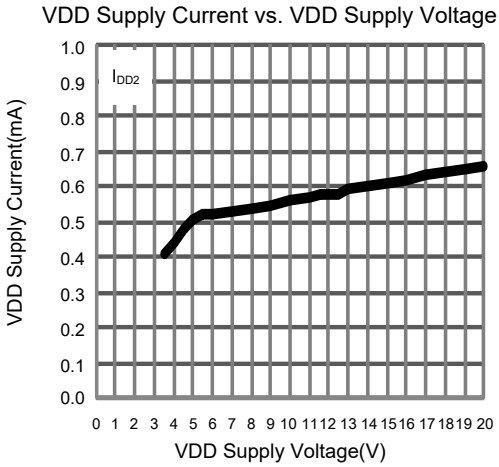
Note 3: For start up only.

Typical Operating Characteristics

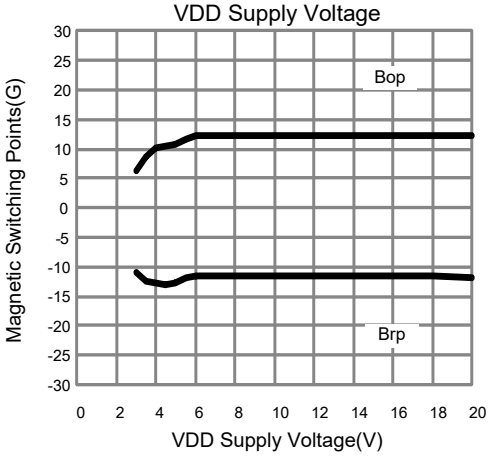
VDD Supply Current vs. VDD Supply Voltage



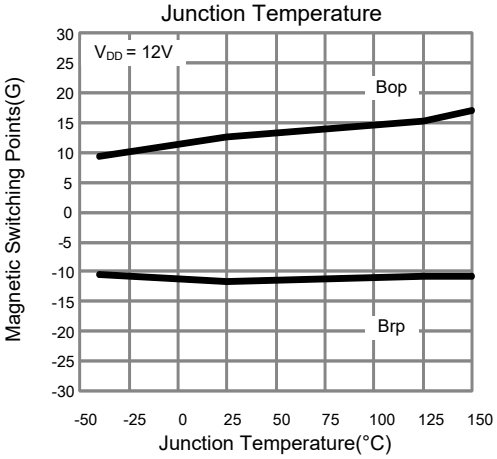
VDD Supply Current vs. VDD Supply Voltage



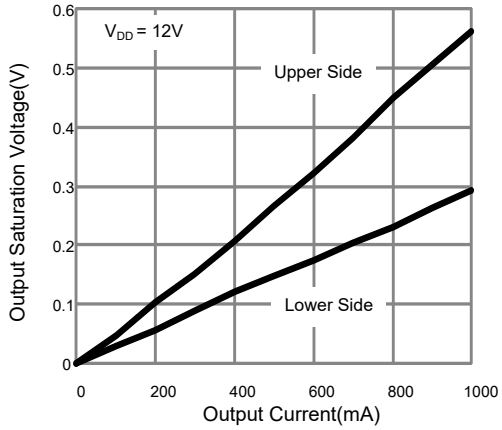
Magnetic Switching Points vs. VDD Supply Voltage



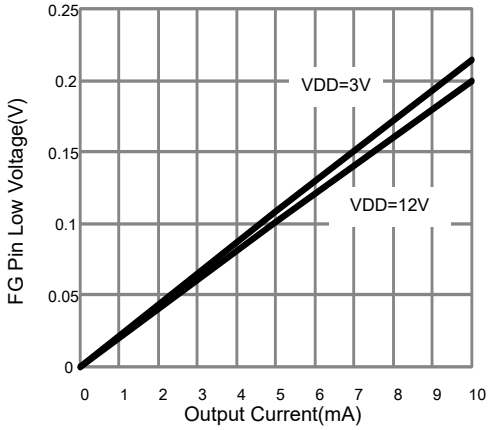
Magnetic Switching Points vs. Junction Temperature



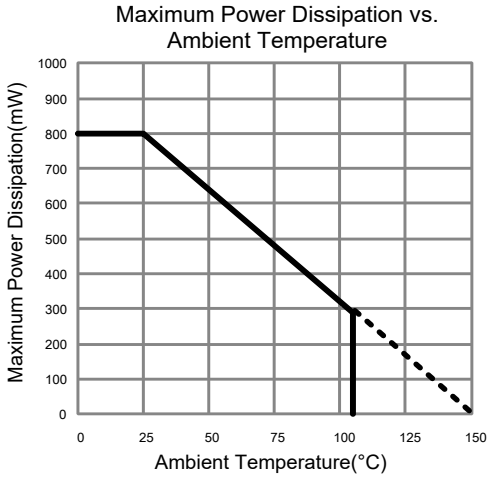
Output Saturation Voltage vs. Output Current



FG Pin Low Voltage vs.Sink Current



Typical Operating Characteristics (Cont.)

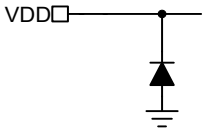


Pin Descriptions

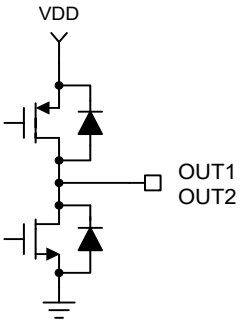
PIN		Function
NO.	NAME	
1	GND	Ground of the IC.
2	VDD	Supply Voltage Input.
3	SO	Rotation Speed or Detection Output. This is an open-drain output.
4	PWM	PWM Signal Input Terminal.
5	OUT2	H-bridge output connection.
6	OUT1	H-bridge output connection.

I/O Equivalent Circuits

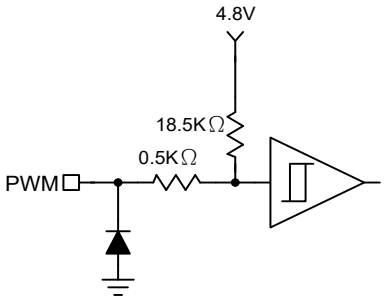
(1) Power supply input pin (VDD)



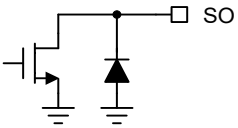
(2) Driver output pin (OUT1, OUT2)



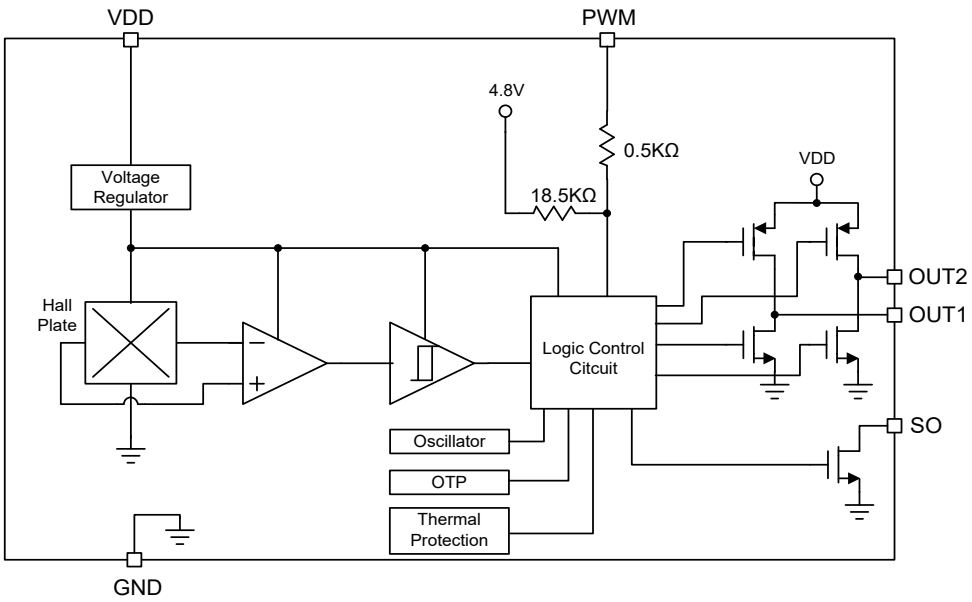
(3) PWM speed control input pin (PWM)



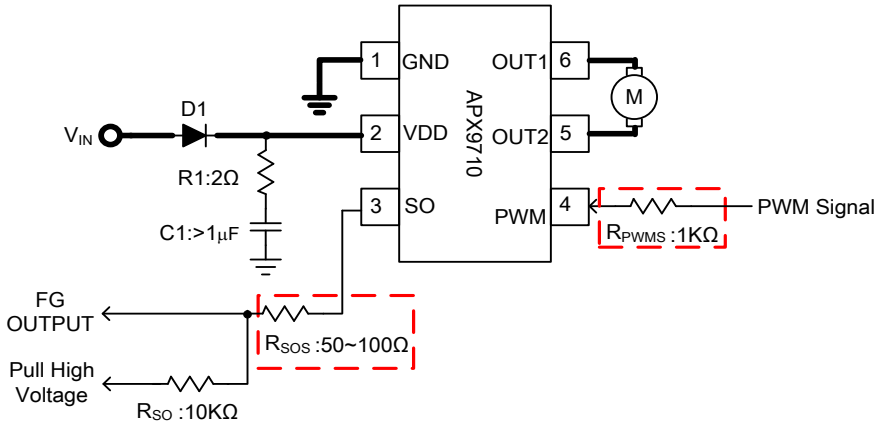
(4) Rotation speed output pin (SO)



Block Diagram



Typical Application Circuits

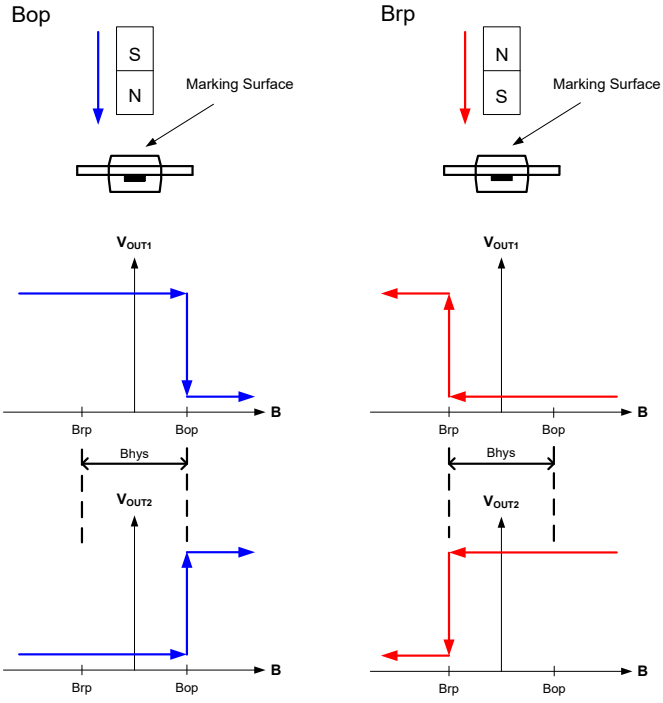


Note: R_{PWMS} and R_{SOS} are optional to protect internal circuit for abnormal voltage stress.

Function Description

Output Switch Principle

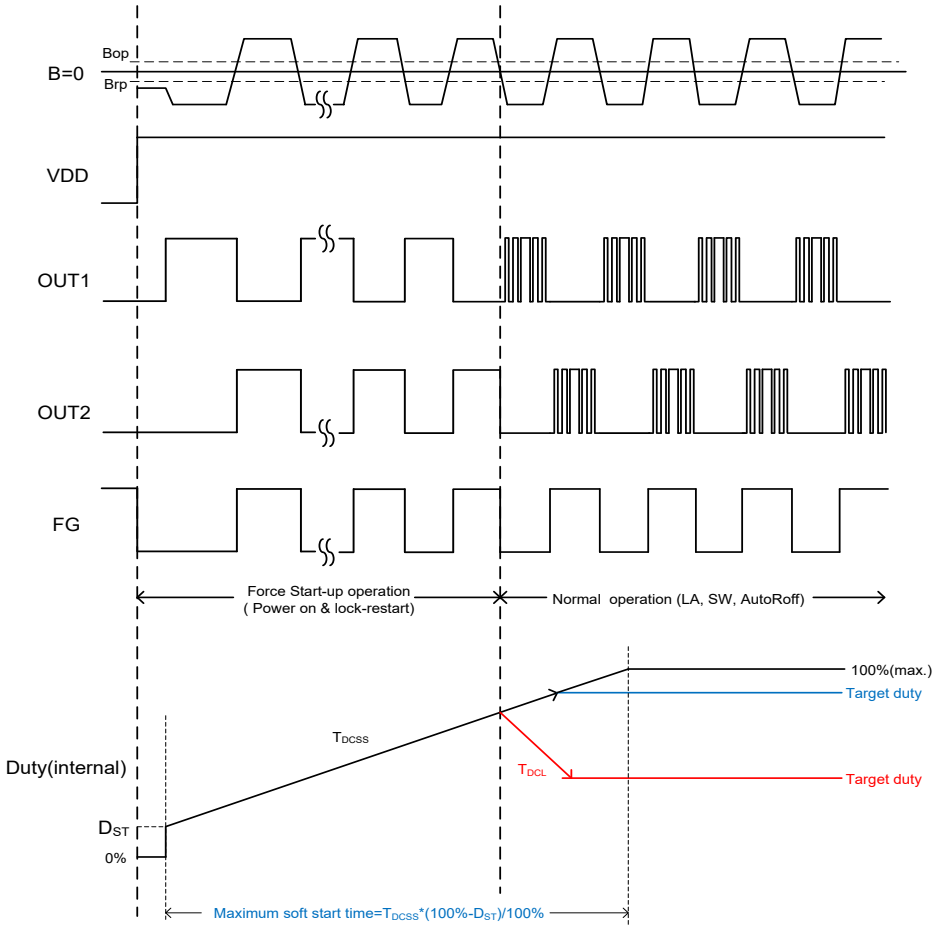
The APX9710 built in a Hall-effect sensor plate to sense the vertical magnetic flux density (B). There are two output drivers in APX9710 to drive single-phase DC brushless motor. When the N pole magnetic field close to the IC marking surface and the magnetic flux density higher than operate point (Bop), the OUT1 pin output will turn to LOW and the OUT2 pin output will turn to HIGH. When the N pole magnetic field far away the IC marking surface and S pole magnetic field close to the IC marking surface until the magnetic flux density higher than release point (Brp), the OUT1 pin output will turn to HIGH and the OUT2 pin output will turn to LOW. In addition, the output logic can be set to reverse by OTP programming.



Function Description (Cont.)

Soft Start & Normal Operation

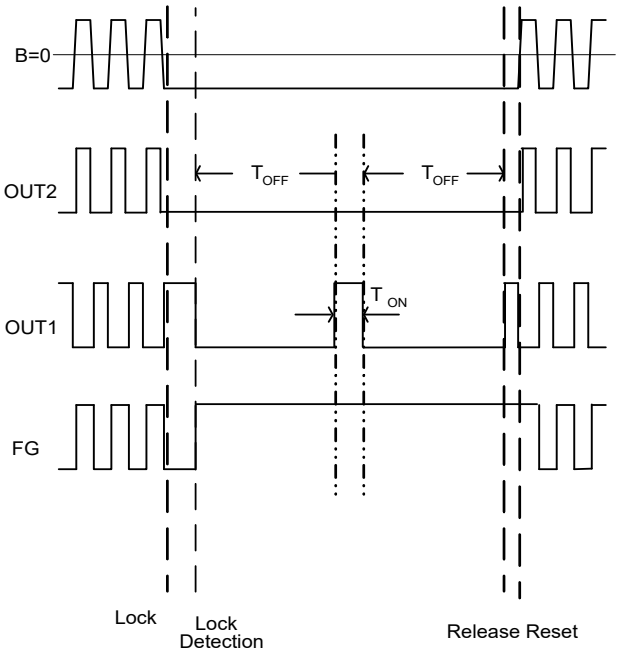
The APX9710 built in PWM soft-switch, phase-shift and Auto-Off output control circuits to improve the vibration and noise of fan motor operation. At start-up operation, the APX9710 drive the output driver by square wave to force the fan motor start to rotate. After several square wave outputs (start ok), the setting of internal PWM control circuits will be enable to drive fan motor to improve vibration and noise.



Function Description (Cont.)

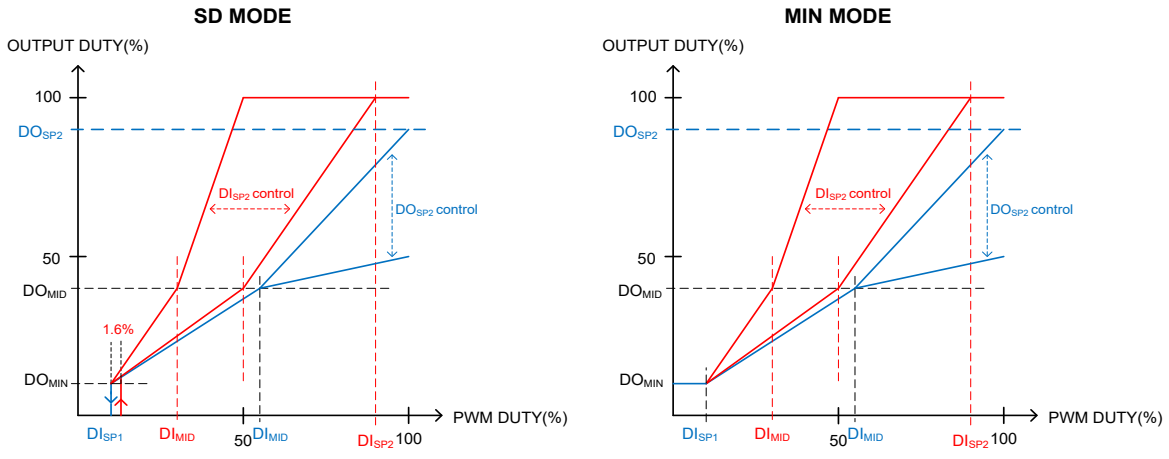
Lockup Protection and Automatic Restart

The APX9710 detects the rotation of the motor by internal hall sensor signal, and adjusts lock detection ON time (T_{ON}) and lock detection OFF time (T_{OFF}) by internal counter. The OTP banks embedded in APX9710 can set the T_{ON}, T_{OFF} or to disable lock protection function.



Speed Control by Direct PWM Input Signal

Applying PWM pulses to the PWM pin directly, the duty cycle of PWM pulses will control the output driver ON duty that follow the duty control curve setting by OTP. The OTP banks embedded in APX9710 has three points for minimum, maximum and middle input/output duty setting.

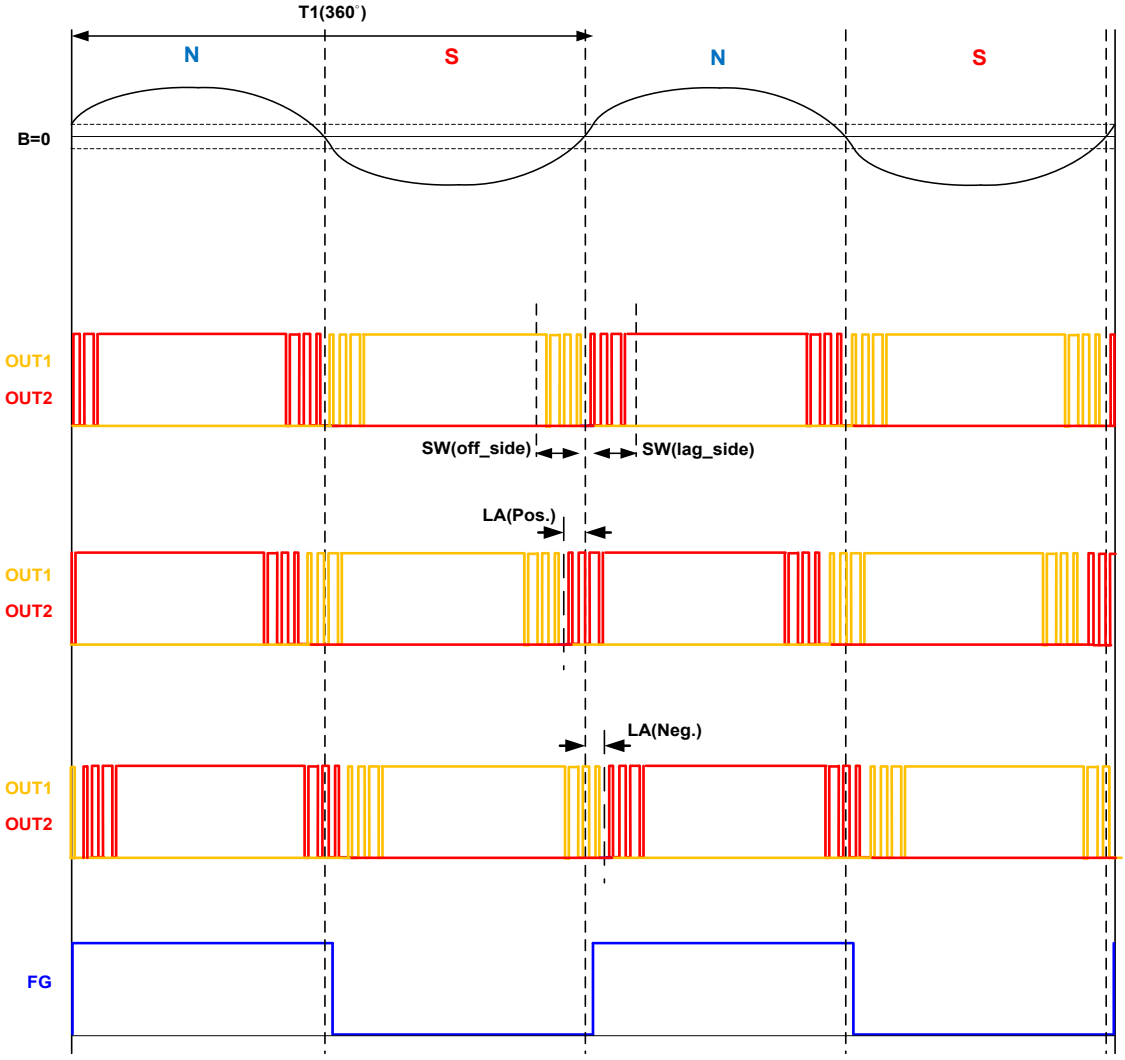


Note:
DI_{SP2} and DO_{SP2} can't set at the same time.
$DI_{MID}=DI_{SP1}+(100\%-DI_{SP1})/2$ in DO_{SP2} control
$DI_{MID}=DI_{SP1}+(DI_{SP2}-DI_{SP1})/2$ in DI_{SP2} control

Function Description (Cont.)

PWM Soft-Switch (SW) & Phase-shift Angle (LA)

The soft-switch and phase-shift angle functions can provide the designer to optimize the current of coil for lower noise and higher efficiency when fan motor operation.

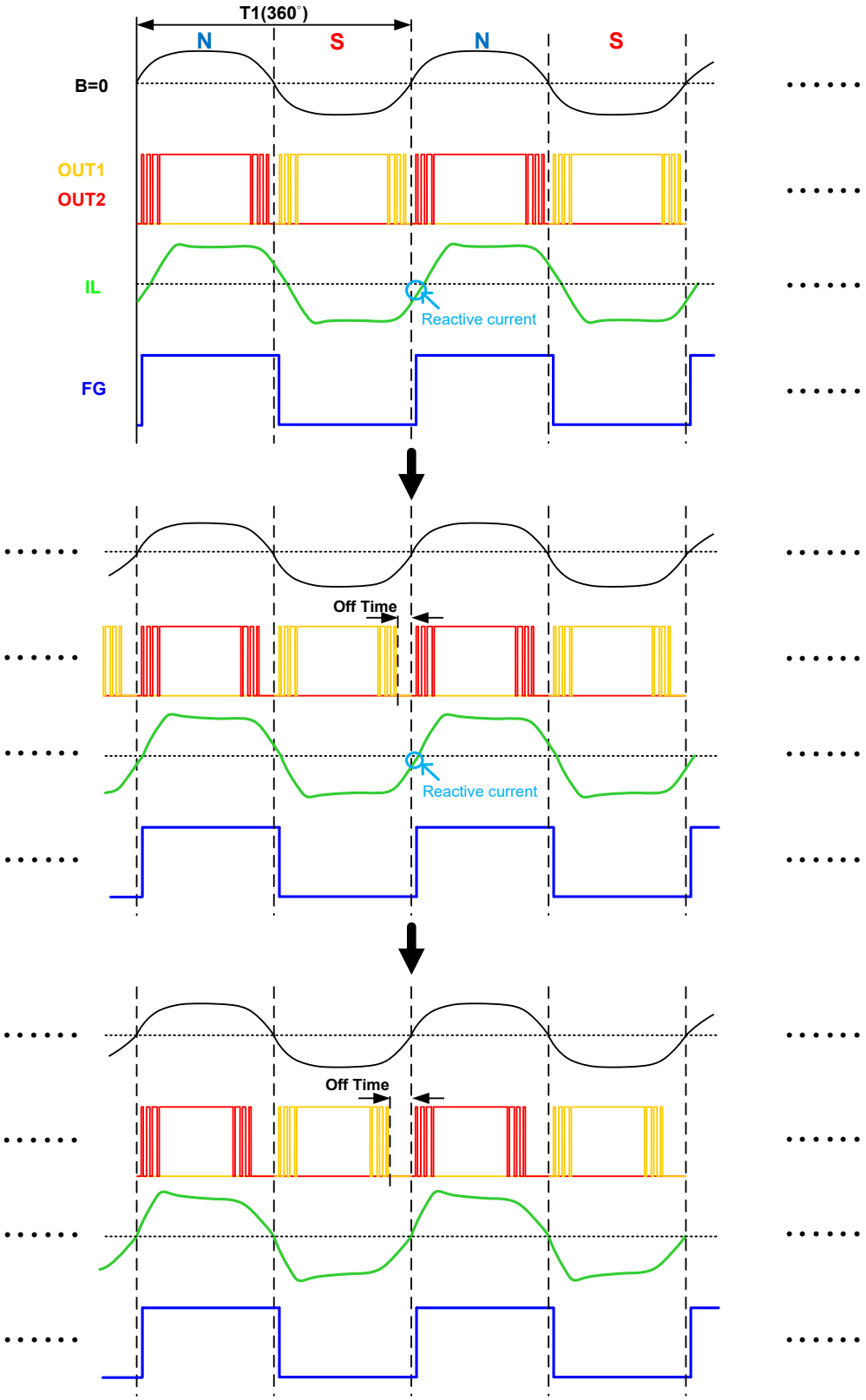


Note:
LA setting range is -5.5° ~ +15.1°.
SW(off_side) setting range is 0° ~ 90°.
SW(lag_side) setting range is 0° ~ 90°.
The angles of LA and SW setting are constant in any rotation state.

Function Description (Cont.)

Auto-Off

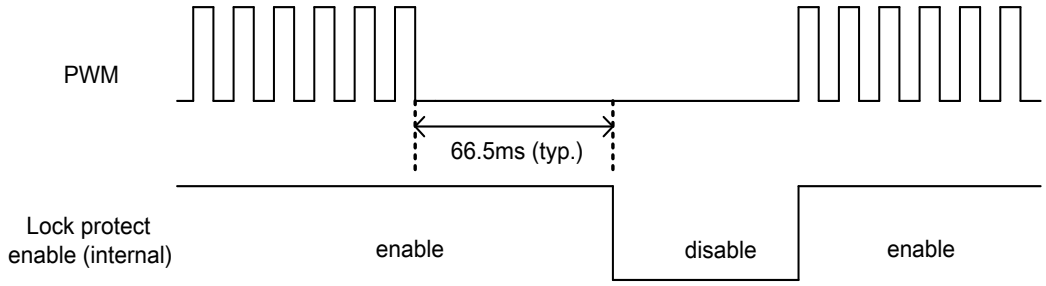
Since the motor is inductive load, the reactive current may store in the coil during normal output phase change. The reactive current will cause more power loss on power MOS or other clamp devices. The reactive current even causes acoustic noise at motor. The APX9710 built in auto-off function to reduce reactive current through increase off time gradually during output phase change. The maximum off time in auto-off mode is 22.5° of electrical angle.



Function Description (Cont.)

Quick Start (SD mode only)

This IC would enter quick start mode when the PWM input keeps low level more than 66.5m (typ.). In quick start mode, it will shutdown amplifier, SO and disable the lock protection function, therefore, the fan start up immediately when PWM input duty lager than DI_{SP1}+1.6%.



Truth Table (Forward)

Input		Output			Mode
B	DUTY	OUT1	OUT2	FG	
Bop	H	L	H	OFF	Operation Mode
Brp		H	L	L	
Bop	L	L	L	OFF	
Brp		L	L	L	
Bop	-	L	L	OFF	Lock Mode
Brp		L	L	OFF	
-	L	OFF	OFF	OFF	Shut Down Mode

Application Information

Input Protection Diode & Capacitor

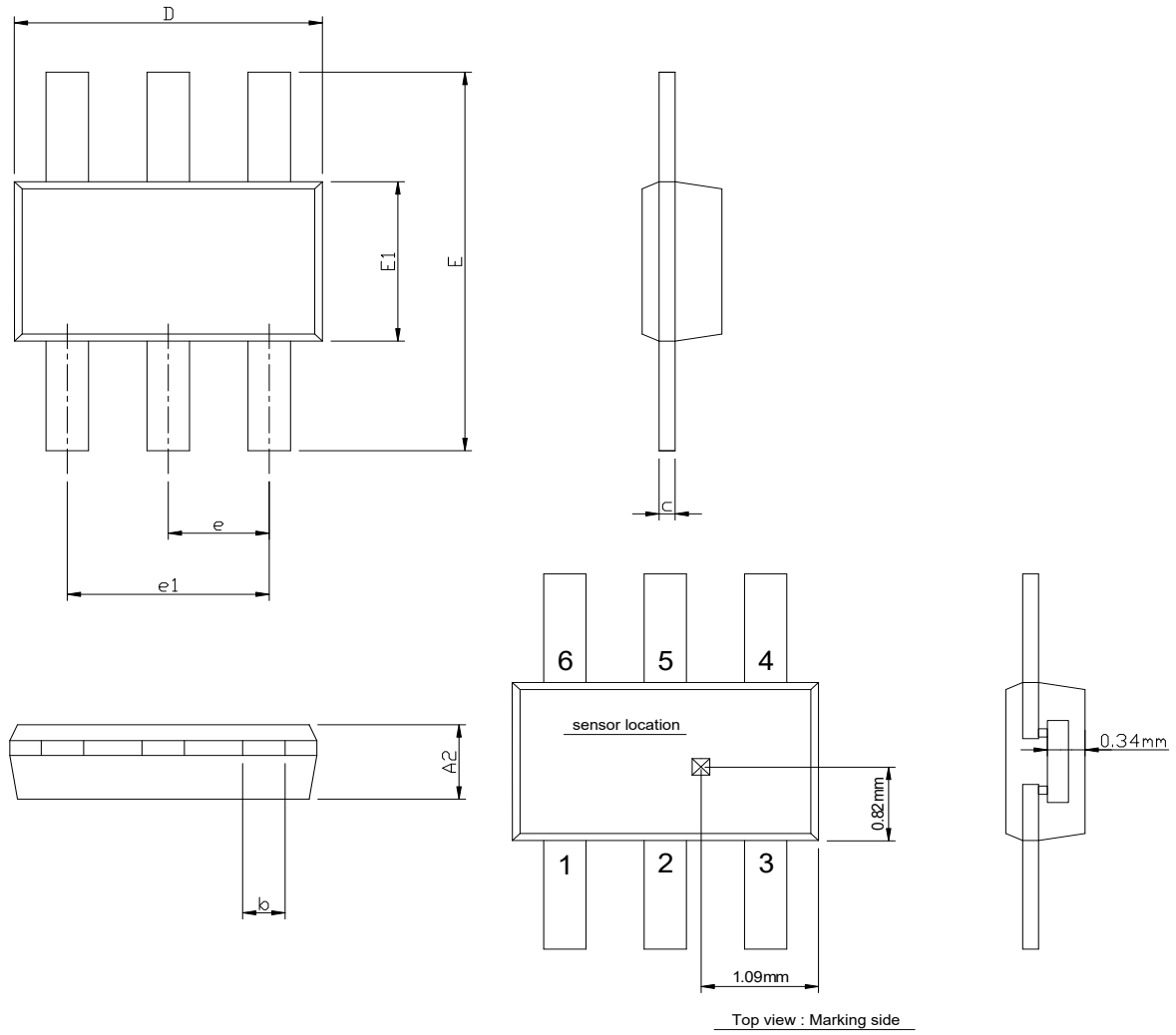
The IC should be added a protection diode (D1) to prevent the damage from the power reverse connection. However, the protection diode will cause a voltage drop on the supply voltage. The current rating of the diode must be greater than the maximum output current. For the noise reduction purpose, a capacitor (C1) must connect between VDD and GND. It is the suggestion that C1 should be placed as close as possible to the device VDD pin.

Current Limit

The APX9710 can select one of four current limit trigger levels through OTP programming. The output current rise rate depends on coil inductance and DCR (direct current resistor). When the coil current is lager and high rise rate, the output current will have more overshoot at lower current limit level setting. In this condition, the higher current limit level will be suggested to select.

Package Information

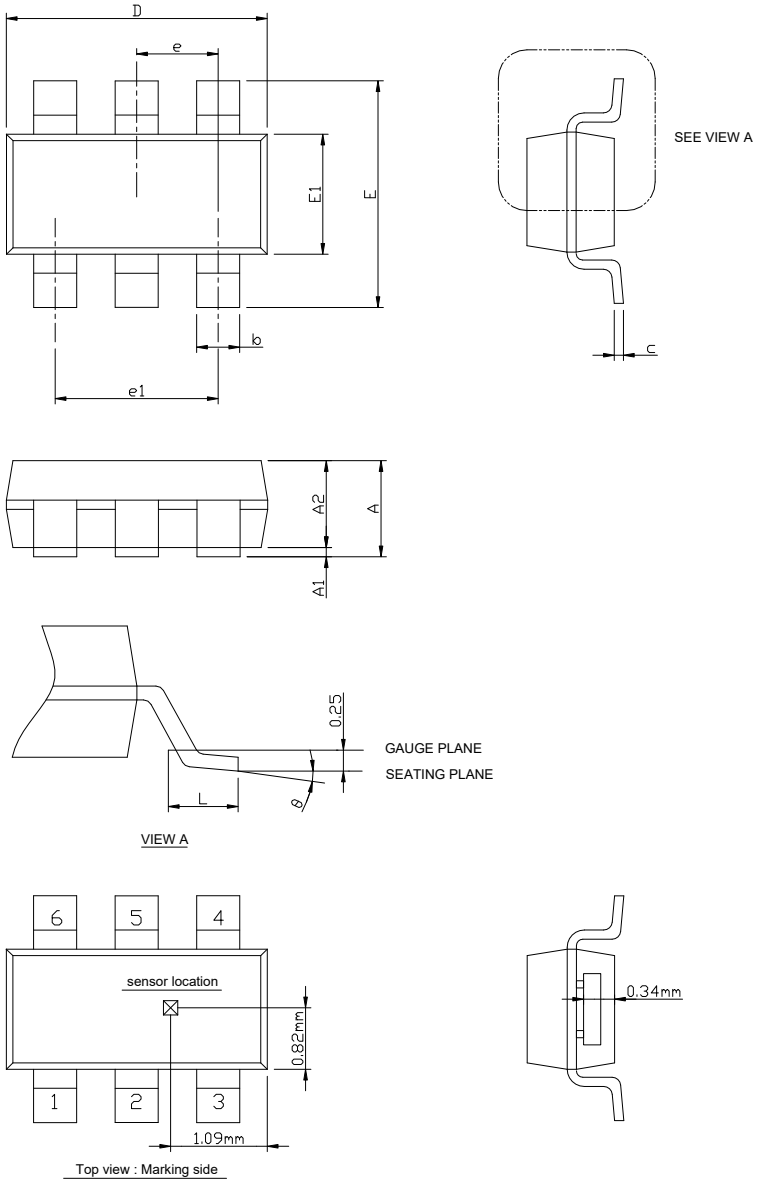
TSOT-23-6F



SYMBOL	TSOT-23-6F			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A2	0.70	1.00	0.028	0.039
b	0.30	0.50	0.012	0.020
c	0.08	0.22	0.003	0.009
D	2.80	3.00	0.110	0.118
E	3.70	3.90	0.146	0.154
E1	1.50	1.70	0.059	0.067
e	0.95 BSC		0.037 BSC	
e1	1.90 BSC		0.075 BSC	

Package Information

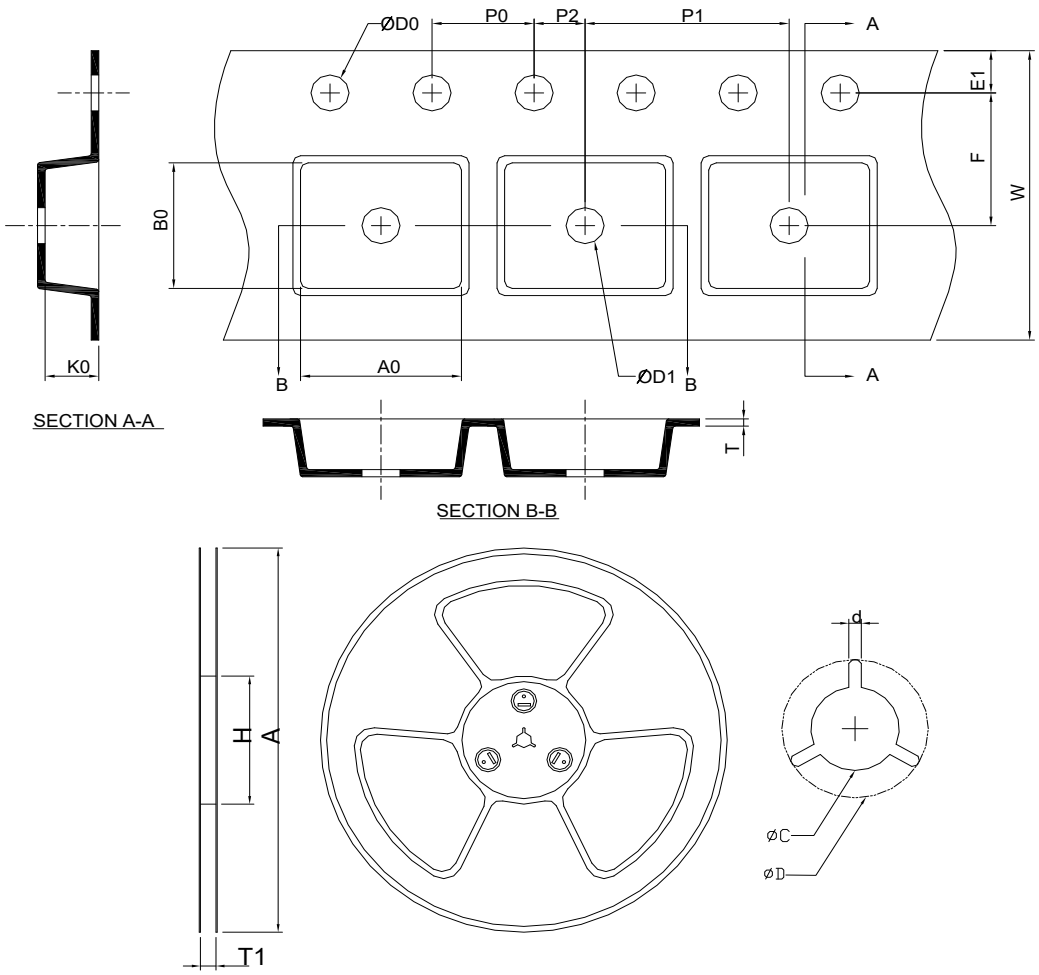
TSOT-23-6A



SYMBOL	TSOT-23-6A			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.70	1.00	0.028	0.039
A1	0.01	0.10	0.000	0.004
A2	0.70	0.90	0.028	0.035
b	0.30	0.50	0.012	0.020
c	0.08	0.20	0.003	0.008
D	2.70	3.10	0.106	0.122
E	2.60	3.00	0.102	0.118
E1	1.40	1.80	0.055	0.071
e	0.95 BSC		0.037 BSC	
e1	1.90 BSC		0.075 BSC	
L	0.30	0.60	0.012	0.024
θ	0°	8°	0°	8°

Note : 1. Followed from JEDEC TO-178 AB.
2. Dimension D and E1 do not include mold flash, protrusions or gate burrs. Mold flash, protrusion or gate burrs shall not exceed 10 mil per side.

Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
TSOT 23-6F	178.0±2.00	50 MIN.	13.2+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±0.10
	P0	**P1**	**P2**	**D0**	**D1**	**T**	**A0**	**B0**	**K0**
	4.0±0.10	4.0±0.10	2.0±0.05	1.5+0.10 -0.00	1.0 MIN.	0.6+0.00 -0.40	3.10±0.20	4.00±0.20	1.15±0.20
Application	**A**	**H**	**T1**	**C**	**d**	**D**	**W**	**E1**	**F**
TSOT 23-6(A)	178.0±2.00	50 MIN.	8.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	8.0±0.30	1.75±0.10	3.5±0.05
	P0	**P1**	**P2**	**D0**	**D1**	**T**	**A0**	**B0**	**K0**
	4.0±0.10	4.0±0.10	2.0±0.05	1.5+0.10 -0.00	1.0 MIN.	0.6+0.00 -0.40	3.20±0.20	3.10±0.20	1.20±0.20

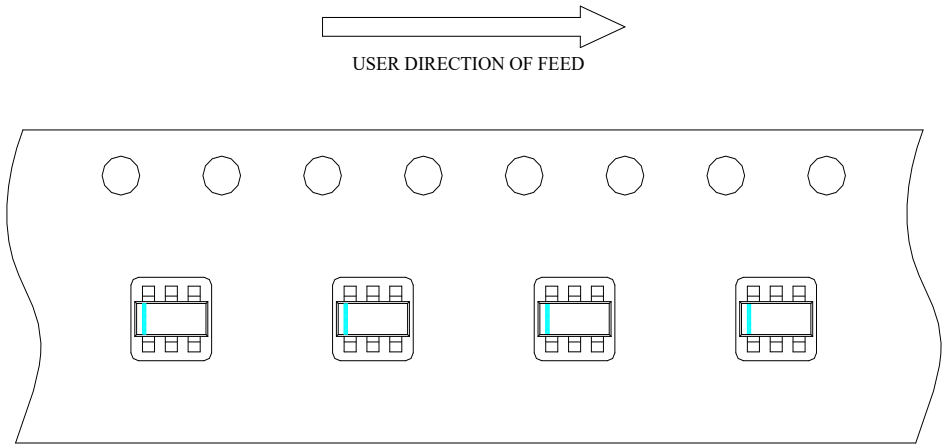
(mm)

Devices Per Unit

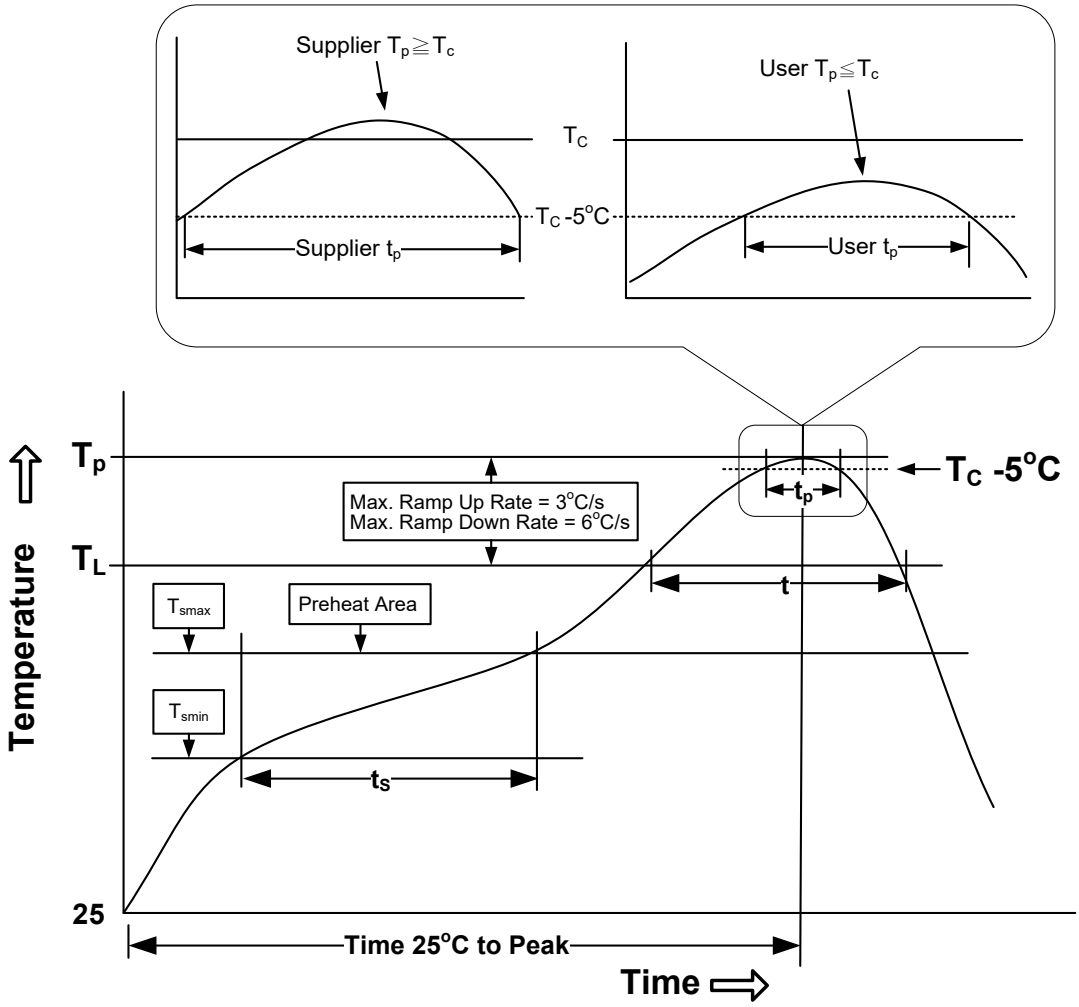
Package type	Packing	Quantity
TSOT-23-6F	Tape & Reel	3000
TSOT-23-6(A)	Tape & Reel	3000

Taping Direction Information

TSOT-23-6F/6A



Classification Profile



Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Preheat & Soak Temperature min (T_{smin}) Temperature max (T_{smax}) Time (T_{smin} to T_{smax}) (t_s)	 100°C 150°C 60-120 seconds	 150°C 200°C 60-120 seconds
Average ramp-up rate (T_{smax} to T_P)	3°C/second max.	3°C/second max.
Liquidous temperature (T_L) Time at liquidous (t_L)	183°C 60-150 seconds	217°C 60-150 seconds
Peak package body Temperature (T_p)*	See Classification Temp in table 1	See Classification Temp in table 2
Time (t_P)** within 5°C of the specified classification temperature (T_c)	20** seconds	30** seconds
Average ramp-down rate (T_p to T_{smax})	6°C/second max.	6°C/second max.
Time 25°C to peak temperature	6 minutes max.	8 minutes max.
* Tolerance for peak profile Temperature (T_p) is defined as a supplier minimum and a user maximum. ** Tolerance for time at peak profile temperature (t_p) is defined as a supplier minimum and a user maximum.		

Note: ANPEC's green products meet or exceed the lead-free requirements of IPC/JEDEC J-STD-020D for MSL classification at lead-free peak reflow temperature.

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 @ 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 ≧ 8KV
MM	JESD-22, A115	VMM ≧ 400V
Latch-Up	JESD 78	10ms, 1_{tr} ≧ 100mA

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