

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

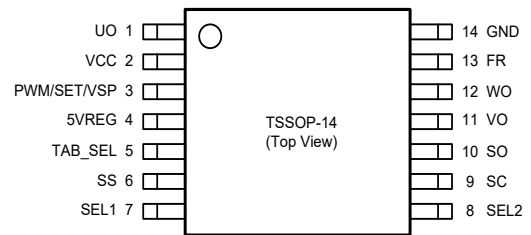
Features

- Three-Phase Full-Wave Sine-Wave Driver
- Sensor-Less driver control
- PWM/SET/VSP Speed Control
- DC Speed Control
- Minimum Speed Setting
- Power Saving Function
- Built-in 5V LDO Regulator
- Built-in Current Limit Circuit
- Built-in Over Current Protection
- Built-in Lock Protection and Auto Restart Function
- Soft Start Function
- FG, 1/2FG, 1/3FG or RD Output
- Rotation Direction Selectable
- Built-in Thermal Shutdown Protection
- Built-in Tailwind Start-Up and Headwind Start-Up

General Description

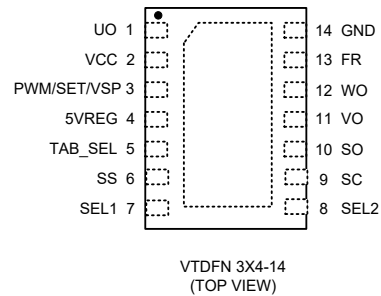
The APX9324A is a three-phase full-wave sine-wave brushless motor drive by sensor-less . This IC built-in linear or direct PWM input speed control, current limit and soft start features suitable for the three-phase brushless DC motors. The APX9324A is available in TSSOP-14 and VTDFN3x4-14 packages (see Pin Configuration).

Pin Configuration

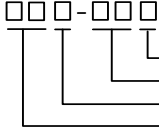


Applications

- Home Appliance Cooling Fan
- Instrumentation Fan



Ordering and Marking Information

<p>APX9324A </p> <p>Assembly Material Handling Code Temperature Range Package Code</p>	<p>Package Code O : TSSOP-14 QF : VTDFN3x4-14 Operating Ambient Temperature Range I : -40 to 105 °C Handling Code TR : Tape & Reel Assembly Material G : Green Part</p>
<p>APX9324A O :</p> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <p>APX9324A XXXXX</p> </div>	<p>XXXXXX - Date Code</p>
<p>APX9324A QF :</p> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <p>APX9324A XXXXX</p> </div>	<p>XXXXXX - Date Code</p>

Note1: ANPEC's green product compliant RoHS and Halogen free.

Absolute Maximum Ratings (Note 2)

Symbol	Parameter	Ratings	Unit
V_{CC}	VCC Pin Supply Voltage (VCC to GND)	-0.3 to 18	V
I_{OUT}	UO, VO, WO Pin Maximum Output Peak Current	2.7	A
$V_{UO, VO, WO}$	UO, VO and WO Pins Output Voltage	$V_{GND}-0.3$ to V_{CC}	V
V_{SEL1}	SEL1 Pins Input Voltage (SEL1 to GND)	-0.3 to 7	V
V_{SEL2}	SEL2 Pin Input Voltage (SEL2 to GND)	-0.3 to 7	V
V_{TAB_SEL}	TAB_SEL Pin Input Voltage (TAB_SEL to SGND)	-0.3 to 7	V
I_{5VREG}	5VREG Pin Output Source Current	0 to 20	mA
V_{SO}	SO Pin Output Voltage	-0.3 to 18	V
I_{SO}	SO Pin Maximum Output Sink Current	10	mA
$V_{PWM/SET/VSP}$	PWM/SET/VSP Pin Input Voltage (PWM/SET/VSP to GND)	-0.3 to VCC	V
T_J	Maximum Junction Temperature	150	°C
T_{STG}	Storage Temperature	-65 to 150	°C
T_{SDR}	Maximum Lead Soldering Temperature, 10 Seconds	260	°C

Note 2: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Thermal Characteristics

Symbol	Parameter	Typical Value	Unit
θ_{JA}	Thermal Resistance-Junction to Ambient ^(Note 3) TSSOP-14 VTDFN3x4-14	147	°C/W
		83	
P_D	Power Dissipation, $T_A=25^\circ\text{C}$ TSSOP-14 VTDFN3x4-14	0.85	W
		1.5	

Note 3: θ_{JA} is measured with the component mounted on a high effective thermal conductivity test board in free air. The exposed pad of TSSOP-14 (VTDFN3x4-14) is soldered directly on the PCB.

Recommended Operating Conditions

Symbol	Parameter	Range	Unit
V_{CC}	VCC Pin Supply Voltage Range	4.5 to 16	V
V_{SEL1}	SEL1 Pins Input Voltage	0 to V_{5VREG}	V
V_{SEL2}	SEL2 Pin Input Voltage	0 to V_{5VREG}	V
V_{FR}	FR Pin Input Voltage	0 to V_{5VREG}	V
V_{TAB_SEL}	TAB_SEL Pin Input Voltage	0 to V_{5VREG}	V
T_A	Ambient Temperature	-40 to 105	°C
T_J	Junction Temperature	-40 to 125	°C

Electrical Characteristics

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

Symbol	Parameter	Test Conditions	APX9324A			Unit
			Min.	Typ.	Max.	
SUPPLY CURRENT						
V_{5VREG}	5VREG Pin Output Voltage	$I_{5VREG}=-5mA$	4.8	5	5.2	V
I_{CC1}	Operating Current	Rotation Mode	3	5	7	mA
I_{CC2}	Operating Current	Lock Protection Mode	2.5	4.5	6.5	mA
I_{CC3}	Standby Mode	PWM=GND (FG, 1/2FG, 1/2FG & Shutdown mode)	-	280	330	μA
OUTPUT DRIVERS						
V_{OL}	Low-side Output Saturation Voltage	$V_{CC}=12V$; $I_{OUT}=400mA$	-	0.08	0.11	V
V_{OH}	High-side Output Saturation Voltage	$V_{CC}=12V$; $I_{OUT}=400mA$	-	0.1	0.13	V
V_{SO}	SO Pin Low Voltage	$I_{SO}=5mA$	-	0.2	0.3	V
I_{SO}	SO Pin Off Leakage Current	$V_{SO}=12V$	-	0.2	1	μA
ZC Comparator						
VZC	Floating Node Zero Crossing Hysteresis	VCC=12V	-	70	140	mV
START UP OSCILLATOR						
V_{SCH}	SC Pin High Level Voltage		1	1.2	1.4	V
V_{SCL}	SC Pin Low Level Voltage		0.5	0.6	0.7	V
I_{SC1}	SC Pin Charge Current	$V_{SC}=0V$	30	40	50	μA
I_{SC2}	SC Pin Discharge Current	$V_{SC}=2V$	30	40	50	μA
SOFT START OSCILLATOR						
V_{SSH}	SS Pin High Level Voltage		1	1.2	1.4	V
V_{SSL}	SS Pin Low Level Voltage		0.5	0.6	0.7	V
I_{SS1}	SS Pin Charge Current	$V_{SS}=0V$	6	10	14	μA
I_{SS2}	SS Pin Discharge Current	$V_{SS}=2V$	6	10	14	μA
FR						
V_{FRH}	FR Pin High Level Voltage		2.5	-	V_{5VREG}	V
V_{FRL}	FR Pin Low Level Voltage		0	-	1	V

Electrical Characteristics (Cont.)

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

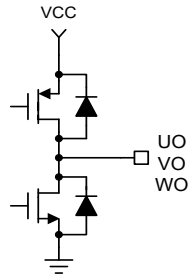
Symbol	Parameter	Test Conditions	APX9324A			Unit
			Min.	Typ.	Max.	
PWM MODE						
V_{PWH}	High Level Voltage for PWM Mode		2.5	-	5.5	V
V_{PWL}	Low Level Voltage for PWM Mode		0	-	0.8	V
R_{PWI}	PWM Internal pull-up Resistor		-	22	-	K Ω
V_{PWI}	PWM Internal pull-up Voltage		-	4.8	-	V
F_{PWM}	PWM Input Frequency		1	-	50	KHZ
F_{OUT}	Output Switch Frequency	Please refer to Table1, 2	-	25	-	KHZ
F_{OUT}	Output Switch Frequency	Please refer to Table1, 2	-	50	-	KHZ
LOCK PROTECTION						
$T_{ON(S)}$	Lock Protection Detection On Time	40% duty start up (SS=0V or 5VREG)	1.875	2.5	3.125	sec
$T_{ON(F)}$	Lock Protection Detection On Time	Full duty start up (SS=0V or 5VREG)	1.2	1.5	1.875	sec
T_{OFF}	Lock Protection Detection Off Time		5	6.25	7.5	sec
TQS	Quick Start Enable Time		-	60	-	ms
Soft Start						
T_{SS}	Soft Start Time ($D_{OUT}=0\sim 100\%$)	SS=0V or 5VREG ($V_{CC}=12V$)	-	2.5	-	sec
Start up						
$T_{SC(S)}$	Start up Time	40% duty start up (SC=0V)	-	160	-	ms
$T_{SC(F)}$	Start up Time	Full duty start up (SC=0V)	-	100	-	ms
CURRENT PROTECTION						
I_{LIM}	Current Limit Level of Start up	40% duty start up mode	0.375	0.6	0.75	A
	Current Limit Level of Normal Operation	40% duty start up mode	1	1.4	1.8	A
	Current Limit Level of Start up	Full duty start up mode	1	1.4	1.8	A
	Current Limit Level of Normal Operation	Full duty start up mode	1	1.4	1.8	A
I_{OCP}	Over Current Protection		1.6	2.2	2.7	A
THERMAL PROTECTION						
	Thermal Protection Temperature		-	165	-	$^\circ C$
	Thermal Protection Hysteresis		-	30	-	$^\circ C$

Pin Descriptions

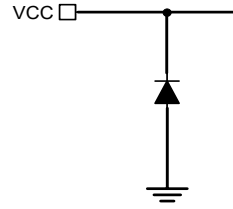
PIN		FUNCTION
NO.	NAME	
1	UO	Driver Output Pin. Output signal for driving motor phase U.
2	VCC	Supply Voltage Input Pin.
3	PWM/ SET/VSP	PWM Signal or DC Voltage Input Terminal.
4	5VREG	5V Regulator Output. This is a 5V constant-voltage output for application circuit biases.
5	TAB_SEL	Mode Setting. Connect to GND or floating.
6	SS	Soft-Start Time Setting. Connect a capacitor to SGND to set soft-start time to reduce the large current at power on and lock-restart mode.
7	SEL1	Mode Setting. Use a voltage divider from 5VREG to set SEL1 pin voltage for setting.
8	SEL2	Mode Setting. Use a voltage divider from 5VREG to set SEL2 pin voltage for setting.
9	SC	Start-up Time Setting Input Pin. Connect a capacitor to SGND to set the start-up timing.
10	SO	Rotation Speed Output or Rotation Detection Output. This is an open-drain output.
11	VO	Driver Output Pin. Output signal for driving motor phase V.
12	WO	Driver Output Pin. Output signal for driving motor phase W.
13	FR	Rotation Direction Control. High Level Input (short to 5VREG): U → W → V (Reverse) Low Level Input (short to GND): U → V → W (Forward)
14	GND	Ground Pin.

I/O Equivalent Circuits

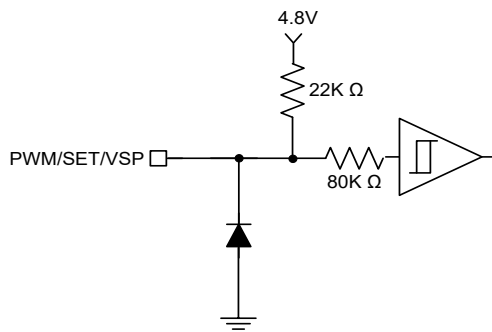
Driver output : pin1 (UO), pin11 (VO), pin12 (WO)



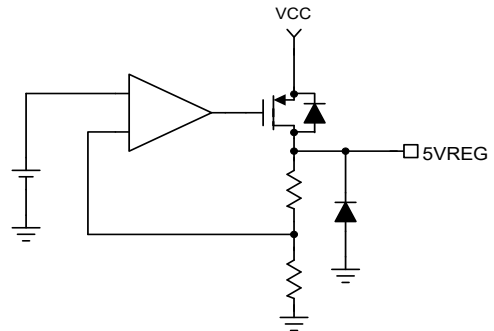
Power supply input : pin2 (VCC)



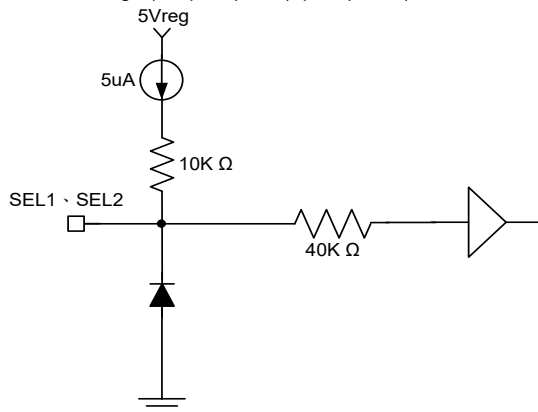
PWM/SET/VSP speed control input : pin3 (PWM/SET/VSP)



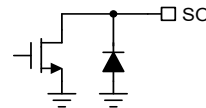
Regulator output : pin4 (5VREG)



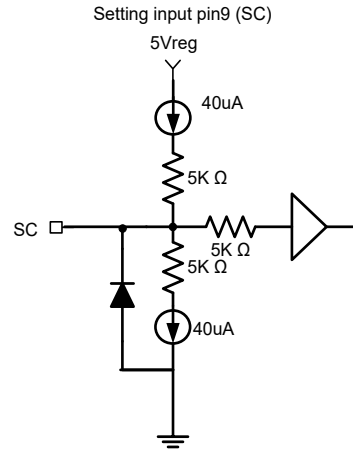
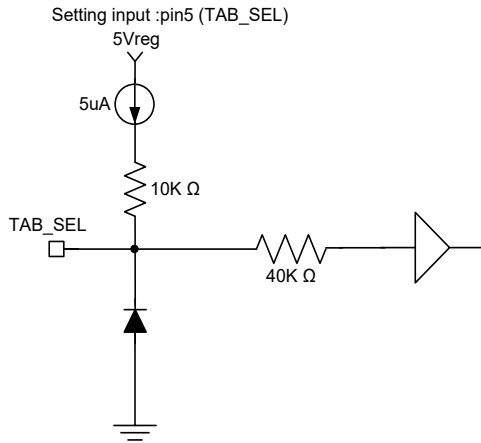
Setting input : pin7 (SEL1), pin8 (SEL2)



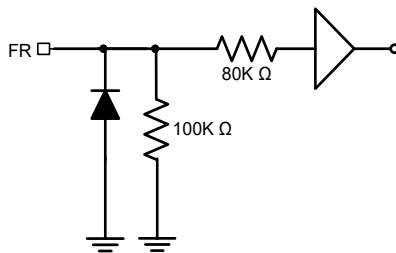
Rotation speed output: pin10 (SO)



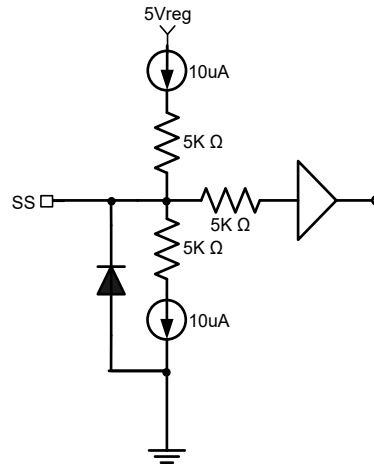
I/O Equivalent Circuits (Cont.)



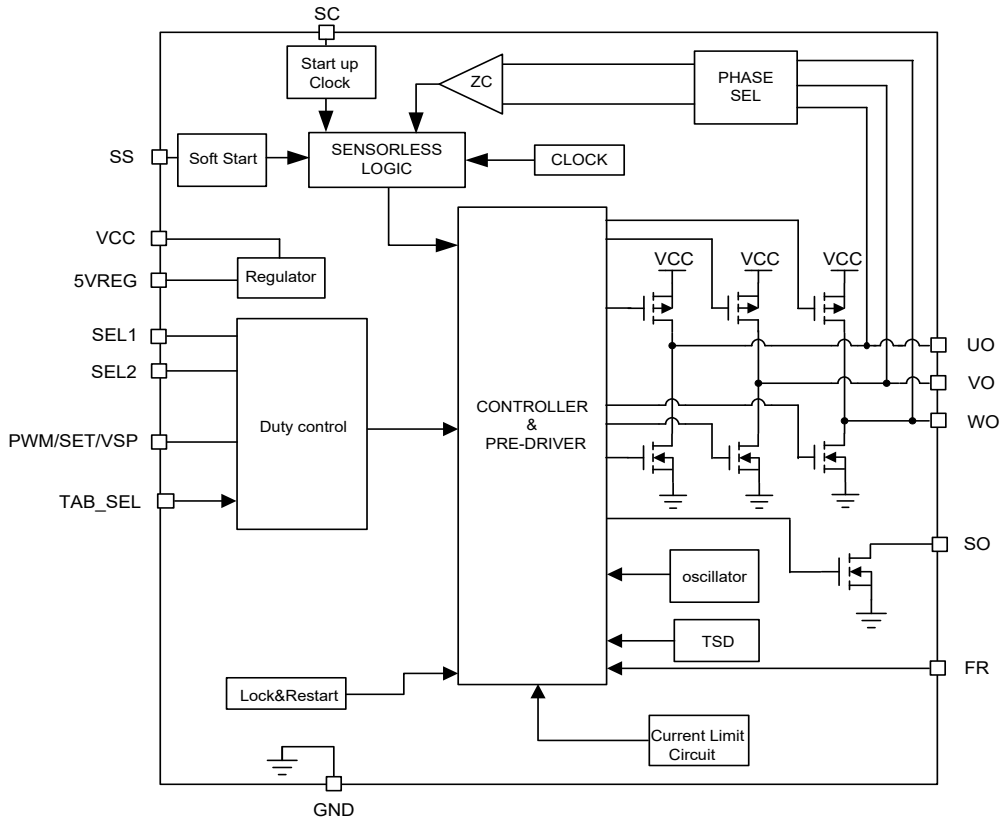
Setting input pin13 (FR)



Setting input pin6 (SS)

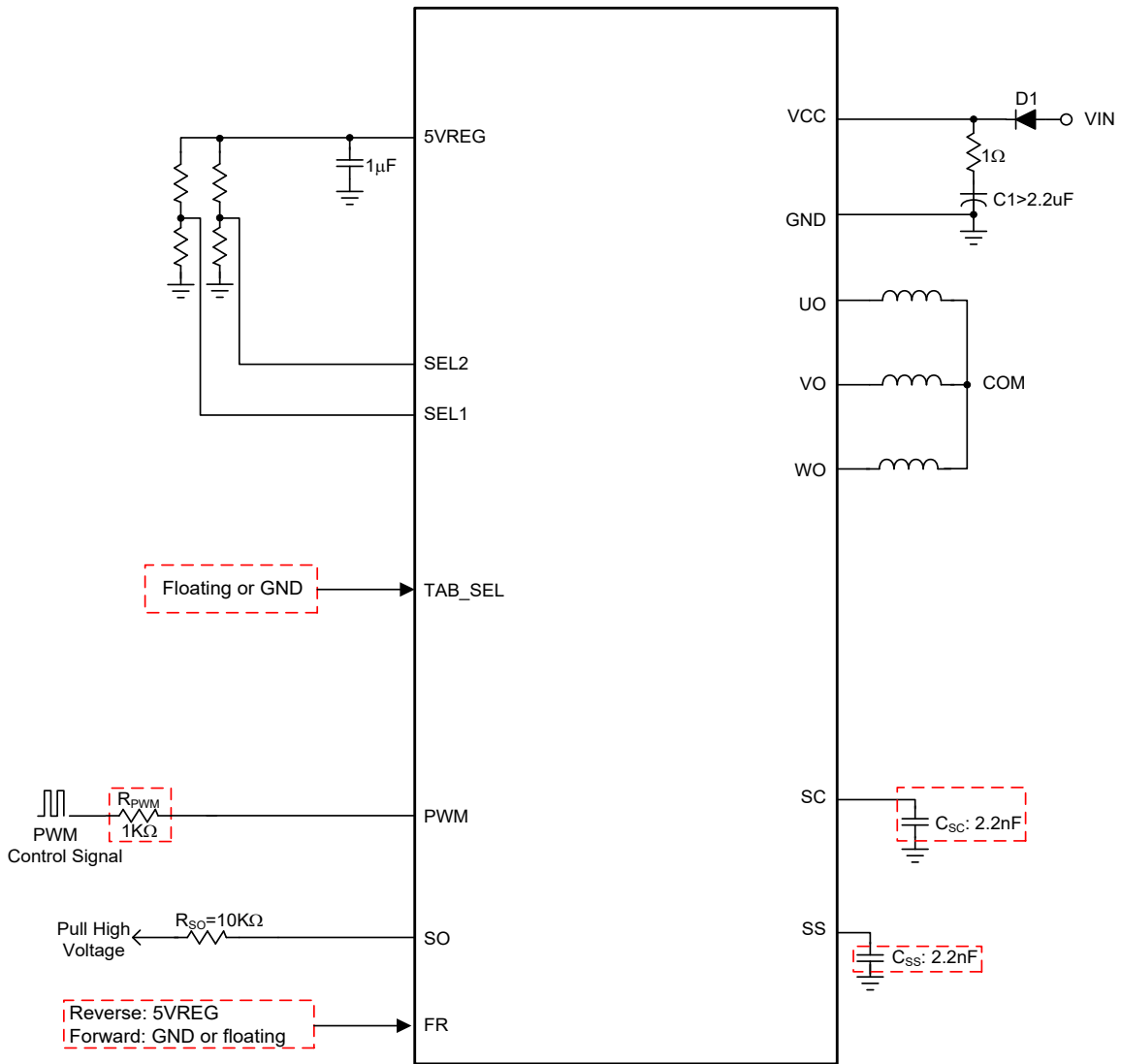


Block Diagram



Typical Application Circuit

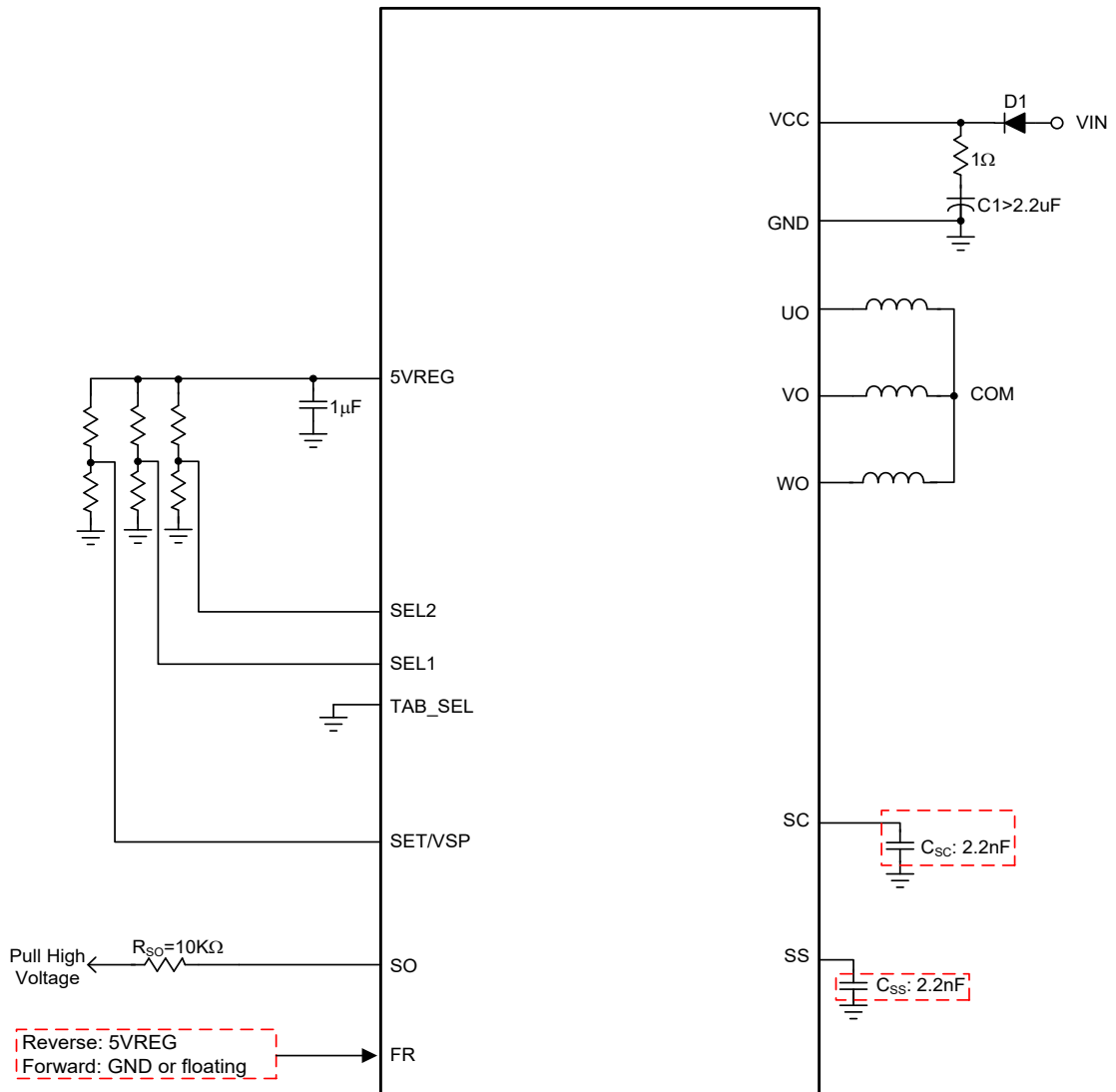
Circuit 1: PWM Speed Control



- Note: 1. The capacitance of C_{SS} , C_{SC} can be fine tune for different parameter of motor.
 2. R_{PWM} is optional to protect internal circuit for abnormal voltage stress.
 3. FR prohibited changing the level when fan operation.

Typical Application Circuit

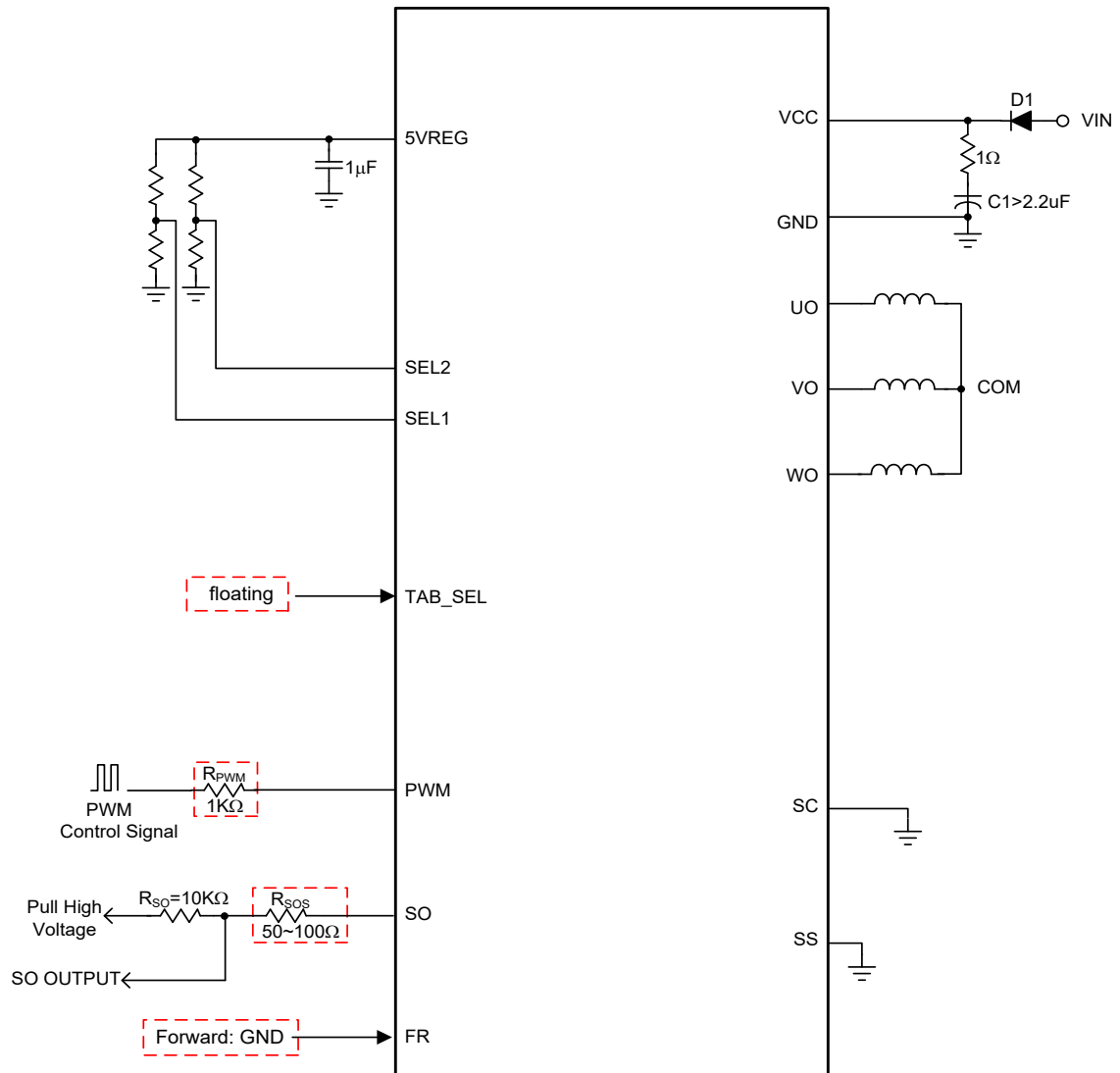
Circuit 2: DC Speed Control



Note: 1. The capacitance of C_{SS} , C_{SC} can be fine tune for different parameter of motor.
2. FR prohibited changing the level when fan operation.

Typical Application Circuit

Circuit 3: Save SC and SS capacitor (APX9323A)



Note: 1. R_{PWM} and R_{SOS} are optional to protect internal circuit for abnormal voltage stress.
2. Function Table 1.

Function Descriptions

SEL1 and SEL2 Control

The APX9324A has two input pin SEL1, SEL2 to control output duty of driver for the rotation speed of motor and SO output.

When TAB_SEL=Floating

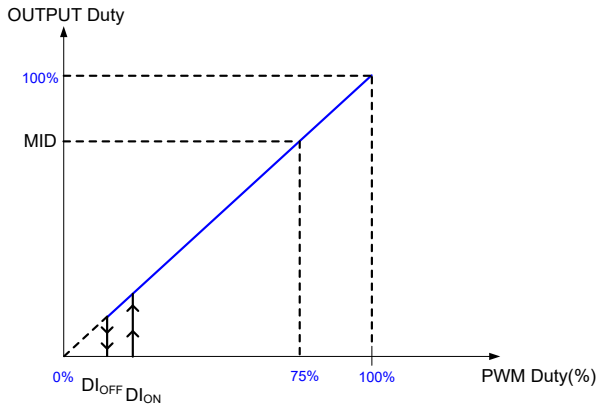


Figure 1: Shutdown mode Output Duty Control Curve

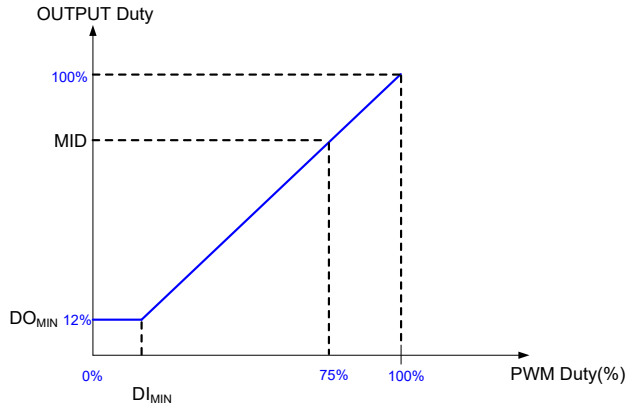


Figure 2: Minimum mode Output Duty Control Curve

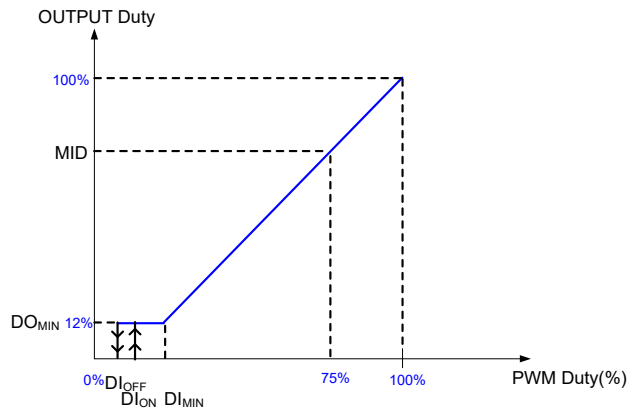


Figure 3: Shutdown and Minimum mode Output Duty Control Curve

Function Descriptions (Cont.)

Table1

SO	F _{OUT}	DI _{ON}	DI _{OFF}	DO _{MIN}	DI _{MIN}	MID	V_SEL1	V_SEL2	Note
FG	50K	X	X	12%	12%	75%	0	0	AutoMode and start up (0~40%) [Figure2]
		7%	5%	12%	12%	75%	0	5	Full duty start up and AutoMode [Figure3]
		10%	8%	X	X	75%	1.5	3.5	Non-Auto Mode and start up (0~40%) [Figure1]
		X	X	12%	12%	75%	2.5	1.5	Non-Auto Mode and start up (0~40%) [Figure2]
		10%	8%	X	X	75%	3.5	5	Full duty start up and Non-Auto Mode [Figure1]
		10%	8%	X	X	75%	5	3.5	Full duty start up and AutoMode [Figure1]
		10%	8%	X	X	75%	5	5	AutoMode and start up (0~40%) [Figure1]

SO	F _{OUT}	DI _{ON}	DI _{OFF}	DO _{MIN}	DI _{MIN}	MID	V_SEL1	V_SEL2	Note
1/2FG	50K	X	X	12%	12%	75%	0	1.5	AutoMode and start up (0~40%) [Figure2]
		10%	8%	X	X	75%	0	2.5	Full duty start up and Non-Auto Mode [Figure1]
		7%	5%	12%	12%	75%	0	3.5	Full duty start up and AutoMode [Figure3]
		10%	8%	X	X	75%	2.5	0	Non-Auto Mode and start up (0~40%) [Figure1]
		X	X	12%	12%	75%	3.5	0	Non-Auto Mode and start up (0~40%) [Figure2]
		10%	8%	X	X	75%	5	0	AutoMode and start up (0~40%) [Figure1]
		10%	8%	X	X	75%	5	2.5	Full duty start up and AutoMode [Figure1]

SO	F _{OUT}	DI _{ON}	DI _{OFF}	DO _{MIN}	DI _{MIN}	MID	V_SEL1	V_SEL2	Note
1/3FG	50K	10%	8%	X	X	75%	1.5	0	AutoMode and start up (0~40%) [Figure1]
		X	X	12%	12%	75%	1.5	2.5	AutoMode and start up (0~40%) [Figure2]
		10%	8%	X	X	75%	1.5	5	Full duty start up and Non-Auto Mode [Figure1]
		10%	8%	X	X	75%	3.5	1.5	Non-Auto Mode and start up (0~40%) [Figure1]
		10%	8%	X	X	75%	5	1.5	Full duty start up and AutoMode [Figure1]

SO	F _{OUT}	DI _{ON}	DI _{OFF}	DO _{MIN}	DI _{MIN}	MID	V_SEL1	V_SEL2	Note
FG	25K	10%	8%	X	X	75%	1.5	1.5	Full duty start up and Non-Auto Mode [Figure1]
		X	X	12%	12%	75%	2.5	3.5	AutoMode and start up (0~40%) [Figure2]
		10%	8%	X	X	75%	2.5	5	Non-Auto Mode and start up (0~40%) [Figure1]
		10%	8%	X	X	75%	3.5	2.5	Full duty start up and AutoMode [Figure1]
		10%	8%	X	X	75%	3.5	3.5	AutoMode and start up (0~40%) [Figure1]

SEL1 and SEL2 function table (V_SEL1 and V_SEL2 voltage value when 5VREG=5V)

*Non-Auto mode Maximum RPM 28000 (experimental data)

*Auto mode Maximum RPM 18000 (experimental data)

*Minimum RPM 250 (experimental data)

Function Descriptions (Cont.)

When TAB_SEL=GND

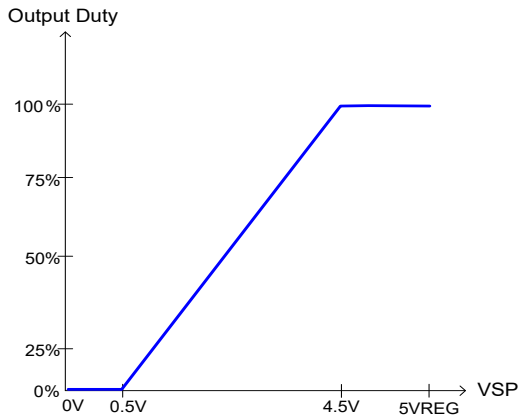


Figure4: VSP Control

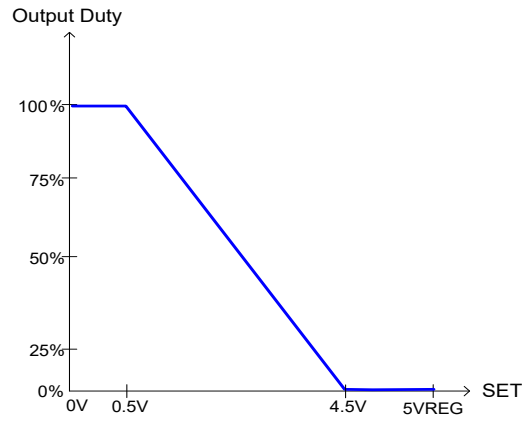


Figure5: SET Control

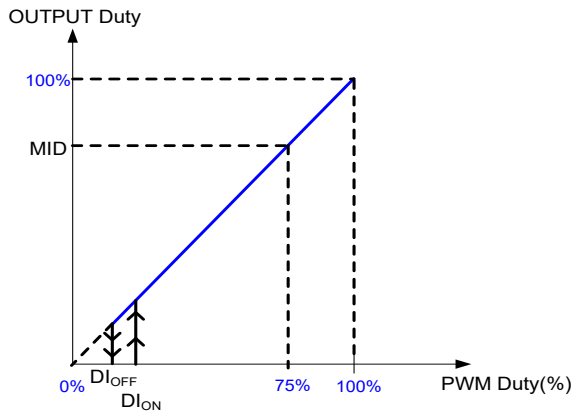


Figure6: Shutdown mode Output Duty Control Curve

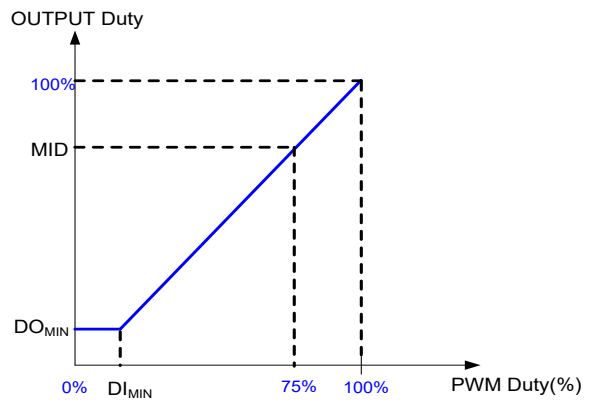


Figure7: Minimum mode Output Duty Control Curve

Function Descriptions (Cont.)

Table2

SO	F _{OUT}	MODE	DI _{ON}	DI _{OFF}	DO _{MIN}	DI _{MIN}	MID	V_SEL1	V_SEL2	Note
FG	50K	PWM	X	X	12%	12%	65%	0	0	AutoMode and start up (0~40%)
		SET	X	X	12%	12%	75%	1.5	1.5	AutoMode and start up (0~40%)
		PWM	10%	8%	X	X	65%	1.5	0	AutoMode and start up (0~40%)
		PWM	10%	8%	X	X	65%	1.5	5	Non-Auto Mode and start up (0~40%)
		VSP	10%	8%	X	X	75%	5	5	AutoMode and start up (0~40%)

SO	F _{OUT}	MODE	DI _{ON}	DI _{OFF}	DO _{MIN}	DI _{MIN}	MID	V_SEL1	V_SEL2	Note
1/2FG	50K	PWM	X	X	12%	12%	65%	0	1.5	AutoMode and start up (0~40%)
		SET	X	X	12%	12%	75%	0	2.5	AutoMode and start up (0~40%)
		PWM	10%	8%	X	X	65%	0	3.5	AutoMode and start up (0~40%)
		PWM	10%	8%	X	X	65%	2.5	0	Non-Auto Mode and start up (0~40%)
		VSP	10%	8%	X	X	75%	5	0	AutoMode and start up (0~40%)

SO	F _{OUT}	MODE	DI _{ON}	DI _{OFF}	DO _{MIN}	DI _{MIN}	MID	V_SEL1	V_SEL2	Note
1/3FG	50K	VSP	10%	8%	X	X	75%	0	5	AutoMode and start up (0~40%)
		PWM	X	X	12%	12%	65%	1.5	2.5	AutoMode and start up (0~40%)
		PWM	10%	8%	X	X	65%	2.5	2.5	Non-Auto Mode and start up (0~40%)
		PWM	10%	8%	X	X	65%	2.5	5	AutoMode and start up (0~40%)
		SET	X	X	12%	12%	75%	3.5	1.5	AutoMode and start up (0~40%)
		PWM	X	X	12%	12%	75%	5	3.5	AutoMode and start up (0~40%)

SO	F _{OUT}	MODE	DI _{ON}	DI _{OFF}	DO _{MIN}	DI _{MIN}	MID	V_SEL1	V_SEL2	Note
RD	50K	PWM	X	X	12%	12%	75%	1.5	3.5	Non-Auto Mode and start up (0~40%)
		PWM	10%	8%	X	X	65%	2.5	1.5	Non-Auto Mode and start up (0~40%)
		PWM	X	X	12%	12%	65%	2.5	3.5	AutoMode and start up (0~40%)
		PWM	10%	8%	X	X	65%	3.5	5	AutoMode and start up (0~40%)
		VSP	10%	8%	X	X	75%	3.5	3.5	AutoMode and start up (0~40%)
		SET	X	X	12%	12%	75%	5	1.5	AutoMode and start up (0~40%)

SEL1 and SEL2 function table (V_SEL1 and V_SEL2 voltage value when 5VREG=5V)

*Non-Auto mode Maximum RPM 28000 (experimental data)

*Auto mode Maximum RPM 18000 (experimental data)

*Minimum RPM 250 (experimental data)

Function Descriptions (Cont.)

Lock Protection and Auto Restart

The restart time (T_{ON}) is related to soft start time (T_{SS}). The shutdown time (T_{OFF}) is fixed time. Following the formula to calculate shutdown time and restart time.



When SS connect capacitor:

$$\text{Restart Time } T_{ON(S)} = T_{SS} (0\% \text{ to } 40\%) + 1.25 \text{ (S)}$$

$$T_{ON(F)} = 1.5 \text{ (S)}$$

When SS connect GND or 5VREG:

$$\text{Restart Time } T_{ON(S)} = 1.25 + 1.25 \text{ (S)}$$

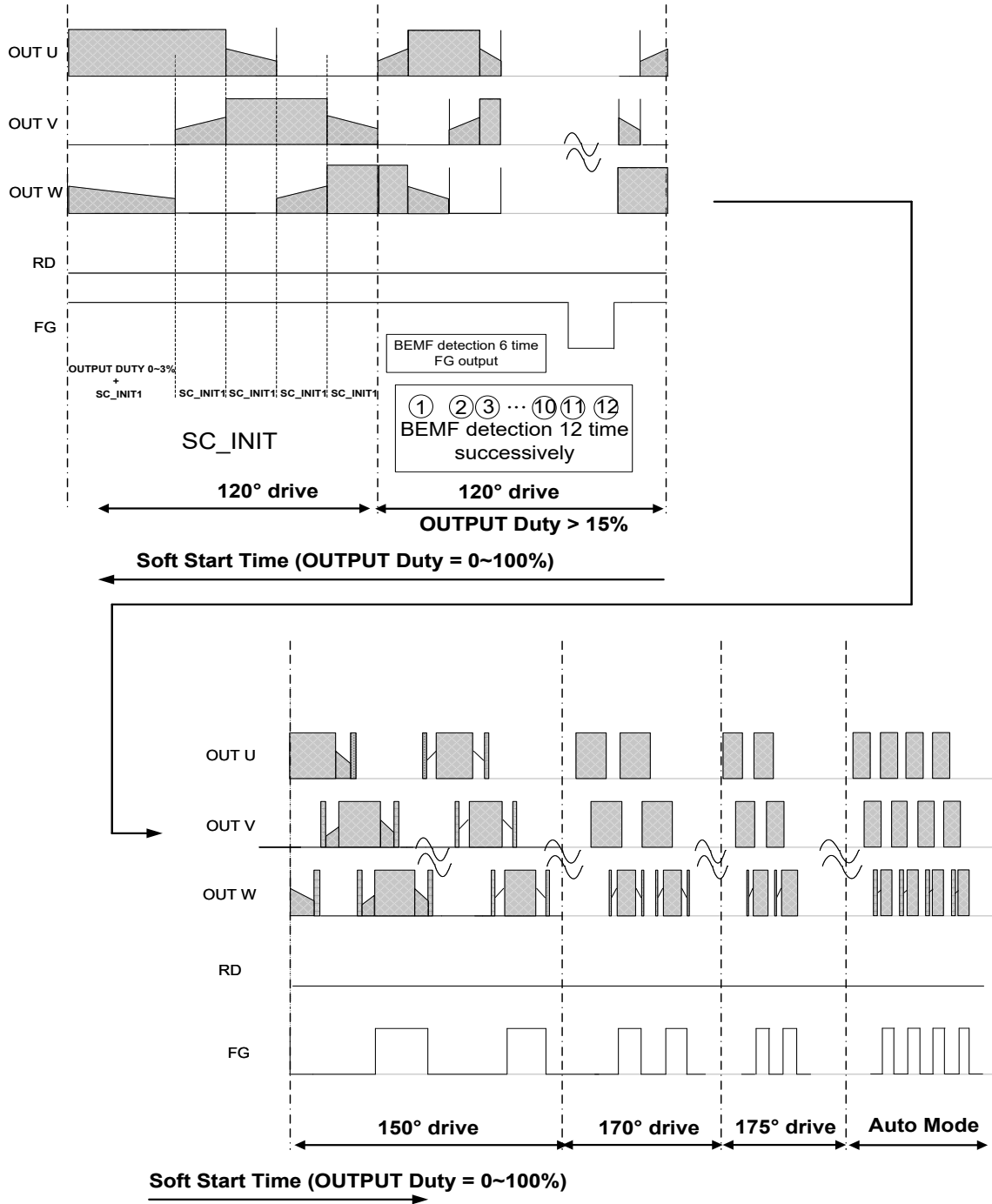
$$T_{ON(F)} = 1.5 \text{ (S)}$$

Shutdown Time (T_{off}) = 6.25(S)

Function Descriptions (Cont.)

Start-Up

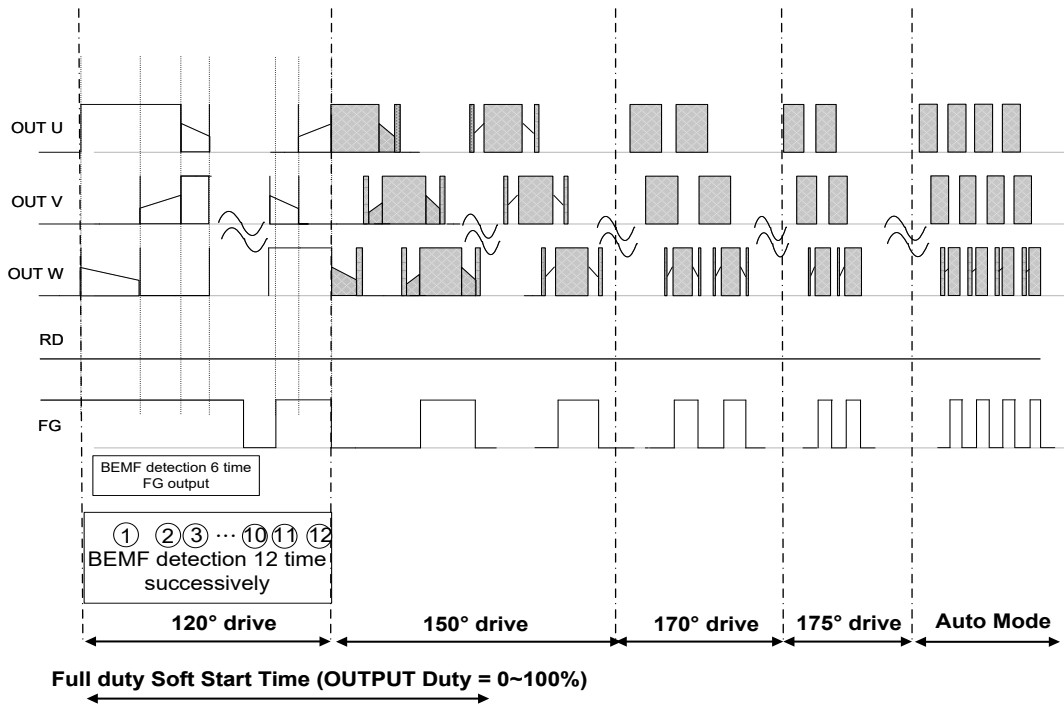
APX9324A start mechanism is forcibly start-up mechanism. When BEMF signal isn't detected for constant time at startup, outputs output logic forcibly signal and makes motor drive.



*The picture is for reference only, please refer to the motor.

Function Descriptions (Cont.)

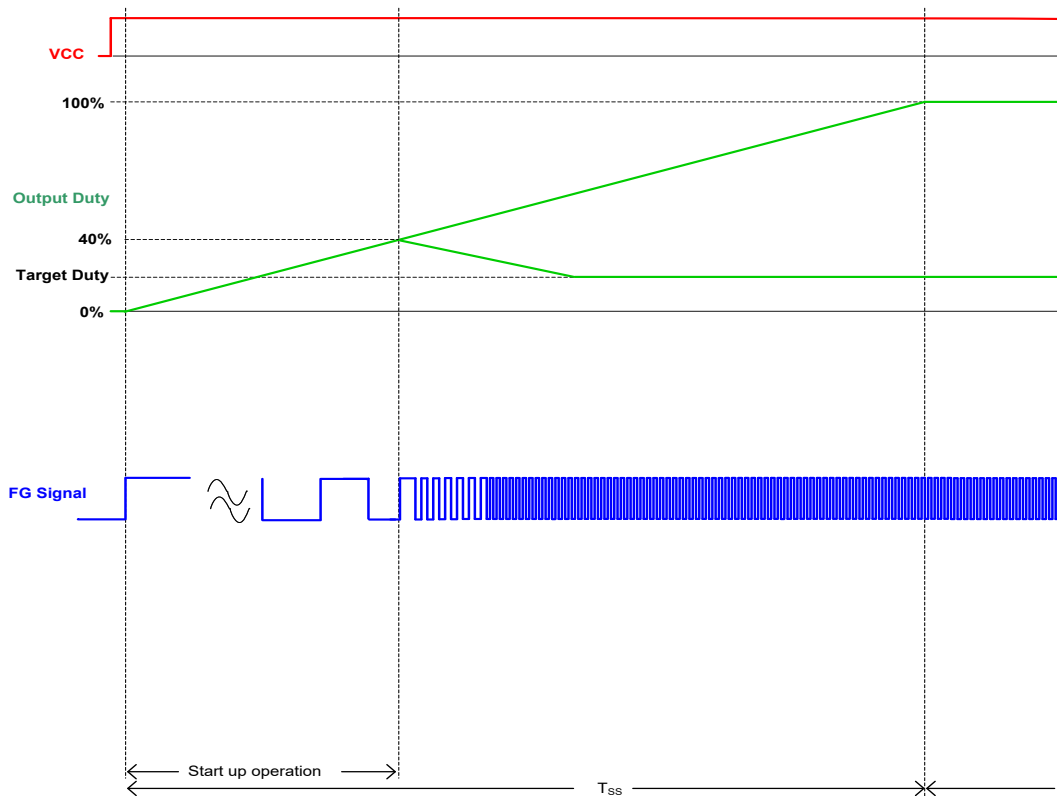
Start-Up (Cont.)



*The picture is for reference only, please refer to the motor.

Soft-Start Function

The APX9324A provides the soft-start function to avoid peak current at power-on and lock-restart moments. At the soft start time, the output initial duty is 0% and the TSS is output duty from 0 to 100%.

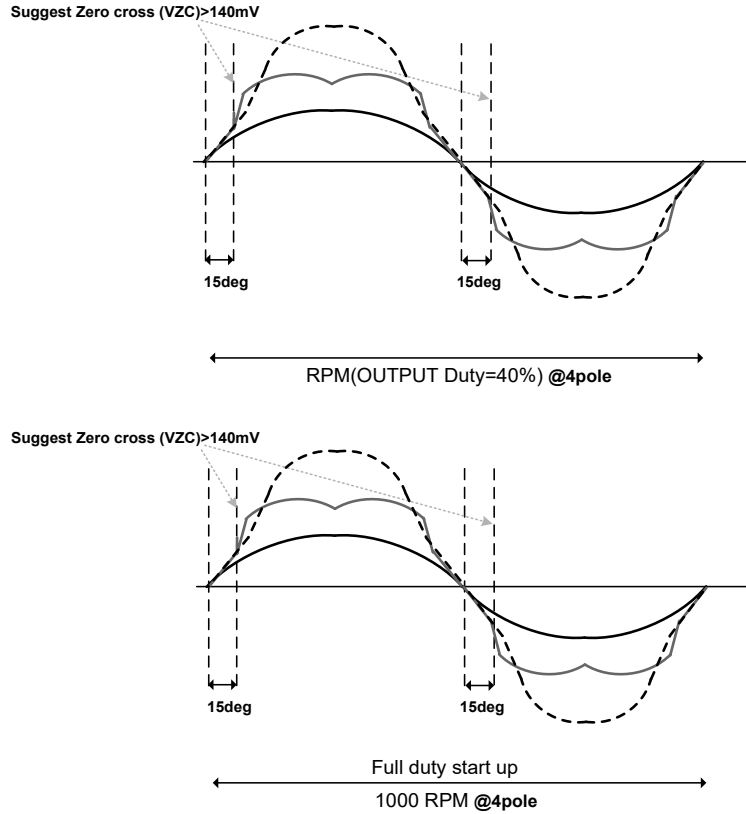


Soft-Start Timing Chart

Function Descriptions (Cont.)

BEMF Zero Crossing

APX9324A has a BEMF detected comparator. However, BEMF characteristic at zero cross point is very flat, if rotor was at this position, the BEMF would not be able to detected. The fan makes drive need adequate BEMF.



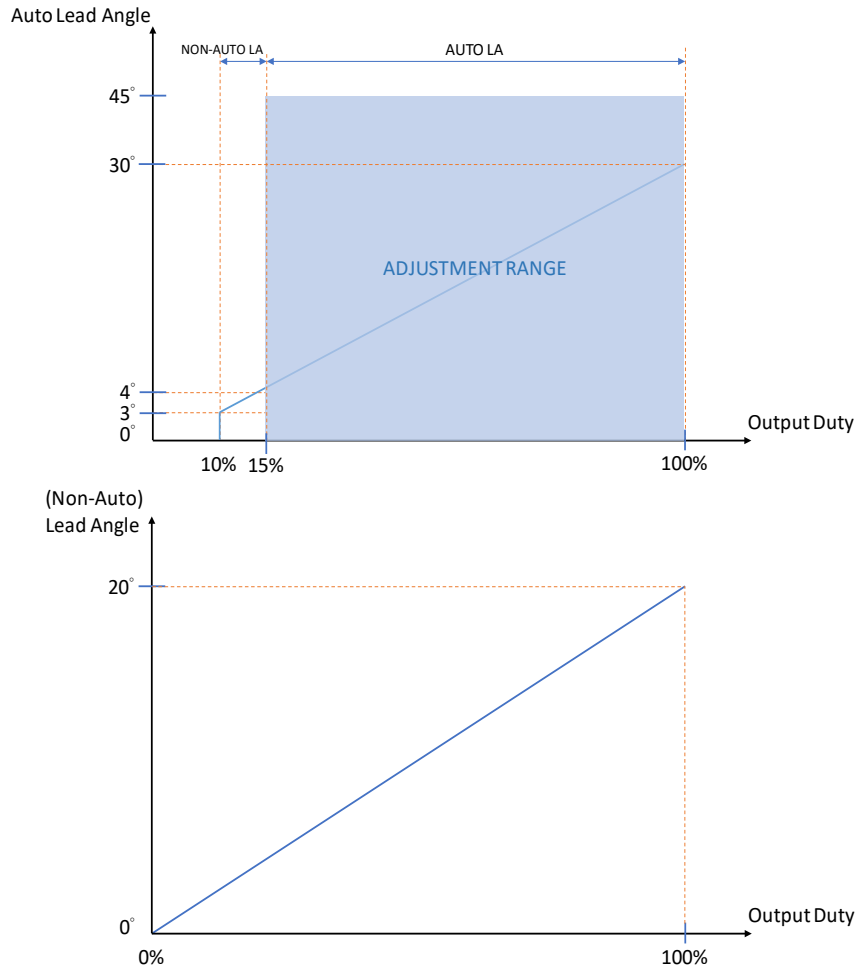
Current Limit and Over Current Protection (OCP)

The APX9324A includes an internal current sense circuits for current limit and over-current protection (OCP). When the total current of three phase over the current limit level, the high side driver will be turned off to stop supplying current to the motor. If the total output current over the OCP current level, the OCP function will be enable to turn-off all of the output driver to prevent output short through condition until pull low PWM pin or re-power on or wait 2.5 seconds.

Function Descriptions (Cont.)

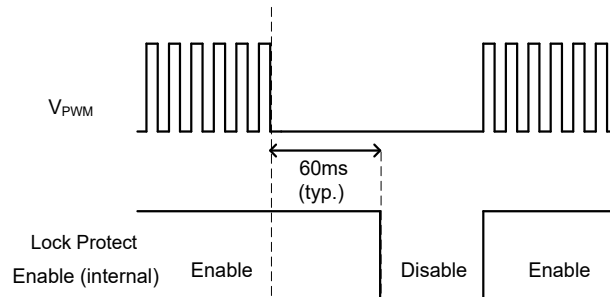
Lead Angle

The APX9324A built in lead angle controlled (Auto Mode adjustment range=0 ~ 45°, Recommended operating RPM <18000rpm)(Non-Auto Mode adjustment range=0 ~ 20°, Recommended operating RPM<28000rpm). The Non-Auto lead angle control range is 0 to 20° for Output Duty 0% to 100%.



Quick Start

This IC would enter standby mode when the PWM input keeps low level for more than 60ms (typ.). In standby mode, the supply current is around 280μA and the lock protection function doesn't work, therefore, starting fan is unobstructed when releasing standby mode.



Thermal Protection

The APX9324A is designed with a thermal protection to protect the IC from the damage of over temperature. When internal junction temperature reaches 165°C, the output devices will be switched off. When the IC's junction temperature cools by 30°C, the thermal sensor will turn the output devices on again resulting in a pulsed output during continuous thermal overload.

Application Information

Input Protection Diode & Capacitor

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

SC Capacitor

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

$$SC_INIT1 = \frac{2 \times (V_{SCH} - V_{SCL}) \times C_{SC}}{I_{SC}} \times 128 \times 19$$

$$T_{SC(S)} = \frac{2 \times (V_{SCH} - V_{SCL}) \times C_{SC}}{I_{SC}} \times 128 \times 30$$

$$T_{SC(F)} = \frac{2 \times (V_{SCH} - V_{SCL}) \times C_{SC}}{I_{SC}} \times 128 \times 19$$

For example:

$$V_{SCL} = 0.6V, V_{SCH} = 1.2V, I_{SC} = (I_{SC1} + I_{SC2}) / 2 = 40\mu A$$

$$C_{SC} = 1.0nF \gggg SC_INIT1 = 73mS, T_{SC(S)} = 115ms, T_{SC(F)} = 73ms$$

⋮

$$C_{SC} = 2.2nF \gggg SC_INIT1 = 160mS, T_{SC(S)} = 253ms, T_{SC(F)} = 160ms$$

⋮

$$C_{SC} = 3.3nF \gggg SC_INIT1 = 240mS, T_{SC(S)} = 380ms, T_{SC(F)} = 241ms$$

⋮

$$C_{SC} = GND \gggg SC_INIT1 = 100mS, T_{SC(S)} = 160ms, T_{SC(F)} = 100ms$$

SS Capacitor

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

$$VCC = 12V, T_{SS} = \frac{2 \times (V_{SSH} - V_{SSL}) \times C_{SS}}{I_{SS}} \times 7 \times 255 \times 8$$

For example:

$$VCC = 12V, C_{SS} = 1nF, V_{SSL} = 0.6V, V_{SSH} = 1.2V, I_{SS} = 10\mu A$$

$$C_{SS} = 1.0nF \gggg T_{SS} = 1.71s$$

$$C_{SS} = 2.2nF \gggg T_{SS} = 3.76s$$

⋮

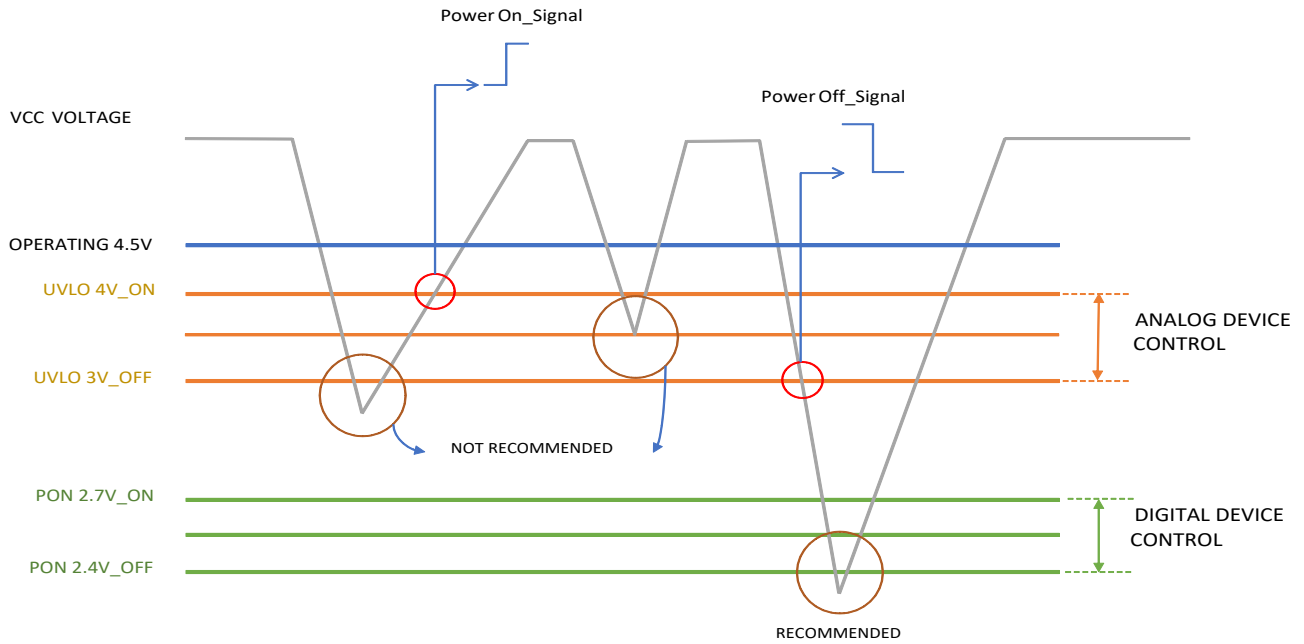
$$C_{SS} = 5nF \gggg T_{SS} = 8.55s$$

⋮

$$C_{SS} = GND \text{ or } 5VREG \gggg T_{SS} = 2.5s$$

Application Information (Cont.)

Power Supply Sequence



Recommended : Pon VCC > 4.5V
Poff VCC = 0V

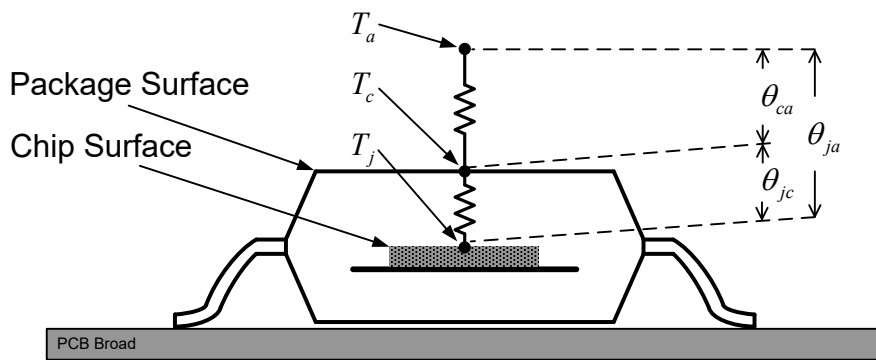
Application Information (Cont.)

Power Dissipation

The power dissipation of IC, it indicates permission consumed power at ambient temperature ($T_a=25^\circ\text{C}$). But its value is related to some conditions of the surrounding, such as the PCB board size and mounting condition and ambient temperature (T_a). Therefore power dissipation and thermal resistance isn't a fixed value at the same IC package. The power dissipation is determined by IC chip surface permission maximum junction temperature and thermal resistance (θ_{ja}). The below figure is descriptions the thermal resistance from chip surface to ambient temperature and junction temperature (T_j) calculation.

Table X. Thermal Resistance and Temperature Symbol Description

symbol	Parameter
T_j	Chip Surface (Junction) Temperature
T_c	Package Surface (Case) Temperature
T_a	Ambient (Air) Temperature
θ_{jc}	Junction to Case Resistance
θ_{ca}	Case to Air Resistance
θ_{ja}	Junction to Air Resistance



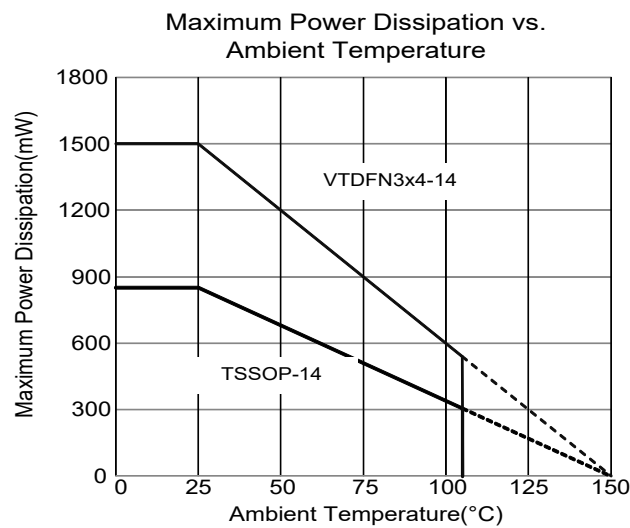
$$T_j = \theta_{ja} \times P + T_a (\text{ }^\circ\text{C})$$

$$\theta_{jc} = \frac{T_j - T_c}{P} (\text{ }^\circ\text{C}/\text{W})$$

$$\theta_{ca} = \frac{T_c - T_a}{P} (\text{ }^\circ\text{C}/\text{W})$$

$$\theta_{ja} = \frac{T_j - T_a}{P} (\text{ }^\circ\text{C}/\text{W})$$

Note : P is mean the Power(W)



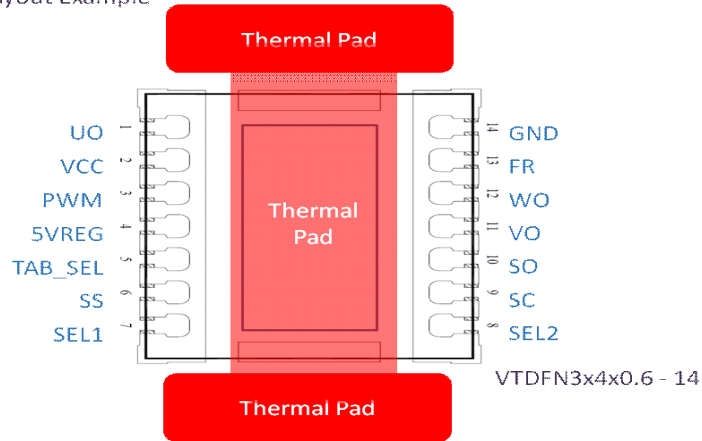
Note: Above $T_a=25^\circ\text{C}$, derating by $6.8 \text{ m W}/^\circ\text{C}$ (TSSOP-14).
 $T_a=25^\circ\text{C}$, derating by $12 \text{ m W}/^\circ\text{C}$ (VTDFN3x4-14).

Application Information (Cont.)

Layout Guidelines

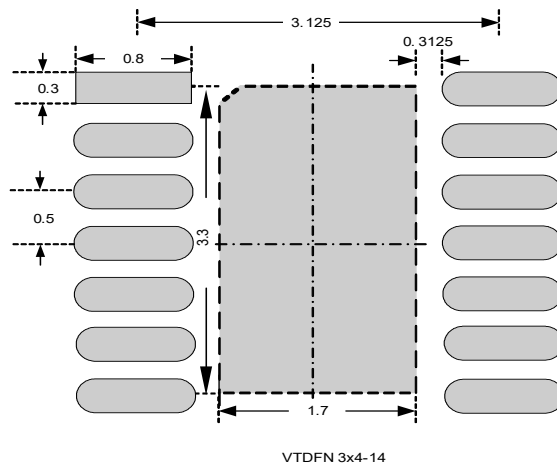
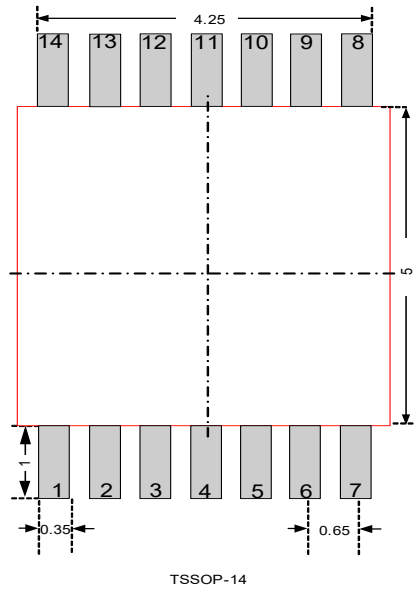
- Place the >2.2uF capacitor between VCC and GND, and close to the VCC and GND pins as possible.
- Keep the thermal pad connection as large as possible. It should be one piece of copper without any gaps.

Thermal Pad Layout Example



Application Information (Cont.)

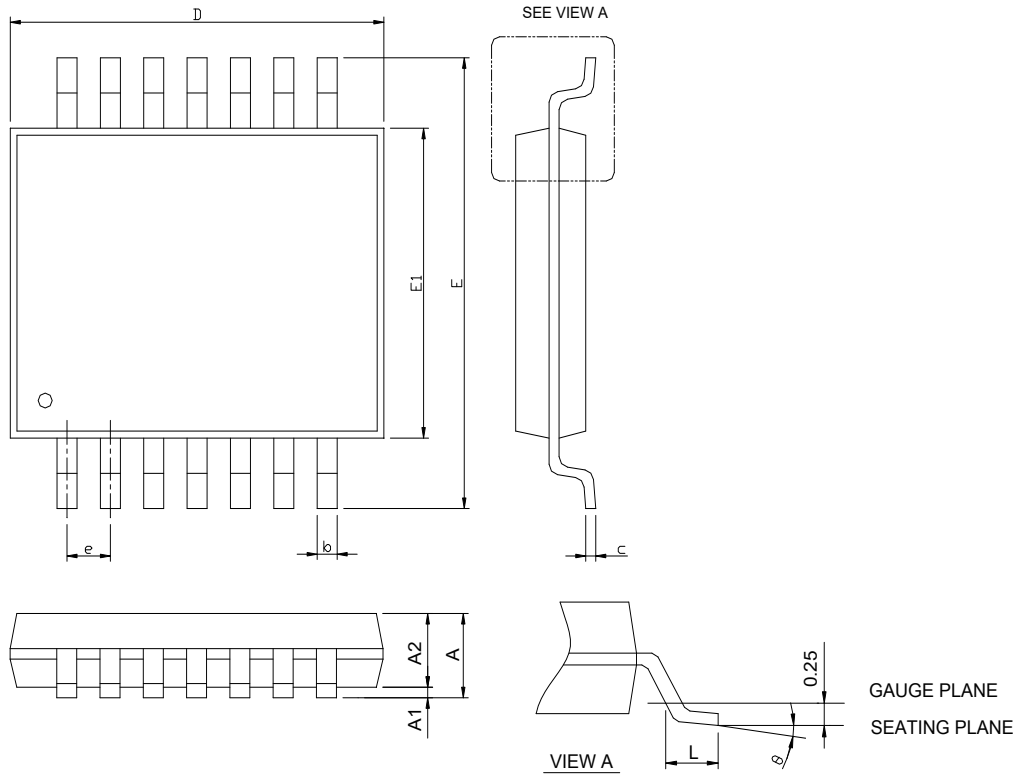
Recommended Minimum Footprint



Unit: mm

Package Information

TSSOP-14



SYMBOL	TSSOP-14			
	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
E	6.20	6.60	0.244	0.260
E1	4.30	4.50	0.169	0.177
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-1.

2. Dimension "D" does not include mold flash, protrusions or gate burrs.

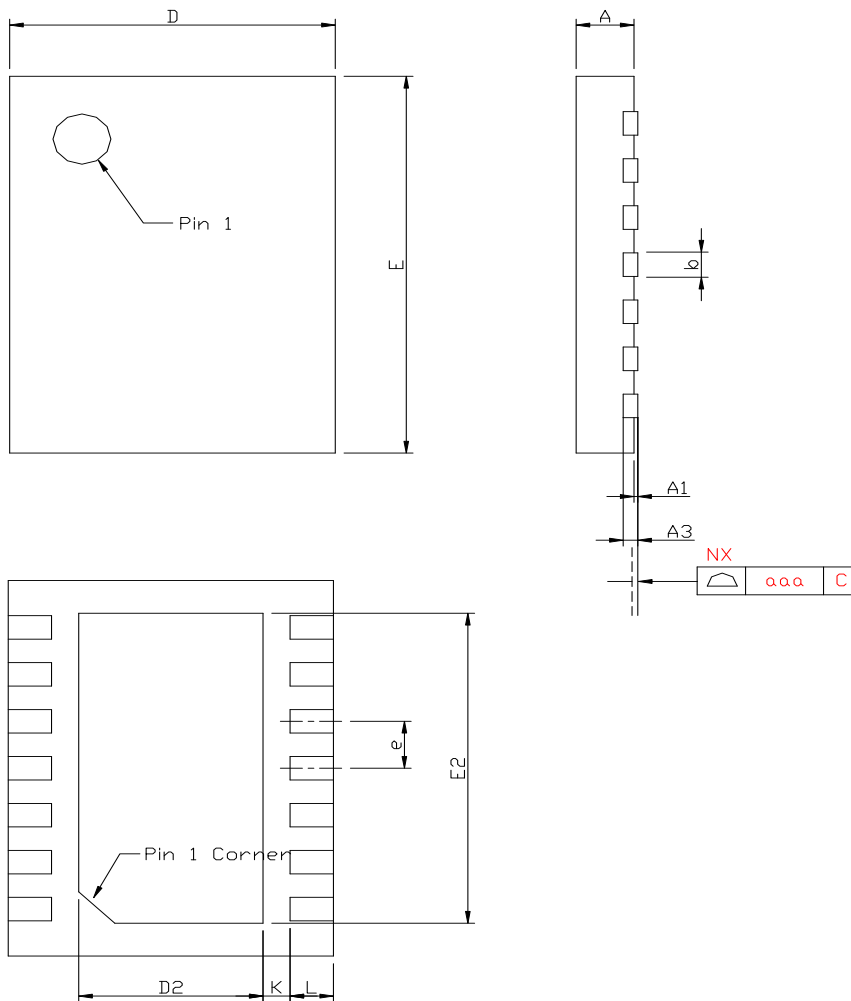
Mold flash, protrusion or gate burrs shall not exceed 6 mil per side.

3. Dimension "E1" does not include inter-lead flash or protrusions.

Inter-lead flash and protrusions shall not exceed 10 mil per side.

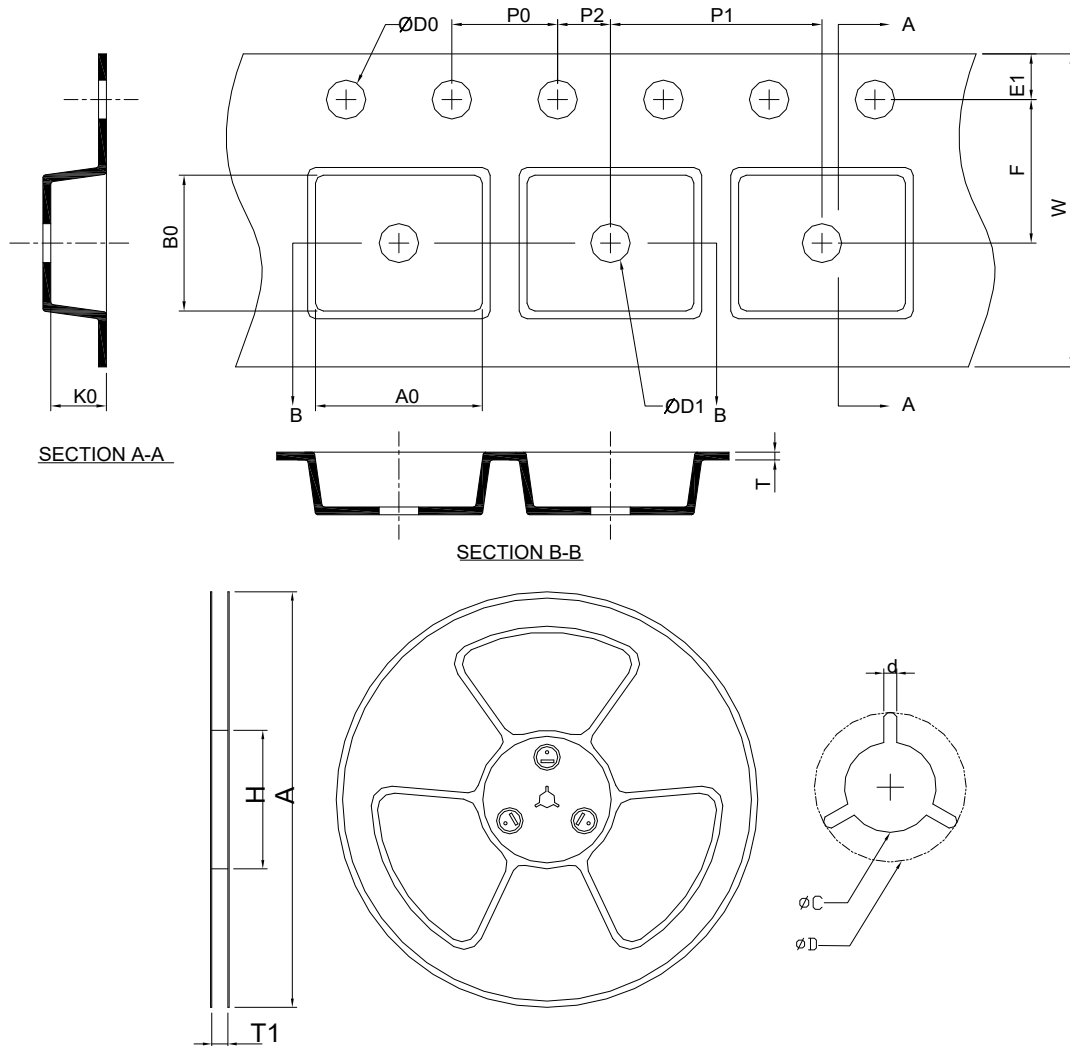
Package Information

VTDFN3x4-14



SYMBOL	VTDFN3*4-14			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.50	0.60	0.020	0.024
A1	0.00	0.05	0.000	0.002
A3	0.152 REF		0.006 REF	
b	0.18	0.30	0.007	0.012
D	2.90	3.10	0.114	0.122
D2	1.60	1.80	0.063	0.071
E	3.90	4.10	0.153	0.161
E2	3.20	3.40	0.126	0.134
e	0.50 BSC		0.020 BSC	
L	0.30	0.50	0.012	0.020
K	0.20		0.008	
aaa	0.08		0.003	

Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
TSSOP-14(P)	330.0±2.00	50 MIN.	12.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	12.0±0.30	1.75±0.10	5.5±0.05
	P0	P1	P2	D0	D1	T	A0	B0	K0
	4.0±0.10	8.0±0.10	2.0±0.05	1.5+0.10 -0.00	1.5 MIN.	0.6+0.00 -0.40	6.80±0.20	5.40±0.20	1.60±0.20
Application	A	H	T1	C	d	D	W	E1	F
VTDFN 3x4	330.0±2.00	50 MIN.	12.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	12.0±0.30	1.75±0.10	5.5±0.10
	P0	P1	P2	D0	D1	T	A0	B0	K0
	4.0±0.20	8.0±0.10	2.0±0.05	1.5+0.10 -0.00	1.5 MIN.	0.6+0.00 -0.40	3.30±0.20	4.30±0.20	0.75±0.20

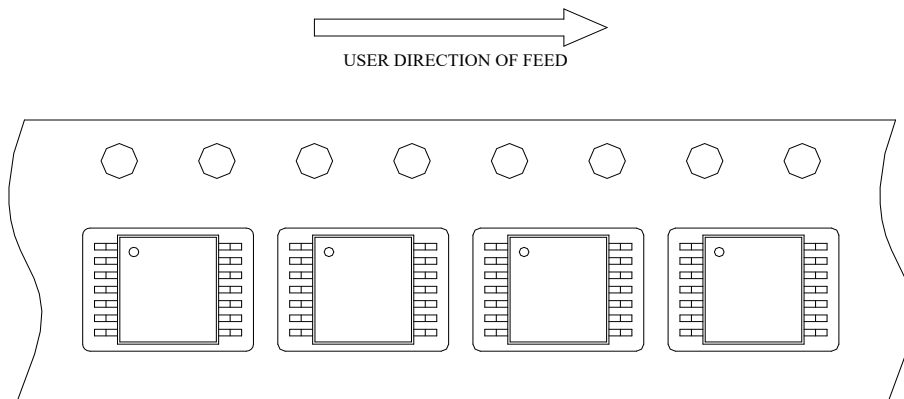
(mm)

Devices Per Unit

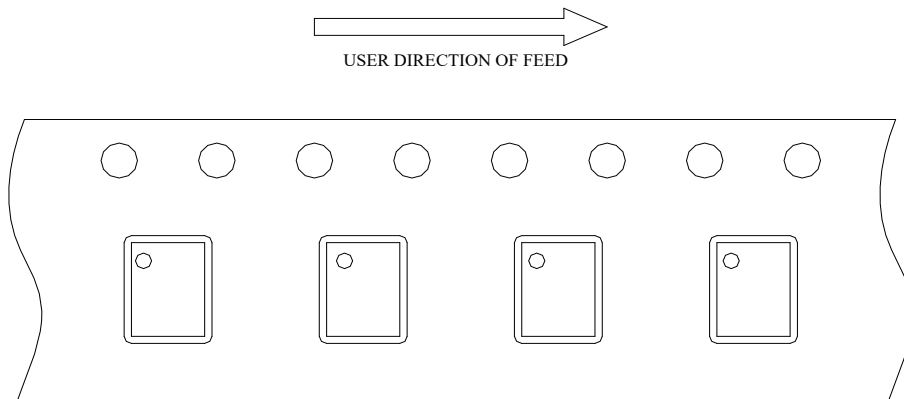
Package type	Packing	Quantity
TSSOP-14(P)	Tape & Reel	2500
VTDFN(3x4)	Tape & Reel	3000

Taping Direction Information

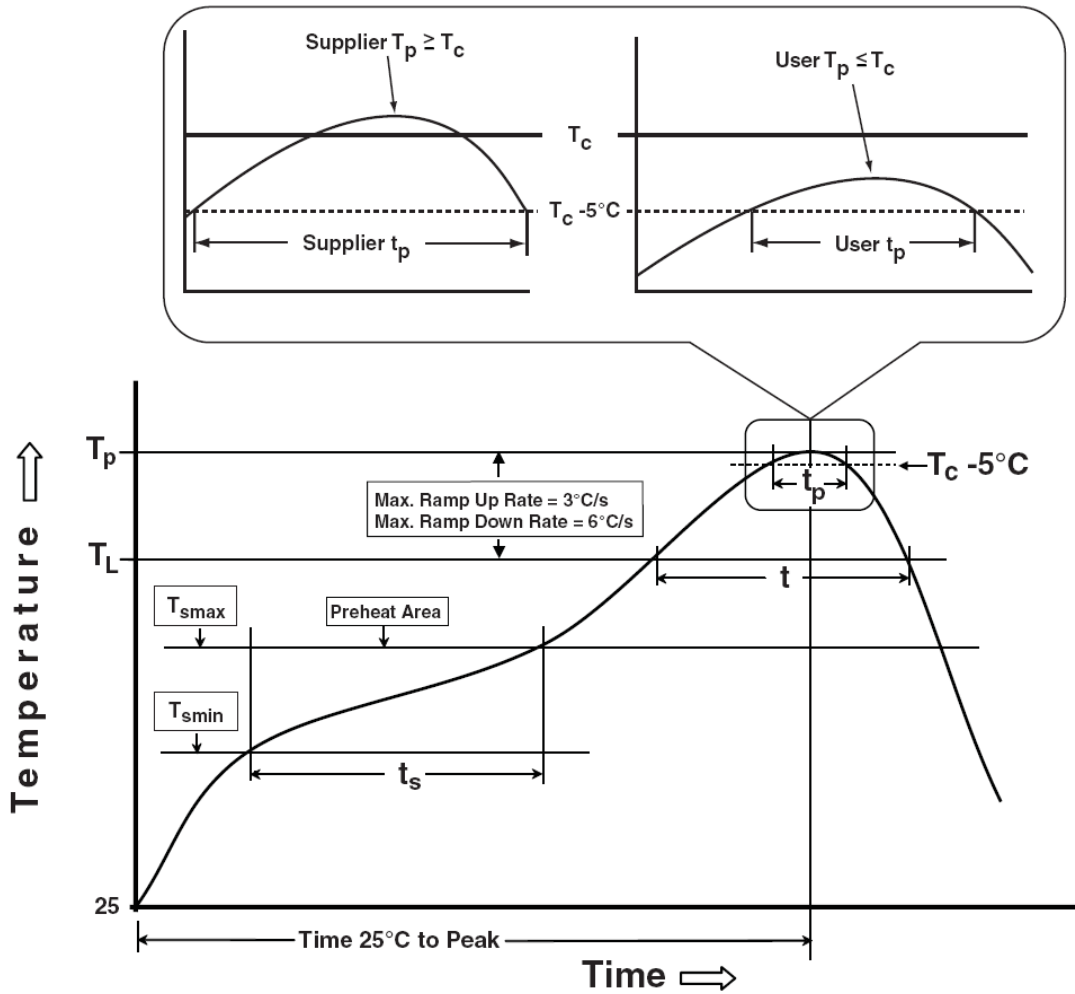
TSSOP-14



VTDFN3x4-14



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.		

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 (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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