APX9365A/B/C

Three-Phase Sensor-Less Fan Motor Driver

Features

- **Three-Phase Full-Wave Sensor-Less Drive Method**
- **Adjustable Forced Commutation Frequency (for Start-up)**
- **Built-In External PWM Speed Control**
- **Built-In Quick Start Function**
- **FG (Rotation Speed Detection) Output (for APX9365A)**
  RD (Lock Detection) Output (for APX9365B)
  1/2FG (Rotation Speed Detection) Output (for APX9365C)
- **Soft Switching Circuit (for Noise Reducing)**
- **Power Saving Function (PWM Duty Input is 0%)**
- **Built-In Lock Protection and Auto Restart Function**
- **Thermal Shutdown Circuit**
- **Lead Free and Green Devices Available (RoHS Compliant)**

Applications

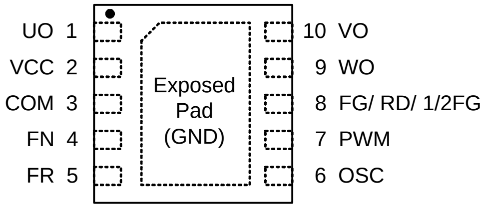
- **Motor Driver For Silent Fan Motors**

General Description

The APX9365A/B/C provides all the circuitry for sensor-less speed control of three-phase brushless DC motor. The controller functions include start-up circuit, back-EMF commutation control, Pulse Width Modulation (PWM) speed control, lock protection, and thermal shutdown circuit.

The APX9365A/B/C is suitable for both game machine and CPU cooler that need silent drivers. It is available in VTDFN3x3-10 package.

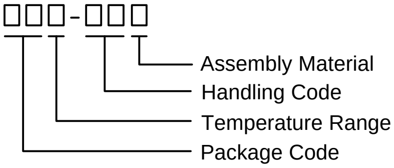
Pin Configuration



VTDFN3X3-10
(TOP VIEW)

⬚ = Exposed Pad (connected to the ground of power)

Ordering and Marking Information

APX9365A/B/C □□□-□□□  Assembly Material Handling Code Temperature Range Package Code	Package Code QF : VTDFN3x3-10 Operating Ambient Temperature Range I : -40 to 105 °C Handling Code TR : Tape & Reel Assembly Material G : Halogen and Lead Free Device
APX9365A/B/C QF : APX 9365A XXXXX APX 9365B XXXXX APX 9365C 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-020D for MSL classification at lead-free peak reflow temperature. ANPEC defines "Green" to mean lead-free (RoHS compliant) and halogen free (Br or Cl does not exceed 900ppm by weight in homogeneous material and total of Br and Cl does not exceed 1500ppm by weight).

Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Rating	Unit
V_{CC}	VCC Pin Supply Voltage	-0.3 to 7	V
I_{OUT}	UO/VO/WO Pin Output Current	0 to 1	A
$V_{UO}/V_{VO}/V_{WO}$	UO/VO/WO Pin Output Voltage	-0.3 to 7	V
$V_{FG/RD}$	FG/RD Pin Output Voltage	-0.3 to 7	V
$I_{FG/RD}$	FG/RD Pin Sink Current	0 to 10	mA
V_{FR}	FR Pin Input Voltage	-0.3 to 7	V
T_J	Junction Temperature	-40 to 150	°C
T_{STG}	Storage Temperature	-65 to 150	°C
T_{SDR}	Maximum Lead Soldering Temperature, 10 Seconds	260	°C

Note1: 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
θ_{JA}	Thermal Resistance-Junction to Ambient (Note2) VTDFN3x3-10	119	°C/W
P_D	Power Dissipation, T_A=25°C VTDFN3x3-10	1.05	W

Note 2: θ_{JA} is measured with the component mounted on a 55mm x 40mm x 1.6mm glass epoxy board (two-layer) in free air.

Recommended Operating Conditions

Symbol	Parameter	Range	Unit
V_{CC}	VCC Pin Supply Voltage Range	1.8 to 6	V
V_{PWM}	PWM Pin Input Voltage Range	0 to V_{CC}	V
T_A	Ambient Temperature	-40 to 105	°C
I_{OUT}	UO/VO/WO Pin Average Output Current	0 to 400	mA

Electrical Characteristics (V_{CC}=5V, T_A=25°C, unless otherwise specified)

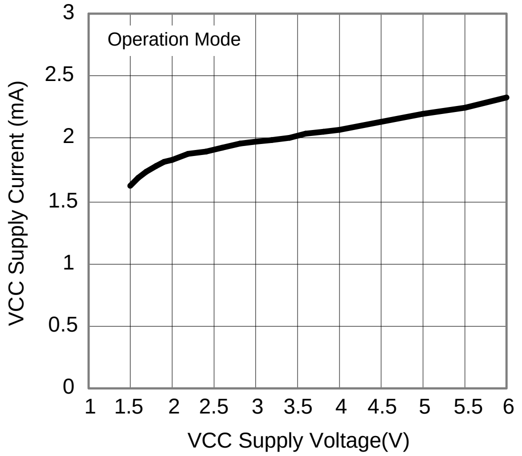
Symbol	Parameter	Test Conditions	APX9365A/B/C			Unit
			Min.	Typ.	Max.	
SUPPLY CURRENT						
I_{CC1}	Operating Current	Rotation Mode	-	3	5	mA
I_{CC2}	Standby Supply Current	PWM=0	-	100	150	μA
PWM INPUT						
V_{PWMH}	PWM Input High Level Voltage		2.5	-	V_{CC}+0.5	V
V_{PWML}	PWM Input Low Level Voltage		0	-	1	V
F_{PWM}	PWM Input Frequency		15	-	50	kHz
OUTPUT DRIVERS						
V_O	Output Driver Saturation Voltage	I_{OUT}=250mA, Upper and Lower total	-	0.3	0.44	V

Electrical Characteristics (Cont.) (V$_{CC}$=5V, T$_A$=25°C, unless otherwise specified)

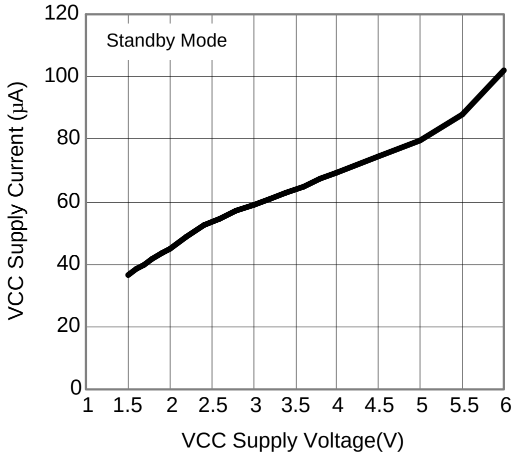
Symbol	Parameter	Test Conditions	APX9365A/B/C			Unit
			Min.	Typ.	Max.	
OUTPUT DRIVERS (CONT.)						
$V_{FG/RD}$	FG/RD Pin Low Voltage	$I_{FG/RD}$=5mA	-	0.2	0.3	V
$I_{FGL/RDL}$	FG/RD Pin Leak Current	$V_{FG/RD}$=7V	-	-	10	µA
V_{FR}	FR Pin Input Threshold Voltage		-	0.5 x V_{CC}	-	V
LOCK PROTECTION						
T_{ON}	Lock Detection On Time		0.85	1	1.15	sec
T_{OFF}	Lock Detection Off Time		4.25	5	5.75	sec
THERMAL SHUTDOWN						
OTS	Over Temperature Shutdown		-	160	-	°C
	Over Temperature Shutdown Hysteresis		-	30	-	
QUICK START						
T_{QS}	Quick Start Enable Time		-	2	-	ms

Typical Operating Characteristics

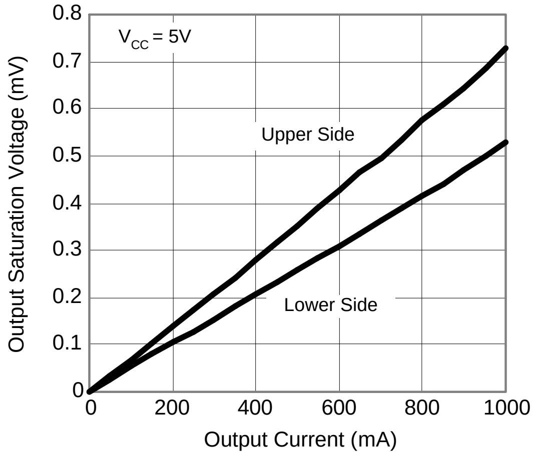
VCC Supply Current vs. VCC Supply Voltage



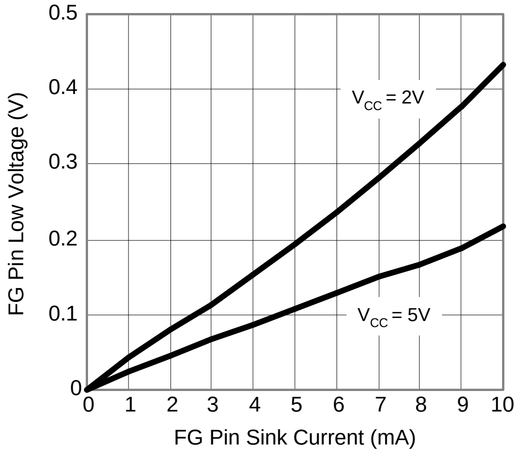
VCC Supply Current vs. VCC Supply Voltage



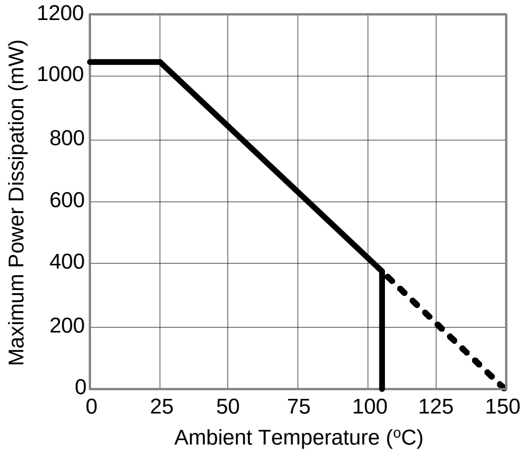
Output Saturation Voltage vs. Output Current



FG Pin Low Voltage vs. Sink Current

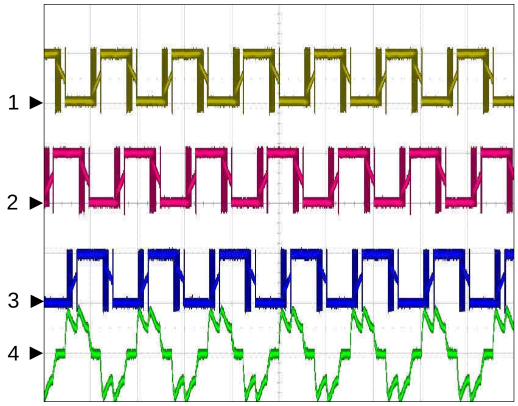


Maximum Power Dissipation vs.
Ambient Temperature



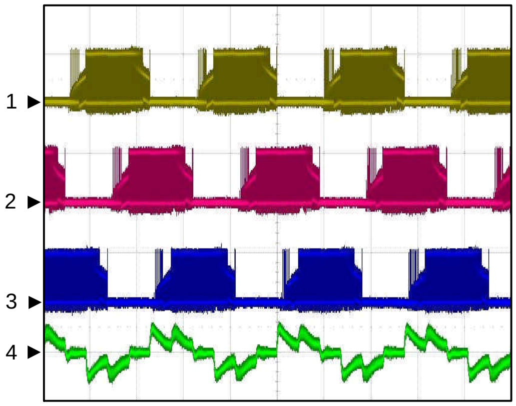
Operating Waveforms

Rotation Mode Waveform (NORMAL)



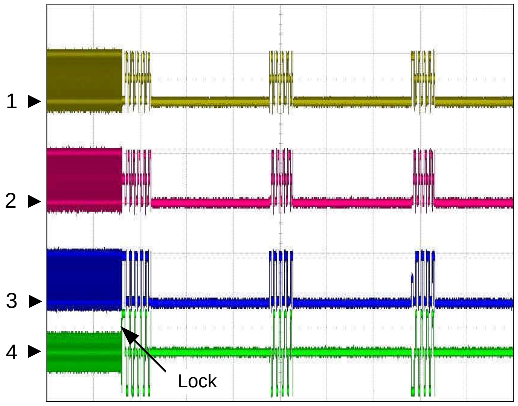
CH1: V_{UO}, 5V/div, DC
CH2: V_{VO}, 5V/div, DC
CH3: V_{WO}, 5V/div, DC
CH4: I_{UO}, 200mA/div, DC
Time: 5ms/div

Rotation Mode Waveform (PWM)



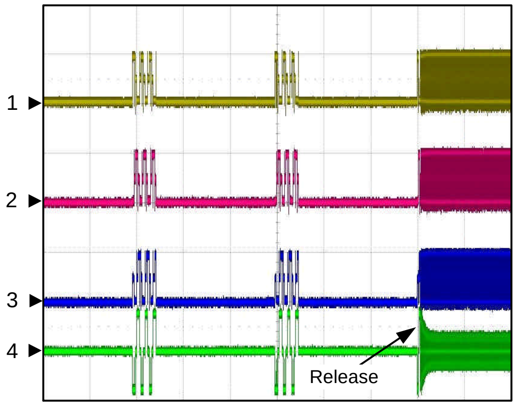
CH1: V_{UO}, 5V/div, DC
CH2: V_{VO}, 5V/div, DC
CH3: V_{WO}, 5V/div, DC
CH4: I_{UO}, 200mA/div, DC
Time: 5ms/div

Lock Protection Waveform (Lock)



CH1: V_{UO}, 5V/div, DC
CH2: V_{VO}, 5V/div, DC
CH3: V_{WO}, 5V/div, DC
CH4: I_{UO}, 500mA/div, DC
Time: 2s/div

Lock Protection Waveform (Release)

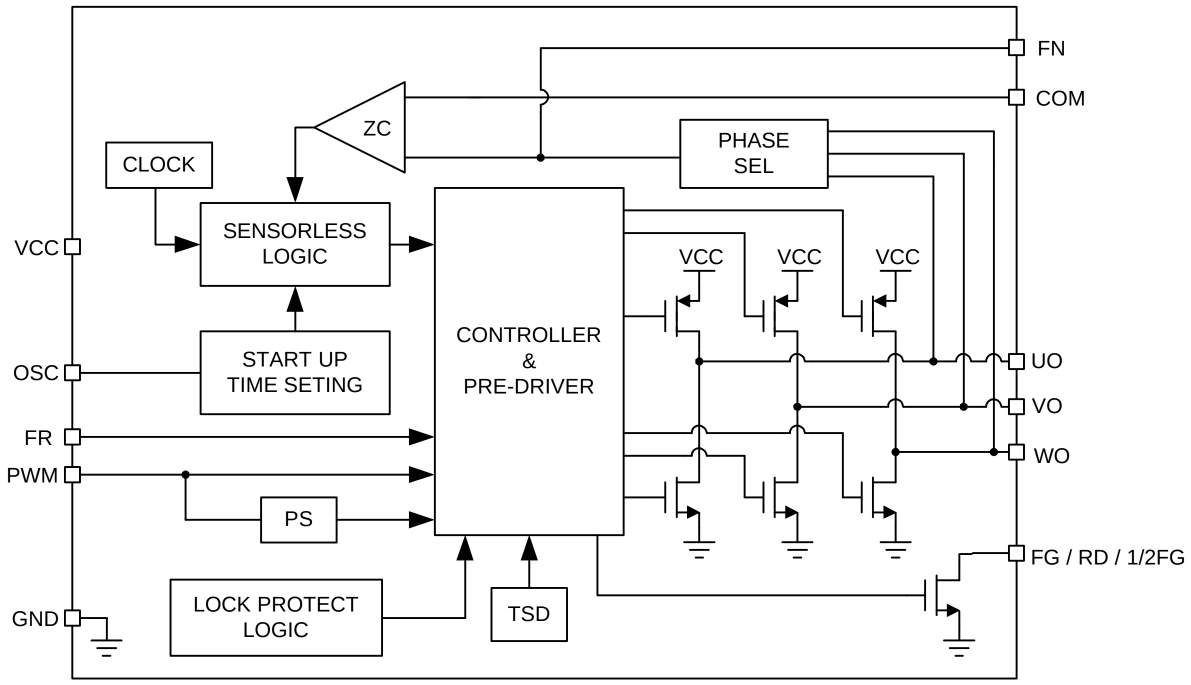


CH1: V_{UO}, 5V/div, DC
CH2: V_{VO}, 5V/div, DC
CH3: V_{WO}, 5V/div, DC
CH4: I_{UO}, 500mA/div, DC
Time: 2s/div

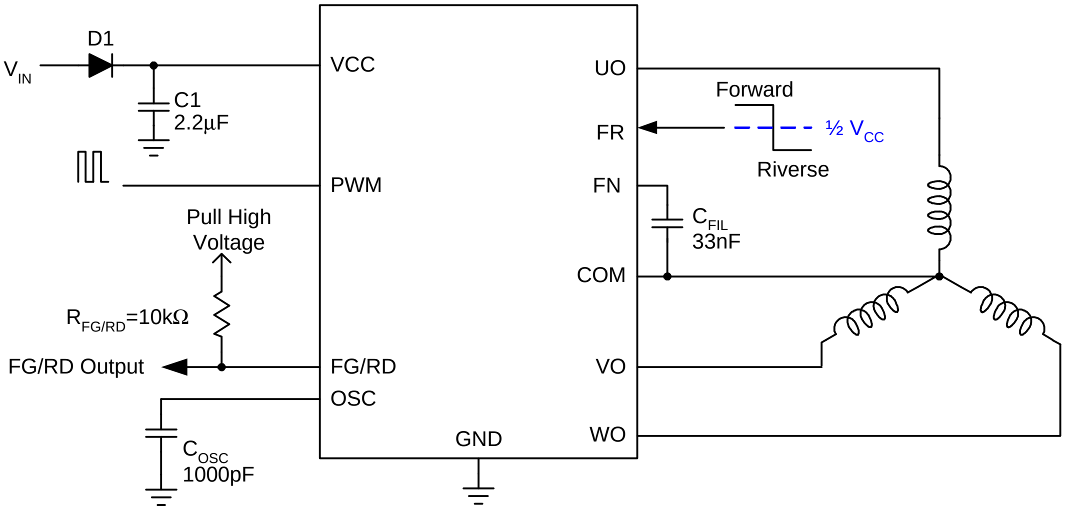
Pin Description

PIN		FUNCTION
NO.	NAME	
1	UO	Driver Output Pin. Output signal for driving motor phase U.
2	VCC	Supply Voltage Input Pin.
3	COM	Motor Neutral Point Input Pin
4	FN	Motor Floating Terminal Voltage Output.
5	FR	Motor Spin Direction Control Pin. High Level Input: U→ V → W Low Level Input: U→ W → V
6	OSC	Start-up Commutation Time Setting. Connect a capacitor to GND to set start-up commutation time.
7	PWM	PWM Signal Input Pin. Input PWM signal to control rotation speed.
8	FG(APX9365A)	Rotation Speed Output. This is an open-drain output.
	RD(APX9365B)	Rotation Detection Output. This is an open-drain output.
	1/2FG(APX9365C)	Rotation Speed Output. This is an open-drain output.
9	WO	Driver Output Pin. Output signal for driving motor phase W.
10	VO	Driver Output Pin. Output signal for driving motor phase V.
Exposed Pad	GND	Ground Pin.

Block Diagram



Typical Application Circuit



Note : D1 is to prevent the damage from the power reverse connection.

Function Description

PWM Speed Control

It is possible to change rotation speed of the motor by switching high side output transistor. The on-duty of switching depends on the signal from input to PWM terminal. (See Figure 1 PWM Input Waveform)

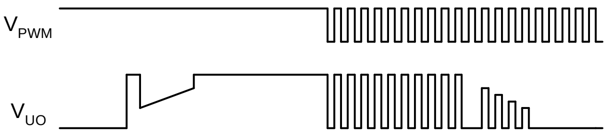


Figure 1. PWM Input Waveform

Quick Start

This IC disables the lock protection function when the PWM input keeps low level for more than 2ms. (See Figure 2 Quick Start Waveform)

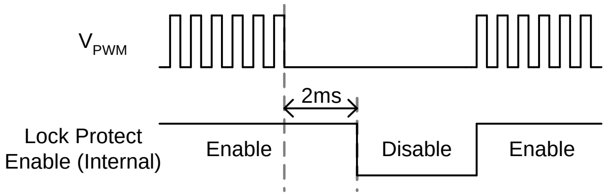


Figure 2. Quick Start Waveform

FG Output

The FG pin is an open-drain output, connecting a pull up resistor to a high level voltage for the speed detection function. When UO pin voltage switches to high, the FG is high (switch off) and the UO pin voltage switches to low then FG is low (switch on). The FG output only works in sensor- less mode. (See Figure 3 FG Output Waveform)

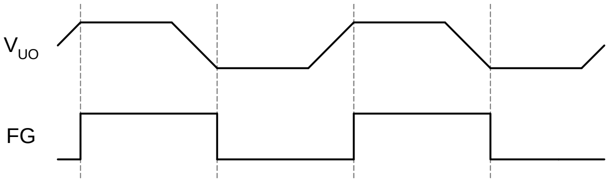


Figure 3. FG Output Waveform

Soft Switch

The APX9365A/B/C is equipped with a soft switch function to make phase current become more gentle, which can reduce the noise of motor in switching interval.

Lock Protection and Automatic Restart

The APX9365A/B/C provides the lock protection and automatic restart functions to prevent the coil burnout while the fan is locked. As the fan is locked, the IC will come into start-up operation for 1 second. Then, the IC will switch to lock protection mode to close output driver for 6 seconds. After lock protection mode, the IC switches to start-up operation again. If the locked condition still remains, the lock-and-restart process will be recurred until the locked condition is released.

Thermal Protection

The APX9365A/B/C has thermal protection. When internal junction temperature reaches 160°C, the output devices will be switched off. When the IC's junction temperature cools down 30°C, the thermal sensor will turn on the output devices again, resulting in a pulsed output during continuous thermal protection.

Application Information

Input Protection Diode & Capacitor

It is necessary to add 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 larger than the maximum output current. For the noise reduction purpose, a capacitor (C1) is connected between VCC and GND. (see Typical Application Circuit) It's suggested that C1 should be placed as close as possible in the VCC pin.

OSC Capacitor

The capacitor connects from OSC pin to GND can be determined the frequency of force commutation. The optimal design of the frequency could make sure the motor start-up in succeed. Its capacitance from 1000pF to 3300pF is recommended.

FIL Capacitor

The capacitor connects between FN and COM pin to filter the noise when phase change to make sure phase change correctly. Its capacitance from 10nF to 100nF is recommended.

FG/RD Resistor

The value of FG/RD resistor could be decided by the following equation:

$$R_{FG/RD} = \frac{V_{CC} - V_{FG/RD}}{I_{FG/RD}}$$

For example:

$V_{CC} = 5V$, $I_{FG/RD} = 5mA$, $V_{FG/RD} = 0.2V$, $R_{FG/RD} = 0.96k\Omega$

The value of resistor in the range of 1kΩ to 10kΩ is recommended.

Thermal Consideration

Refer to "Maximum Power Dissipation vs. Ambient Temperature", the IC is safe to operate below the curve and it will cause the thermal protection if the operating area is above the line. For example, $T_A = 75°C$, the MSOP-10 package maximum power dissipation is about 0.48W. The power dissipation can be calculated by the following equation:

$$P_D = \left(V_{CC} - \left|V_{UO} - V_{VO}\right|\right) \times I_{UO} + V_{CC} \times I_{CC}$$

For example:

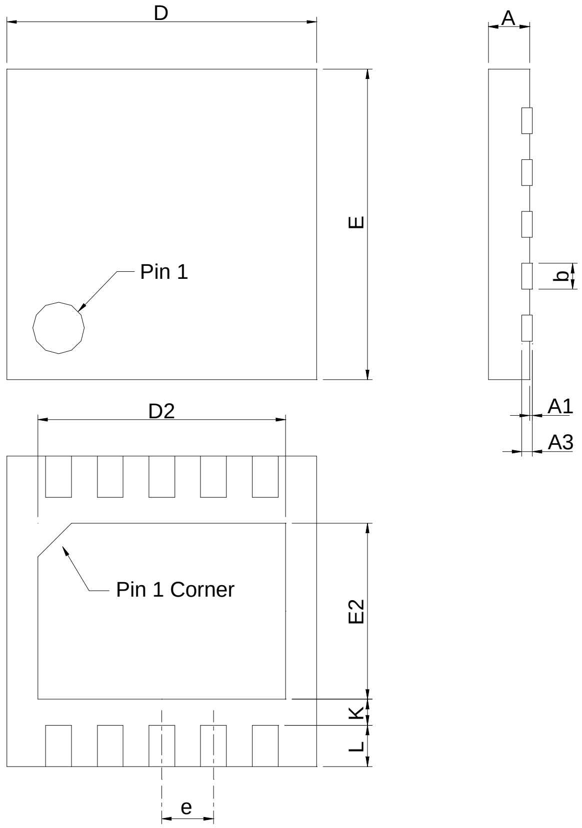
$V_{CC} = 5V$, $I_{CC} = 3mA$, $I_{OUT} = 250mA$, $V_{UO} = 4.85V$,

$V_{VO} = 0.15V$, then $P_D = 0.09W$

The GND pin provides an electrical connection to the ground and channeling heat away. The printed circuit board (PCB) forms a heat sink and dissipates most of the heat into ambient air.

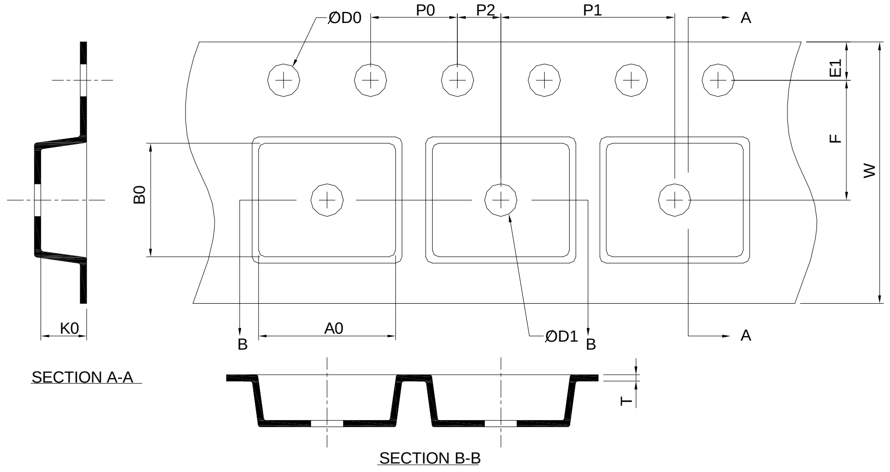
Package Information

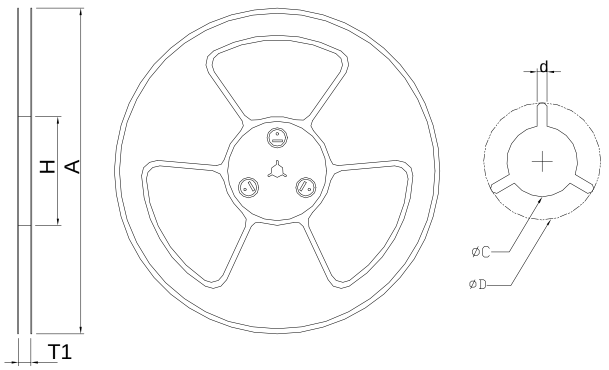
VTDFN3x3-10



SYMBOL	VTDFN3x3-10			
	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	0.20 REF		0.008 REF	
b	0.18	0.30	0.007	0.012
D	2.90	3.10	0.114	0.122
D2	2.20	2.70	0.087	0.106
E	2.90	3.10	0.114	0.122
E2	1.40	1.75	0.055	0.069
e	0.50 BSC		0.016 BSC	
L	0.30	0.50	0.012	0.020
K	0.20		0.008	

Carrier Tape & Reel Dimensions





Application	A	H	T1	C	d	D	W	E1	F
VTDFN3x3-10	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	3.30±0.20	3.30±0.20	1.30±0.20

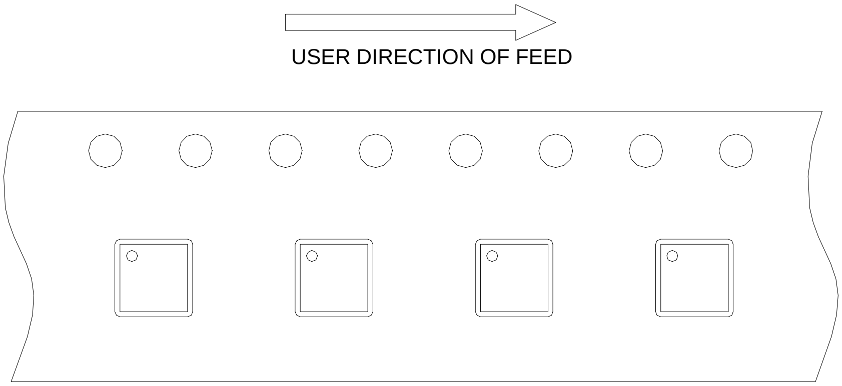
(mm)

Devices Per Unit

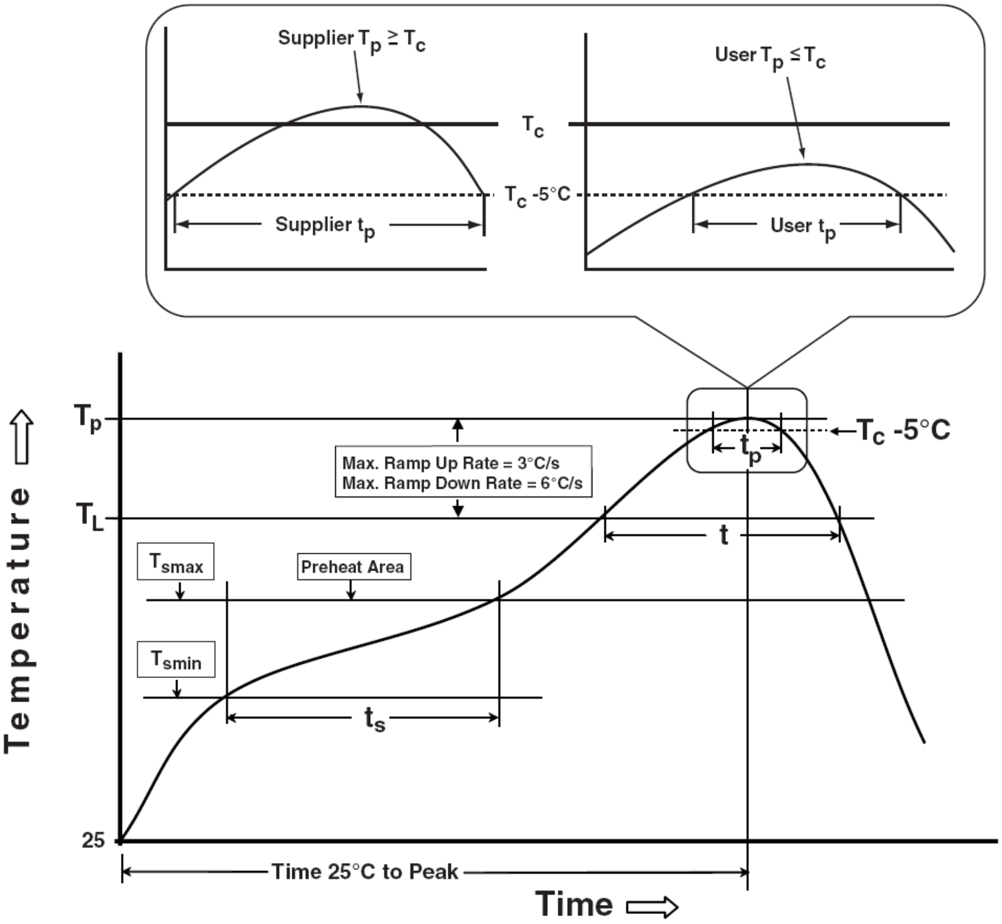
Package Type	Unit	Quantity
VTDFN3x3-10	Tape & Reel	3000

Taping Direction Information

VTDFN3x3-10



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.		

Table 1. SnPb Eutectic Process – Classification Temperatures (Tc)

Package Thickness	Volume mm^3 <350	Volume mm^3 ^{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≧2KV
MM	JESD-22, A115	VMM≧200V
Latch-Up	JESD 78	10ms, 1_{tr}≧100mA