Single-Phase Full-Wave Motor Pre-Driver for Fan Motor

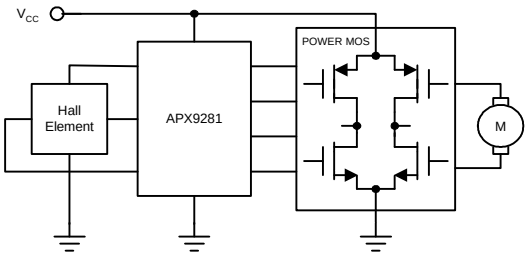
Features

- **Single Phase Fan Pre-Driver**
- **Low Supply Current**
- **Soft-Start Function**
- **Built-in Variable Speed Control Function**
- **Minimum Speed Setting**
- **Built-in Current-Limit**
- **Built-in Lock Protection and Auto Restart Function**
- **FG (Rotation Speed Dectection) Output**
- **Built-in Thermal Protection Circuit**
- **Lead Free and Green Devices Available (RoHS Compliant)**

General Description

The APX9281 is a single phase, DC brushless motor pre-driver with features of PWM variable speed control, soft-start, and current-limit, which is suitable for fans, blowers, and pump motors. Adequate S-S pin capacitor could reduce the peak current at power on and Lock mode. PWM control system works depending on the comparison among the voltage of SET, MIN, and OSC. The device is equipped with built-in lock protection; when fan is locked, the device will enter the lockup protection mode. It is also with rotation detection output and thermal shutdown function. In normal operation, the supply current is less than 10mA. The APX9281 is available in the SSOP-16 package.

Simplified Application Curcuit



Applications

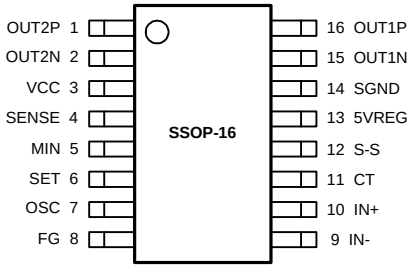
- **Mainframe and Personal Computer Fans and Blowers**
- **Instrumentation Fans**
- **Variable Speed Control Fans**

Ordering and Marking Information

APX9281 □□-□□□ Assembly Material Handling Code Temperature Range Package Code	Package Code N : SSOP-16 Operating Ambient Temperature Range I : -40 to 90°C Handling Code TR : Tape & Reel Assembly Material L : Lead Free Device G : Halogen and Lead Free Device
APX9281 N : APX9281 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 in homogeneous material and total of Br and Cl does not exceed 1500ppm by weight).

Pin Configuration



Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Ratings	Unit
V_{CC}	VCC Pin Supply Voltage	-0.3 to 18	V
I_{OUTP}	Output Pin (OUT1P, OUT2P) Sink Current	20	mA
I_{OUTN}	Output Pin (OUT1N, OUT2N) Sink and Source Current	20	mA
$V_{OUTP,OUTN}$	Output Pin (OUT1P, OUT2P, OUT1N, OUT2N) Output Voltage	-0.3 to18	V
V_{S-S}	S-S Pin Withstand Voltage	-0.3 to 7	V
$V_{SET/MIN}$	SET/MIN Pin Input Voltage	-0.3 to 7	V
	FG Pin Output Voltage	-0.3 to 18	V
I_{FG}	FG Pin Output Sink Current	10	mA
I_{5VREG}	5VREG Pin Output Source Current	20	mA
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

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 (Note 2) SSOP-16	125	°C/W
P_D	Power Dissipation, T_A=25°C	800	mW

Note 2: Mounted on a board (80x80x1.6 mm Glass epoxy).

Recommended Operating Conditions

Symbol	Parameter	Rating	Unit
V_{CC}	VCC Pin Supply Voltage Range	5.5 to 16	V
V_{SET}	SET Pin Input Voltage Range	0 to 5	V
V_{MIN}	MIN Pin Input Voltage Range	0 to 5	V
V_{ICM}	Hall Input Common-Phase Input Voltage Range	0.2 to 3	V
T_A	Operating Ambient Temperature	-40 to 95	°C
T_J	Junction Temperature	-40 to 125	°C

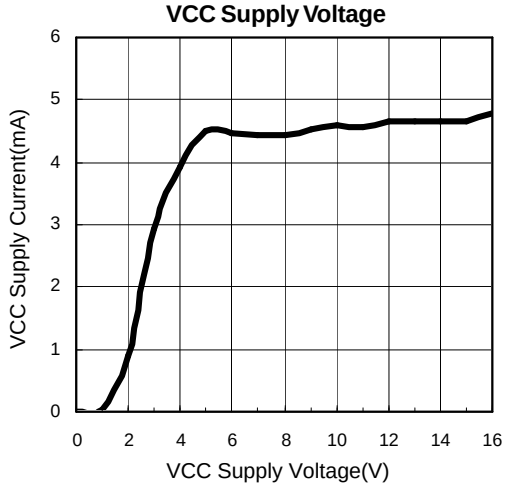
Electrical Characteristics (Cont.)

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

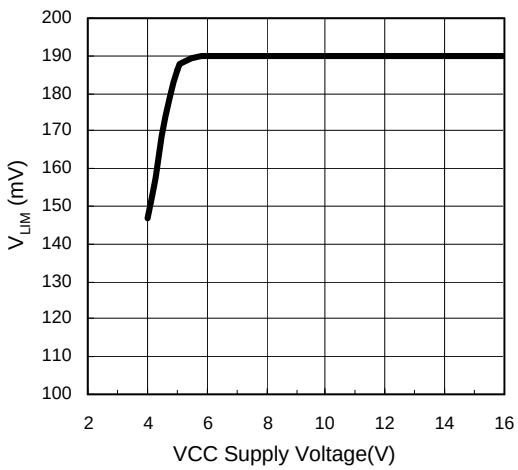
Symbol	Parameter	Test Conditions	APX9281			Unit
			Min.	Typ.	Max.	
SUPPLY CURRENT						
V_{5VREG}	5VREG Pin Output Voltage	I_{5VREG} = 5mA	4.75	5	5.25	V
I_{CC1}	V_{CC} Operating Current	Rotation Mode	3	5	7	mA
I_{CC2}		Lock Protection Mode	3	5	7	mA
OSCILLATOR						
V_{OSCH}	OSC High Level Voltage	C_{OSC} = 220pF	2.75	3	3.25	V
V_{OSCL}	OSC Low Level Voltage	C_{OSC} = 220pF	0.85	1	1.15	V
I_{OSC1}	OSC Charge Current	V_{OSC}= 0V	24	30	36	µA
I_{OSC2}	OSC Discharge Current	V_{OSC} = 3.5V	24	30	36	µA
F_{OSC}	OSC Oscillation Frequency	C_{OSC} = 220pF	25	30	35	kHz
LOCK PROTECTION						
V_{CTH}	CT Pin High Level Voltage	C_{CT} = 1µF	2.7	3	3.2	V
V_{CTL}	CT Pin Low Level Voltage	C_{CT} = 1µF	0.85	1	1.15	V
I_{CT1}	CT Charge Current	V_{CT} = 0.5V	1.6	2	2.5	µA
I_{CT2}	CT Discharge Current	V_{CT} = 3.5V	0.16	0.2	0.28	µA
R_{CT}	CT Charge/Discharge Current Ratio	$R_{CT} = I_{CT1}/I_{CT2}$	8	10	12	-
OUTPUT DRIVERS						
V_{OUTPL}	OUT_P Output Low Voltage	I_{OUTP} = 20mA	-	0.5	1	V
I_{OUTPH}	OUT_P Output High Leakage Current	VOUTP = 12V	-	40	100	µA
V_{OUTNH}	OUT_N Output High Voltage	I_{OUTN} = -20mA	V_{CC}-2	V_{CC}-1.5	-	V
V_{OUTNL}	OUT_N Output Low Voltage	I_{OUTN} = 20mA		0.5	1	V
V_{FG}	FG Pin Low Voltage	I_{FG} = 5mA	-	0.15	0.3	V
I_{FGL}	FG Pin Leakage Current	V_{FG} = 12V	-	0.1	1	µA
PROTECTION						
V_{LIM}	Internal Current-Limit Reference Voltage		180	200	220	mV
I_{S-S}	S-S Pin Charge Current	V_{S-S} = 1V	-	0.5	-	µA
HALL SENSITIVITY						
V_{HN}	Hall Input Sensitivity	Zero to peak including offset and hysteresis	-	10	20	mV
THERMAL SHUTDOWN						
OTS	Over-Temperature Shutdown Threshold		-	160	-	°C
	Over-Temperature Shutdown Hysteresis		-	20	-	

Typical Operating Characteristics

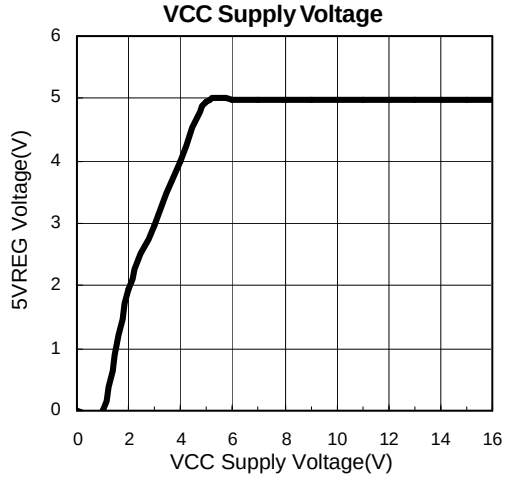
VCC Supply Current vs. VCC Supply Voltage



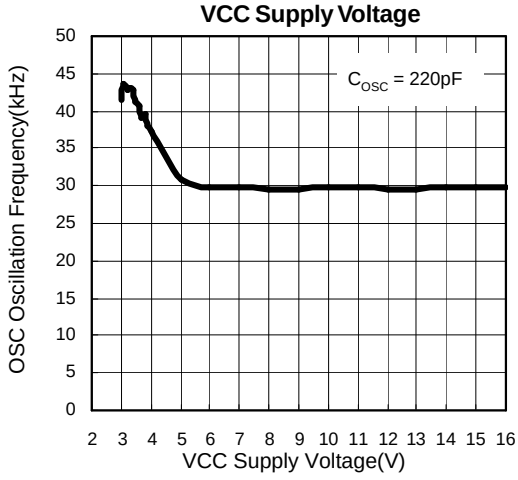
V_{LIM} vs. VCC Supply Voltage



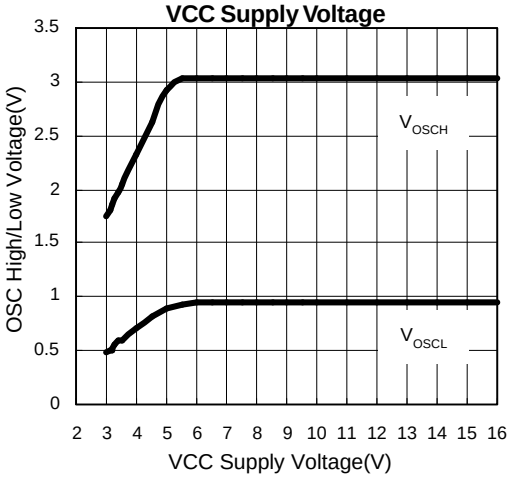
5VREG Voltage vs. VCC Supply Voltage



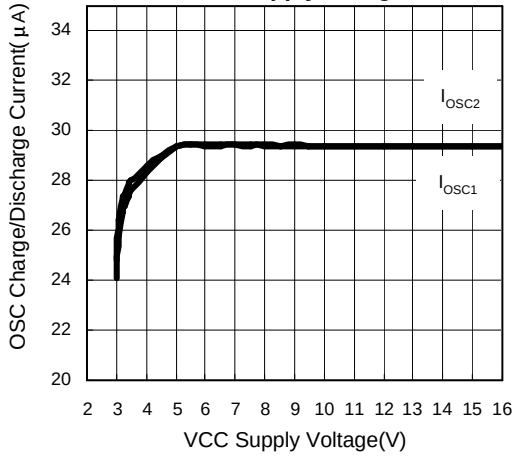
OSC Oscillation Frequency vs. VCC Supply Voltage



OSC High/Low Voltage vs. VCC Supply Voltage

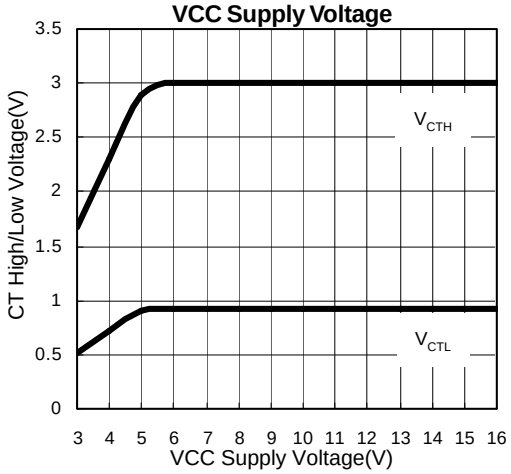


OSC Charge/Discharge Current vs. VCC Supply Voltage

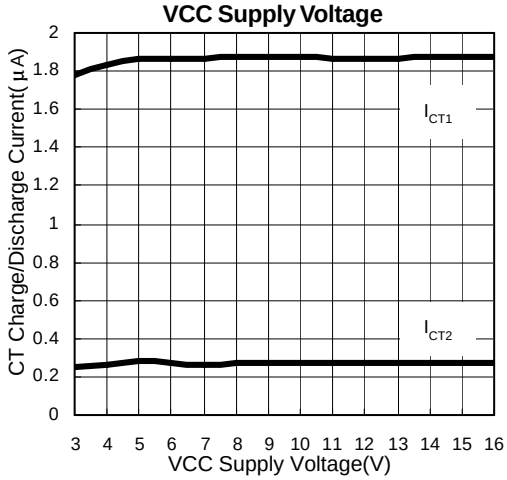


Typical Operating Characteristics (Cont.)

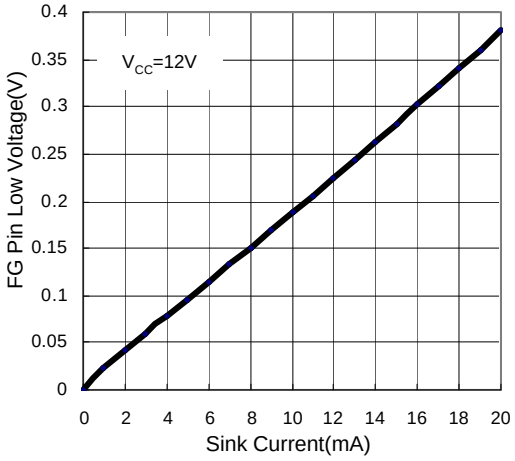
CT High/Low Voltage vs. VCC Supply Voltage



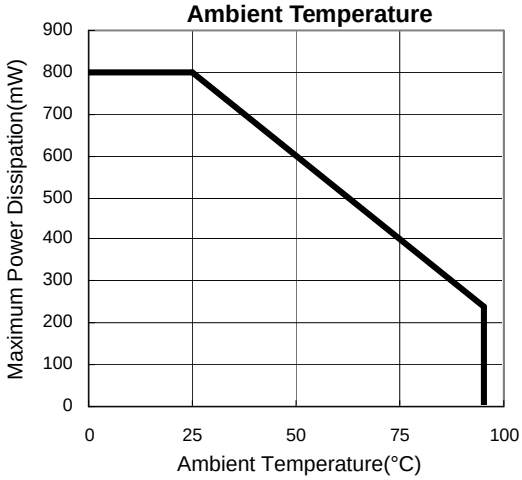
CT Charge/Discharge Current vs. VCC Supply Voltage



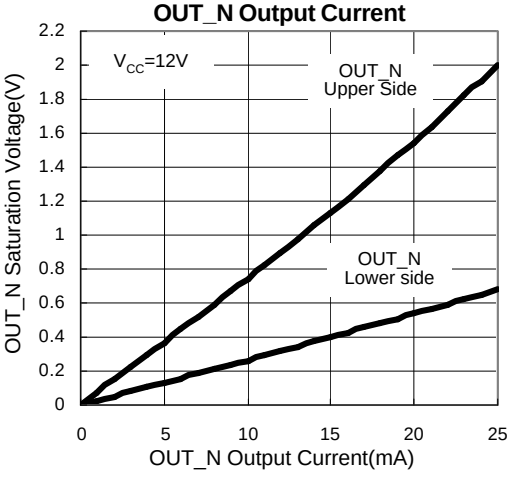
FG Pin Low Voltage vs. Sink Current



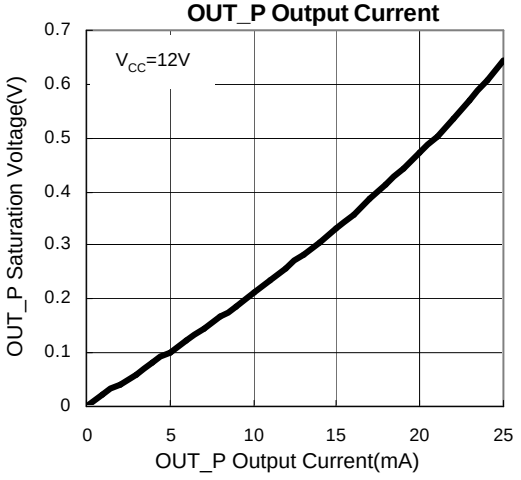
Maximum Power Dissipation vs. Ambient Temperature



OUT_N Saturation Voltage vs. OUT_N Output Current

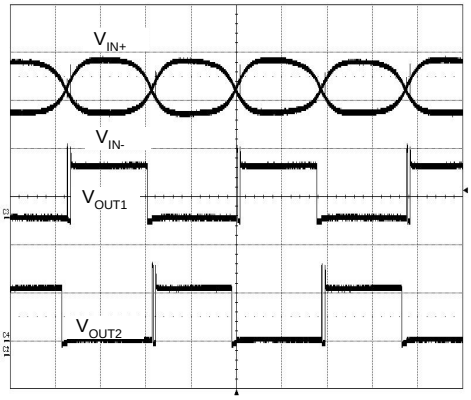


OUT_P Saturation Voltage vs. OUT_P Output Current



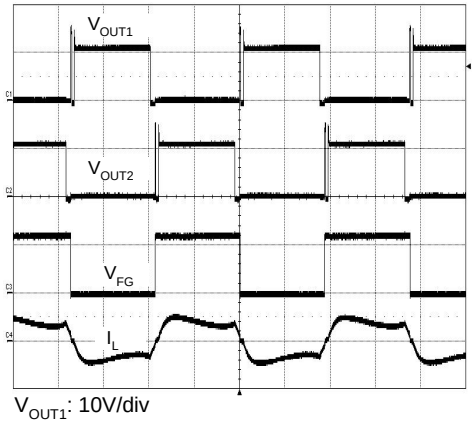
Operating Waveforms (V_{CC} = 12V, T_A = 25°C)

Rotation Mode Waveform1



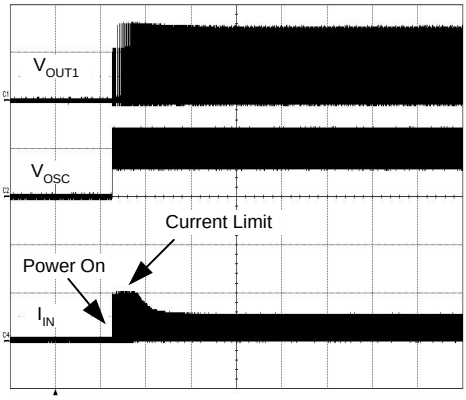
V_{IN+}: 100mV/div
V_{IN-}: 100mV/div
V_{OUT1}: 10V/div
V_{OUT2}: 10V/div
Time: 2ms/div

Rotation Mode Waveform2



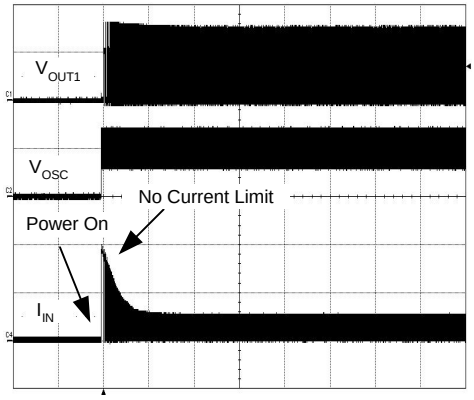
V_{OUT1}: 10V/div
V_{OUT2}: 10V/div
V_{FG}: 10V/div
I_L: 2A/div
Time: 2ms/div

Rotation Mode Waveform3 without C_{S-S}



V_{OUT1}:1 0V/div
V_{OSC}: 2V/div
I_{IN}: 2A/div
Time:1s/div

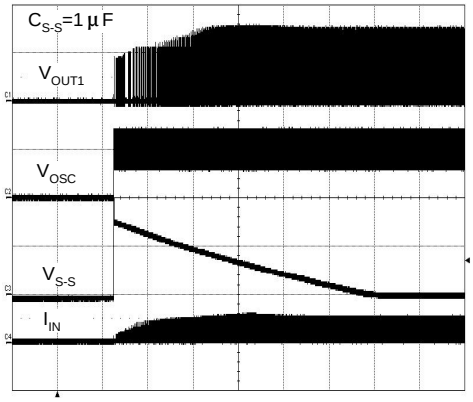
Rotation Mode Waveform3 without C_{S-S}



V_{OUT1}: 10V/div
V_{OSC}: 2V/div
I_{IN}: 2A/div
Time: 1s/div

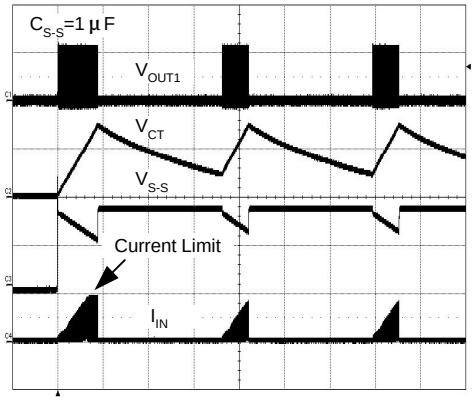
Operating Waveforms (Cont.) (V_{CC} = 12V, T_A = 25°C)

Rotation Mode Waveform4 with C_{S-S}



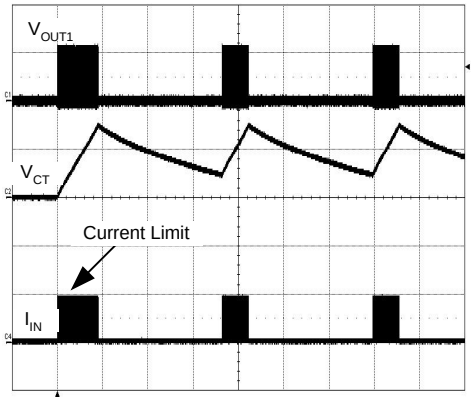
V_{OUT1}: 10V/div
V_{OSC}: 2V/div
V_{S-S}: 2V/div
I_{IN}: 2A/div
Time: 1s/div

Lock Protection Waveform1 with C_{S-S}



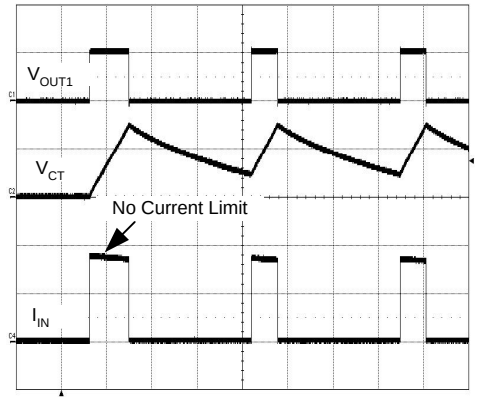
V_{OUT1}: 10V/div
V_{CT}: 2V/div
V_{S-S}: 2V/div
I_{IN}: 2A/div
Time: 2s/div

Lock Protection Waveform1 without C_{S-S}



V_{OUT1}: 10V/div
V_{CT}: 2V/div
I_{IN}: 2A/div
Time: 2s/div

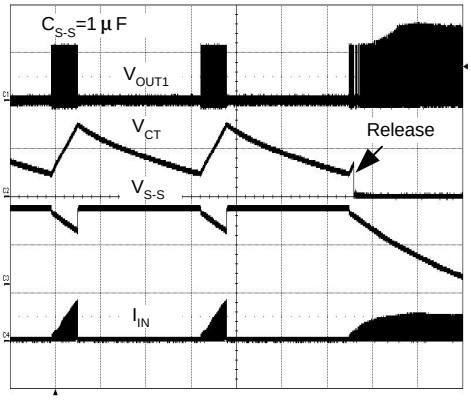
Lock Protection Waveform1 without C_{S-S}



V_{OUT1}: 10V/div
V_{CT}: 2V/div
I_{IN}: 2A/div
Time: 2s/div

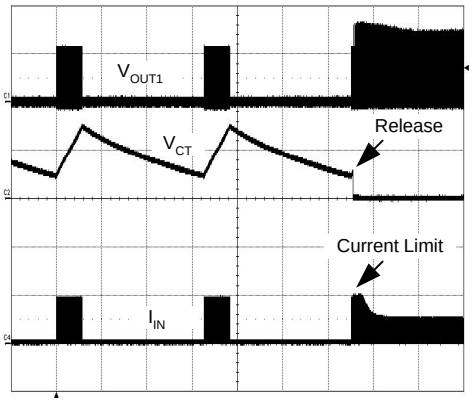
Operating Waveforms (Cont.) (V_{CC} = 12V, T_A = 25°C)

Lock Protection Waveform2 with C_{S-S}



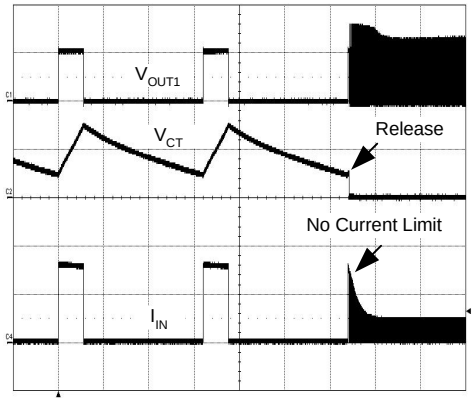
V_{OUT1}: 10V/div
V_{CT}: 2V/div
V_{S-S}: 2V/div
I_{IN}: 2A/div
Time: 2s/div

Lock Protection Waveform2 without C_{S-S}



V_{OUT1}: 10V/div
V_{CT}: 2V/div
I_{IN}: 2A/div
Time: 2s/div

Lock Protection Waveform2 without C_{S-S}

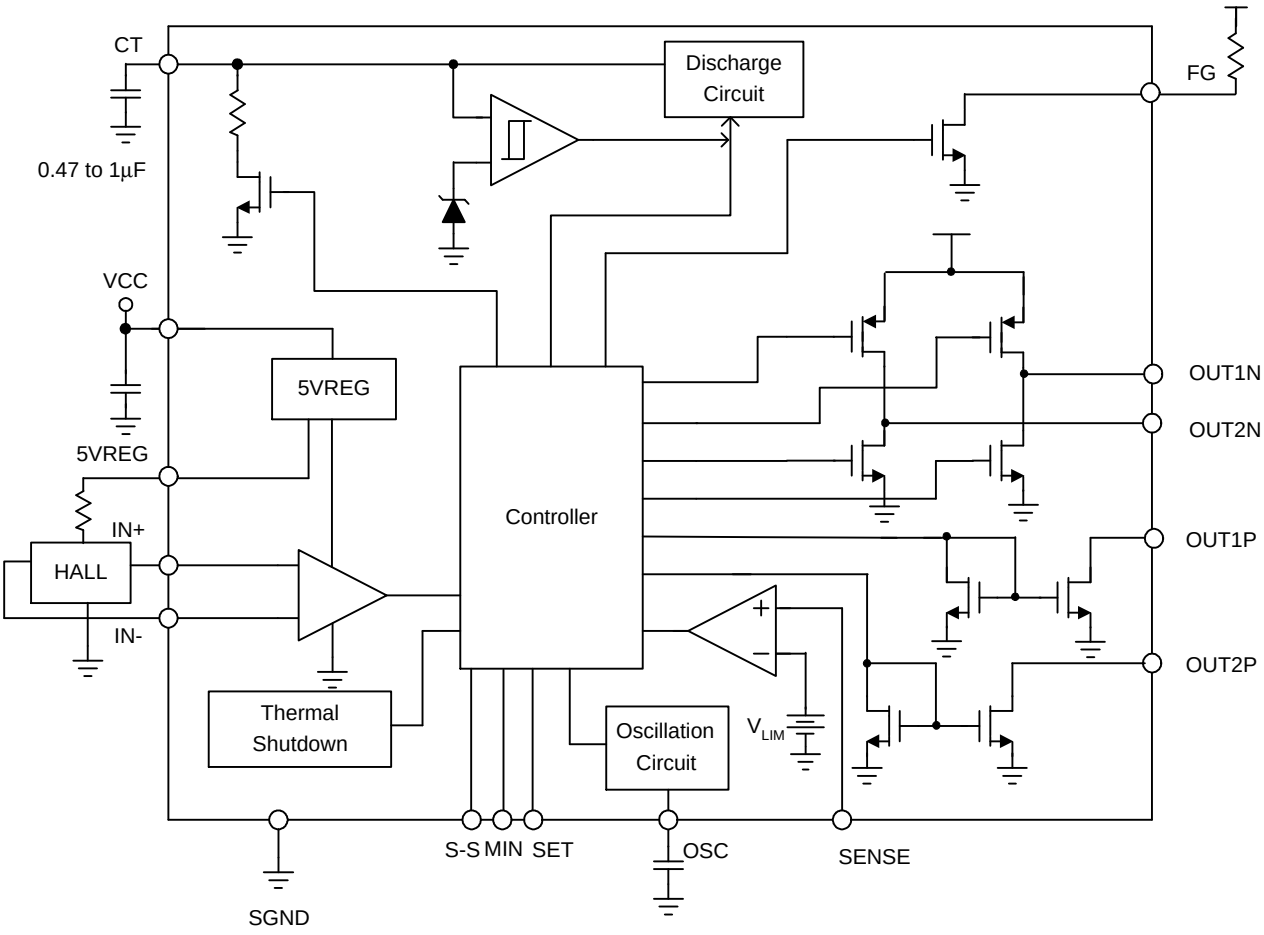


V_{OUT1}: 10V/div
V_{CT}: 2V/div
I_{IN}: 2A/div
Time: 2s/div

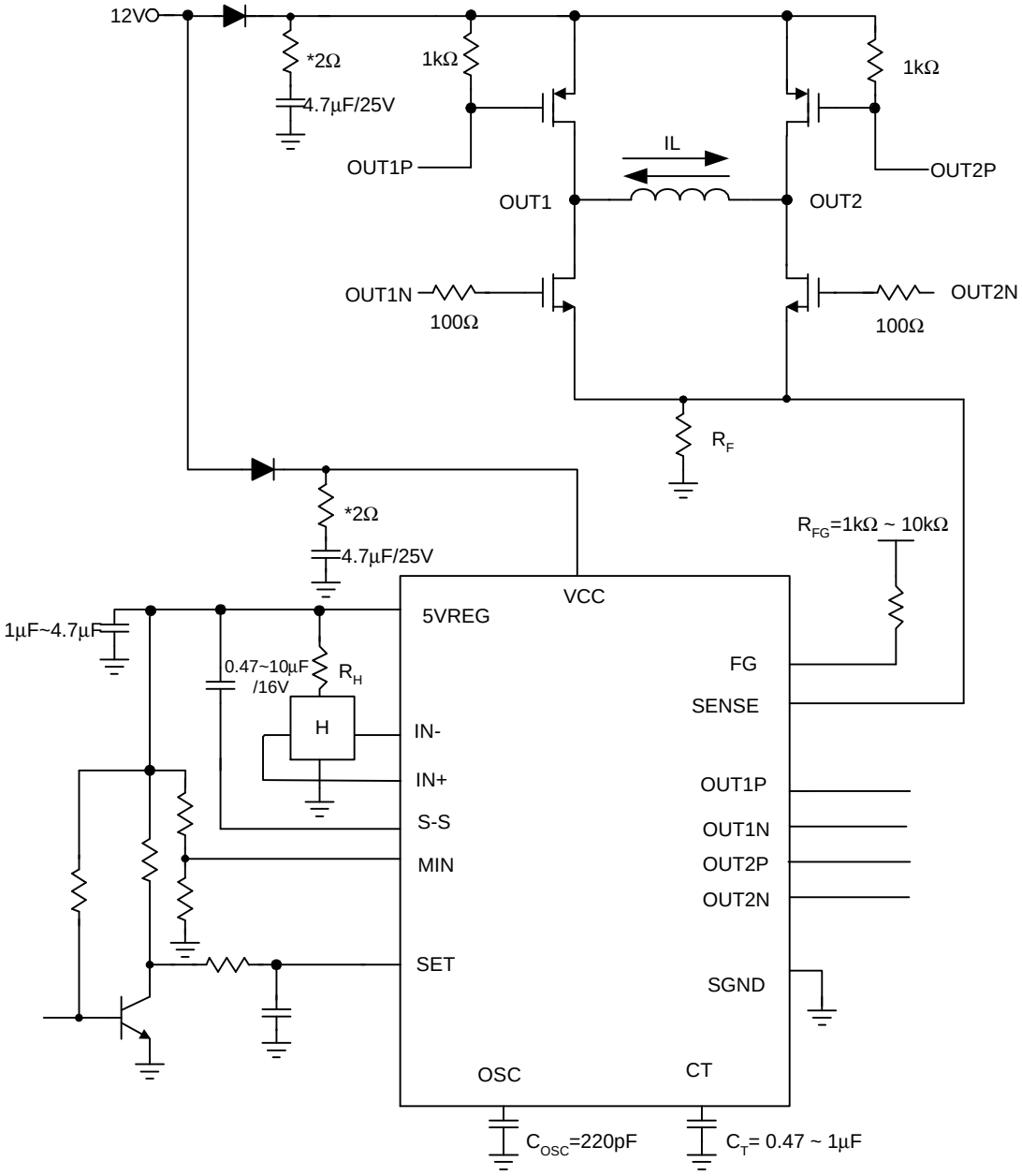
Pin Description

PIN		FUNCTION
NO.	NAME	
1	OUT2P	High side external H-bridge Driver. Connect this pin to the upper P-MOSFET gate of OUT2.
2	OUT2N	Low side external H-bridge Driver. Connect this pin to the lower N-MOSFET gate of OUT2.
3	VCC	Supply Voltage Input. Provide a 5.5V to 16V bias supply for the chip to this pin.
4	SENSE	Current-Limit Input. Connect to external N-MOSFET source pins and connect a resistor R_F to GND to sense coil current.
5	MIN	Minimum Speed Setting. Use a voltage divider from 5VREG to set MIN pin voltage to set minimum speed of fan.
6	SET	Speed Setting. Input an external voltage to SET pin to set fan speed.
7	OSC	Oscillation Frequency Setting. Connect a capacitor to GND to set oscillation frequency.
8	FG	Rotation Speed Output. This pin is an open-collector output.
9	IN-	Hall Input -. Connect to hall element negative output.
10	IN+	Hall Input +. Connect to hall element positive output.
11	CT	Shutdown Time and Restart Time Setting. Connect a capacitor to GND to set shutdown time and restart time in lock mode.
12	S-S	Soft-Start Time Setting. Connect a capacitor to 5VREG to set soft-start time to reduce the peak current at power on and lock mode.
13	5VREG	5V Regulator Output. This is a 5V constant-voltage output for application circuit biases.
14	SGND	Control stage GND.
15	OUT1N	Low side external H-bridge Driver. Connect this pin to the lower N-MOSFET gate of OUT1.
16	OUT1P	High side external H-bridge Driver. Connect this pin to the upper P-MOSFET gate of OUT1.

Block Diagram



Typical Application Circuit



*2Ω resistor and 4.7µF capacitor circuits are to decline peaking voltage in hot plug condition.

Function Description

Variable speed control

The APX9281 has a variable speed controller. The speed is controlled by comparing the voltage of OSC, MIN, and SET. The lowest speed drive duty is set by comparing the OSC oscillating voltage and MIN pin voltage when MIN pin voltage is lower than SET. When SET pin voltage is lower than MIN, PWM control system works by comparing the voltage of SET and OSC. When SET pin voltage is lower than OSC, upper and lower side's transistors are ON. When SET pin voltage is higher than OSC, upper side transistors are OFF and coil current re-circulates lower side transistor. The lower SET pin voltage is, the more output ON duty will be. Hence, the coil current will be enlarged and motor speed will be faster. Rotation speed is able to feedback by FG output. PWM basic frequency will be 30 kHz when putting on C_P=220pF (See Figure1 Rotation Waveform).

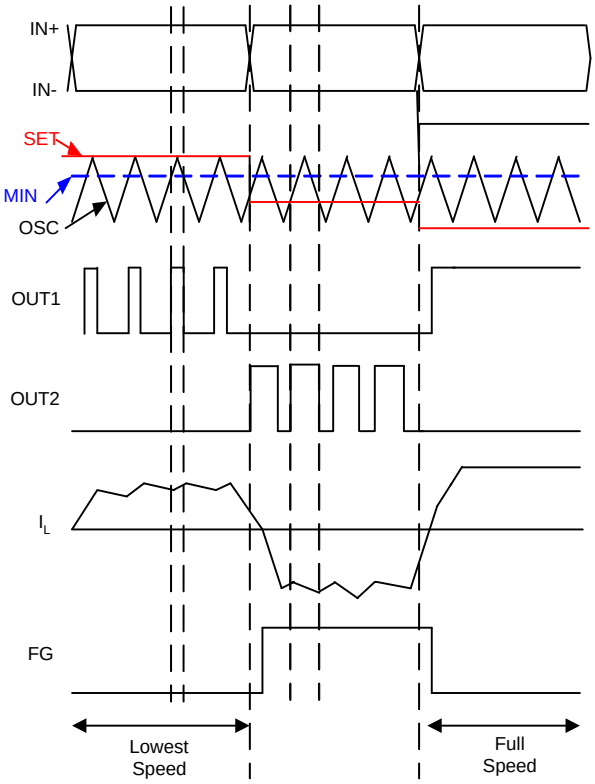


Figure 1 Rotation Waveform

Lockup Protection and Automatic Restart

The APX9281 provides the lockup protection and automatic restart functions for preventing the coil burnout while the fan is locked. Connecting the capacitor from CT pin to GND can determine the shutdown time and restart time. As the fan is locked, the charge/discharge circuit will charge the CT capacitor to 3V by a 2μA source current for a locked detection time, and then the circuit will switch the capacitor to discharge. During the discharging interval, the output drivers are switched off until the CT voltage is discharged to 1V by a 0.2μA sink current, and the circuit will switch the capacitor to charge. During this charging interval, the IC enters restart time; one output is high and another is low, which makes a torque for fan rotation until the CT voltage is charged to 3V by a 2μA source current. If the locked condition still remains, the charge/discharge process will be recurred until the locked condition is released (See Figure2 Lock/Auto Restart Waveform).

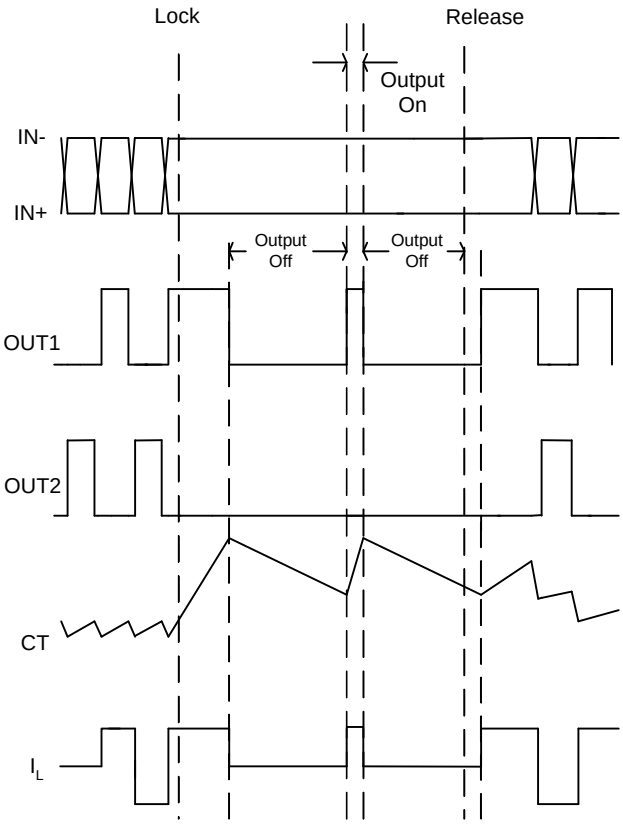


Figure 2 Lock/Auto Restart Waveform

Function Description (Cont.)

Soft-Start Function

The APX9281 provides the soft-start function to avoid peak current at power-on and lock-restart moments. Connecting the capacitor from S-S pin to 5VREG can determine the soft-start time. The soft-start function works depending on the comparison among the voltage of S-S, SET, MIN, and OSC.

An internal constant sink current charges an external capacitor C_{S-S} on the S-S pin from V_{OSCH} to 0V. When the S-S pin voltage is lower than OSC, S-S pin starts to control output driver ON duty. The lower S-S pin voltage is, the more output driver ON duty will be. Hence, the coil current will become larger and motor speed will become higher. S-S pin controls the output ON duty until its pin voltage is lower than SET (See Figure 3 Soft-Start Waveform at V_{SET} <V_{MIN}) or MIN (See Figure 4 Soft-Start Waveform at V_{SET}> V_{MIN}).

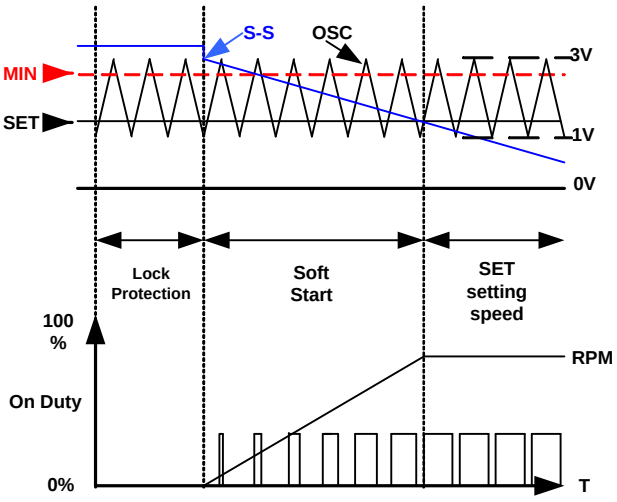


Figure 3 Soft-Start Waveform at V_{SET}<V_{MIN}

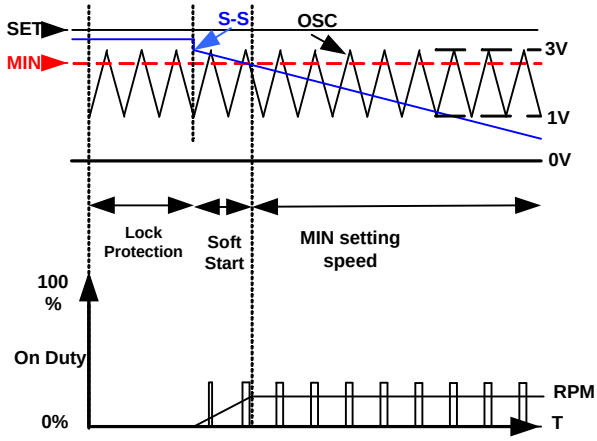


Figure 4 Soft-Start Waveform at V_{SET}>V_{MIN}

Rotation Detection Function

The FG pin is an open collector output, connecting a pull up resistor to a high level voltage for the rotation detection function. When IN- is larger than IN+, the FG is low (switch on); when IN- is smaller than IN+, the FG is high (switch off) (See Truth Table). Open the terminal when not in using.

Current-Limit Function

The APX9281 is equipped with external current-limit circuit. The external current-limit circuit works when SENSE pin voltage is higher than V_{LIM}. V_{LIM} is defined in APX9281 internal circuit and its typical value is 200mV.

$$\text{Limit Current} = \frac{V_{LIM}}{R_F}$$

where:

V_{LIM} = internal reference voltage for current-limit

R_F = SENSE pin resistor

For example:

V_{LIM} = 0.2V, R_F = 0.1Ω

Limit Current = 2A

PCB layout wiring of R_F between N-MOSFET source pins, SENSE pin and GND must to be short to set an accurate limit current value.

Function Description (Cont.)

Thermal Protection

The APX9281 has thermal protection. When internal junction temperature reaches 160°C, the output devices will be switched off. When the IC's junction temperature cools by 20°C, the thermal sensor will turn the output devices on again, resulting in a pulsed output during continuous thermal protection.

Truth Table

Input				Output					
IN-	**IN+**	**OSC**	**CT**	**OUT1P**	**OUT1N**	**OUT2P**	**OUT2N**	**FG**	Mode
H	L	H	L	L	-	-	H	L	Rotation (Drive)
L	H			-	H	L	-	OFF	
H	L	L		OFF	-	-	H	L	Rotation (Re-Circulation)
L	H			-	H	OFF	-	OFF	
H	L	-	H	OFF	-	-	H	OFF	Lock Mode
L	H			-	H	OFF	-	OFF	

OSC-H corresponds to $V_{OSC}>V_{SET}$ and OSC-L corresponds to $V_{OSC}<V_{SET}$

Application Information

Hall input

Please use suitable hall element bias resistor R_H to adjust hall input signal. To be short lines between hall element output and IC's hall input is for noise immunity. Hall input amplifier has 20mV hysteresis. Then we recommend the hall input level to be 60mV or over.

CT Capacitor

The capacitor that is connected from CT pin to GND determines the shutdown time and restart time.

$$\text{Locked Detection Time} = \frac{C_{CT} \times (V_{CTH} - 0.2V)}{I_{CT1}}$$

$$\text{Restart Time} = \frac{C_{CT} \times (V_{CTH} - V_{CTL})}{I_{CT1}}$$

$$\text{Shutdown Time} = \frac{C_{CT} \times (V_{CTH} - V_{VTL})}{I_{CT2}}$$

where:
C_{CT} = CT pin capacitor
For example:
V_{CC}=12V, C_{CT}=1µF
Locked Detection Time = 1.7s
Restart Time = 1s
Shutdown Time= 10s
The value of charge capacitor is recommended 0.47µF to 1µF.

S-S Capacitor

The capacitor that is connected from S-S pin to 5VREG determines the soft-start time.

Case 1:$V_{OSCL} < V_{SET} < V_{MIN}$

$$\text{Soft Start Time} = \frac{C_{S-S} \times (V_{OSCH} - V_{SET})}{I_{S-S}}$$

where:
C_{S-S} = S-S pin capacitor
For example:
V_{CC}=12V, V_{OSCH}=3V, V_{OSCL}=1V,V_{SET}=1.4V, I_{S-S}=0.5µA,
C_{S-S}=1µF
Soft-Start Time = 3.2s

Case 2:$V_{SET} < V_{OSCL} < V_{MIN}$

$$\text{Soft - Start Time} = \frac{C_{S-S} \times (V_{OSCH} - V_{OSCL})}{I_{S-S}}$$

For example:
V_{CC}=12V, V_{OSCH}=3V, V_{OSCL}=1V, V_{SET}=0.5V, I_{S-S}=0.5µA,
C_{S-S}=1µF
Soft-Start Time = 4s

The recommended value of S-S pin capacitor is 0.47µF to 10µF. When select CT pin and S-S pin capacitors, it is necessary to consider that fan must start-up during restart time at lock mode. When the C_{CT} is determined but the fan can't start-up in power-on or lock-restart mode, it is suggested that decrease the C_{S-S} capacitance in order to start-up the fan successfully. However, it will reduce the soft-start time.

FG Resistor

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

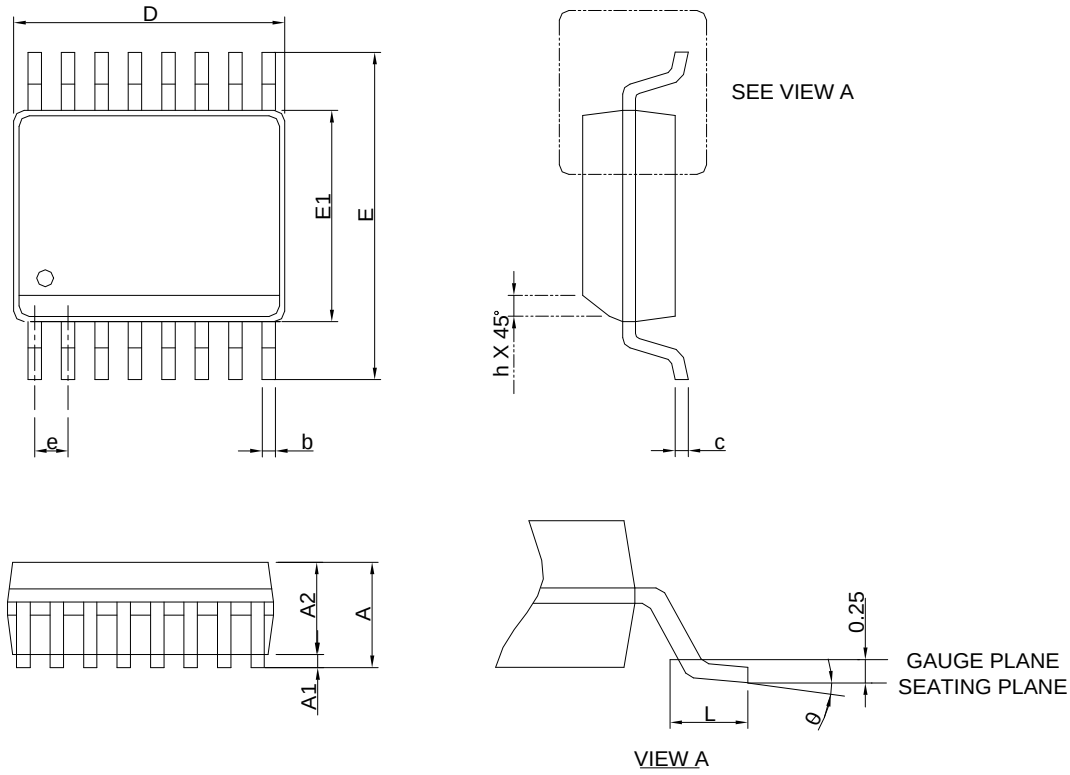
$$R_{FG} = \frac{V_{CC} - V_{FG}}{I_{FG}}$$

For example:
V_{CC}=12V, I_{FG} =5mA, V_{FG}=0.1V, R_{FG}=2.38kΩ

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

Package Information

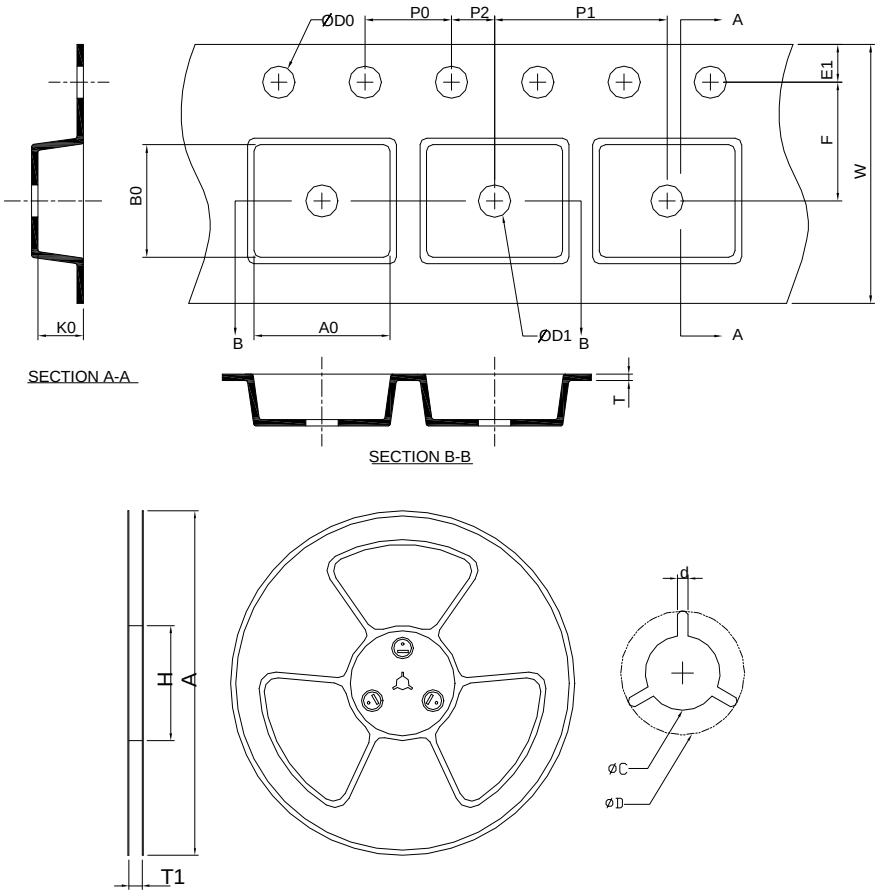
SSOP-16



SYMBOL	SSOP-16			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A		1.75		0.069
A1	0.10	0.25	0.004	0.010
A2	1.24		0.049	
b	0.20	0.30	0.008	0.012
c	0.15	0.25	0.006	0.010
D	4.80	5.00	0.189	0.197
E	5.80	6.20	0.228	0.244
E1	3.80	4.00	0.150	0.157
e	0.635 BSC		0.025 BSC	
L	0.40	1.27	0.016	0.050
h	0.25	0.50	0.010	0.020
θ	0°	8°	0°	8°

Note : 1. Follow JEDEC MO-137 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 "E" does not include inter-lead flash or protrusions. Inter-lead flash and protrusions shall not exceed 10 mil per side.

Carrier Tape & Reel Dimensions



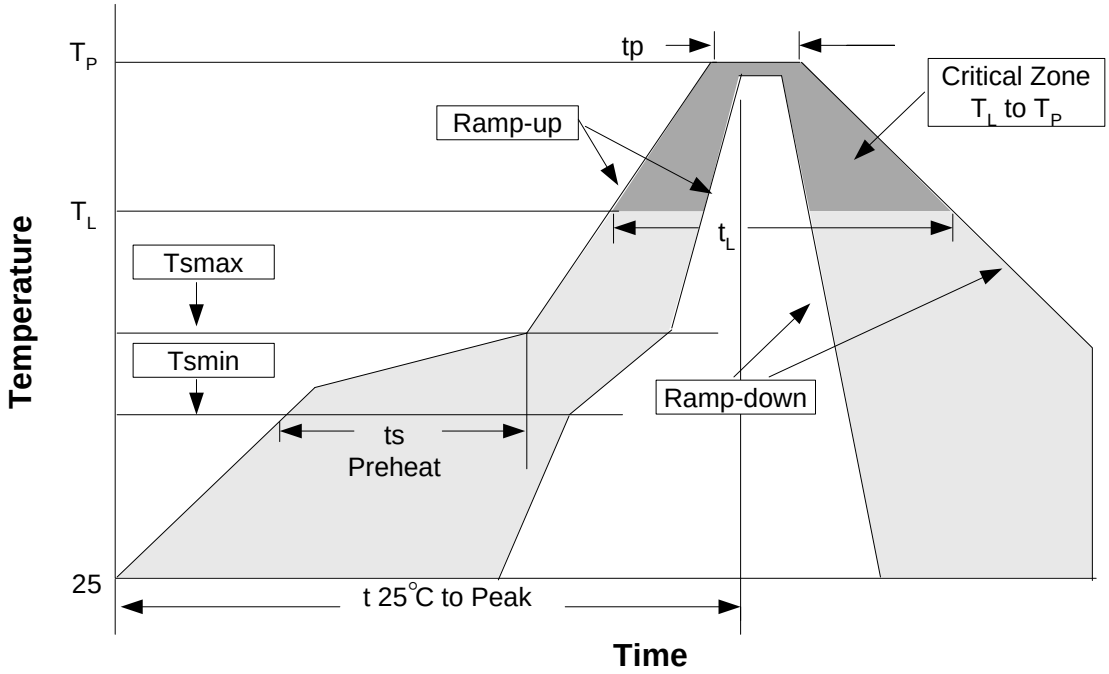
Application	A	H	T1	C	d	D	W	E1	F
SSOP-16	330.0±2.00	50 MIN.	16.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	12.0±0.30	1.75±0.10	5.50±0.10
	P0	**P1**	**P2**	**D0**	**D1**	**T**	**A0**	**B0**	**K0**
	4.00±0.10	8.00±0.10	2.00±0.10	1.5+0.10 -0.00	1.5 MIN.	0.6+0.00 -0.40	6.40±0.20	5.20±0.20	2.10±0.20

(mm)

Devices Per Unit

Package Type	Unit	Quantity
SSOP- 16	Tape & Reel	2500

Reflow Condition (IR/Convection or VPR Reflow)



Reliability Test Program

Test item	Method	Description
SOLDERABILITY	MIL-STD-883D-2003	245°C, 5 sec
HOLT	MIL-STD-883D-1005.7	1000 Hrs Bias @125°C
PCT	JESD-22-B, A102	168 Hrs, 100%RH, 121°C
TST	MIL-STD-883D-1011.9	-65°C~150°C, 200 Cycles
ESD	MIL-STD-883D-3015.7	VHBM > 2KV, VMM > 200V
Latch-Up	JESD 78	10ms, 1_{tr} > 100mA

Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Average ramp-up rate (T_L to T_P)	3°C/second max.	3°C/second max.
Preheat - Temperature Min (Tsmin) - Temperature Max (Tsmax) - Time (min to max) (ts)	100°C 150°C 60-120 seconds	150°C 200°C 60-180 seconds
Time maintained above: - Temperature (T_L) - Time (t_L)	183°C 60-150 seconds	217°C 60-150 seconds
Peak/Classification Temperature (Tp)	See table 1	See table 2
Time within 5°C of actual Peak Temperature (tp)	10-30 seconds	20-40 seconds
Ramp-down Rate	6°C/second max.	6°C/second max.
Time 25°C to Peak Temperature	6 minutes max.	8 minutes max.

Notes: All temperatures refer to topside of the package. Measured on the body surface.

Classification Reflow Profiles (Cont.)

Table 1. SnPb Eutectic Process – Package Peak Reflow Temperatures

Package Thickness	Volume mm^3 <350	Volume mm^3 ³350
<2.5 mm	240 +0/-5°C	225 +0/-5°C
≥2.5 mm	225 +0/-5°C	225 +0/-5°C

Table 2. Pb-free Process – Package Classification Reflow Temperatures

Package Thickness	Volume mm^3 <350	Volume mm^3 350-2000	Volume mm^3 >2000
<1.6 mm	260 +0°C*	260 +0°C*	260 +0°C*
1.6 mm – 2.5 mm	260 +0°C*	250 +0°C*	245 +0°C*
≥2.5 mm	250 +0°C*	245 +0°C*	245 +0°C*
*Tolerance: The device manufacturer/supplier **shall** assure process compatibility up to and including the stated classification temperature (this means Peak reflow temperature +0°C. For example 260°C+0°C) at the rated MSL level.			

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