

## Description

The AM9469 is a high performance, ultra-low noise single phase (single-coil) brushless direct current (BLDC) fan and motor driver. The integrated full-bridge driver output stage uses BTL linear driver architecture to minimize audible switching noise and Electromagnetic Interference (EMI) providing a low noise solution.

For system flexibility the motor speed can be controlled by either an external PWM signal or by a DC voltage or from a thermistor network. Based on the input signal, the AM9469 adjusts the output duty cycle.

To help protect the motor coil, the AM9469 provides Rotor Lock Protection which shuts down the output drive if rotor lock is detected. The device automatically restarts when the rotor lock is removed. In case of over voltage, the device shuts down the output drive and enters standby mode to help prevent over voltage stress on the coil. Over temperature shutdown provides thermal protection for the device.

A Tachometer output is provided by the open-drain Frequency Generator (FG) Pin which allows external interface to monitor motor rotation or speed. The FG output is the magnetic change frequency. Additionally, a rotor lock detect output is provided by the open-drain RD Pin.

AM9469 is available in thermally enhanced TSSOP-16EP (Type DX) with exposed pad.

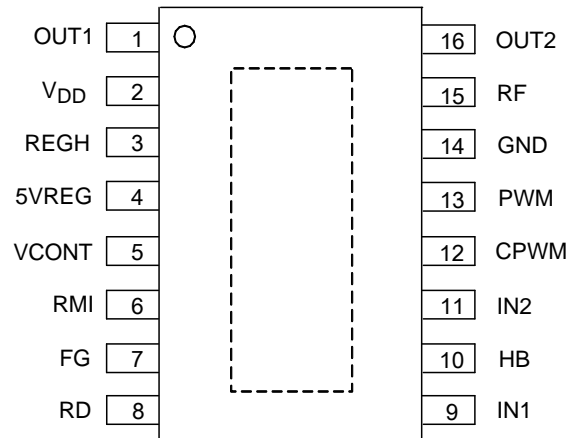
## Features

- Single-Phase Full Wave BLDC Fan/Motor Drive with BTL Output (BTL Amplifier Gain = 49dB)
- Low Noise Architecture
- Wide Operating Voltage Range: 2.4V to 18V
- PWM Speed Control with External PWM Input
- DC Voltage Speed Control by Adjusting VCONT and RMI Voltage
- Hall Bias Output:  $V_{HB} = 1.25V$
- Built-In Quick Start Circuit
- Lock Protection with Automatic Restart
- Frequency Generator (FG) Output
- Rotor Lock Detection (RD) Output
- Current Limit Circuit
- $R_F$  Defines The Current Limit;  $R_F = 1\Omega$  will Achieve 250mA Current Limit
- Thermal Shut-Down (TSD) Circuit
- Low Profile Package: TSSOP-16EP (Type DX) with Exposed Pads for Power Handling Capability
- **Lead-Free Finish; RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**

- Notes:
1. EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant. All applicable RoHS exemptions applied.
  2. See <https://www.diodes.com/quality/lead-free/> for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
  3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds

## Pin Assignments

(Top View)

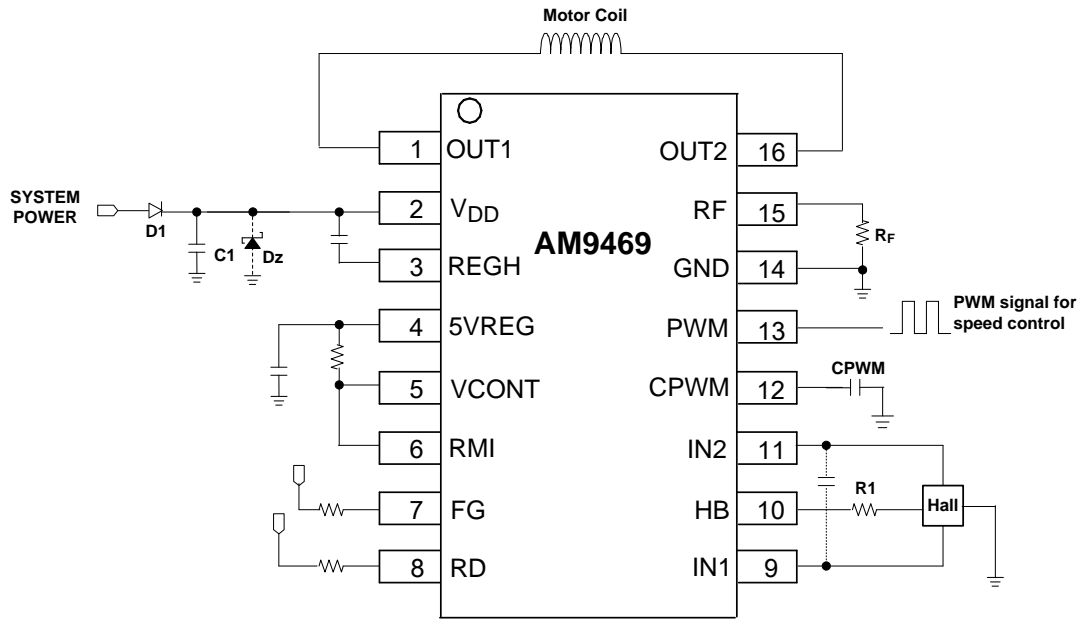


**TSSOP-16EP (Type DX)**

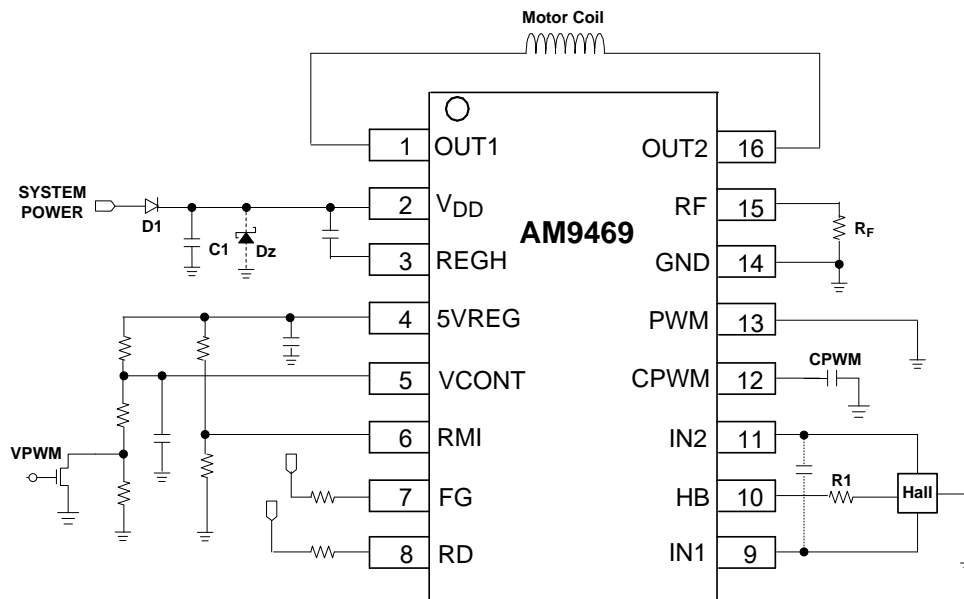
## Applications

- 9V/12V/15V BLDC Cooling Fans and Motors
- CPU Cooling Fans for Notebooks and Desktop BLDC Fans
- Instruments Cooling Fans
- Medium Voltage, Low Power BLDC Motors

**Typical Applications Circuit** (Notes 4 & 5)



**Typical Applications Circuit for PWM Speed Control**



**Typical Applications Circuit for VCONT/RMI Control**

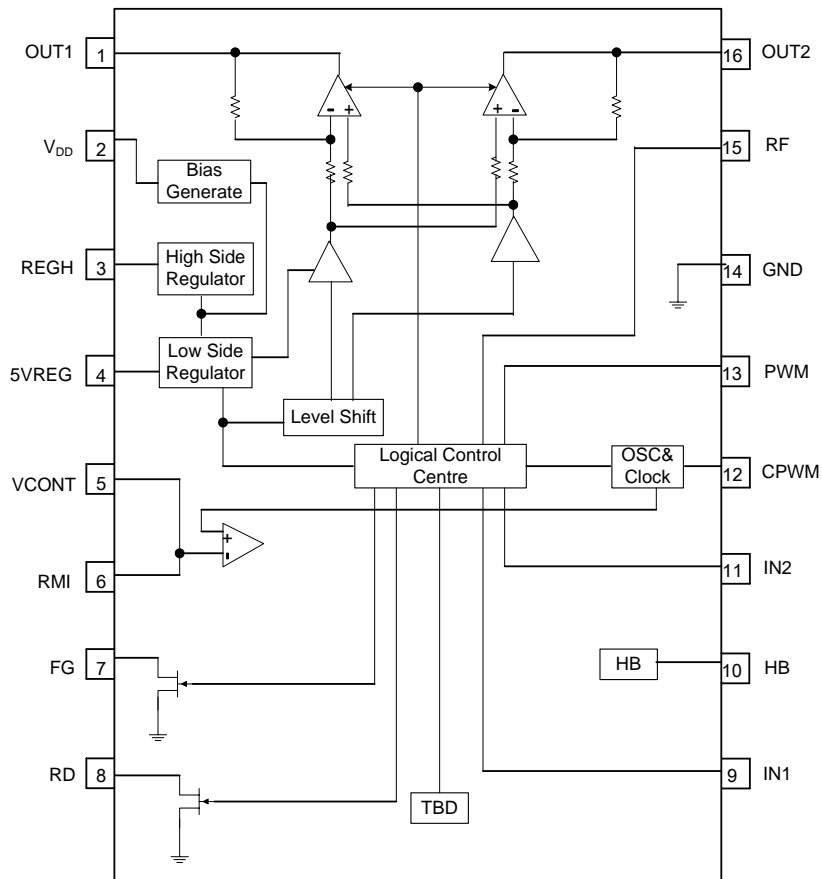
Notes:

4. C1 is for power stabilization and to strengthen the noise immunity and should be as close to the V<sub>DD</sub> pin as possible. The recommended value for C1 is 1μF typically. The value of capacitor can be optimized depending on the operating mode, motor voltage and the motor current. For PWM speed control mode, with datasheet current capability, the recommended capacitor value is 1μF. The value of the C1 should be checked in the motor design and route in its operating conditions if it is reduced or increased from the recommended value of 1μF.
5. Diode D1 is for the reverse connection protection. In addition to power stabilization and noise immunity, C1 also absorbs regenerative motor spikes. Depending on the amount of regenerative voltage spike, value of C1 needs to be adjusted. The zener diode Dz is used to clamp the regenerative voltage spike from the motor operation to safe level when reverse blocking diode D1 is used. If reverse blocking diodes is not used, the use of zener clamp Dz depends on the supply voltage capability to effectively sink the regenerative energy and voltage spike. The value of C1 and the requirement Dz needs to be verified on each application design.

**Pin Descriptions**

Pin Number	Pin Name	Description
1	OUT1	Output Drive – Source and Sink Capable Pin
2	V <sub>DD</sub>	Power Supply Input Pin
3	REGH	High-Side Regulator Output Voltage
4	5VREG	5V Regulator Output Voltage
5	VCONT	Output duty control pin for in DC signal speed control mode. Voltage in VCONT is compared with triangular wave on CPWM for the output duty ratio.
6	RMI	Output Minimum Duty (Minimum Speed) Control Pin for CPWM
7	FG	Frequency Generator (FG) – The FG Output is Same as the Magnetic Change Frequency
8	RD	Rotor Lock Detect Open Drain Output
9	IN1	Hall Device Positive Input Pin
10	HB	Hall Bias Voltage
11	IN2	Hall Device Negative Input Pin
12	CPWM	Capacitor Connection Pin for PWM Oscillator and Main Clock
13	PWM	PWM signal input pin for PWM speed control mode. The PWM on this pin controls the output duty directly.
14	GND	Ground Pin
15	RF	Current Limit Set Pin – Connect a resistor between RF pin and GND, current limit is defined by $250\text{mV}/R_F$
16	OUT2	Output Drive – Source and Sink Capable Pin
Pad	Pad	Exposed Pad for Thermal Dissipation. It can be connected to GND or left open circuit.

**Functional Block Diagram**



**Absolute Maximum Ratings** (Note 6) (@T<sub>A</sub> = +25°C, unless otherwise specified.)

Symbol	Characteristics	Rating	Unit	
V <sub>DD_MAX</sub>	Maximum Supply Voltage (Note 7)	24	V	
V <sub>REVERSE</sub>	Reverse Supply Voltage on All Pins	-0.3	V	
V <sub>PWM_MAX</sub>	Maximum Voltage on Logic PWM Pin	7	V	
I <sub>OUT(PEAK)</sub>	Maximum Output Current (Peak)	1,200	mA	
I <sub>OUT(CONT)</sub>	Maximum Continuous Current	750	mA	
I <sub>RD</sub>	Maximum RD Output Current	5	mA	
V <sub>RD</sub>	Maximum RD Voltage	24	V	
I <sub>FG</sub>	Maximum FG Output Current	5	mA	
V <sub>FG</sub>	Maximum FG Voltage	24	V	
I <sub>HB</sub>	Maximum HB Output Current	10	mA	
P <sub>D</sub>	Power Dissipation (Notes 8 & 9)	TSSOP-16EP (Type DX)	3,520	mW
T <sub>STG</sub>	Storage Temperature Range	-65 to +150	°C	
T <sub>J</sub>	Maximum Junction Temperature	+150	°C	
ESD HBM	Human Body Model ESD Capability	4	kV	

- Notes:
- Stresses greater than the 'Absolute Maximum Ratings' specified above may cause permanent damage to the device. These are stress ratings only; functional operation of the device at these or any other conditions exceeding those indicated in this specification is not implied. Device reliability may be affected by exposure to absolute maximum rating conditions for extended periods of time.
  - The absolute maximum V<sub>DD</sub> of 24V is a transient stress rating and is not meant as a functional operating condition. It is not recommended to operate the device at the absolute maximum rated conditions for any period of time.
  - For thermal de-rating curves under different PCB size and layout conditions, see thermal performance section.
  - AM9469 exposed pad soldered to minimum recommended landing pads (see Package Outline Dimension section) on 3inch x 4.5inch four-layer 2oz.copper glass epoxy PCB (1.6mm thickness), calculated in accordance with JESD 51-7. See thermal performance section.

**Recommended Operating Conditions**

Symbol	Characteristic	Conditions	Min	Max	Unit
V <sub>DD</sub>	Supply Voltage when the device is operating normally with all circuits active	Operating; All Circuits Active	2.4	18	V
V <sub>ICM</sub>	Hall Input Common-Mode Input Voltage Range	—	0.3	V <sub>5VREG</sub> -1.5V	V
V <sub>CONTIN</sub>	VCONT Input Voltage Range	—	0.3	V <sub>5VREG</sub>	V
V <sub>RMIN</sub>	RMI Input Voltage Range	—	0.3	V <sub>5VREG</sub>	V
T <sub>A</sub>	Operating Temperature Range	Operating	-40	+105	°C

**Electrical Characteristics** (Note 10) (@T<sub>A</sub> = +25°C, V<sub>DD</sub> = 12V, unless otherwise specified.)

Symbol	Characteristics	Conditions	Min	Typ	Max	Unit
I <sub>DD</sub>	Supply Current	—	—	2.5	4.0	mA
V <sub>OV_TH</sub>	Over Voltage Protection Threshold for Shutdown to Standby Mode	Voltage Increasing	19.5	20.5	21.5	V
V <sub>OV_RLTH</sub>	Over Voltage Release Threshold	Voltage Decreasing	18.3	19.5	20.5	V

- Note: 10. Typical data is measured at T<sub>A</sub> = +25°C, V<sub>DD</sub> = 12V. The maximum and minimum parameters values over operating temperature range are not tested in production, they are guaranteed by design, characterization and process control.

**Electrical Characteristics** (Continued) (Note 11) (@T<sub>A</sub> = +25°C, V<sub>DD</sub> = 12V, unless otherwise specified.)

Symbol	Characteristics	Conditions	Min	Typ	Max	Unit
V <sub>O</sub>	Output On Voltage, Source + Sink	I <sub>OUT</sub> = 750mA (Source + Sink) T <sub>A</sub> = -40°C to +105°C	—	0.65	1.05	V
V <sub>RF</sub>	Current Limit Voltage	T <sub>A</sub> = -40°C to +105°C	230	250	270	mV
V <sub>RGL</sub>	5VREG Output Voltage	I <sub>SVREG</sub> = 5mA, T <sub>A</sub> = -40°C to +105°C	4.8	5	5.2	V
V <sub>RGH</sub>	REGH Output Voltage	I <sub>REGH</sub> = 5mA	V <sub>DD</sub> - 4.6	V <sub>DD</sub> - 4.2	V <sub>DD</sub> - 3.9	V
V <sub>HB</sub>	Hall Bias Output Voltage	I <sub>HB</sub> = 5mA, T <sub>A</sub> = -40°C to +105°C	1.20	1.25	1.30	V
I <sub>HIN</sub>	Hall Input Bias Current	—	—	—	0.5	μA
V <sub>INOFFS</sub>	Hall Amplifier Output Offset Voltage	—	-5	—	5	mV
G <sub>H</sub>	Hall Amplifier Voltage Gain	—	48	52	—	dB
V <sub>PWML</sub>	PWM Pin Input Low	—	0	—	1.2	V
V <sub>PWMH</sub>	PWM Pin Input High	—	1.8	—	5VREG	V
I <sub>PWM</sub>	PWM Pin Bias Current	PWM = GND	-17	-10	-6	μA
t <sub>PWM_MIN</sub>	Input PWM Smallest Width	—	2	—	—	μs
f <sub>PWM_RANGE</sub>	External Input PWM Frequency Range	—	8	—	100	kHz
I <sub>CPC</sub>	CPWM Charge Current	T <sub>A</sub> = -40°C to +105°C	16.4	—	19.6	μA
I <sub>CPD</sub>	CPWM Discharge Current	T <sub>A</sub> = -40°C to +105°C	16.4	—	19.6	μA
R <sub>CP</sub>	CPWM Charge/Discharge Current Ratio	R <sub>CP</sub> = I <sub>CPC</sub> / I <sub>CPD</sub>	0.9	1	1.11	—
V <sub>CPH</sub>	CPWM Oscillation High Level	T <sub>A</sub> = -40°C to +105°C	3.35	3.5	3.65	V
V <sub>CPL</sub>	CPWM Oscillation Low Level	T <sub>A</sub> = -40°C to +105°C	0.95	1.0	1.05	V
V <sub>CPA</sub>	CPWM Oscillation Amplitude	T <sub>A</sub> = -40°C to +105°C	2.3	2.5	2.7	V
f <sub>CPWM</sub>	CPWM Oscillation frequency	CPWM = 100pF	—	36	—	kHz
I <sub>CONT</sub>	VCONT Pin Input Bias Current	—	—	—	0.3	μA
I <sub>RMI</sub>	RMI Pin Input Bias Current	—	—	—	0.3	μA
V <sub>RD</sub>	RD Output Low Voltage	I <sub>RD</sub> = 3mA	—	—	0.3	V
I <sub>RDL</sub>	RD Output Leakage Current	V <sub>RD</sub> = 18V	—	—	1	μA
V <sub>FG</sub>	FG Output Low Voltage	I <sub>FG</sub> = 3mA	—	—	0.3	V
I <sub>FGL</sub>	FG Output Leakage Current	V <sub>FG</sub> = 18V	—	—	1	μA
ΔV <sub>FG</sub>	FG Comparator Hysteresis	—	—	±5	—	mV
t <sub>LCK_DET_ON</sub>	Output ON Time in Lock Detection	C <sub>PWM</sub> = 100pF	—	0.5	—	s
t <sub>OFF</sub>	Output OFF Time in Lock Mode	C <sub>PWM</sub> = 100pF	—	4.5	—	s
R <sub>T</sub>	Output OFF/ON Ratio in Lock Detection	C <sub>PWM</sub> = 100pF, R <sub>T</sub> = t <sub>ACT</sub> / t <sub>DET</sub>	—	9	—	s
T <sub>J_SDN_TH</sub>	IC Junction Temperature Thermal Shutdown Threshold	—	—	+175	—	°C
T <sub>J_SDN_HYST</sub>	IC Junction Temperature Thermal Shutdown Hysteresis	—	—	+25	—	°C

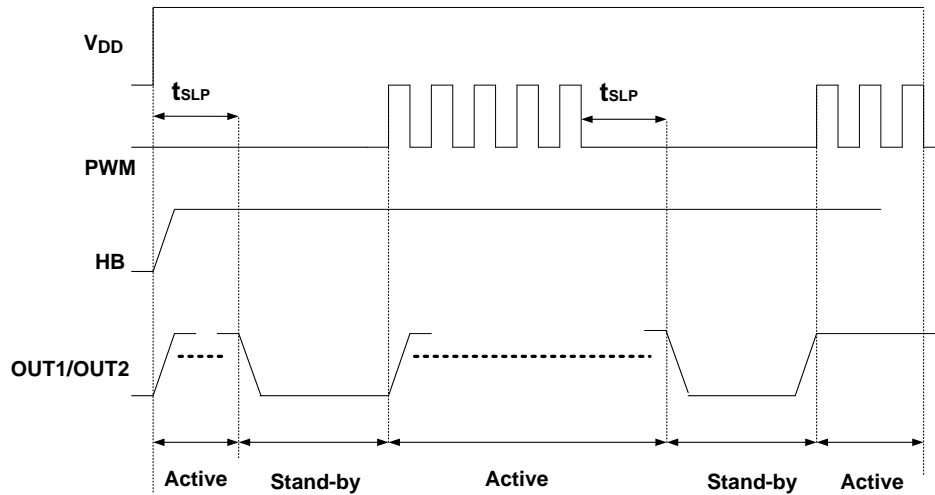
Note: 11. Typical data is measured at T<sub>A</sub> = +25°C, V<sub>DD</sub> = 12V. The maximum and minimum parameters values over operating temperature range are not tested in production, they are guaranteed by design, characterization and process control.

## Operating Characteristics

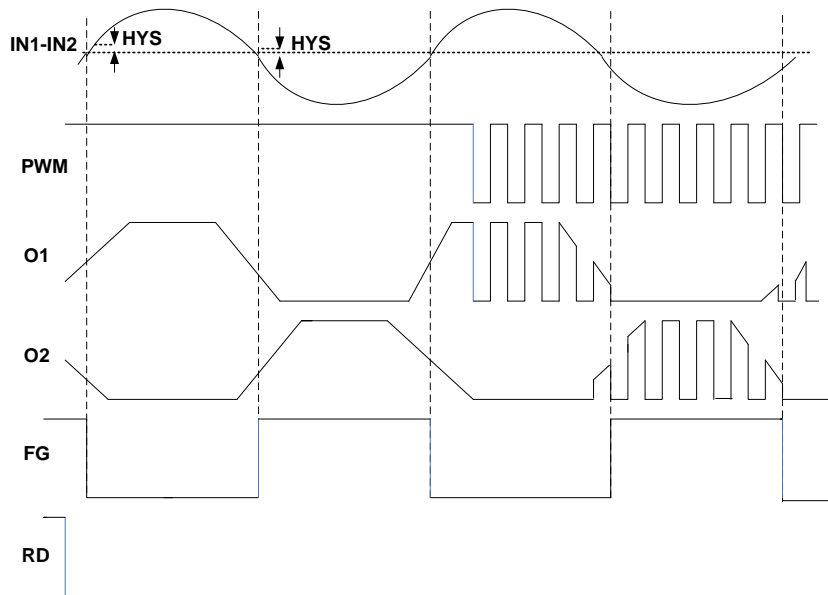
### Standby and Start-Up Timing

When the PWM Pin input signal is logic “L” level continuously for a longer time than  $t_{SLP}$ , the device enters standby mode as shown below. When the PWM Pin signal is “H” level, the device turns active and operates normally. The PWM Pin is also used to control the motor speed with external PWM signal into this pin. The lowest frequency PWM signal is defined by  $t_{SLP}$ , i.e. the PWM duty low time has to be smaller  $t_{SLP}$  for motor speed control.

$t_{SLP} = 400\mu s$  typical



### In Normal Operation/Rotation

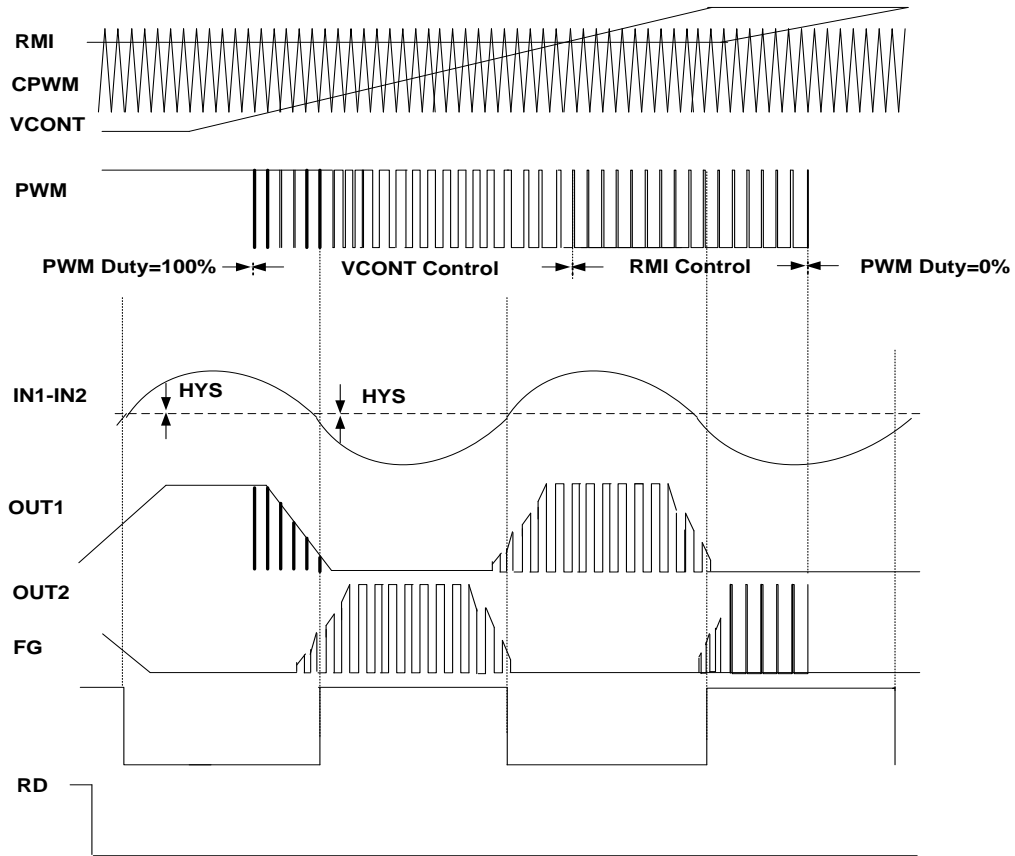


Truth Table for Various Modes with PWM Pin

IN1	IN2	PWM	OUT1	OUT2	FG	MODE
H	L	H	H	L	L	Drive
		L	L	L		Regenerate
L	H	H	L	H	OFF	Drive
		L	L	L		Regenerate

**Operating Characteristics** (Continued)

**VCONT/RMI Control**



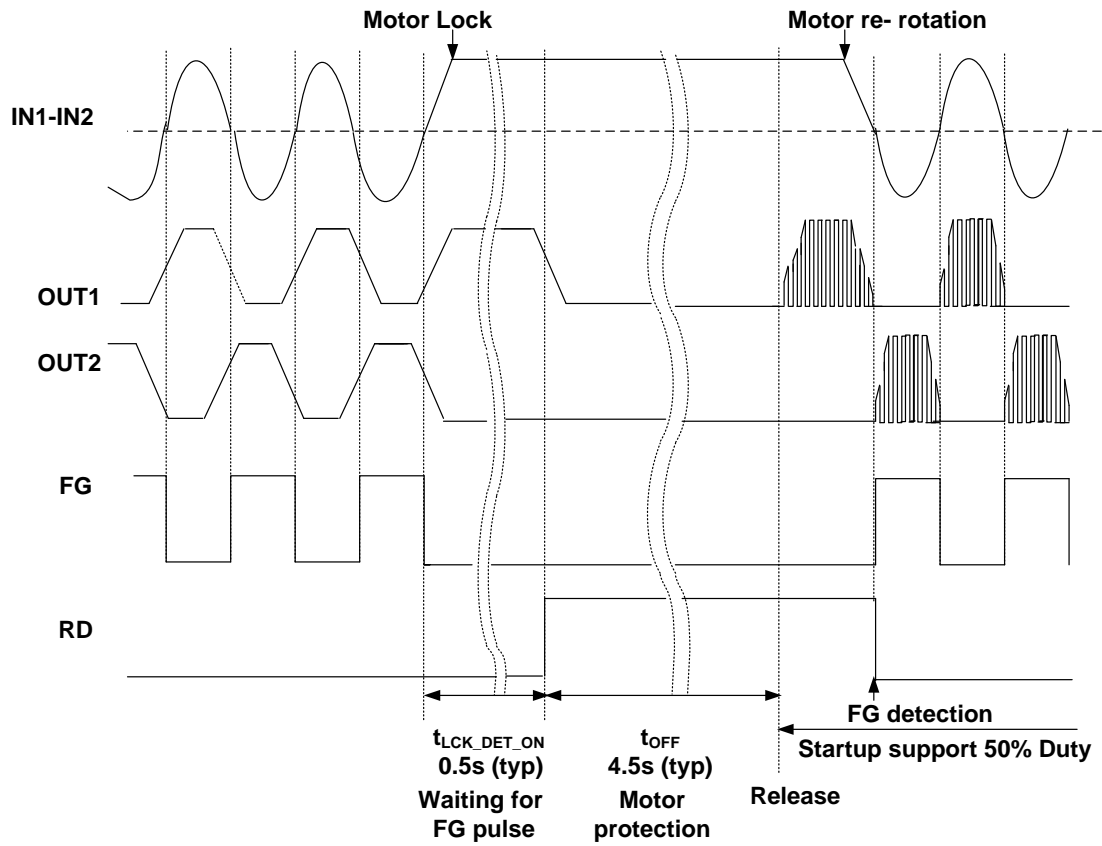
**Truth Table for Various Modes with VCONT/RMI Pin**

IN1	IN2	PWM2 (Note 12)	OUT1	OUT2	FG	MODE
H	L	H	H	L	L	Drive
		L	L	L		Regenerate
L	H	H	L	H	OFF	Drive
		L	L	L		Regenerate

Note: 12. PWM2 is internal signal.

**Operating Characteristics** (Cont.)

**Motor Lock**





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## Application Notes

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### H-Bias – Hall Bias Output

This is a 1.25V nominal voltage source to bias a differential un-buffered Hall element sensor. If a Hall element requires a lower voltage than the H-Bias output, connect an appropriate value resistor between the H-Bias Pin and the Hall element supply pin.

### IN1 and IN2 – Hall Inputs

The rotor position is detected by a Hall sensor, with the output of Hall sensor applied to the IN1 and IN2 Pins. This sensor can be either a 4-pin “naked” Hall device or of the 3-pin buffered switching type. For a 4-pin device the differential Hall output signal is connected to the IN1 and IN2 Pins. For a buffered Hall sensor, the Hall device output is attached to the IN1 Pin, with a pull-up attached if needed. Meanwhile, the IN2 pin has an external potential divider attached to hold the pin at half  $V_{REF}$ . When IN1 is high in relation to IN2, OUT2 is the active drive.

### PWM Pin – External PWM Signal Input for PWM Speed Control Mode

In PWM speed control mode, external PWM signal is applied at this PWM Pin to control the motors speed. The duty ratio of the PWM signal input to this pin controls the fan motor speed by varying the output PWM drive directly.

### CPWM Pin

Internal motor control triangular wave is generated based on the capacitor on this pin. A capacitor of 100pF ( $C_{PWM} = 100\text{pF}$ ), will provide a triangular wave of 36kHz (typ). The VCONT and RMI signals are compared with this triangular wave to generate the speed control PWM drive and minimum speed control clamp points. The output PWM drive frequency is the same as the triangular waveform frequency.

### FG/RD Pin

FG is the Frequency Generator (tachometer) output and is a buffered signal from the Hall sensor. RD is the fan locked status detector. FG and RD are open-drain outputs and will require external pull-up resistors. Typically, a pull-up resistor of 10k $\Omega$  is recommended from the FG and RD Pins to the supply voltage.

### RF Pin

The current limiter is activated when the voltage between current detection resistor exceeds 0.25V between GND and RF. The current limiter is activated at  $I_O = 250\text{mA}$  when  $R_F = 1\Omega$ . The current limit is set with a  $R_F$  resistor between the RF Pin and GND Pin.

### RMI Pin – Minimum Speed Setting Pin

RMI is the minimum speed setting pin. DC voltage on this pin sets the minimum speed value. If you do not use RMI (minimum speed control), please connect it to 5VREG.

### VCONT Pin – DC Voltage Speed Control

VCONT is DC voltage inputs speed control pin. The voltage on the VCONT Pin is compared with the triangular oscillation on the CPWM Pin to generate the output drive PWM signal. For the control method, refer to the timing chart.

### REGH/5VREG Pin

Please insert capacitor value 1 $\mu\text{F}$  between 5VREG and GND for regulated output voltage stabilization; insert capacitor value 1 $\mu\text{F}$  value between  $V_{DD}$  and REGH for stable output voltage.

### OUT1 and OUT2 Pins

OUT1 and OUT2 Pins provide H-bridge driver output for fan and motor coil connection.

### $V_{DD}$ – Device Supply Voltage

This provides the supply for the device.

### GND – Supply Return

This is the device supply ground return pin for control signal.

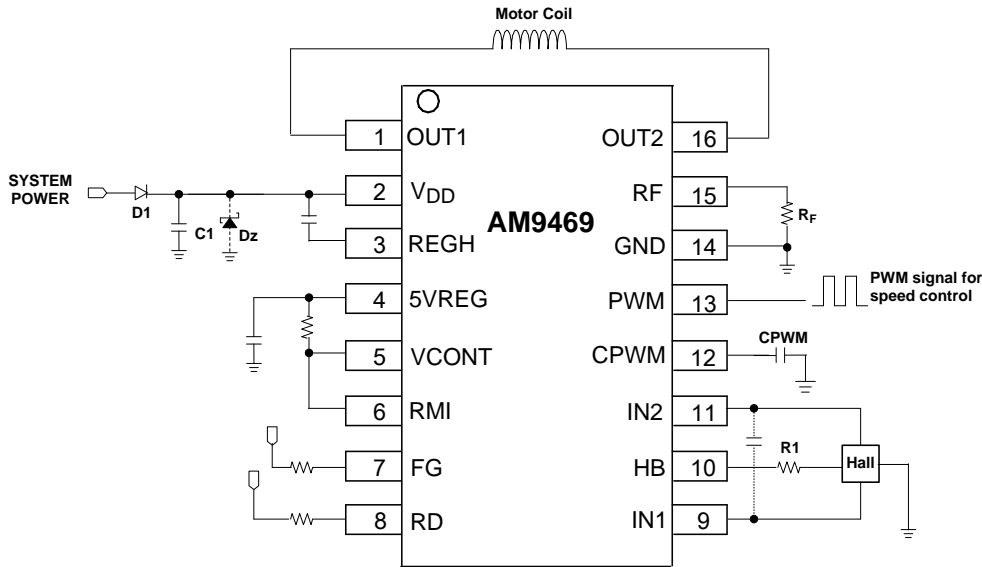
**Application Notes** (Continued)

**Speed Control**

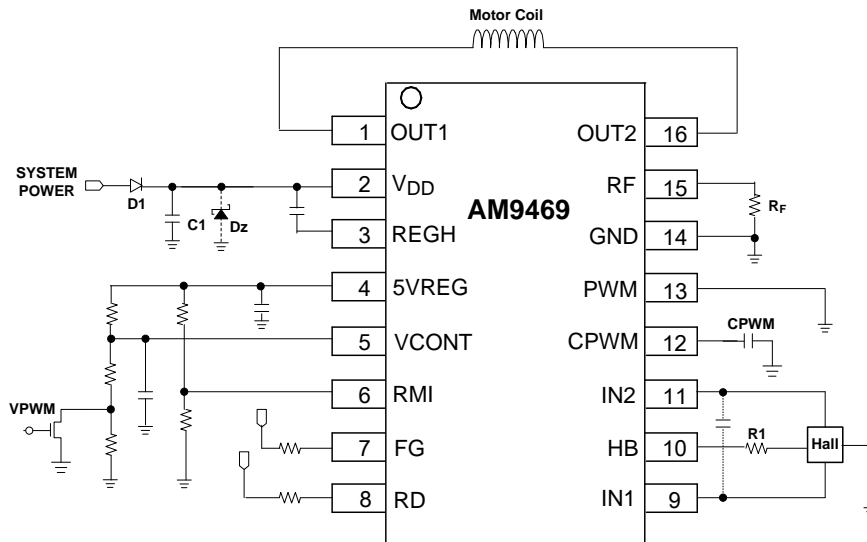
This device allows both the DC voltage input and PWM signal input for speed control. Typically, only one of the methods is used to control the motor speed. In DC voltage speed control mode, the voltage on the VCONT Pin is compared with the CPWM triangular wave to generate internal PWM signal to drive the output. In PWM speed control mode, the PWM signal on the PWM Pin directly controls the output PWM drive.

The typical application circuits shows the two speed control methods.

**1. Speed Control by PWM Pin**

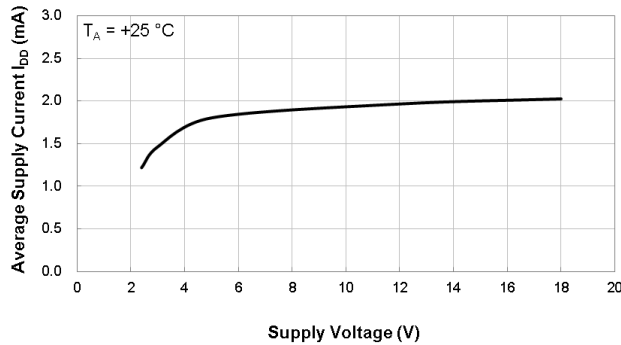


**2. Speed Control by VCONT/RMI Pin**

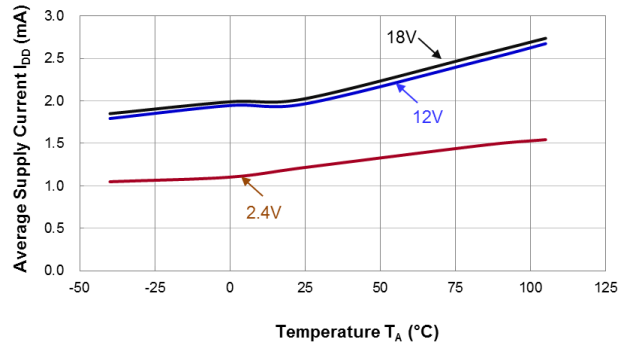


## Typical Operating Characteristics

### Average Supply Current

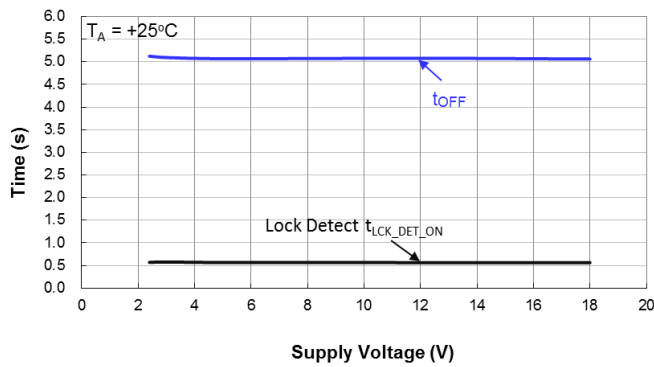


Average Supply Current vs. Supply Voltage

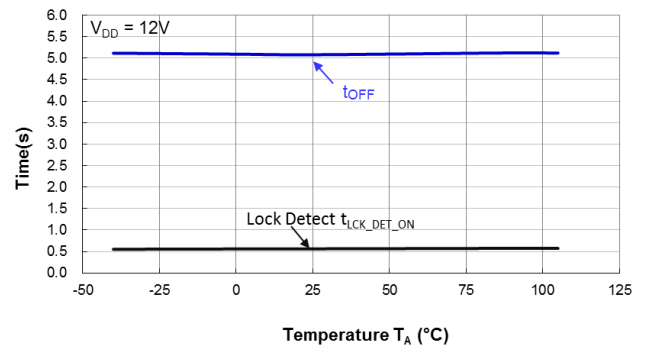


Average Supply Current vs. Temperature

### Lock Detect $t_{LCK\_DET\_ON}$ and Shutdown $t_{OFF}$ Periods

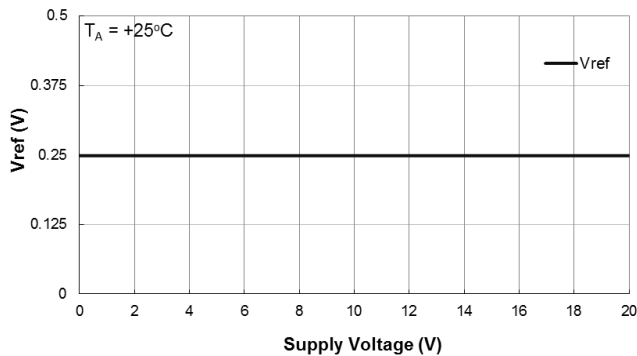


Lock Detect  $t_{LCK\_DET\_ON}$  And  $t_{OFF}$  vs. Supply Voltage

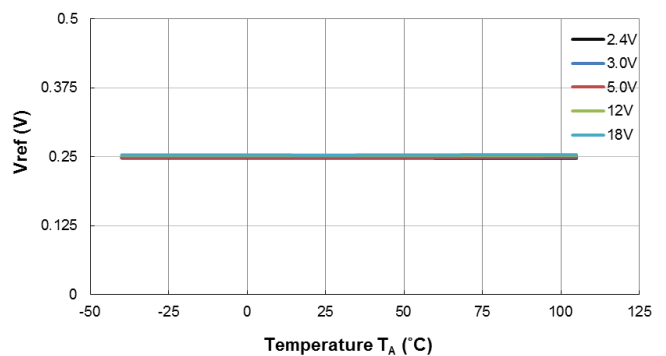


Lock Detect  $t_{LCK\_DET\_ON}$  And  $t_{OFF}$  vs. Temperature

### Current Limits



Current limit (250mV) vs. Supply Voltage

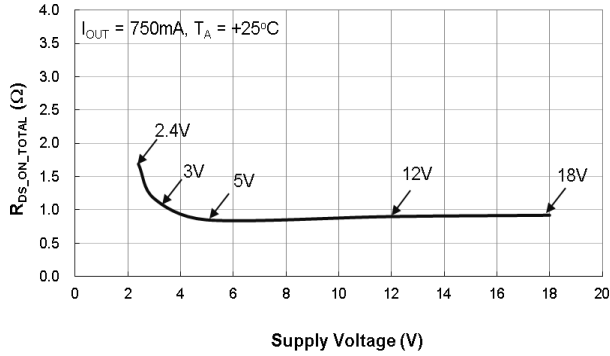


Current Limit (250mV) vs. Temperature

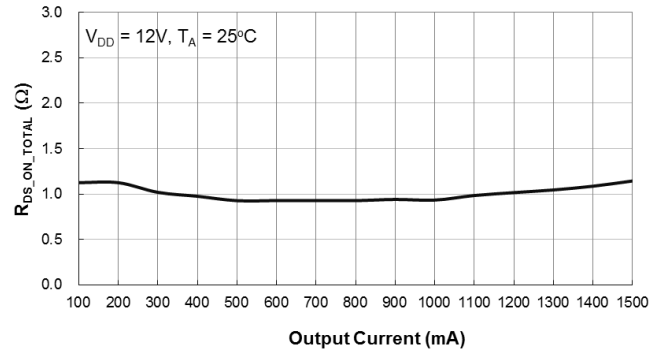
**Typical Operating Characteristics** (Continued)

**AM9469 Total Resistance**

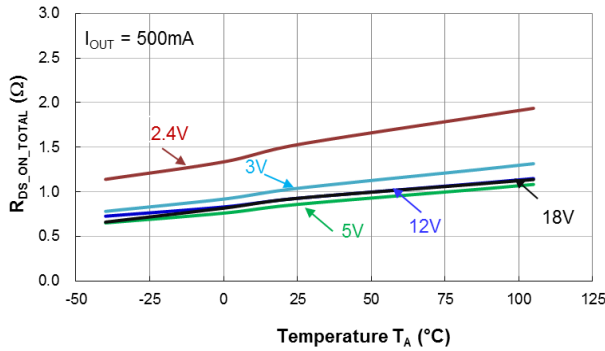
**Total H-Bridge Path Resistance – Total  $R_{DS(ON)}$  of High Side and Low Side Switches**



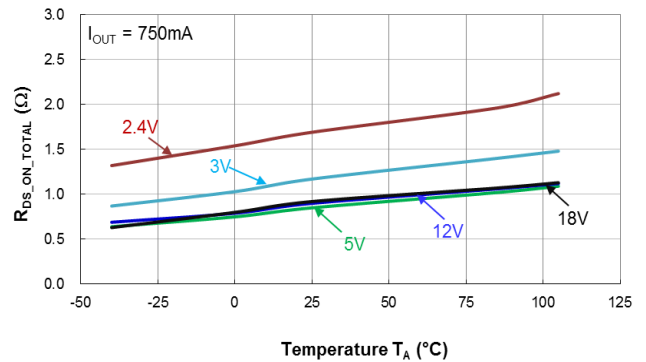
High+Low Side Resistance  $R_{DS\_ON\_TOTAL}$  vs. Supply Voltage



High+Low Side Resistance  $R_{DS\_ON\_TOTAL}$  vs. Current



High+Low Side Resistance  $R_{DS\_ON\_TOTAL}$  vs. Temperature

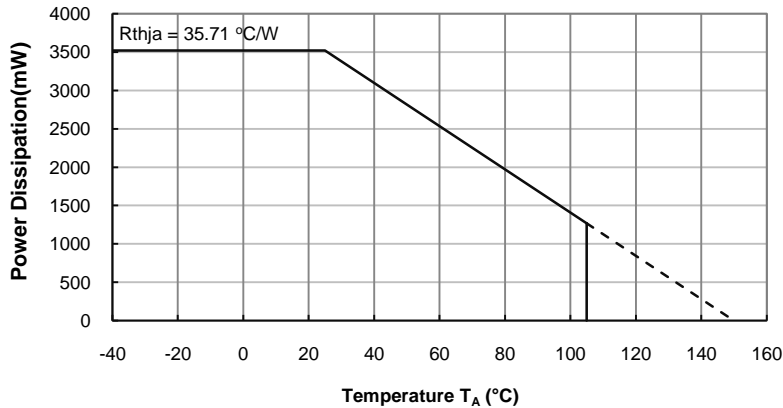


High+Low Side Resistance  $R_{DS\_ON\_TOTAL}$  vs. Temperature

**Thermal Performance**

**TSSOP-16EP (Type DX) Power Dissipation De-rating Curve 1 (Note 13)**

T <sub>A</sub> (°C)	-40	0	25	50	60	70	80	85	90	95	100	105	110	120	125	130	140	150
P <sub>D</sub> (mW)	3,520	3,520	3,520	2,816	2,534	2,253	1,971	1,830	1,690	1,549	1,408	1,267	1,126	845	704	563	282	0

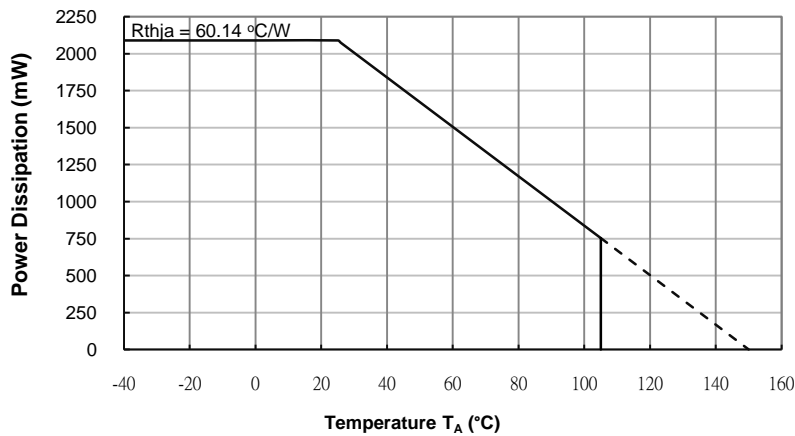


**TSSOP-16EP (Type DX) Thermal Derating Curve**

Note: 13. TSSOP-16EP (Type DX) is soldered on FR-4 substrate 4-layer 1.6mm thickness PCB board, calculated in accordance with JESD 51-7.

**TSSOP-16EP (Type DX) Power Dissipation De-rating Curve 2 (Note 14)**

T <sub>A</sub> (°C)	-40	0	25	50	60	70	80	85	90	95	100	105	110	120	125	130	140	150
P <sub>D</sub> (mW)	2,090	2,090	2,090	1,672	1,505	1,338	1,170	1,087	1,003	920	836	752	669	502	418	334	167	0



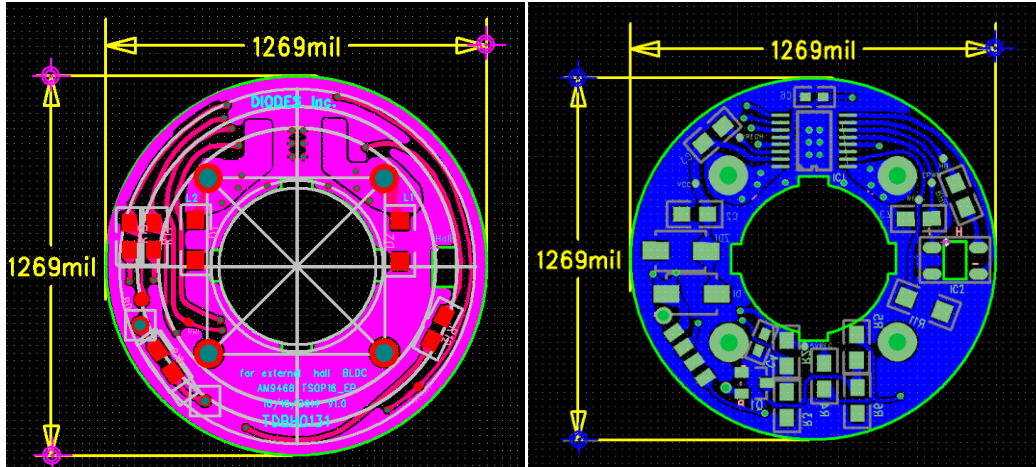
**TSSOP-16EP (Type DX) Thermal Derating  
(Custom Circular PCB with Centre Hole Cut-Out)**

Note: 14. TSSOP-16EP (Type DX) is soldered to the circular PCB diameter 1.2" with the center circular cutout diameter of 0.53". The Hall element space cut-out is 0.12"x0.08". 2-layer 2oz.copper FR-4 PCB (1.6mm thickness) with partial copper flood on the bottom layer.

**Thermal Performance** (Continued)

**Circular PCB Dimensions**

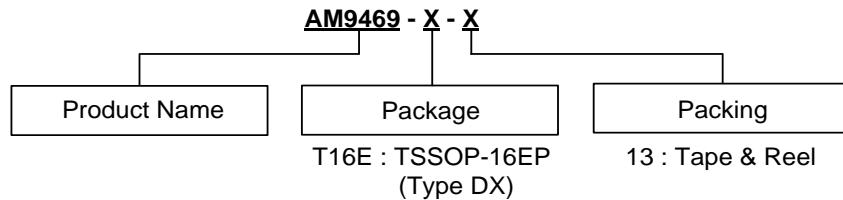
The circular PCB diameter is 1.2" with the center circular cut-out diameter of 0.53". The Hall element space cut-out is 0.12"x0.08". 2-layer 2oz.copper FR-4 PCB (1.6mm thickness) with partial copper flood on the bottom layer.



Custom Circular PCB – Top View

Custom Circular PCB – Bottom View

**Ordering Information** (Note 15)

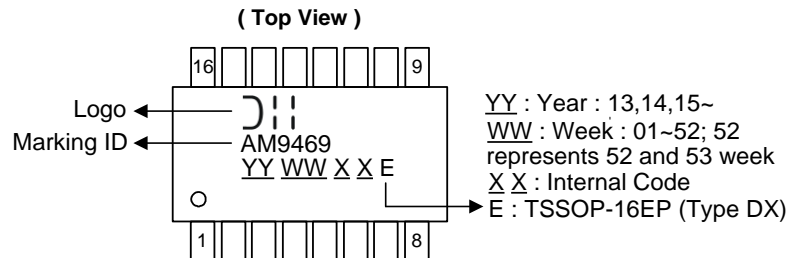


Part Number	Package Code	Packaging	13" Tape and Reel	
			Quantity	Part Number Suffix
AM9469-T16E-13	T16E	TSSOP-16EP (Type DX)	2,500/Tape & Reel	-13

Note: 15. For packaging details, go to our website at <https://www.diodes.com/design/support/packaging/diodes-packaging/>.

**Marking Information**

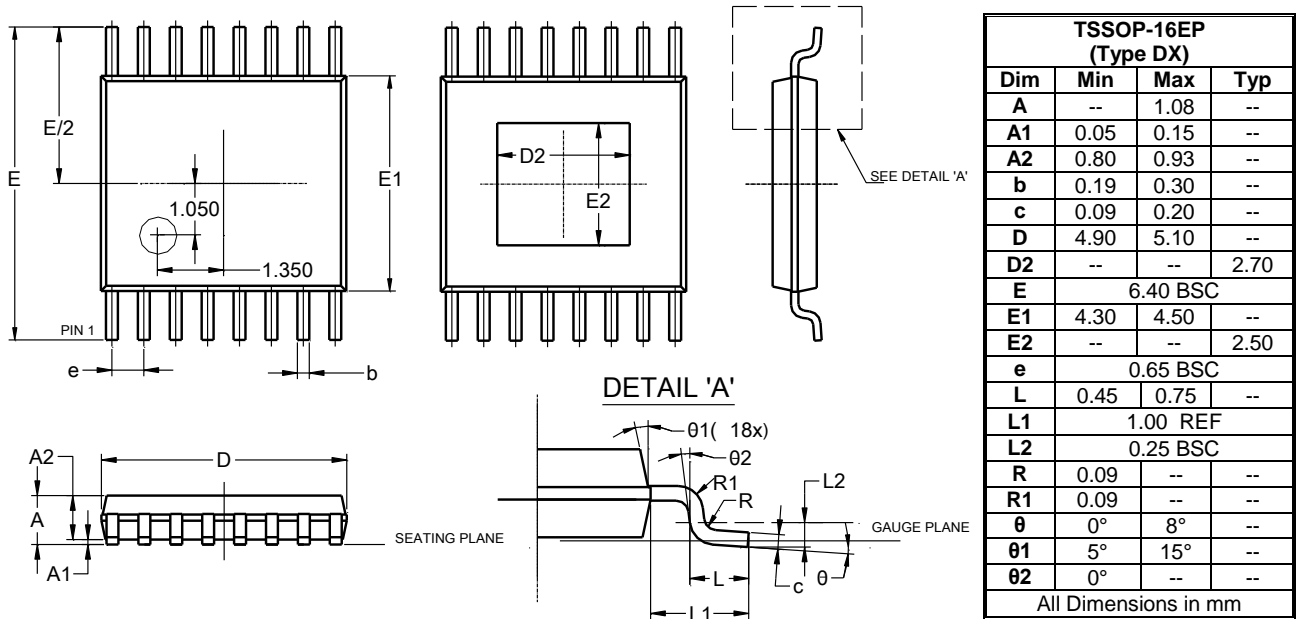
(1) Package Type: TSSOP-16EP (Type DX)



**Package Outline Dimensions**

Please see <http://www.diodes.com/package-outlines.html> for the latest version.

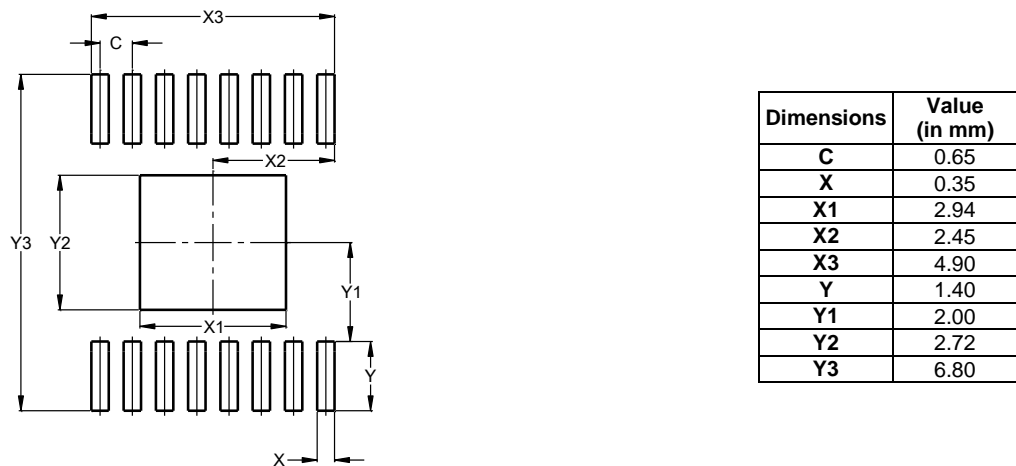
**TSSOP-16EP (Type DX)**



**Suggested Pad Layout**

Please see <http://www.diodes.com/package-outlines.html> for the latest version.

**TSSOP-16EP (Type DX)**



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