Digital Single-Phase Full Wave BLDC Fan Controller

General Description

The RT8749 is a highly integrated digital control IC for regulating single-phase full wave brushless DC (BLDC) fans at a programmed speed. The controller IC accepts a Pulse-Width Modulated (PWM) signal provided by the host, and decodes the duty-ratio of this PWM signal to 256 counts. The decoded duty-ratio will then be used for mapping to the programmed speed which is stored at the embedded flash memory. This speed profile can be programmed by users for different fan models and applications. By integrating a low $R_{DS(ON)}$ power MOSFET, the RT8749 minimizes component count on the PCB, thus reducing board size and cost of the motor/fan module.

A frequency generator output is included to provide commutation signals to the host for the current rotating speed. The control IC also provides several protection features, including the peak-current limit, thermal shutdown protection, under-voltage protection and motor lock protection. An automatic restart circuit is designed to rotate the motor after the lock condition is released.

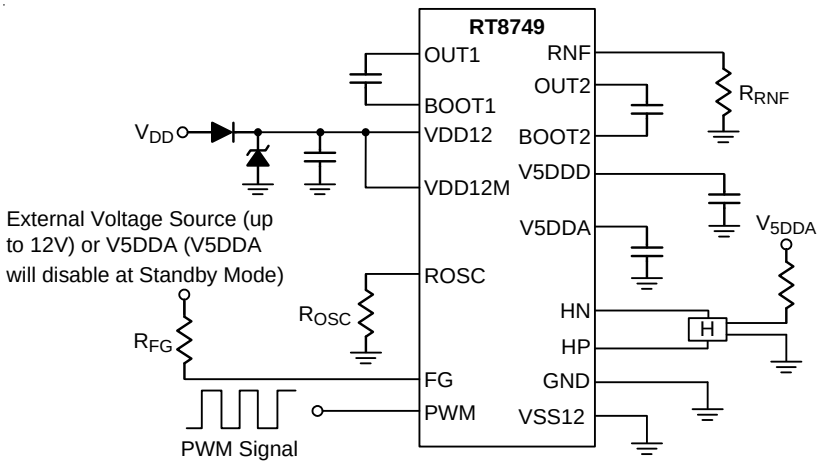
Features

- **Embedded 256 x 16 Bits Flash Memory**
- **Built-in Low $R_{DS(ON)}$ Power MOSFET**
- **External PWM Speed Control**
- **Wide Range External PWM Input Frequency (100Hz to 100kHz)**
- **Built-in Frequency Generator with Selectable FG or FG/2 Output Signal**
- **Built-in Peak Current Limit**
- **Built-in Motor Lock Protection and Automatic Restart Circuit**
- **Built-in Thermal Shutdown Protection**
- **Low Power Standby Mode (when PWM Input is Low)**
- **RoHS Compliant and Halogen Free**

Applications

- PC Fan
- Cooling Fan
- Single-Phase BLDC Motor

Simplified Application Circuit



Ordering Information

RT8749□□

Package Type
QW : WDFN-16L 4x4

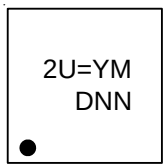
Lead Plating System
G : Green (Halogen Free and Pb Free)

Note :

Richtek products are :

- RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- Suitable for use in SnPb or Pb-free soldering processes.

Marking Information

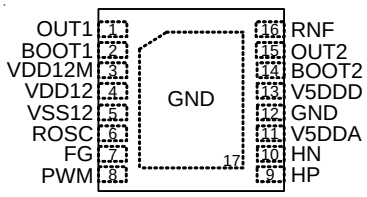


2U= : Product Code

YMDNN : Date Code

Pin Configurations

(TOP VIEW)

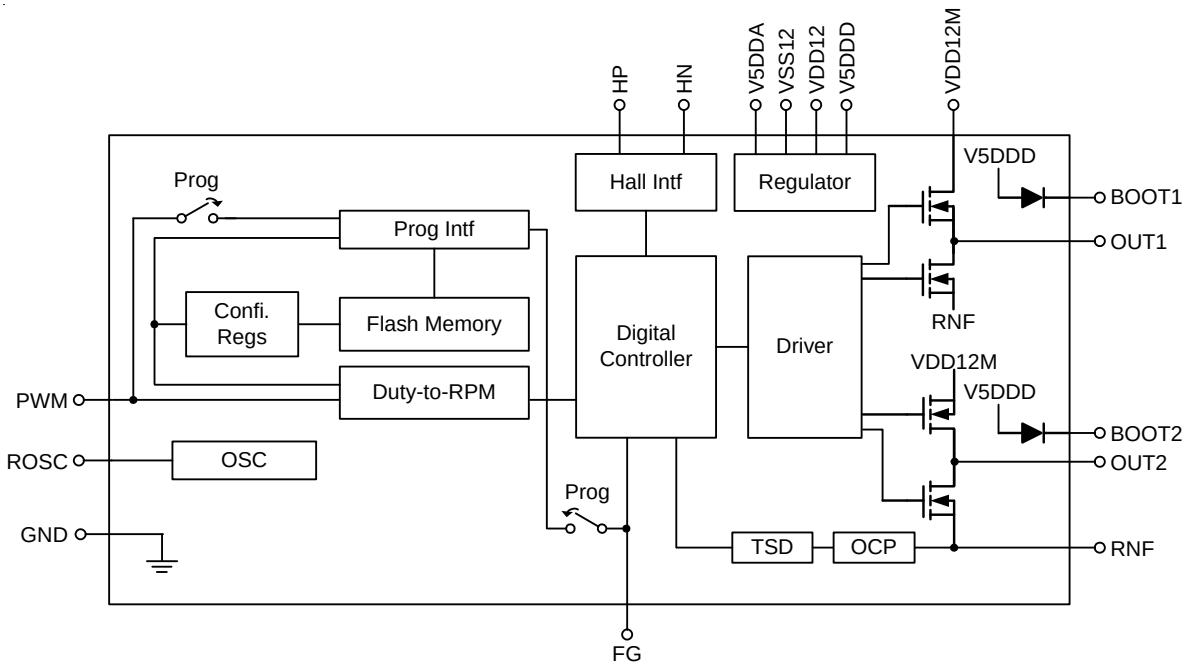


WDFN-16L 4x4

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	OUT1	Driver Output to Motor Terminal 1.
2	BOOT1	Bootstrap Supply for Motor Terminal 1. Connect a capacitor between this pin and OUT1.
3	VDD12M	Input Power Source for H-Bridge Power MOSFET and Driver.
4	VDD12	Input Power Source for Internal Circuits.
5	VSS12	Ground of Internal Circuits.
6	ROSC	Internal Oscillator Frequency Setting. Connect a resistor with low temperature coefficient between this pin and grand.
7	FG	Frequency Output Signal with Open-Drain Logic.
8	PWM	External PWM Input. With an internal pull-high resistor (200kΩ).
9	HP	Positive Input Signal of Hall Sensor.
10	HN	Negative Input Signal of Hall Sensor.
11	V5DDA	Regulated 5V Power Source for Hall Sensor.
12, 17 (Exposed Pad)	GND	Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
13	V5DDD	Regulated 5V Power Source for Digital Circuit.
14	BOOT2	Bootstrap Supply for Motor Terminal 2. Connect a capacitor between this pin and OUT2.
15	OUT2	Driver Output to Motor Terminal 2.
16	RNF	Output Current Detection. Connect to a resistor for H-Bridge over-current protection.

Function Block Diagram



Operation

The highly integrated digital controlled fan controller RT8749 integrates several functions as follows :

OTP

The over-temperature protection block is activated when the junction temperature exceeds 150°C. It will be released when the temperature cools below 120°C. The hysteresis is 30°C.

OCP

The RT8749 features over-current protection function to protect the power MOSFET. Users need to add a resistor RRNF between the low-side N-MOSFET and GND. If over current protection is activated, the RT8749 will be shutdown.

Regulator

The inherent voltage regulator generates regulated 5V output for V5DDD & V5DDA respectively.

Hall Interface

The Hall Interface receives hall element signal and then helps the RT8749 to recognize the fan position. The controller will control the current direction by recognized fan position.

Oscillator

The Oscillator generates the high accuracy 1MHz clock signal for PWM output frequency. The PWM output frequency is 31.25kHz typically.

Digital Controller

This block generates control signal to the driver for motor operation control. It controls the motor speed depending on duty to RPM converter, reference speed table and control parameters which are stored in the flash memory.

Program Interface

The Program Interface is used for programming flash memory purpose.

Absolute Maximum Ratings (Note 1)

- Supply Voltage, VDD12M, VDD12 ---------- –0.3V to 20V
- Output Current, I_{OUT} ---------- 0.95A
- Input Voltage, PWM ---------- –0.3V to 20V
- Output Voltage, OUT1, OUT2, FG ---------- –0.3V to 20V
- BOOT1 to OUT1 ---------- –0.3V to 6V
- BOOT2 to OUT2 ---------- –0.3V to 6V
- FG Output Current ---------- 15mA
- Other Pins ---------- –0.3V to 6V
- Power Dissipation, P_D @ T_A = 25°C
  WDFN-16L 4x4 ---------- 3.38W
- Package Thermal Resistance (Note 2)
  WDFN-16L 4x4, θ_{JA} ---------- 29.5°C/W
  WDFN-16L 4x4, θ_{JC} ---------- 7.5°C/W
- Junction Temperature Range ---------- 150°C
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Model) ---------- 4kV

Recommended Operating Conditions (Note 4)

- Supply Input Voltage, VDD12 ---------- 5.8V to 14V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{DD12} = 12V, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Power Dissipation						
Power Supply Current 1	I_{DD1}	V_{PWM} = 5V Without Loading	--	--	10	mA
Power Supply Current 2	I_{DD2}	V_{PWM} = 0V	--	--	300	μA
Output Driver						
UGATE On-Resistance (N-MOSFET)	$R_{DS(ON)\_UGATE}$	I_{OUT} = 0.8A	--	0.4	0.8	Ω
LGATE On-Resistance (N-MOSFET)	$R_{DS(ON)\_LGATE}$	I_{OUT} = 0.8A	--	0.4	0.8	Ω
V5DDA & V5DDD Output						
V5DDA Output Voltage	V_{DDA5}	Load Current = 15mA	4.65	5	5.35	V
V5DDD Output Voltage	V_{DDD5}	Load Current = 15mA	4.65	5	5.35	V
FG Output						
FG Output Low Level Voltage	V_{FG}	I_{FG} = 5mA	--	0.2	0.3	V
HP, HN Inputs						
Input Voltage Level	V_{HP}, V_{HN}		0.2	1.3	3	V

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
PWM Input							
PWM Input Voltage	Level-High	V_{PWMH}		2.2	--	VDD12	V
	Level-Low	V_{PWML}		0	--	0.7	
PWM Internal Pull-up Current		I_{PWMIN}	V_{PWM} = 0V	--	--	50	μA
PWM Input Frequency		f_{PWMIN}		0.1	--	100	kHz
ROSC Frequency		f_{ROSC}	R_{OSC} = 150kΩ	--	1	--	MHz
Current Limitation							
Current Limit		I_{LIM}	R_{RNF} = 0.25Ω	--	1	--	A
Threshold Voltage		V_{RNF}		0.2	0.25	0.3	V
Thermal Protection							
Thermal Shutdown Temperature		T_{SD}		--	150	--	°C

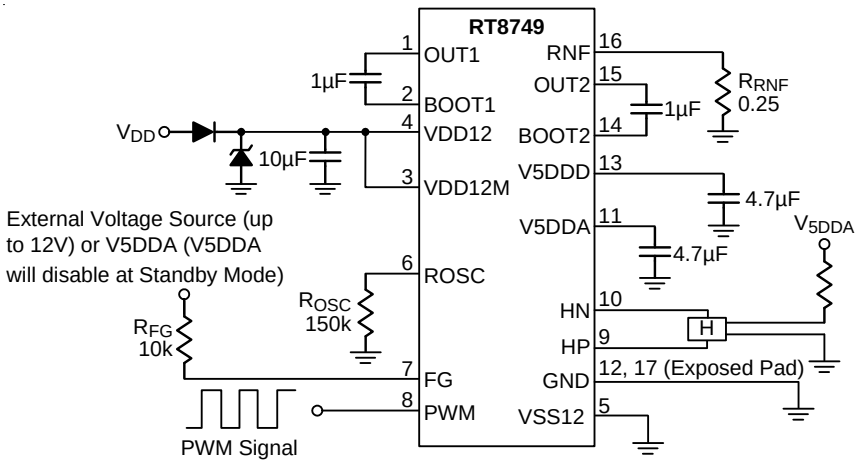
Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Note 2. θ_{JA} is measured at T_A = 25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7. θ_{JC} is measured at the exposed pad of the package.

Note 3. Devices are ESD sensitive. Handling precaution is recommended.

Note 4. The device is not guaranteed to function outside its operating conditions.

Typical Application Circuit



Applications Information

Speed Control

The motor speed can be controlled by the external signal on the PWM pin or controlled by the input voltage on the VDD12 pin. (Switching input voltage is not allowed). When the RT8749 operates in input voltage control mode, the input voltage on VDD12 must be higher than 6V. When the PWM input is fixed at a high level voltage or floating, the motor will rotate with memory table's highest bit speed. When the PWM input is fixed at a low level voltage, the motor will decelerate to stop if the standby mode is enabled. Otherwise, the motor will rotate with memory table's lowest bit speed. When a switching signal is sent as the PWM input, the duty ratio of the input signal will be sampled and converted to a 8-bit code. This code is correspondent to an rotation speed which is stored in the embedded flash memory. The controller will regulate the fan motor's speed to this target speed by adjusting the switching duty ratio of the output drivers. It should be noted that the input PWM frequency is independent of the switching frequency of the output drivers. Hence, the input PWM frequency can be chosen within a wide range, from 100Hz to 100kHz, while keeping the output switching frequency at 31.25kHz.

Peak Current Limitation

The DC-link current of the inverter is limited to protect the power transistors and the motor. When the measured current exceeds the current limit ($\frac{0.25V}{R_{RNF}}$), gate signals to the output drivers will be all turned off until the next switching cycle.

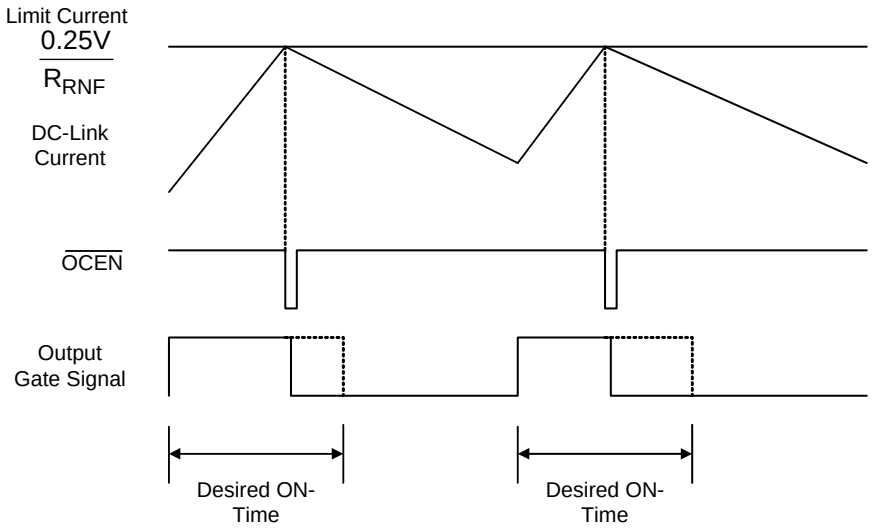


Figure 1

Motor Lock Protection and Automatic Restart Function

When the motor is locked, a lock detection circuit will detect this situation within a time duration (T_{LOCK}) ,and will disable the output drivers regardless of the duty ratio of the PWM to prevent the motor coil from burnout. After the time duration (T_{REL}), the IC will automatically try to restart the motor. If the motor is still locked, then the iteration of the lock detection and restart will be repeated until the lock condition is released or the external PWM input is pulled low.

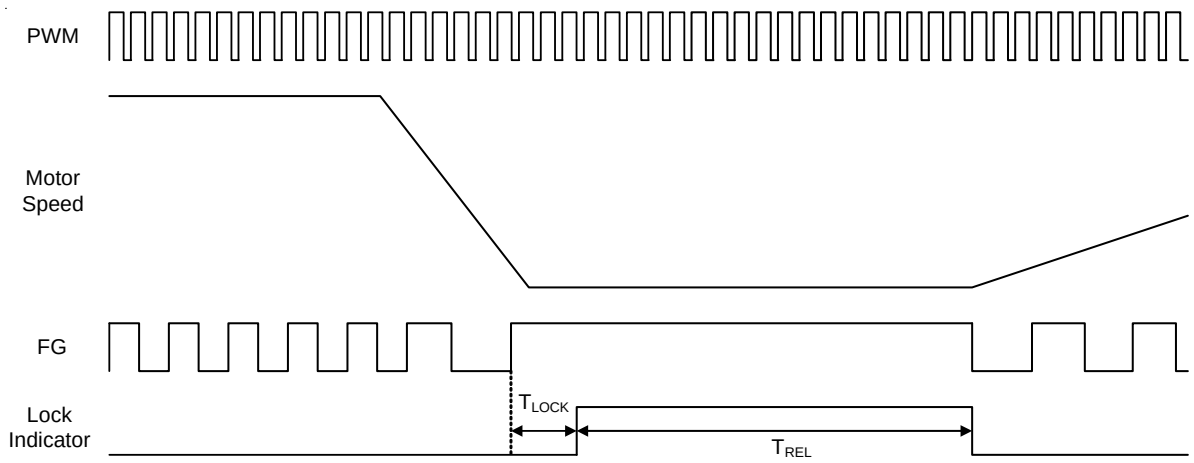


Figure 2. Sequence of Lock and Restart

Low Power Standby Mode

If the PWM input maintains a low level voltage for 20ms when the standby mode is enabled, the IC will enter the "low-power standby mode" until the PWM input is pulled up to a high level voltage. When RT8749 is at standby mode, V5DDA, OUT1 and OUT2 will be disabled.

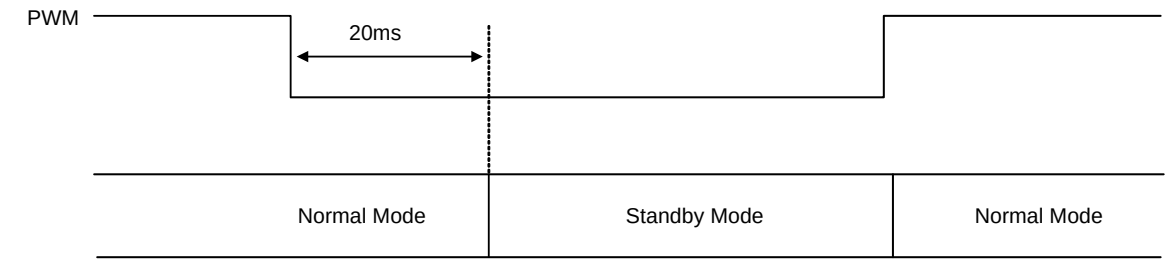


Figure 3. Sequence of Low Power Standby Mode

Over Temperature Protection

The RT8749 includes an Over Temperature Protection (OTP) feature to prevent overheating due to excessive power dissipation. The OTP function shuts down the switching operation when the junction temperature exceeds 150°C. Once the junction temperature cools down by around 25°C, the main converter will automatically resume switching. To maintain continuous operation, the junction temperature should be kept below 125°C.

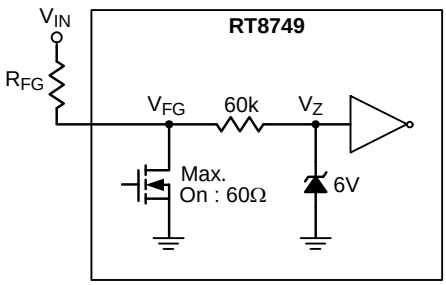


Figure 4

FG Pull-up Resistance Design

The RT8749's pull-up resistance will influence the FG pin's high and low voltage. The function block diagram in Figure 4 shows the FG pin's internal circuits. Note that 60kΩ have ±10% variation and 60Ω is the maximum on-resistance.

The typical high and low level voltage of the FG pin can be calculated by the following formula :

$V_{FGHigh} = V_{IN}$ x (60k ±10%) / (R_{FG} + 60k ±10%) + V_Z x

R_{FG} / (R_{FG} + 60k ±10%)

$V_{FGLow} = V_{IN}$ x 60 / (R_{FG} +60)

For $V_{IN} > 6V$, $V_Z = 6V$

For $V_{IN} \leq 6V$, $V_Z = V_{IN}$

Thermal Considerations

For continuous operation, do not exceed absolute maximum junction temperature. The maximum power dissipation depends on the thermal resistance of the IC package, PCB layout, rate of surrounding airflow, and difference between junction and ambient temperature. The maximum power dissipation can be calculated by the following formula :

$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$

where $T_{J(MAX)}$ is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction to ambient thermal resistance.

For recommended operating condition specifications, the maximum junction temperature is 125°C. The junction to ambient thermal resistance, θ_{JA}, is layout dependent. For WDFN-16L 4x4 package, the thermal resistance, θ_{JA}, is 29.5°C/W on a standard JEDEC 51-7 four-layer thermal test board. The maximum power dissipation at T_A = 25°C can be calculated by the following formula :

$P_{D(MAX)}$ = (125°C – 25°C) / (29.5°C/W) = 3.38W for WDFN-16L 4x4 package

The maximum power dissipation depends on the operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance, θ_{JA}. The derating curve in Figure 5 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

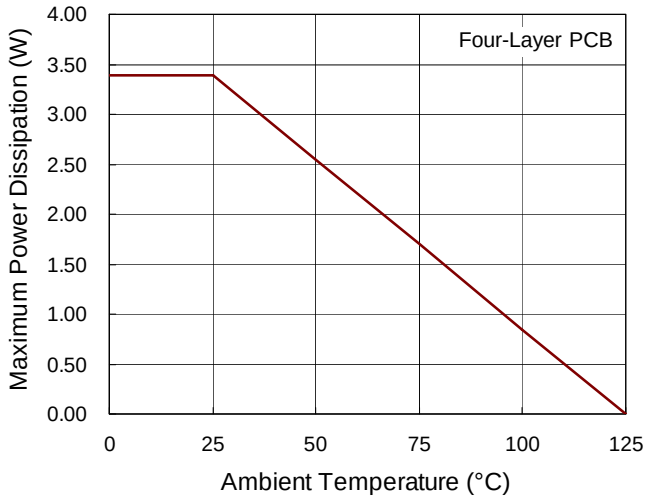
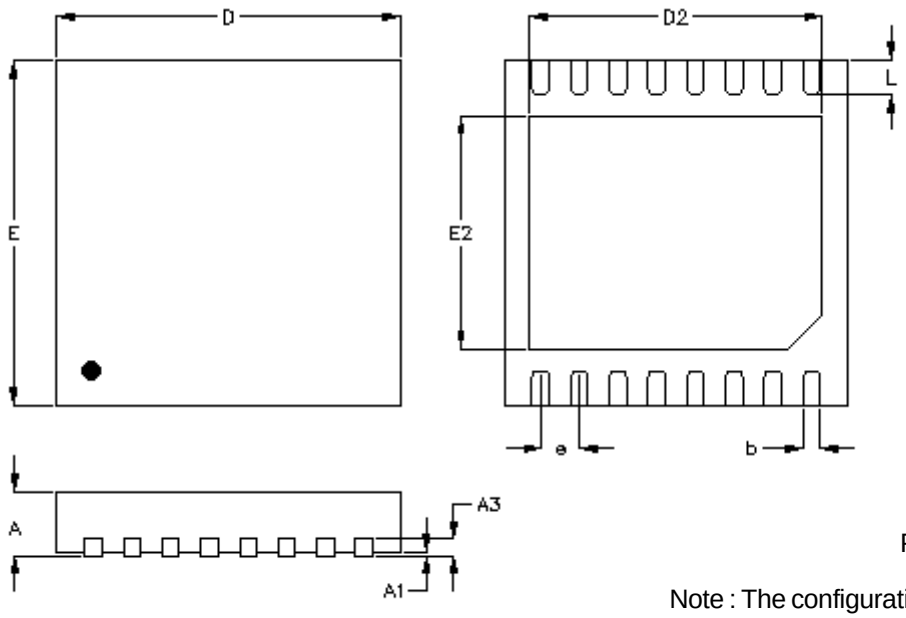
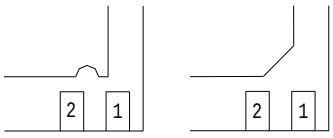


Figure 5. Derating Curve of Maximum Power Dissipation

Outline Dimension





DETAIL A

Pin #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.150	0.250	0.006	0.010
D	3.900	4.100	0.154	0.161
D2	3.350	3.450	0.132	0.136
E	3.900	4.100	0.154	0.161
E2	2.650	2.750	0.104	0.108
e	0.450		0.018	
L	0.350	0.450	0.014	0.018

W-Type 16L DFN 4x4 Package

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