Digital Single-Phase Full Wave BLDC Fan Controller

General Description

The RT8749A is a highly integrated digital controlled pre-driver 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. 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 the user for different fan models and applications.

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

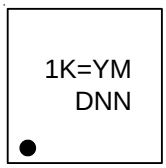
Applications

- Instrumentation Fans
- Central Heating Blowers
- Automotive Climate Control

Features

- **Embedded Flash Memory**
- **External PWM Speed Control**
- **Wide Range External PWM Input Frequency (1kHz 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)**
- **Thin 16-Lead WDFN Package**
- **RoHS Compliant and Halogen Free**

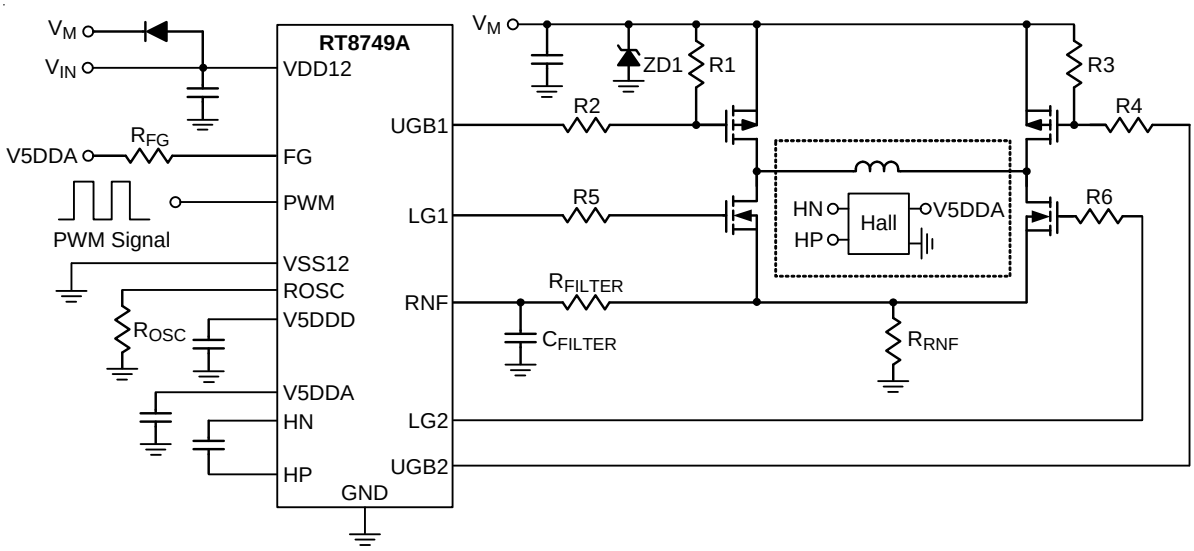
Marking Information



1K= : Product Code

YMDNN : Date Code

Simplified Application Circuit



Ordering Information

RT8749A □□

Package Type
QW : WDFN-16L 4x4 (W-Type)

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

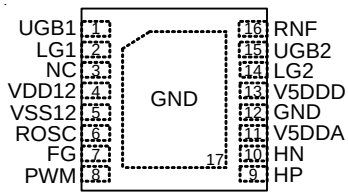
Note :

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.

Pin Configurations

(TOP VIEW)

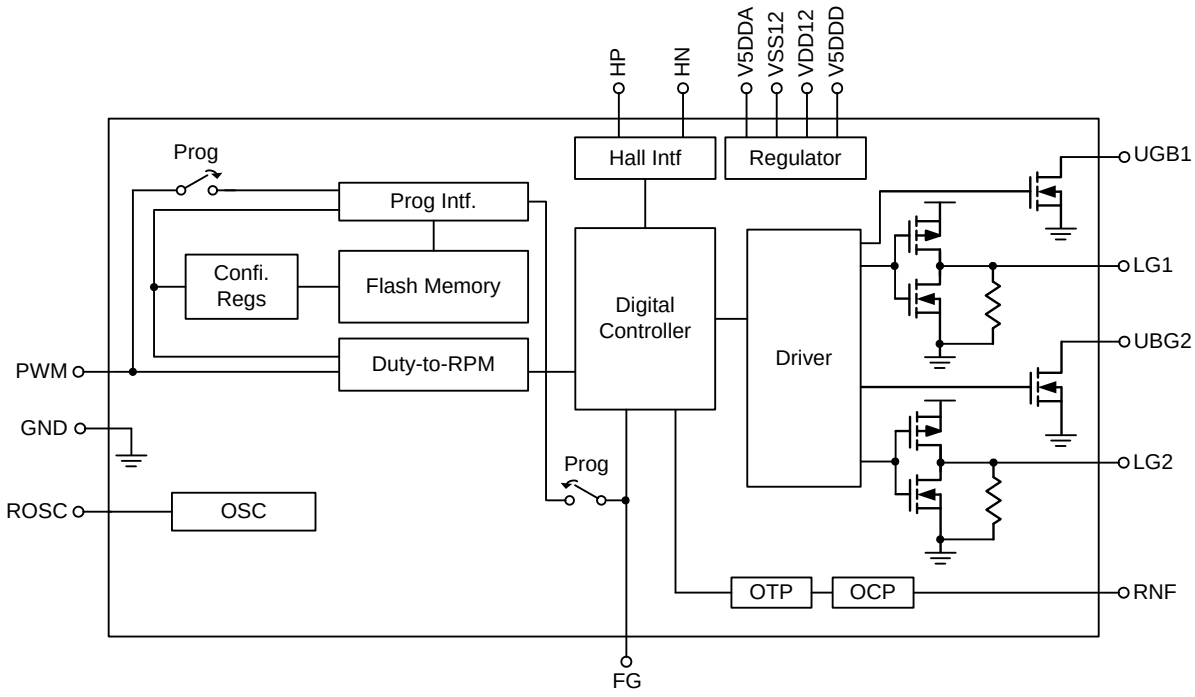


WDFN-16L 4x4

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	UGB1	Channel 1 Open-Drain Output to High-Side P-MOSFET.
2	LG1	Channel 1 Output to Low-Side N-MOSFET.
3	NC	No Internal Connection.
4	VDD12	Power Input 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 ground.
7	FG	Frequency Generator with Open-Drain Output.
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. It will be disabled in standby mode.
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	LG2	Channel 2 Output to Low-Side N-MOSFET.
15	UGB2	Channel 2 Open-Drain Output to High-Side P-MOSFET.
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 RT8749A 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 RT8749A features over-current protection function to protect the power MOSFET. Users need to add a resistor R_{RNF} between the low-side N-MOSFET and GND. If over-current protection is activated, the RT8749A 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 RT8749A 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.

Flash Memory

The Flash Memory stores motor control parameters and speed reference table.

Duty to RPM Converter

The PWM pin injected PWM duty to Duty to RPM Converter. This converter could decode the PWM duty and map to the RPM table (reference speed table) which is stored in the flash memory.

Configure Register

For motor speed control and application flexibility, there are some parameters could be used by configure register which is stored in the flash memory.

FG Pull up Resistance Design

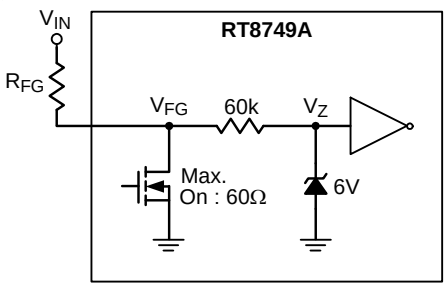


Figure 1

The RT8749A's pull up resistance will influence the FG pin's high and low voltage. The function block diagram in Figure 1 shows the FG pins internal circuits. Note that 60kΩ have ±10% variation and 60Ω is the maximum on resistance.

The typical high and low level voltage of 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)

where V_Z = 6V for V_{IN} > 6V and $V_Z = V_{IN}$ for $V_{IN} \leq$ 6V.

Absolute Maximum Ratings (Note 1)

- Supply Voltage, VDD12 ---------- –0.3V to 20V
- PWM to GND ---------- –0.5V to 20V
- FG to GND ---------- –0.3V to 20V
- UGBx to GND ---------- –0.3V to 20V
- UGBx, LGx Current ---------- 100mA
- FG 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 15V
- 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}	PWM pin = V_{DD12}	--	4	--	mA
Power Supply Current 2		I_{DD2}	PWM pin = 0V	--	--	300	µA
Output Driver							
LGx Output Voltage	High-Side	V_{LGH}	I_{OH} = 10mA	3.6	3.9	--	V
	Low-Side	V_{LGL}	I_{OL} = 10mA	--	0.5	0.6	
UGB Output Low Voltage		V_{UGBL}	I_{OL} = 50mA	--	0.4	0.6	V
Startup Oscillation Pin							
OSC Pin Charge Current		I_{OSC1}	R_{OSC} = 150k	--	8	--	µA
OSC Pin Discharge Current		I_{OSC2}	R_{OSC} = 150k	--	8	--	µA
PWM Input Pin							
PWM Input Voltage	High-Level	V_{PWMIH}		2.2	--	VDD12	V
	Low-Level	V_{PWMIL}		0	--	0.7	
PWM Internal Pull-up Current		I_{PWMIN}	PWM pin = 0V	--	--	–50	µA
PWM Input Frequency		F_{PWMIN}		1	--	100	kHz
PWM Output Frequency		F_{PWM}		--	31.25	--	kHz

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
FG Output Pin						
FG Output Pin Low-Level Voltage	V_{FG}	I_{FG} = 0.5mA	--	40	60	mV
Hall Input Sensitivity	V_{HN}	Zero to peak including offset and hysteresis	--	10	--	mV
Current Limit						
Threshold Voltage	V_{RF}		0.2	0.25	0.3	V
Under-Voltage Protection						
VDD12 Power-on Reset Threshold			--	5.5	--	V
VDD12 POR Hystersis			--	1.1	--	V
V5DDA UVP Threshold			--	3.8	--	V
V5DDA UVP Hystersis	ΔV_{UVLOA}		--	0.6	--	V
Thermal Protection						
Thermal Protection Temperature	T_{SD}		--	150	--	°C
Temperature Hysteresis Width	ΔT_{SD}		--	30	--	°C
Output Voltage Source						
5V Output Voltage for Analog	V_{5DDA}	V_{IN} = 5.5V to 15V, I_{Load} = 15mA	4.7	5	5.3	V
5V Output Voltage for Digital	V_{5DDD}	V_{IN} = 5.5V to 15V	4.7	5	5.3	V

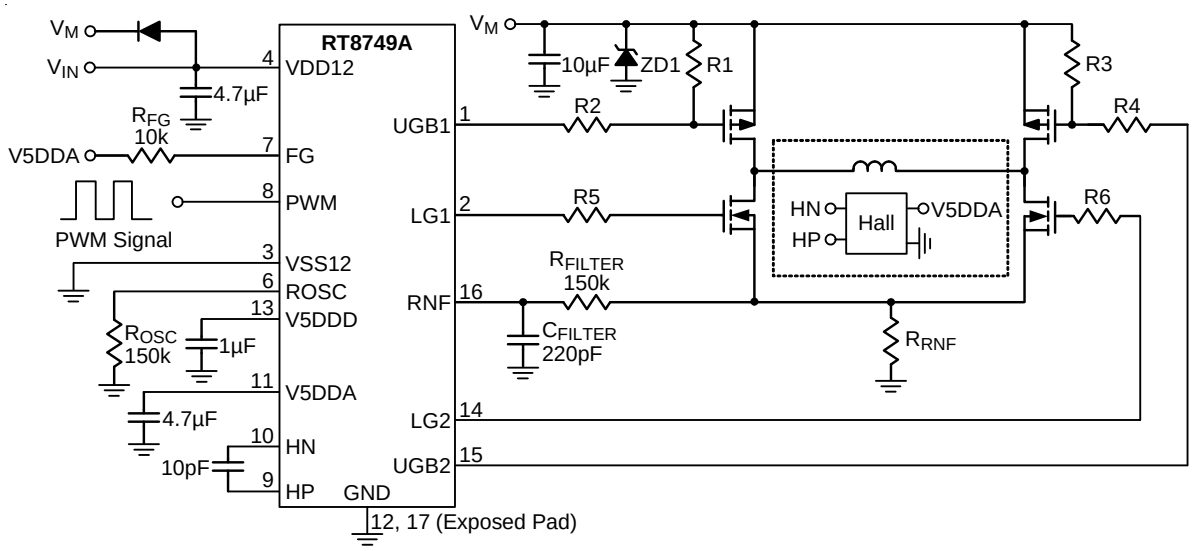
Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure 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 PWM input pin. When the PWM input is fixed at a high level voltage or floating, the motor will rotate with memory table's highest bit's 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's speed. When a switching signal is sent as the PWM input, the duty ratio of the input signal will be sampled and converted to an 7-bit code. This code is correspondent to an rotation speed which is stored at 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 to the switching frequency of the output drivers. Hence, the input PWM frequency can be chosen within a wide range from 1kHz to 100kHz, while keeping the output switching frequency at 31.25kHz.

Peak Current Limit

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.

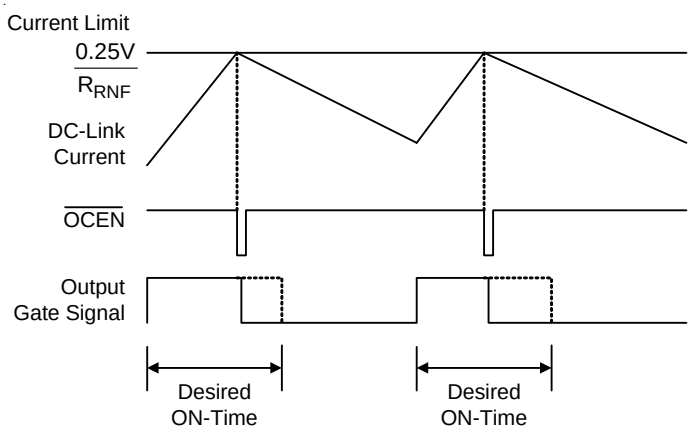


Figure 2

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 another 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.

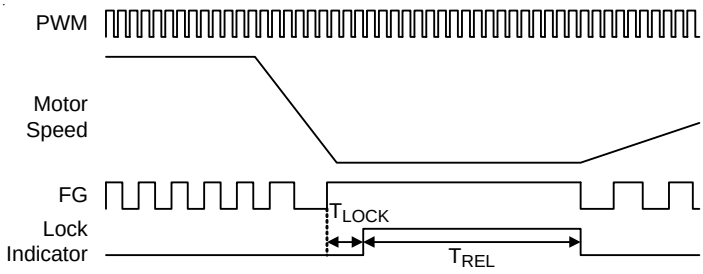


Figure 3. Sequence of Lock and Restart

Low Power Standby Mode

As the PWM input keeps at the low level voltage for 20msec, if 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 RT8749A at standby mode, V5DDA will disable.

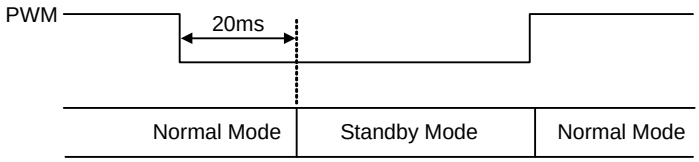


Figure 4. Sequence of Low Power Standby Mode

Over-Temperature Protection

The RT8749A 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.

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.

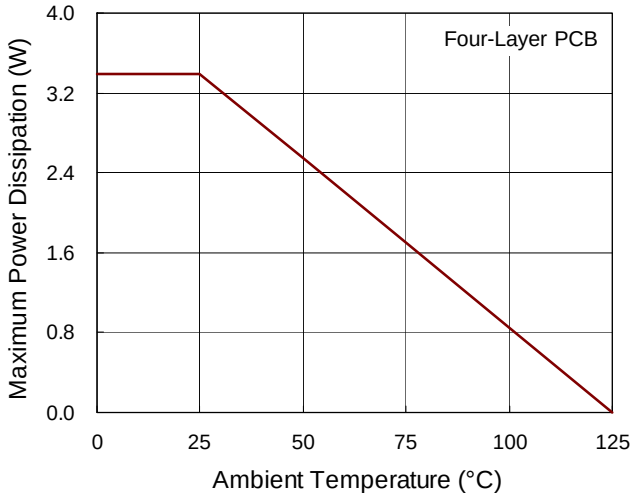


Figure 5. Derating Curve of Maximum Power Dissipation

Layout Consideration

- Capacitors of VDD12, V5DDD, V5DDA, VM, and HP HN as close as possible to IC.
- Resistor of ROSC as close to IC as possible.
- PWM and FG layout path cannot overlap between top and bottom layer.
- Layout path from gate signals to MOSFET as symmetry and short as possible.
- Ground of GNDA (analog) and GNDD (digital) connect at IC bottom ground finally.
- RNF pin needs RC filter, which as close to IC as possible.

f_{filter} = 1 / (2 x Pi x R x C)

Filter reference value : 150kΩ, 220pF.

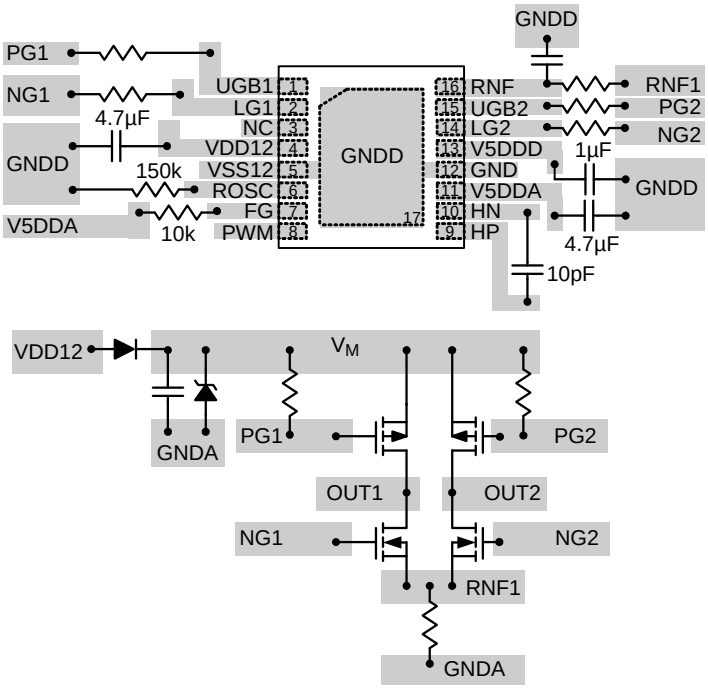
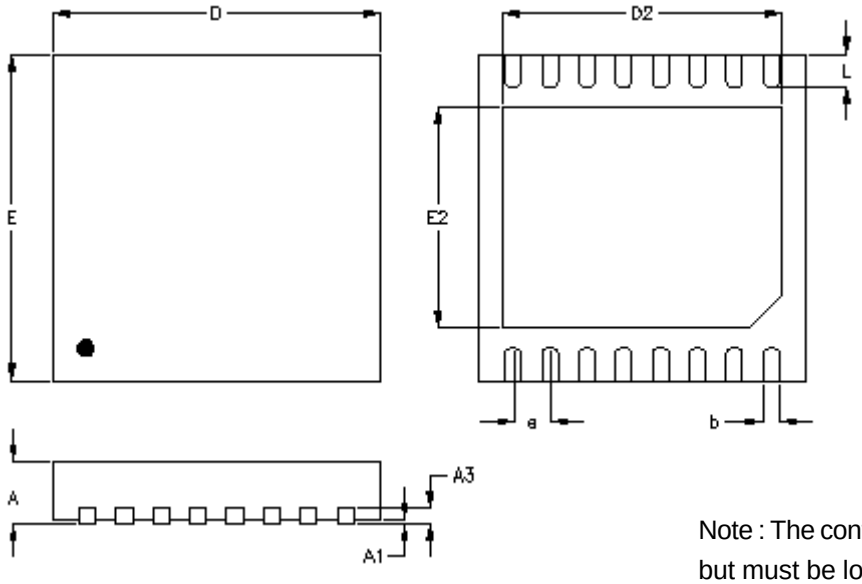
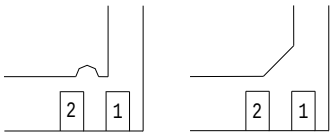


Figure 6. PCB Layout Guide

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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