3-Phase Sensor-less Fan Motor Driver AM8933

The AM8933 is a 3-phase sensor-less DC fan motor driver IC. It senses the BEMF (Back Electro-Motive Force) of the motor in rotation and provides corresponding commutation current to the motor. Rotation speed can be controlled by PWM input signal. The drivers include Lock Detection, Thermal Shutdown, and Over-current Protection. Forward and Reverse control.

Applications

3-Phase sensor-less DC Fan Motor

Features

1) Operation voltage 1.8 to 6.0V
2) Lock detection/Automatic restart function
3) Built-in FG (frequency generation)
4) Thermal shutdown protection
5) Over current protection
6) PWM speed control
7) Soft switching technique to reduce acoustic noise
8) Forward and Reverse control

Absolute Maximum Ratings (Ta = 25℃)

Parameter	Symbol	Limits	Unit
Supply voltage	V_{CC}	6.5	V
Output current	Iomax	1000	mA
FG signal output voltage	V_{FG}	6.5	V
FG signal output current	I_{FG}	10	mA
PWM input voltage	VPWMmax	VCC	V
Power dissipation (JEDEC 2S2P PCB)	Pd	3190*	mW
Operate temperature range	T_{opr}	-40～+125	℃
Storage temperature range	T_{stg}	-55～+150	℃
Junction temperature	Tjmax	150	℃

* Pd de-rated by 25.52mW/°C over 25℃ (based on JEDEC 2S2P board)

Those are stress rating only and functional operating at those conditions for extended periods may damage to the device.

Recommended operating conditions

(Set the power supply voltage taking allowable dissipation into considering)

Parameter	Symbol	Min	Typ	Max	Unit
Operating supply voltage range	Vcc	1.8～6.0			V

Storage Condition

Parameter	Value	Unit
Temperature condition Before Opening	5~40	℃
Humidity condition Before Opening	30~80%	RH
Temperature condition after Opening	<30	℃
Humidity condition after Opening	<60%	RH

Electrical Characteristics

(Unless otherwise specified, Ta = 25℃, VCC = 5.0V)

Parameter	Symbol	Limit Min	Limit Typ	Limit Max	Unit	Conditions
Supply current	I_{CC}	—	1.8	3	mA	PWM pin= VCC
Stand-by current	I_{SC}	—	25	50	μA	PWM pin= 0V
Oscillator						
OSC pin charge current	I_{OSC1}	-10.4	-12.5	-14.6	μA	OSC pin= 0.5V
OSC pin discharge current	I_{OSC2}	10.4	12.5	14.6	μA	OSC pin= 1.5V
FR/PWM input						
Input H level	V_{PWMH}	2.5	—	V_{CC}	V	
Input L level	V_{PWML}	0	—	V_{CC}*0.2	V	
PWM input frequency	F_{PWM}	20	—	50	kHz	
FGS input						
Input H level	V_{FGSH}	Vcc*0.9	—	V_{CC}	V	
Input L level	V_{FGSL}	0	—	V_{CC}*0.1	V	
Output						
Output voltage	V_0	—	0.3	0.4	V	I_0=250mA (Upper + Lower)
FG low voltage	V_{FGL}	—	—	0.4	V	I_{FG} = 5mA
FG leakage current	I_{FGL}	—	—	10	μA	V_{FG} = 5V
Lock protection						
Lock detection ON time	T_{ON}	1.4	2	2.6	sec	T_{ON}=start time + lock detect
Lock detection OFF time	T_{OFF}	3.5	5	6.5	sec	
Thermal						
Thermal shutdown	ThSD	150	170	—	℃	
Thermal shutdown hysteresis	ΔThSD		25		℃	

Block Diagram

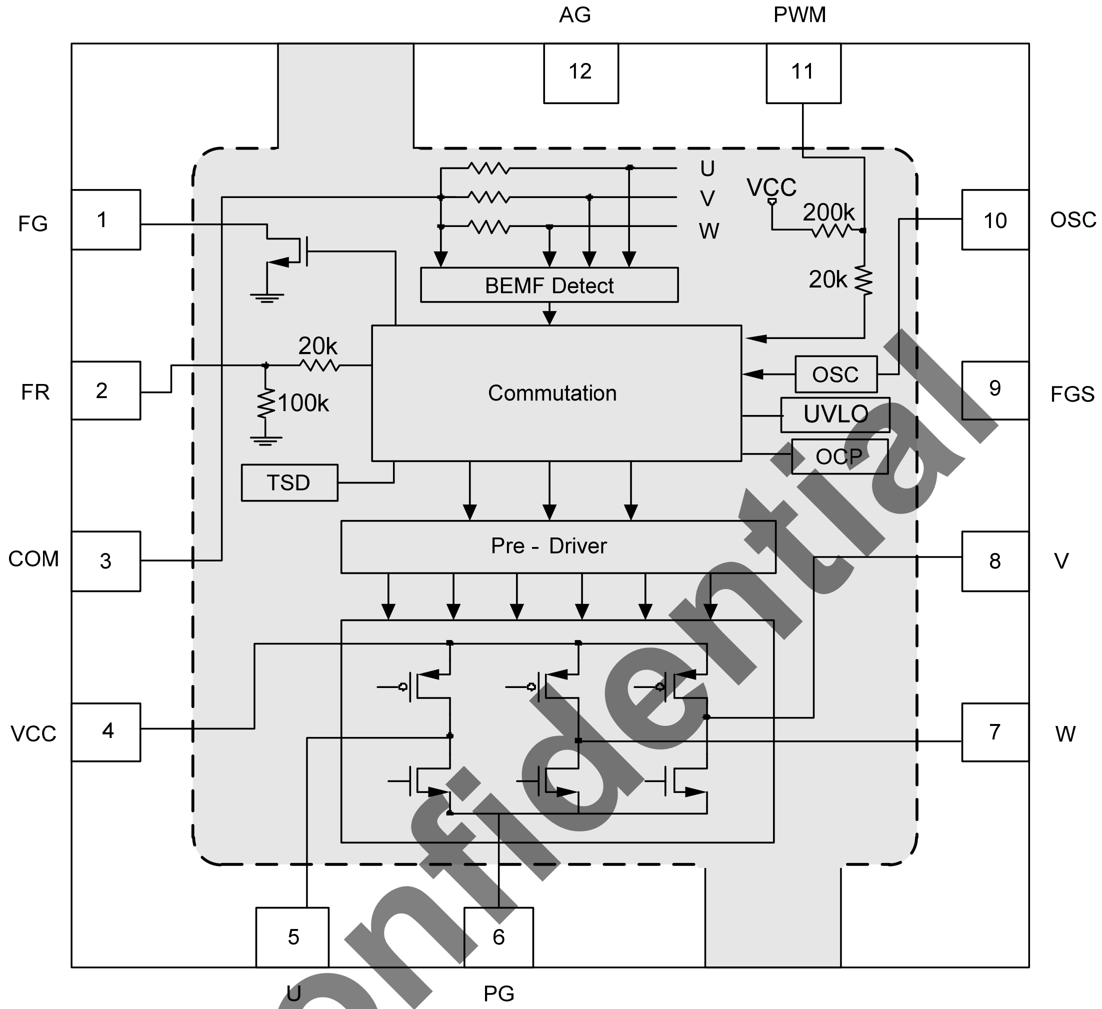


Fig.1 Block diagram

Pin Description

PIN No	Pin Name	Function
1	FG	FG signal output terminal
2	FR	Forward and Reverse control terminal
3	COM	Motor center tap voltage input terminal
4	VCC	Power supply terminal
5	U	U phase output terminal
6	PG	Power ground terminal
7	W	W phase output terminal
8	V	V phase output terminal
9	FGS	FG signal divide frequency selection
10	OSC	Start-up frequency output terminal
11	PWM	PWM signal input terminal
12	AG	Analog ground terminal
E-pad	PG	Power ground terminal

Thermal Information

Θja	junction-to-ambient thermal resistance	39.18℃/W
Ψjt	junction-to-top characterization parameter	0.16℃/W

- **Θja** is obtained in a simulation on a JEDEC-standard 2s2p board as specified inJESD-51.
- The **Θja** number listed above gives an estimate of how much temperature rise is expected if the device was mounted on a standard JEDEC board.
- When mounted on the actual PCB, the **Θja** value of JEDEC board is totally different than the **Θja** value of actual PCB.
- **Ψjt** is extracted from the simulation data to obtain **Θja** using a procedure described in JESD-51, which estimates the junction temperature of a device in an actual PCB.

- The thermal characterization parameter, **Ψjt**, is proportional to the temperature difference between the top of the package and the junction temperature. Hence, it is useful value for an engineer verifying device temperature in an actual PCB environment as described in JEDEC JESD-51-12.
- When Greek letters are not available, **Ψjt** is written Psi-jt.
- Definition:

DFEINITION $\psi_{jt} = (T_j - T_t) / P_d$

Where :

Ψjt (Psi-jt) = Junction-to-Top(of the package) °C/W
Tj= Die Junction Temp. °C
Tt= Top of package Temp at center. °C
Pd= Power dissipation. Watts

- Practically, most of the device heat goes into the PCB, there is a very low heat flow through top of the package, So the temperature difference between **Tj** and **Tt** shall be small, that is any error caused by PCB variation is small.

- This constant represents that **Ψjt** is completely PCB independent and could be used to predict the **Tj** in the environment of the actual PCB if **Tt** is measured properly.

How to predict Tj in the environment of the actual PCB

Step 1 : Used the simulated **Ψjt** value listed above.

Step 2 : Measure **Tt** value by using

- **Thermocouple Method**

  We recommend use of a small ~40 gauge(3.15mil diameter) thermocouple. The bead and thermocouples wires should touch the top of the package and be covered with a minimal amount of thermally conductive epoxy. The wires should be heat-insulated to prevent cooling of the bead due to heat loss into wires. This is important towards preventing “too cool” **Tt** measurements, which would lead to the calculated **Tj** also being too cool.

- **IR Spot Method**

  An IR Spot method should be utilized only when using a tool with a small enough spot area to acquire the true top center “hot spot”.

  Many so-called “small spot size” tools still have a measurement area of 0~100+mils at “zero” distance of the tool from the surface. This spot area is too big for many smaller packages and likely would result in cooler readings than the small thermocouple method. Consequently, to match between spot area and package surface size is important while measuring **Tt** with IR sport method.

Step 3 : calculating power dissipation by

$$P \cong (VCC - |Vo_{\_Hi} - Vo_{\_Lo}|) \times I_{out} + VCC \times Icc$$

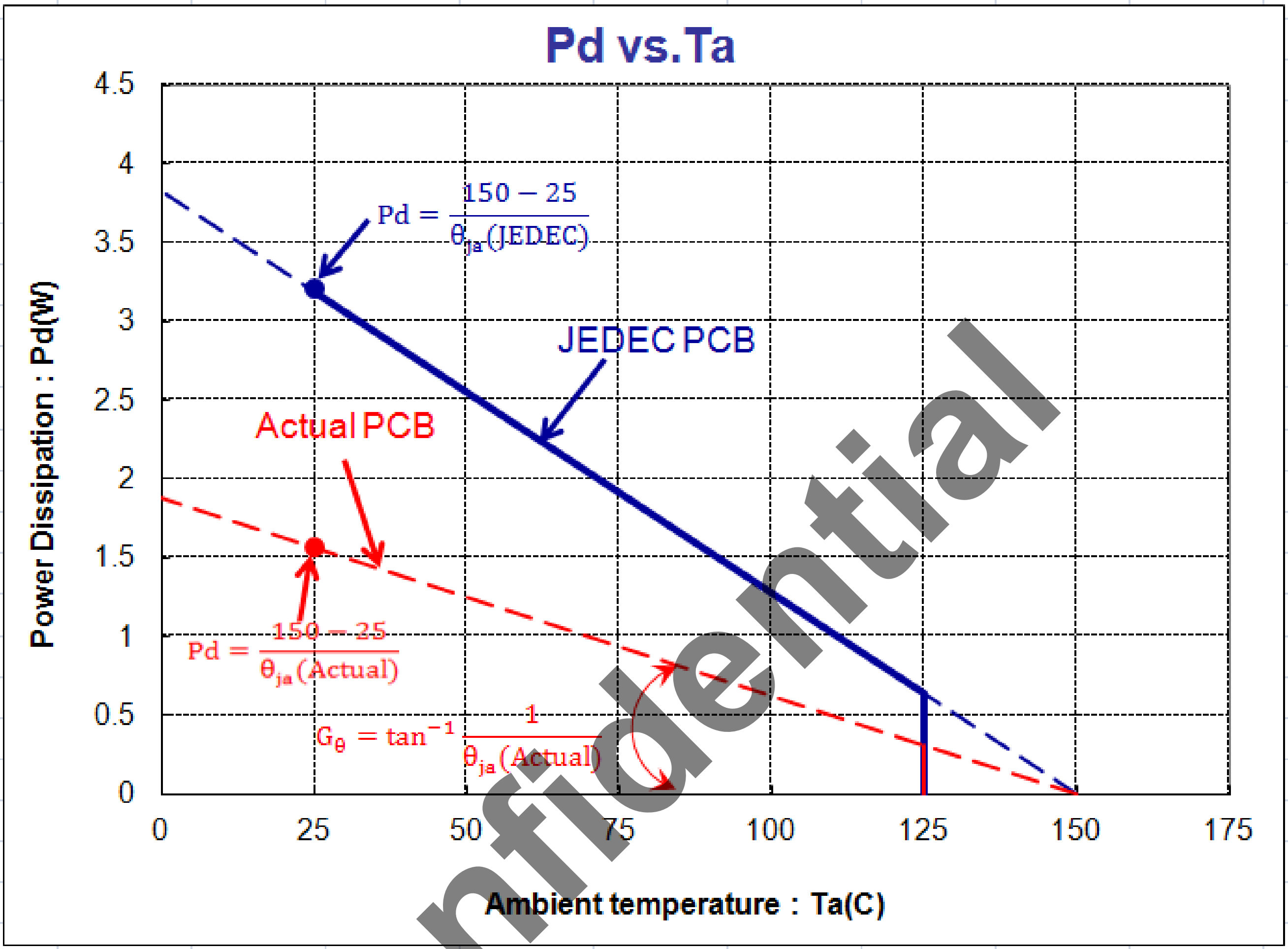
Step 4 : Estimate **Tj** value by

$$Tj = \Psi jt \times P + Tt$$

Step 5: Calculated Θja value of actual PCB by the known **Tj**

$$\Theta ja(actual) = (Tj - Ta)/P$$

Maximum Power Dissipation (de-rating curve) under JEDEC PCB & actual PCB



Application circuit

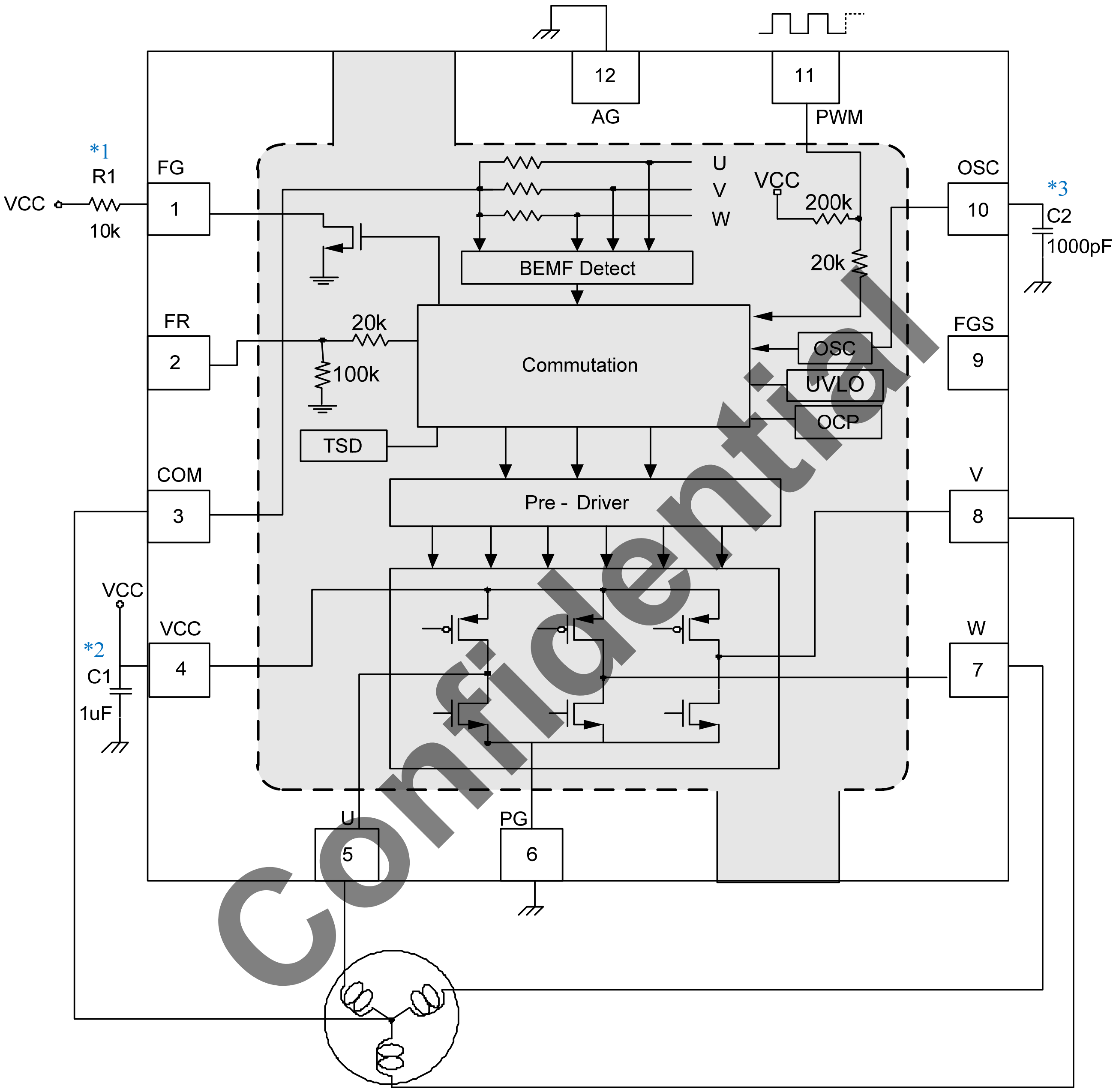


Fig. 2 Application circuit

*1 Open drain output. A pull-up resistances of 10kΩ should be inserted.

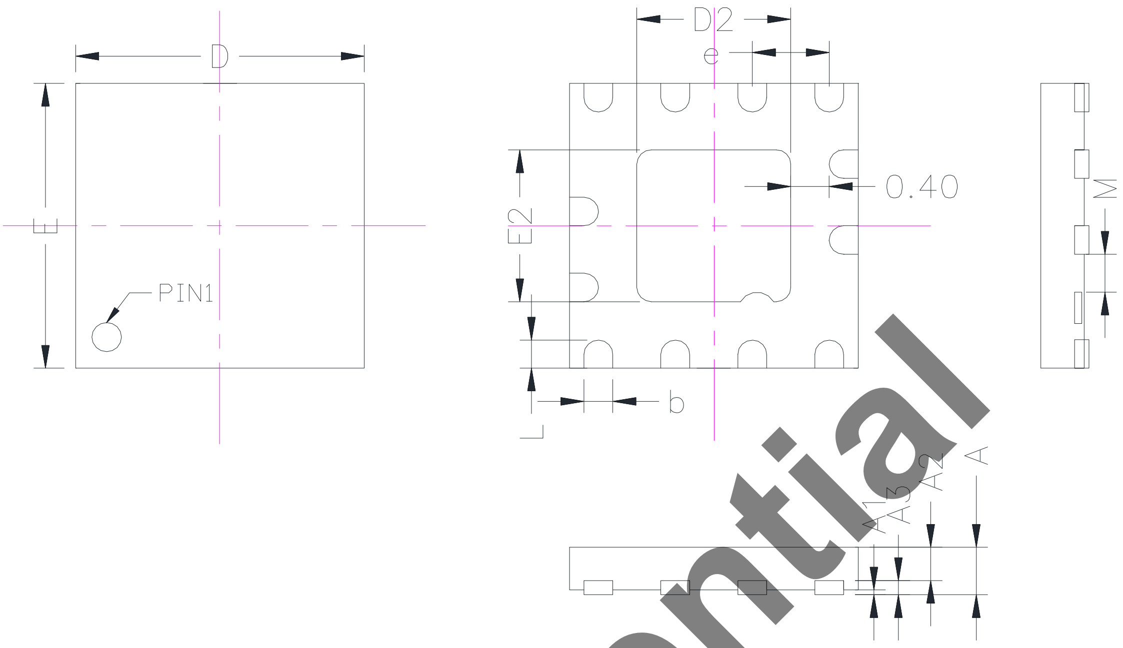
*2 The wiring patterns from the VCC terminal and GND terminal to the bypass capacitor must be routed as short as possible. With respect to the wiring pattern

*3 This Capacitor 1000pF is only for reference. Variable Motors should select suitable capacitor for optimum start-up characteristics.

Operation notes

1) Power supply line
The BEMF causes re-circulate current to power supply, please connect a capacitor between power supply and ground as a route of re-circulate current. And please determine the capacitance after confirmation that the capacitance does not causes any problems.
2) Ground potential
Ground potential AG and PG pin connect the lowest voltage on the chip and short the path as possible.
3) PWM speed control
This IC offer PWM pin direct control output transistors for motor speed control. Higher frequency will reduce output current noise. The control input frequency recommended operation between 20 KHz to 50 KHz. If frequency is slower than 6.5kHz (typ.), it will go into stand-by mode.
This pin connect internal pull-high resistor 200K ohm. When connect to VCC or floating. The motor will rotate in the full speed.
4) Soft Switching Circuit
This IC use duty-variable switching for low acoustic noise and vibration.
5) Start-up Circuits
The OSC pin is defined a sensor-less start-up commutation frequency. The connecting capacitor is between the OSC pin and ground. Variable Motors start-up characteristic are variable with different capacitors. Variable Motors should select suitable capacitor for optimum start-up characteristics. If the capacitance value is larger, the variation start-up time is longer. Also, if the capacitance value is smaller, the motor start-up time is shorter and might cause start-up failed by fan friction.
6) FG (Function Generator) function
This FG pin is made up with an open drain output.
Recommend connect a resistance of 10k ohm to VCC.
7) Thermal design and Thermal shutdown
The thermal design should allow enough margins for actual power dissipation. In case the IC is left running over the allowable loss, the junction temperature rises, and the thermal-shutdown circuit works at the junction temperature of 170°C (typ.) (the outputs of all the channels are turned off). When the junction temperature drops to 145°C (typ.), the IC start operating again.
8) FR (Forward and Reverse) function
FR high: U -> V-> W ； FR low: U->W->V 。There is a internal pull low 100kΩ resistor which means the default setting is low if this pin is floating. Motor direction can be forward or reverse by switching FR Voltage level. When motor direction is going to be changed, larger pick current level will be happened. Please consider the current and power dissipation.
9) FGS (FG frequency Selection) function
FGS is designed for different FG frequency application. Normally, FGS pin is floating for original FG frequency. FGS=High, FG frequency divide 2. FGS=Low, FG frequency divide 3.

- **Package Outline --- QFN 3X3 12L** **Unit : mm**



SYMBOL	MILLIMETERS		INCHES	
	Min.	Max.	Min.	Max.
A	-	0.50	-	0.020
A1	-	0.05	-	0.002
A2	-	0.35	-	0.014
A3	0.15 REF		0.006 REF	
b	0.25	0.35	0.010	0.014
D/E	3.00 BSC		0.118 BSC	
D2	1.55	1.65	0.061	0.065
E2	1.55	1.65	0.061	0.065
L	0.25	0.35	0.010	0.014
M	0.35	0.45	0.014	0.018
e	0.8 BSC		0.031 BSC	

Reflow profile

(A). Manual Soldering

Time / Temperature $\leq$ 3 sec / 390 $\pm$ 10 °C （2 Times）

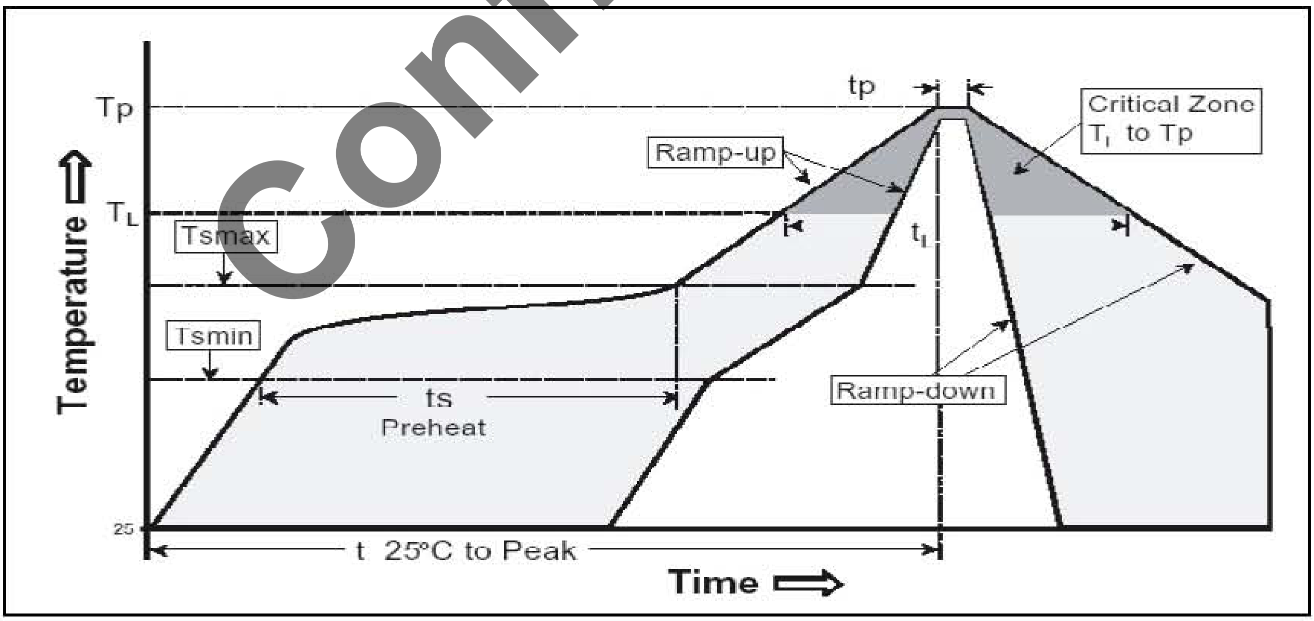
Test Results：0 fail/ 22 tested

Manual Soldering count：2 Times

(B). Re-flow Soldering (follow IPC/JEDEC J-STD-020D)

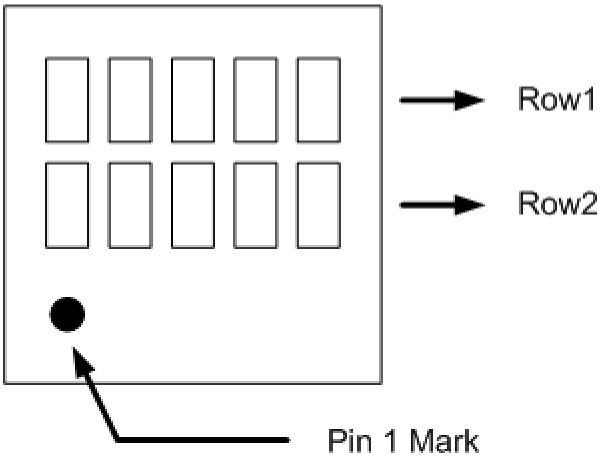
Classification Reflow Profile

Profile Feature	Pb-Free Assembly
Average ramp-up rate (T_L to T_P)	3°C/second max.
Preheat - Temperature Min (Ts min) - Temperature Max (Ts max) - Time (ts) from (Tsmin to Tsmax)	150°C 200°C 60-120 seconds
Ts max to T_L - Temperature Min (Ts min)	3°C/second max.
Time maintained above: - Liquid us temperature (T_L) - Time (t_L) maintained above TL	217°C 60-150 seconds
Peak package body temperature (Tp)	260 +0/-5°C
Time with 5°C of actual Peak - Temperature (tp)	30 seconds
Ramp-down Rate	6°C/second max.
Time 25°C to Peak Temperature	8 minutes max.



Test Results：0 fail/ 32 tested Reflow count：3 cycles

Marking Identification



Row 1

A8933

Row 2

Date & Lot number