US651 / US661

Two-Coil Low Noise Fan Driver

Features and Benefits

- Soft Switching for low noise applications
- Slope control setting by dedicated pin
- One-chip solution *(Hall + Drivers)*
- Advanced Protection *(enhanced locked rotor, reverse voltage, thermal, output clamping)*
- Integrated tachometer (US651) or alarm (US661) signal output

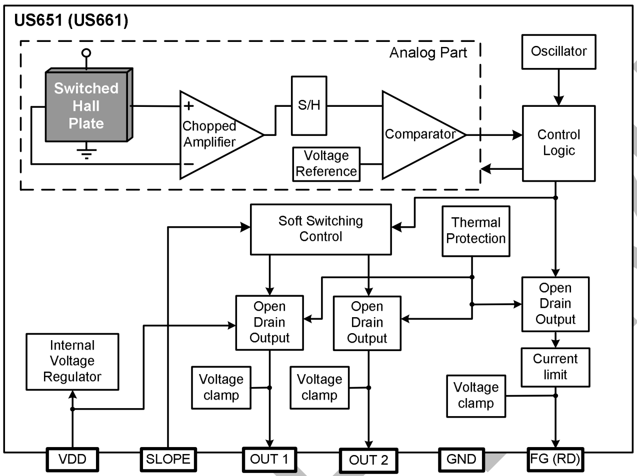
Application Examples

- 5V/12V DC brushless motors
- Continuous output current up to 350mA
- Low noise brushless cooling fans
- PC, server, laptop cooling fan
- Power supply cooling fan
- Large and small fan size

Ordering Information

Part No.	Temperature Code	Package Code
US651	E (-40°C to 85°C)	DC (8-pin narrow SOIC8)
US661	E (-40°C to 85°C)	DC (8-pin narrow SOIC8)

1 Functional Diagram



2 General Description

The US651/661 is a one-chip solution for driving two-coil brushless DC fan and motors. It is especially suitable for relatively high-current rated operation as it can drive up to 350mA continuous output current.

The use of Melexis Soft Switching concept lowers the acoustic and electrical motor noise and provides smoother operation. This efficient solution is combined with an innovative slope control design controllable via a dedicated pin.

The device includes reverse voltage protection, locked rotor protection and thermal protection. Therefore, the IC robustness perfectly suits for consumer and automotive-on-board applications.

Tachometer (FG) or Alarm (RD) open-drain output is available. It makes the connectivity with external interface such as hardware monitoring or Super I/O IC easier.

The device is delivered in RoHS compliant DC package (SMD) for automatic soldering

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3 Glossary of Terms

Two-coil fan	A fan with two-coil windings where current alternates from 1 coil to the other depending on the direction of the magnetic field.
MilliTesla (mT), Gauss	Units of magnetic flux density : 1mT = 10 Gauss
Peak output current	The current flowing in the coil at start-up, only limited by the coil resistance R_{COIL} and the output driver resistance R_{DSON}.
Continuous output current	Average absolute value of the output current when the fan is spinning.
Locked rotor	The state when the fan stopped spinning due to mechanical blockage.
FG	Frequency generator or tachometer output
RD	Rotation detection or alarm output

4 Absolute maximum ratings

Parameter	Symbol	Value	Units
Supply Voltage	V_{DD}	-12 to 18	V
FG / RD voltage	V_{FG} (V_{RD})	-7 to 18	V
Voltage on pin SLOPE	V_{SLOPE}	-0.5 to 18	V
Peak output current	I_{OUTp}	700	mA
Continuous output current	I_{OUTc}	350	mA
Operating Temperature Range	T_A	-40 to 85	°C
Junction temperature	T_J	125	°C
Storage Temperature Range	T_S	-55 to 150	°C
Magnetic flux density	B	Unlimited	mT

Table 1: Absolute maximum ratings

Exceeding the absolute maximum ratings may cause permanent damage. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

5 Pin definitions and descriptions

Pin Name	Function	Pin number (DC)
FG (RD)	Tachometer (Alarm) open-drain output	1
VDD	Power Supply pin	2
SLOPE	Slope Control pin	3
OUT1	Open Drain Coil Driver 1	4
GND	Ground pin	5
OUT2	Open Drain Coil Driver 2	6
NC	Not connected	7
NC	Not connected	8

Table 2: Pin definitions and descriptions

6 General Electrical Specifications

DC Operating Parameters $T_J = 25^oC$, $V_{DD} = 12V$ (unless otherwise specified)

Parameter.	Symbol	Test Conditions	Min	Typ	Max	Units
Supply Voltage	V_{DD}	Operating	3	12	18	V
Supply Current	I_{DD}			3	5	mA
OUT1, OUT2 ON Resistance	$R_{DSON\ 1,2}$			3	5	Ω
OUT1, OUT2 Clamp Voltage	$V_{OUT\ 1,2}$		36			V
FG / RD Output Low Voltage	V_{OL}	I_{OL} = 4mA		0.35	0.5	V
FG / RD Output Clamp Voltage	V_{CLMP}		18			V
FG / RD Output Leakage Current	I_{LEAK}	V_{FG} (V_{RD}) = 5V			10	µA
FG / RD Output Current Limit	I_{FGLIM}	V_{FG} (V_{RD}) = 12V		20		mA
Output Switching Slope Duration (1)	T_{SW}	V_{DD} = 12V, pin SLOPE left open	40	70	160	µs
Output Switching Slope Duration (1)	T_{SW}	V_{DD} = 12V, R_{SLOPE} =100k	87	120	189	µs
Output Switching Slope Duration (1)	T_{SW}	V_{DD} = 5V, pin SLOPE left open	73	126	250	µs
Output Switching Slope Duration (1)	T_{SW}	V_{DD} = 5V, R_{SLOPE} =100k	87	120	189	µs
Locked Rotor Period	T_{ON}	V_{DD} = 12V	0.24	0.29	0.39	s
Locked Rotor Period	T_{OFF}	V_{DD} = 12V	1.44	1.5	2.34	s
Locked Rotor Period	T_{ON}	V_{DD} = 5V	0.48	0.6	0.89	s
Locked Rotor Period	T_{OFF}	V_{DD} = 5V	2.88	3.65	5.34	s
Thermal Protection Shutdown	T_{SD}	Note 2		160		°C
Thermal Protection Release	T_{REL}	Note 2		130		°C
DC Package Thermal Resistance	R_{TH}	Single layer PCB		150		°C/Watt

Table 3: Electrical specifications

Note 1: *Measured with active load connected to the output, from 10% to 90% of the V_{DD} voltage.*
Note 2: *Guarantied by design*

7 Magnetic Specifications

DC Operating Parameters $T_J = 25^oC$, $V_{DD} = 12V$ (unless otherwise specified)

Parameter.	Symbol	Test Conditions	Min	Typ	Max	Units
Operate point	B_{OP}			3	6	mT
Release point	B_{RP}		-6	-3		mT
Hysteresis	B_{HYST}		2	6		mT

Table 4: Magnetic specifications

8 Output Behaviour vs Magnetic Pole

Parameter	Test Conditions	OUT1	OUT2	FG
North pole	B < Brp	Low	High	Low
South pole	B > Bop	High	Low	High

Table 5: Driver output vs magnetic pole

***Note :** The magnetic pole is applied facing the branded side of the package*

9 Detailed General Description

The US651/661 is a one-chip solution for driving two-coil brushless DC fans. Based on CMOS process, the chip contains a Hall-effect sensor with dynamic offset correction, logic control and two low-ohmic open-drain output drivers.

The output drivers OUT1 and OUT2 are fully protected against switching transients. So there is no need of external zener diode to cut the high voltage spikes induced by the fan coils.

In case the junction temperature T_J exceeds T_{SD}, the thermal protection stops the current flowing through the full bridge by setting the outputs OUT1 and OUT2 low and setting the output FG (RD) high.
The IC stays in this state until the junction temperature decreases below T_{REL}.

Reverse voltage protection is integrated on the V_{DD} pin.
The FG/RD open drain output has an internal current limit which protects the driver in case of accidentally big current flow through the logic driver. It could occur if a low-ohmic pull-up resistor is used or if the FG/RD output is directly short connected to a supply voltage.

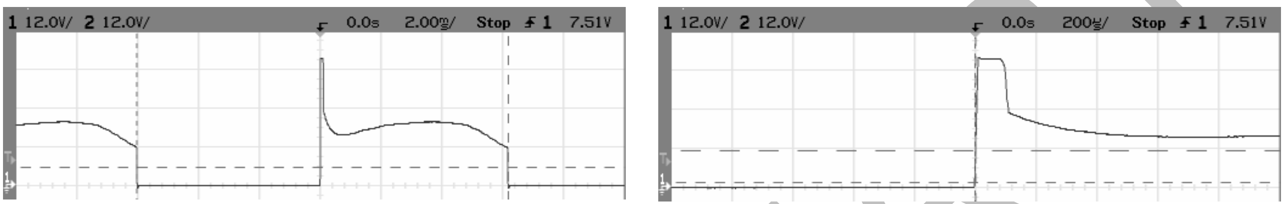
The US651 has an open-drain tachometer FG output that follows the Hall signal, thus enabling to determine the rotation speed of the fan.
In the US661, the open-drain alarm output RD is a safety signal which allows detecting if the fan rotates or not. It is active low during normal spinning of the motor. It goes high when the magnetic flux switching frequency drops below nearly:
- 2Hz for 12V application (60RPM for 2 pole-pair fan)
- 1Hz for 5V application (30RPM for 2 pole-pair fan)

10 Unique Features

10.1 Soft Switching & Slope setting

The US651/661 provides an efficient solution for low noise application with internal slope control circuit, controllable via a dedicated pin.

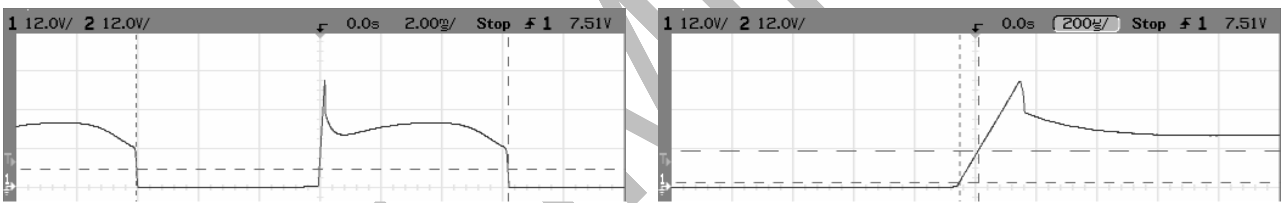
In Two-coil fan driver, the predominant source of electrical noise is when the output driver is switched off. Due to the electromotive force of the fan coil, the output voltage sharply increases but is internally clamped by the fan driver. This effect lasts until the energy in the coil is dissipated, then the output voltages decreases to a normal value, equal to the sum of the fan supply voltage plus the back EMF of the fan in rotation.
The resulting swift change in the coil current increases the overall acoustic noise.



(a) – General view *(b) – Enlarged view on output switching*

***Figure 1** – Output voltage without slope control (R_{SLOPE} = 0ohm)*

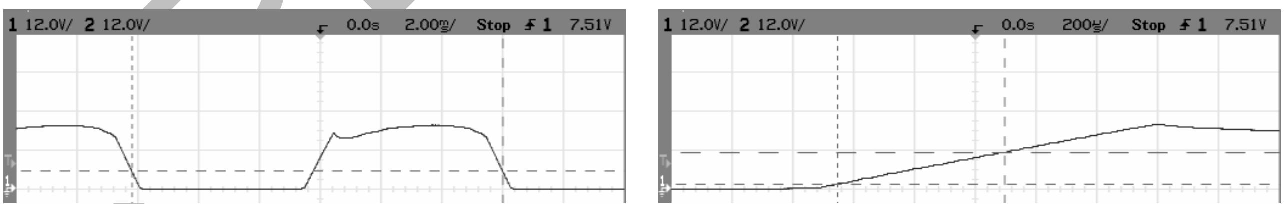
In the above Fig.1a is observed the US651/661 output voltage with traditional driving technique, also referred as "hard switching". In this case, the output driver is directly switched on and off which results in large voltage spikes, clamped at the output clamping voltage value (Fig.1b).



(a) – General view *(b) – Enlarged view on output switching*

***Figure 2** – Output voltage with internal slope control (R_{SLOPE} not connected, SLOPE pin left open)*

When the SLOPE pin is left open (not connected), the US651/661 provides internally defined output slope duration. In contrast with the "hard switching", the "soft switching" technique controls the output voltage at the switching event and a rise/fall time is implemented to the driving signal. On Fig.2b, the output clamping voltage is even not reached, result of a smoother recirculation of the fan coil current.



(a) – General view *(b) – Enlarged view on output switching*

***Figure 3** – Output voltage with long output slope duration (R_{SLOPE} = 500k)*

When a simple resistor is connected between the SLOPE pin the ground, the US651/661 modifies the output slope duration in relation with the value of the resistor R_{SLOPE}. The output slope duration can be increased so that the output voltages spikes from Fig.1 are totally removed on Fig.3.

For most of the application, the internal soft switching mode from the Fig.2 represents the simplest solution and most adequate balance between low fan acoustic noise and IC power dissipation.

It is also possible to run into the 3 different modes as “hard switching”, “internal soft switching” and “external soft switching”, giving the possibility to adapt the fan design to stringent requirements. For example, high speed fan generally requires longer output slope compared to usual middle or low speed fan.

Increasing the output slope duration inevitably leads to high power dissipation of the IC itself. However, the device is well protected against over power dissipation thanks to the integrated thermal shutdown.

10.2 Enhanced Locked Rotor Protection

Specially designed for driving large fans, the Locked Rotor Protection is optimised for low start-up voltage.

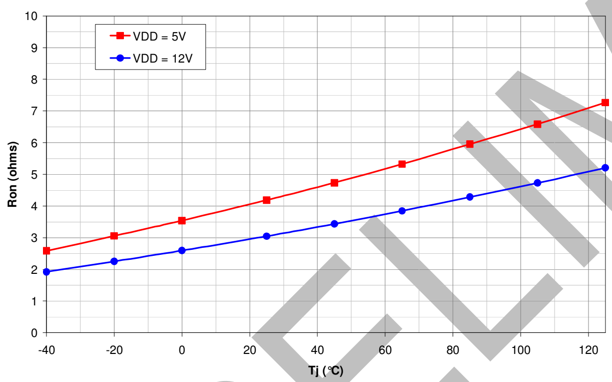
At low voltage, fans inevitably starts rotating slower than at higher voltage. Big fans with large inertia have slow start-up causing a longer first output pulse after power-on. If this pulse duration is longer than the LRP T_{ON} period, the fan may falsely enter locked rotor condition.

The US651/661 provides an adequate and simple solution to prevent this by automatically increasing the locked rotor protection period at low voltage. The device internally compares the supply voltage applied on the V_{DD} and automatically double the LRP periods at 5V (0.6s, 3.65s) compared than 12V (0.29s, 1.5s).

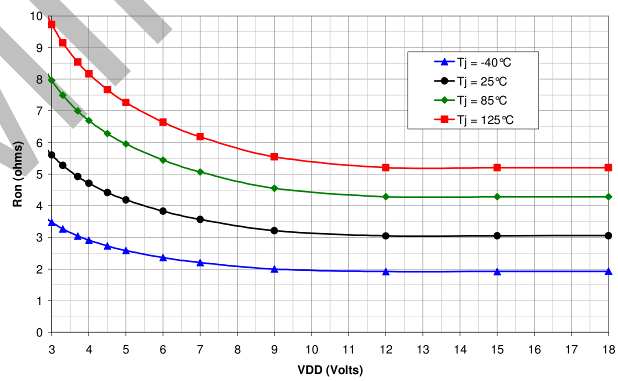
This facilitates driving heavier fans and motors with large inertia without any external component (T_{ON}/T_{OFF} is increased or decreased depending on the fan supply voltage V_{DD}).

11 Performance Graphs

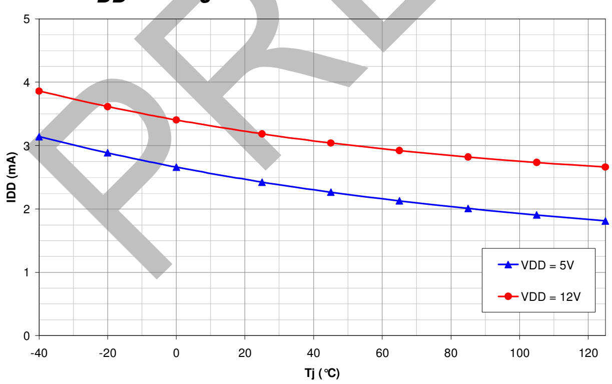
11.1 R_{DSON} vs T_J



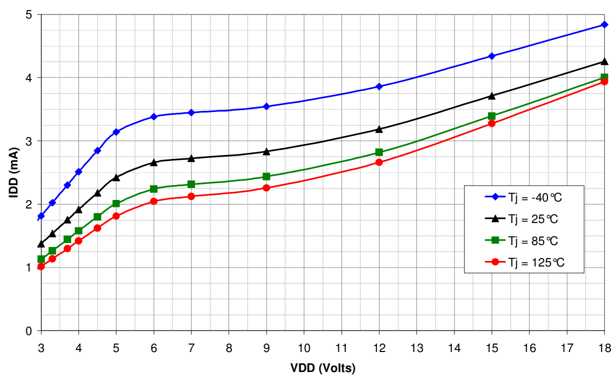
11.2 R_{DSON} vs V_{DD}



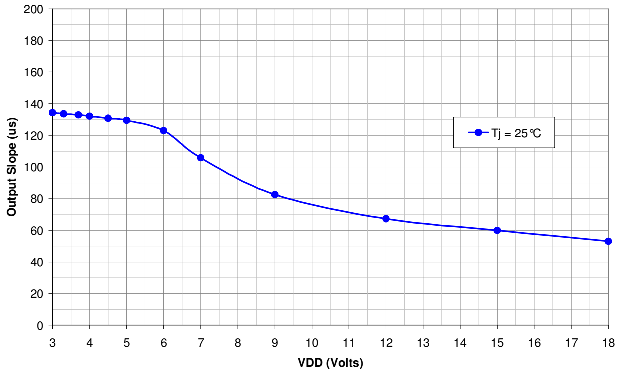
11.3 I_{DD} vs T_J



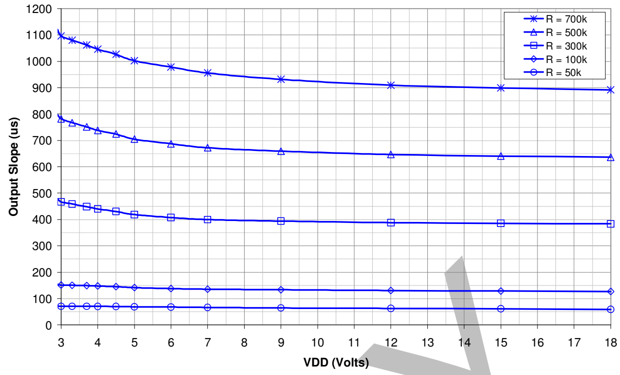
11.4 I_{DD} vs V_{DD}



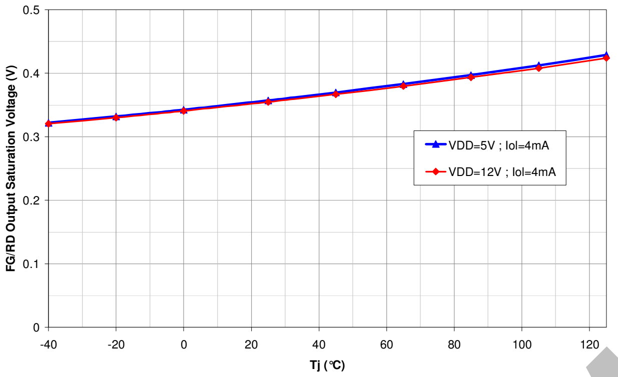
11.5 Internal Slope Duration vs V_{DD}



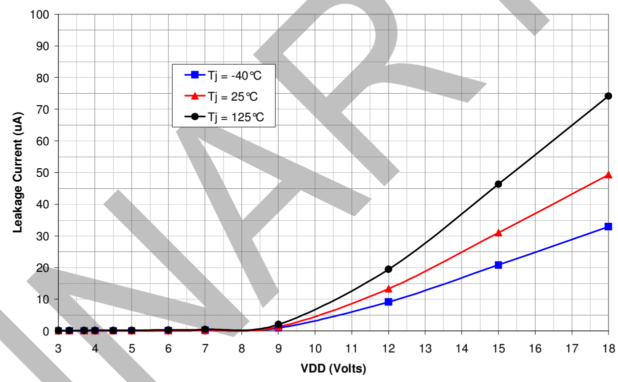
11.6 Slope Duration vs V_{DD}



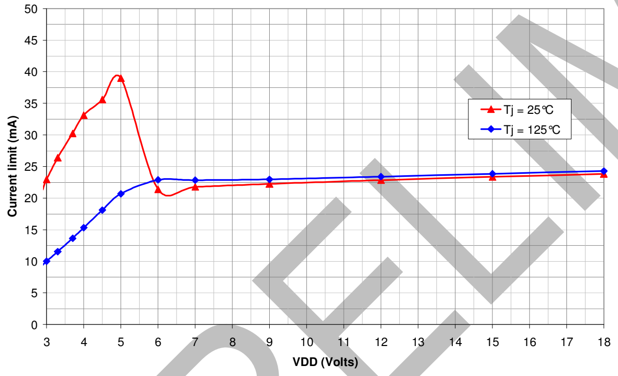
11.7 V_{OL} vs. T_J



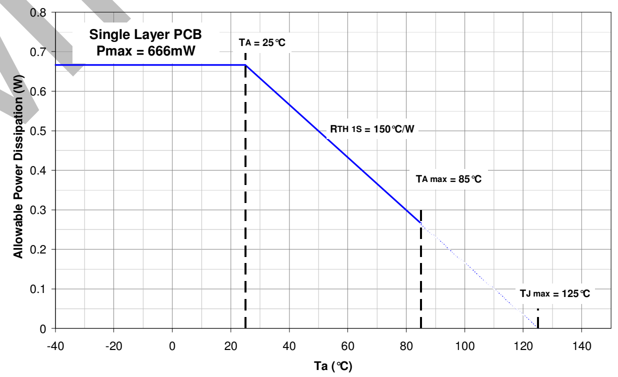
11.8 I_{LEAK} vs. T_J



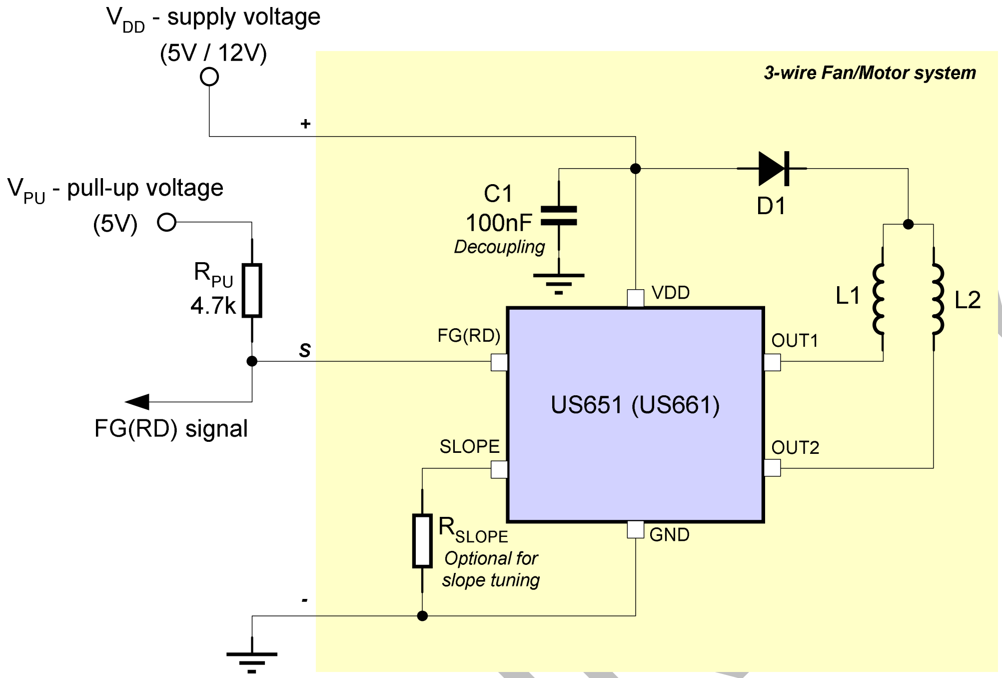
11.9 I_{FGLIM} vs. V_{DD}



11.10 P_{Dmax} vs. T_A



12 Application Information



Typical computer fan application circuit

13 Application Comments

During fan rotation, the coils may affect the stability of the V_{DD} voltage. To filter eventual spikes, it is recommended to add a 100nF decoupling capacitor between V_{DD} pin and GND, closer to the chip.

If the FG/RD pull-up resistor is connected to V_{DD}, a diode should be connected between the fan supply voltage and the common point of the fan coils to avoid parasitic effects on FG/RD output.
The voltage V_{DD} and V_{PU} can be physically the same voltage source. However, the pull-up voltage V_{PU} is generally connected to a different digital power source at 5V as it feeds the FG or RD signal to an IC interface.

When the default slope is sufficient, the pin SLOPE may just be left open.
For slope adjustment, it is required to connect a resistor R_{SLOPE} between the SLOPE pin to ground. The value of the resistor modifies the output slope as shown in the performance graph.

14 Standard information regarding manufacturability of Melexis products with different soldering processes

Our products are classified and qualified regarding soldering technology, solderability and moisture sensitivity level according to following test methods:

Reflow Soldering SMD's (Surface Mount Devices)

- IPC/JEDEC J-STD-020
  Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices
  (classification reflow profiles according to table 5-2)
- EIA/JEDEC JESD22-A113
  Preconditioning of Nonhermetic Surface Mount Devices Prior to Reliability Testing
  (reflow profiles according to table 2)

Wave Soldering SMD's (Surface Mount Devices) and THD's (Through Hole Devices)

- EN60749-20
  Resistance of plastic- encapsulated SMD's to combined effect of moisture and soldering heat
- EIA/JEDEC JESD22-B106 and EN60749-15
  Resistance to soldering temperature for through-hole mounted devices

Iron Soldering THD's (Through Hole Devices)

- EN60749-15
  Resistance to soldering temperature for through-hole mounted devices

Solderability SMD's (Surface Mount Devices) and THD's (Through Hole Devices)

- EIA/JEDEC JESD22-B102 and EN60749-21
  Solderability

For all soldering technologies deviating from above mentioned standard conditions (regarding peak temperature, temperature gradient, temperature profile etc) additional classification and qualification tests have to be agreed upon with Melexis.

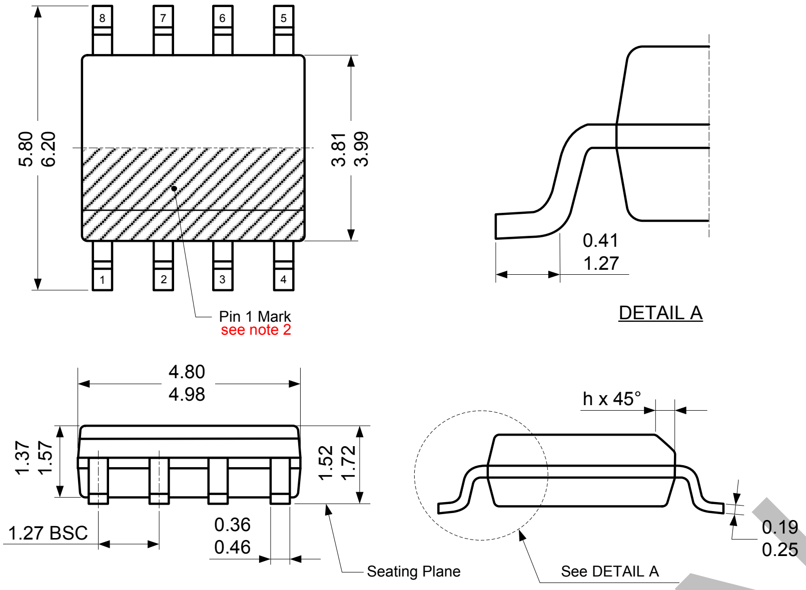
The application of Wave Soldering for SMD's is allowed only after consulting Melexis regarding assurance of adhesive strength between device and board.

Melexis is contributing to global environmental conservation by promoting **lead free** solutions. For more information on qualifications of **RoHS** compliant products (RoHS = European directive on the Restriction Of the use of certain Hazardous Substances) please visit the quality page on our website:
http://www.melexis.com/quality.aspx

15 ESD Precautions

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD).
Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

16 DC Package Information (8-pin narrow SOIC)



Notes:

1. Controlling dimensions in millimeters
2. Detail of pin #1 identifier are optional but must be located within the zone indicated.
3. Lead coplanarity should be to 0.10mm max.
4. All dimensions excluding mold flashes and end flash from the package body shall not exceed 0.25mm per side.

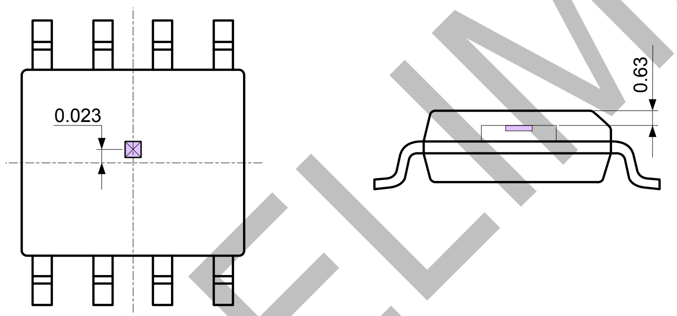
Marking:

Line 1 : US651 (US661) - Name of the Device

Line 2 : XXXXXX - Assembly lot number (6 digits)

Line 3 : YYWW - Assembly date
YY = year
WW = calendar week

Hall plate location



Notes:

1. All dimensions are in millimeters
2. Hall plate location in X and Y relative to package center
3. Assembly tolerances +/-0.1

17 Disclaimer

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