



### Fan speed controller based on STDS75 or STLM75 digital temperature sensor and ST72651AR6 MCU

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#### Introduction

This application note describes the method of defining the system for regulating the speed of the 5 Vdc fan using an ST72651AR6 microcontroller and digital temperature sensor STDS75 or STLM75.

The sensor measures the temperature data and communicates this data to the microcontroller. Based on this temperature data, the microcontroller issues a PWM signal with varying duty cycle to the fan for regulating its speed.

The key features of the system are:

- Microcontroller with I<sup>2</sup>C interface and PWM peripheral to communicate with the sensor and for regulating the fan speed
- Digital temperature sensor to measure the ambient temperature
- 5 Vdc fan to show the speed regulation

[Section 1](#) highlights the features of the STDS75 or STLM75 sensor and explains its interfacing with the microcontroller. [Section 2](#) explains BLDC fan management and PWM signal control to regulate the fan speed. [Section 3](#) focuses on the hardware setup and in [Section 4](#) the application flow of the system is defined.

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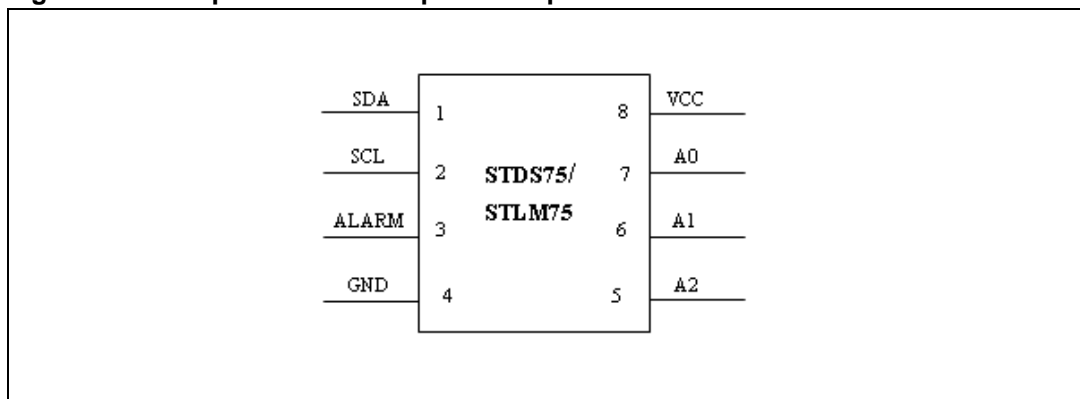
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# 1 Digital temperature sensor

The STDS75 and STLM75 are digital temperature sensors that measure the ambient temperature and give the digital output. Both the STDS75 and STLM75 are 8-pin ICs available in two packages, SO-8 and TSSOP-8. The measurable temperature range of the sensors is -55 °C to 125 °C.

The STLM75 and STDS75 differ only in terms of the resolution of the temperature data. The STLM75 has a fixed 9-bit resolution whereas the STDS75 has configurable resolution starting from 9 to 12 bits. In the present application, we move with the default resolution settings of the sensor that is 9 bits and thus both the STDS75 and STLM75 are dealt with in the same manner.

**Figure 1. Temperature sensor pin description**



**Table 1. Pin description**

Name	Description
SDA	Serial data input output pin
SCL	Serial clock input pin
Alarm	Alarm output pin
GND	DC ground
A0,A1,A2	Address lines
VCC	Supply voltage (2.7 V- 5.5 V)

## 1.1 Theory of operation

This temperature sensor is a high-precision CMOS IC with a delta-sigma analog-to-digital converter (ADC) and I<sup>2</sup>C compatible serial digital interface. The on board delta-sigma ADC converts the measured temperature to a digital value that is calibrated in degree Celsius. Negative temperature is shown in two's complement form. The sensor also has an alarm output signal.

## 1.2 Interfacing of sensor with the microcontroller

The sensor supports the I<sup>2</sup>C communication protocol. It has 3 configurable address lines, thus can support up to 8 different addresses. All 3 address lines are grounded in the present application and hence the address of sensor is made 0x90.

The sensor is connected to the microcontroller through 2 communication lines of I<sup>2</sup>C interface (SDA and SCL).

## 1.3 Configuring the sensor

The sensor has 3 internal registers which are used to configure its behavior:

1. Configuration register: Tconfig (8-bit)
2. Oversaturation register: T<sub>os</sub> (16-bit)
3. Hysteresis register: Thys (16-bit)

Based on the value configured in the configuration register the behavior of sensor is achieved. In our application these settings are made as 0x40. This setting configures the mode of operation of the sensor and the nature of the output alarm signal. For details, please refer to the STDS75 datasheet.

The value set in the oversaturation register defines the threshold value at which fan starts. In our application the fan starts as the temperature rises above 29 degrees Celsius. Thus the setting for this register is made as 0x1D00. Also as the temperature rises above this oversaturation value the alarm signal turns ON. This alarm is shown as an LED in the system.

A setting in the hysteresis register is used to control the output of the alarm output signal of sensor. It is set at 27 degrees Celsius in our application which means that as the temperature falls below 27 degrees Celsius the alarm goes OFF. Thus the settings for this register are made 0x1B00.

## 1.4 Alarm signal behavior

The alarm signal of the sensor is configured to go ON when the measured temperature exceeds 29 degrees Celsius and goes OFF when the temperature falls below 27 degrees Celsius.

## 2 BLDC fan

The basic DC brushless fan is a 2-wire device over which a DC voltage is applied. Brushless DC fans are called "brushless" because the electric motor is commutated electronically.

The basic brushless DC motor consists of two main parts:

- a) the rotor
  - b) the stator
- 
- a) Rotor: As the name implies, the rotor is the part that rotates. The rotor houses the permanent magnets, and in the case of the fan, the fan blades are also attached to the rotor. The number of poles in the permanent magnet varies according to the characteristics of the motor.
  - b) Stator: The stator is the stationary part of the motor. It consists of the motor coil number which varies according to the characteristics of the motor. The stator for the 2-phase motor consists of four coils.

### 2.1 Principle used for fan speed control using PWM

The speed of the DC fan can be modified by varying the DC voltage across the two terminals of the fan motor. However if we take a DC fan and switch on the DC supply across it, the fan motor takes some time to speed up. This is because the fan motor has an inductive coil so it does not respond immediately to the applied voltage. If we switch the power off before the motor reaches full speed, the motor starts to slow down. If we switch the power on and off quickly enough the fan motor and hence the fan run at some speed between the zero and full speed. This is what is achieved through the PWM signal. The fan speed can be modified with the variation in the duty cycle of the PWM signal.

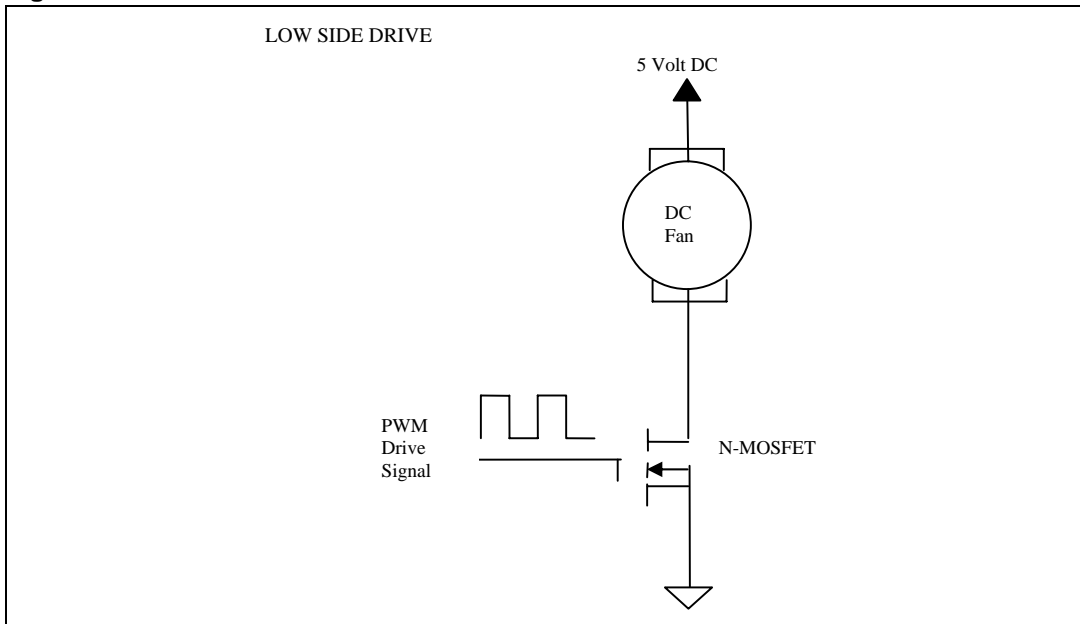
### 2.2 Method of fan speed control using a power MOSFET

To control the speed of the DC fan using the PWM signal, we need to use a switch which can be switched on and off at PWM frequency and hence control the supply voltage across the motor of the DC fan. This switch can be made by using a high switching speed power MOSFET. The action of switch is to connect and disconnect the power across the fan at PWM frequency.

#### 2.2.1 PWM control using transistor at low side drive

In low side drive connection, the fan positive terminal is kept at constant DC voltage (5 V for 5 V fan) while the negative terminal of the fan is connected to the drain of power MOSFET. The source of the power MOSFET is connected to ground. The PWM signal is applied to the gate terminal of the power MOSFET, thus the power MOSFET switches between on and off condition at the rate of the PWM signal. When the power MOSFET is ON, the current builds up in the coil of the fan motor and the fan starts to attain speed, whereas when the power MOSFET is off, the fan starts losing speed. [Figure 2](#) illustrates the low side drive transistor.

Figure 2. Low side drive circuit

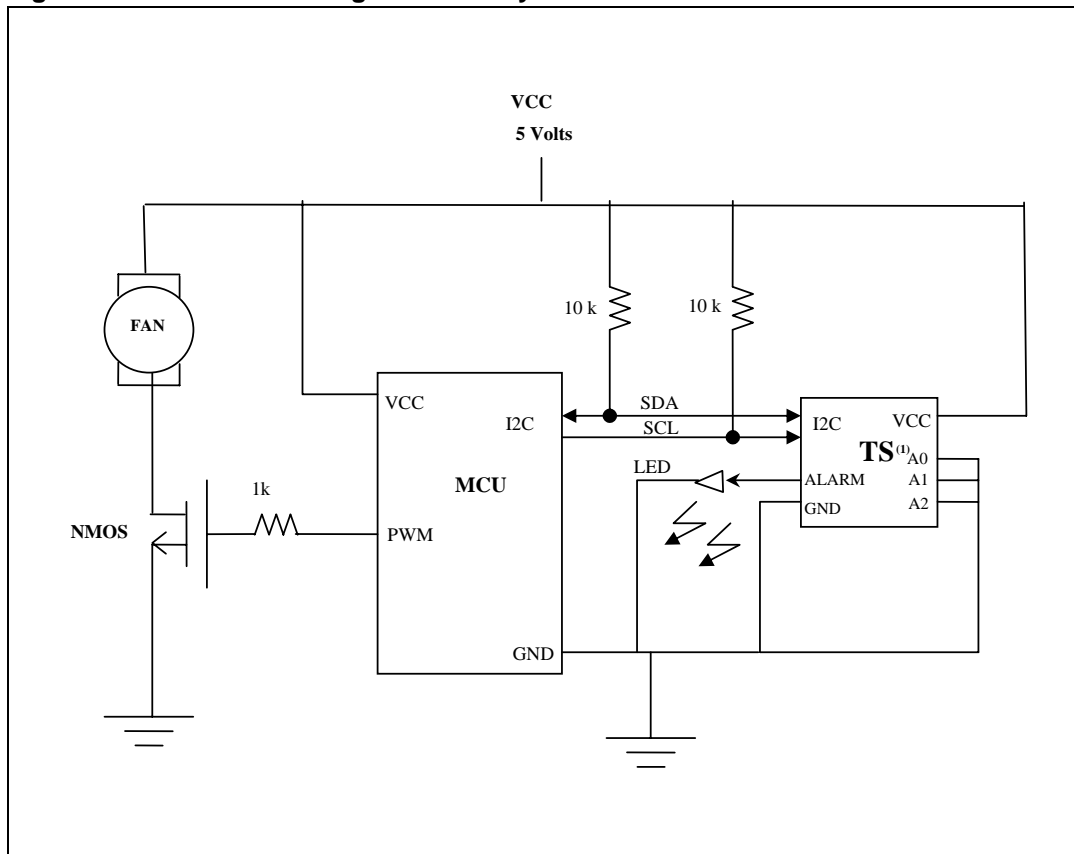


The speed of the DC fan can be regulated by the PWM drive signal that changes the supply across the DC fan. So, varying the duty cycle of this PWM signal modifies the fan speed. At 100% duty cycle the fan runs at full speed.

### 3 Hardware setup

This system consists of an ST72651AR6 microcontroller, STDS75 or STLM75 temperature sensor, 5 V BLDC fan, N-channel power MOSFET and an alarm LED. The power to the system is provided through USB power. *Figure 3* shows the setup for the system.

**Figure 3. Connection diagram of the system**



Note: 1 Temperature sensor STDS75/STLM75

#### 3.1 Description of the hardware setup

The complete system is shown in *Figure 3* with the temperature sensor and fan control logic.

Major components used in the system are:

- Microcontroller: ST72651AR6
- BLDC fan: 5 V
- Temperature sensor: STDS75
- N-Channel power MOSFET: STB100NF03L

For this application we can also choose any other microcontroller having a PWM peripheral and I<sup>2</sup>C interface.

### 3.1.1 Sensor - microcontroller connection

The sensor is connected to the microcontroller using two communication lines of I<sup>2</sup>C interface (SDA and SCL). The address lines of the sensor are grounded so that the address of the sensor is hardwired to 0x90 (refer to the STDS75 datasheet for details). An LED is connected to the alarm output of the sensor to show the alarm signal. Power to the sensor is provided through the 5 V USB power. A pull resistor of 10 k $\Omega$  is connected to the SDA and SCL line of the I<sup>2</sup>C interface.

### 3.1.2 Microcontroller - fan connection

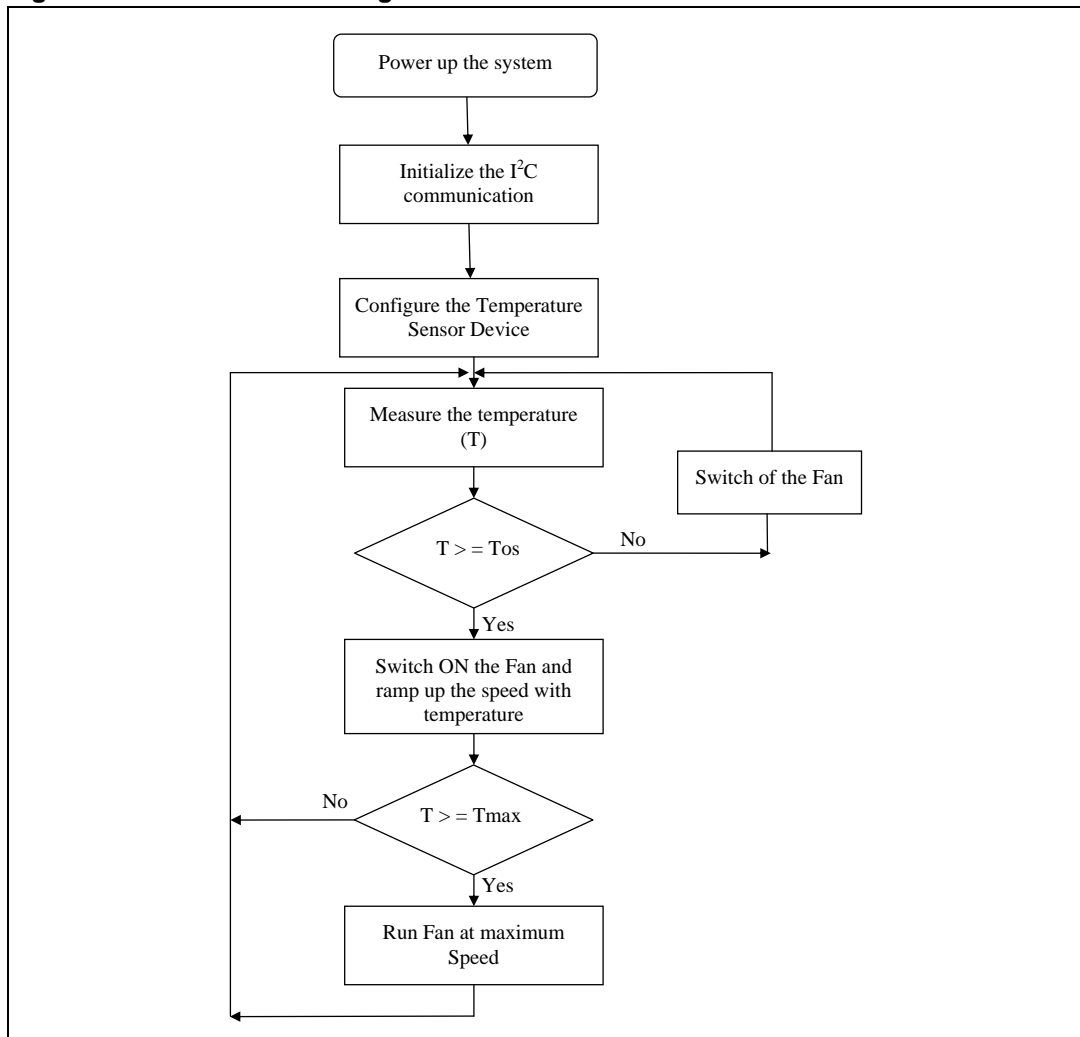
Fan control is achieved through the MOSFET switching action due to PWM signal coming to its gate terminal. An N-channel MOSFET is used in the low side driving of the fan. The positive terminal of the fan is connected to the 5 V power supply and the negative terminal of the fan is connected to the drain of the MOSFET. The source of the MOSFET is grounded while the gate is driven by the PWM output of the microcontroller. Current limiting resistors are connected to the gate terminals of the MOSFET.



## 4 Software flow

The software architecture of the system demonstrates the flow of control of the fan speed on the basis of digital temperature sensed. [Figure 4](#) shows the flow chart of the MCU firmware for the system.

**Figure 4. Software flow diagram for fan control**



### 4.1 Description of fan control logic

For fan control logic, the microcontroller monitors the temperature continuously and changes accordingly the duty cycle of the PWM output signal controlling the fan.

Firstly the system is initialized and temperature is measured. This measured temperature is compared with the threshold value ( $T_{os}$ ) set in the oversaturation register (29 degrees Celsius). If the measured temperature is greater than this value, then the fan is switched ON and the temperature is monitored again. The duty cycle of the PWM signal is changed from

0 to 100% as the measured temperature increases from  $T_{os}$  to  $T_{max}$ .  $T_{max}$  is the value of the temperature set through the firmware at which the fan runs at maximum speed.

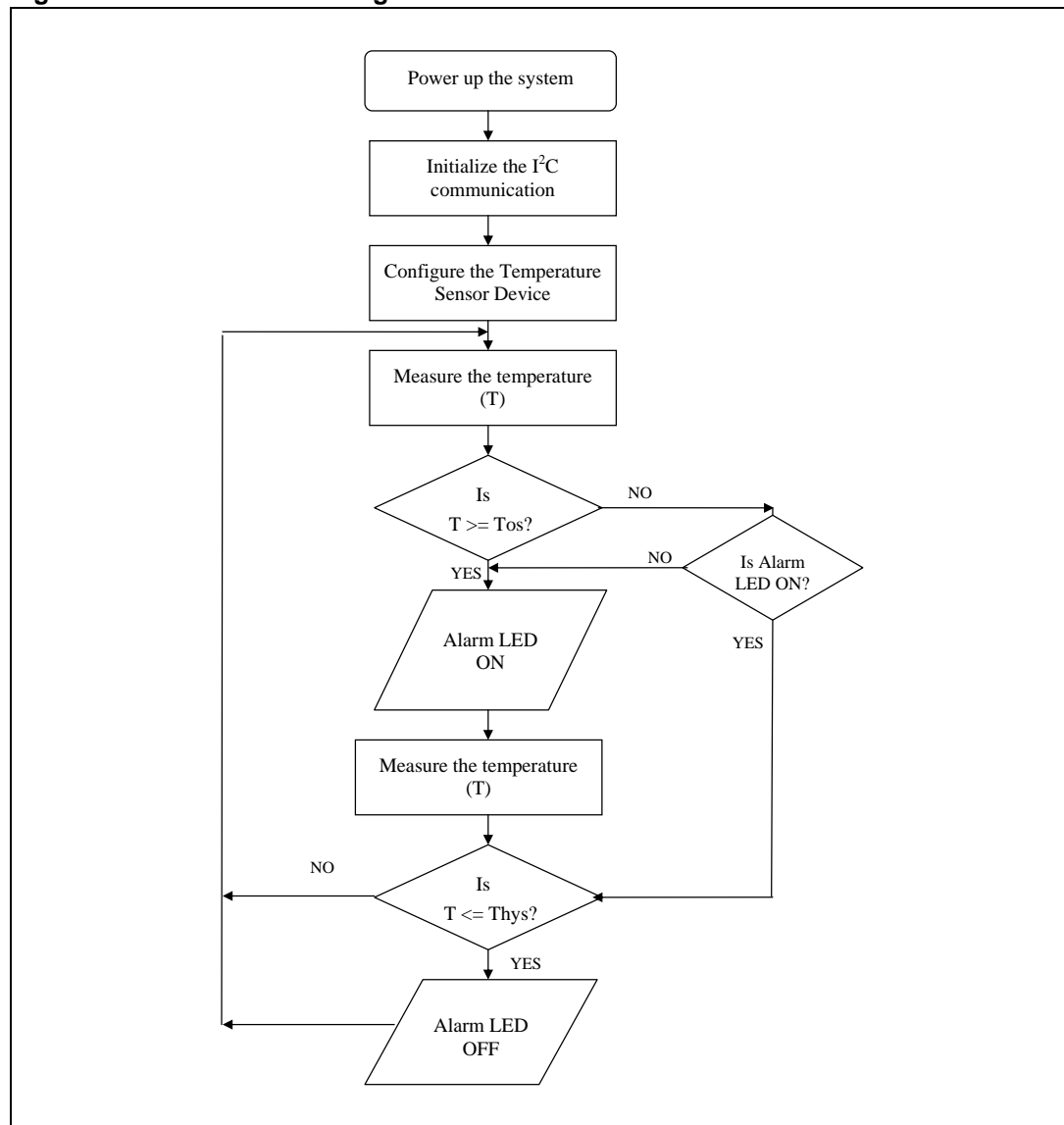
Thus to control the duty cycle of the PWM signal a linear relationship is established between the measured temperature and the duty cycle of PWM. As the measured temperature ramps up, the duty cycle is also moved towards 100%.

The linear relationship with temperature is controlled by the following conditions:

- Temperature < threshold value; duty cycle is made 0% and thus fan is OFF.
- Threshold value < Temperature <  $T_{max}$  value; duty cycle is ramped linearly towards 100%, thus fan runs at variable speed.
- Temperature >  $T_{max}$  value; duty cycle is made 100%, thus fan runs at maximum speed.

The duty cycle is handled by writing in the registers of the PWM peripheral of the microcontroller.

**Figure 5. Software flow diagram for alarm control**



## 4.2 Description of alarm control logic

$T_{OS}$  is the temperature setting put in the oversaturation register and  $Thys$  is the temperature setting put in the hysteresis register. In our application these values are:

- $T_{OS} = 0x1D00$  (29 degrees Celsius)
- $Thys = 0x1B00$  (27 degrees Celsius)
- $T_{max} = 40$  degrees Celsius

The temperature measurement is put in continuous loop. As the measured temperature rises above  $T_{OS}$  for the first time the alarm goes ON. It remains ON until the temperature falls below the  $Thys$  value for first time.

Thus alarm behavior for measured temperature (T):

- $T \geq T_{OS}$ ; alarm ON
- $Thys < T < T_{OS}$ ; alarm ON
- $T \leq Thys$ ; alarm OFF

## 5 Firmware

All the source files are in 'C' language and the application uses ST7 firmware library functions.

The source files are only for guidance. STMicroelectronics shall not be liable for any direct, indirect or consequential damages with respect to any claim arising from use of this software.

## 6 References

1. ST72651AR6 microcontroller datasheet
2. STDS75 temperature sensor datasheet
3. STLM75 temperature sensor datasheet
4. STB100NF03L power MOSFET datasheet
5. ST7 software manual user library

## 7 Revision history

**Table 2. Document revision history**

Date	Revision	Changes
06-Feb-2008	1	Initial release

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