BeMicro Max 10 Sensors

ADT7420 Temperature Sensor

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1.1 Theory

1.1.1 Introduction

Temperature sensors are very popular today and are widely used within medical equipment, food transportation and storage, environmental monitoring and laser diode temperature control. The ADT7420 is a low power consumption temperature sensor used on the BeMicro Max 10 board. The benefits of the ADT7420 are that there is no need for calibration by the user, it is durable and outputs high accuracy data that can be used within industrial, instrumentation or medical applications. This document will therefore describe how the ADT7420 temperature sensor works.

The ADT7420 is a high accuracy digital temperature sensor which uses a 16-bit ADC. Even though the ADC has a 16-bit resolution, by default, the resolution is set to 13 bits. The sensor works like following; the sensor generates voltage proportional to absolute temperature which is compared to an internal reference voltage. The output of the sensor is converted into digital signal by a sigma-delta modulator described in next section.

1.1.2 Temperature converter

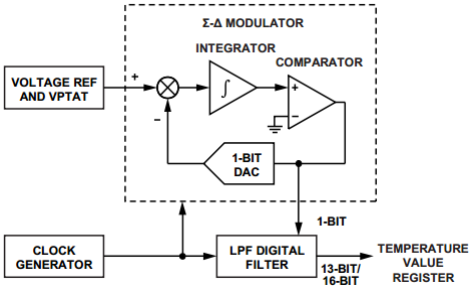

Figure 1: The Σ-Δ modulator consists of an input sampler, a summing network, an integrator, a comparator, and a 1-bit DAC.

In figure 1 the internal circuitry of the sigma-delta (**Σ-Δ**) modulator is shown. It has a negative feedback loop which minimizes the converter output according to input voltage changes. The converter can be configured to run in four different modes: *normal, one-shot, 1 SPS* and *shutdown.*

Normal mode: This is the default power-up mode for the ADT7420. Temperature is converted automatically continuously and takes normally 240 ms to complete for each conversion. The results of each conversion are stored in the temperature value registers. The first conversion after power-up is done in 6 ms and there is no need for an external clock because of a clock generated internally.

The measurement data is compared to the *Critical Temperature Lmit, High Temperature Limit* and *Low Temperature Limit (*T_{CRIT}, T_{HIGH}, T_{LOW}). If temperature exceeds 147 °C (T_{CRIT}), CT pin is set to logic low and if temperature exceeds 64°C (T_{HIGH}) the INT pin is set to logic low.

One-Shot mode: If bit 6 to 0 and bit 5 to 1 of the configuration register at address 0x03 is set, it enables the one-shot mode. In this mode a conversion is completes quickly and then the device goes into shutdown mode. For proper function of the converter, it must have at least 240 ms of time after power up. The One-Shot mode is very useful to reduce power consumption.

1 SPS mode: If bit 1 to 6 and bit 0 to 5 of the configuration register is set, 1 SPS mode is enables. In this mode 1 measurement is performed each second. If one conversion is done after 240 ms, the device goes into an idle state for the rest of the time until 1 second is passed. After that another conversion is done.

Shutdown mode: In this mode the device is shutdown and no conversion or measurement is outputted. When the device is taken out of shutdown mode is takes normally 1 ms and the conversion from last conversion before shutdown can be outputted.

1.1.3 Temperature Data Format

The ADT7420 has a measurement range from +150°C to -40°C and by default it takes measurements in 13-bit mode where one *Least Significant Bit* of the *Analog To Digital Converter* (ADC) corresponds to 0.0625°C. However in 16-bit mode this corresponds to 0.0078°C. Measurements are stored in the 16-bit temperature value and reading back a value form the register requires a 2-byte read.

1.1.4 Registers

The ADT7420 has 14 registers as follows: 9 temperature register, 1 status register, 1 ID register, 1 configuration register, 1 address pointer register and 1 software reset.

Table 1: ADT7420 register description

Register name	Amount	Address	Width	Access
Temperature value register	9	0x00 – 0x01 0x04 – 0x0A	8-bits	Read-only
Status register	1	0x02	8-bits	Read-only
ID register	1	0xB	8 bits	Read-only
Configuration register	1	0x03	8-bits	Read/Write
Address pointer register	1	0x00 (Initial)	8-bits	Read/Write
Software reset register	1	0x2F	8-bits	Write-only

The registers of the ADT7420 are shown in table 1 above. The registers have different functions as follows:

- *Temperature value register:* There are in total 9 of these register and each register consists of 2 bytes, one byte MSB and one byte LSB.
- *Status register:* The status register reflects status of conversion operations and status of over- and under temperature interrupts. The interrupts are reset after temperature value returns within temperature limits.
- *ID register:* This register contains the manufacturer ID.
- *Configuration register:* The configuration register stores configuration modes of the device like operation mode.
- *Address pointer register:* When the ADT7420 is written to, this is the first register to be written. Data written to this register should be the address of the register to which the write or read is intended.

1.1.5 Communication

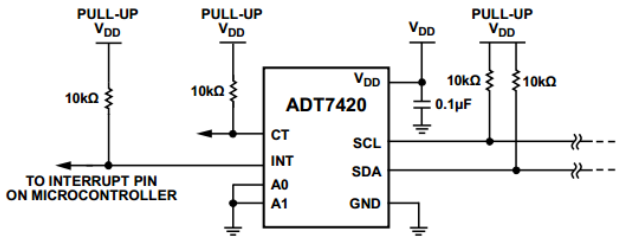

Figure 2: I2C Serial Interface

Communication with the ADT7420 is through the I2C-compatible serial interface. The device is interconnected to the master as a slave and read/write operations are thus controlled by the master. It has a 7-bit serial address where five of these bits are hardwired internally and the last two bits enables the ADT7420 to have 4 different address options, see table 2.

Table 2: I2C Bus Address Options

Address bit 6	Address bit 5	Address bit 4	Address bit 3	Address bit 2	Address bit 1	Address bit 0	Hex
1	0	0	1	0	0	0	0x48
1	0	0	1	0	0	1	0x49
1	0	0	1	0	1	0	0x4A
1	0	0	1	0	1	1	0x4B

To start taking measurements from the ADT7420 the master first establishes a start condition by setting the *Serial Data Address Line (SDA)* to logic low and keeping the *Serial Clock Line* (SCL) logic high. All slaves that are connected shifts in 8 bit of data where 7-bits are the address and the last bit is the read/write (R/W) bit. This bit determines if data is to be written to or read from the slave device. Data transfer requires nine clock pulses, eight bits of data and one acknowledge bit from the receiver of data.

The slave device with the address corresponding to the transmitted address responds by setting the data line to logic low during the low clock period before the 9th clock pulse also known as the acknowledge bit. The selected device waits for data to be read from or written to it, if the R/W bit is a 0, the master writes to the slave device and if the R/W bit is a 1, the master reads from the slave device.

When all data bytes have been read or written, the serial data transfer has to stop. In write mode, the master pulls the data line high during the 10th clock pulse and in read mode, during the low period before the ninth clock pulse, to assert stop condition. It is not possible to mix read and write in one operation because the type of operation is determined at the beginning and cannot be changed without starting a new operation.

1.2 Reference

1. Analog Devices, ADT7420 datasheet, URL: http://www.analog.com/media/en/technical-documentation/data-sheets/ADT7420.pdf?ref=ASC-PR-478 (Downloaded: 2016-10-01).