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1°C Triple Temperature Sensor with Beta Compensation and Hotter of Two Zones

PRODUCT FEATURES

Datasheet

General Description

The EMC1043 is a family of System Management Bus (SMBus) temperature sensors that monitors three temperature zones, one internal diode and two externally connected diodes, for PC and embedded environments. The EMC1043 includes beta compensation circuitry to correct for variation in the beta of measurement transistors. Other extended features include resistance error correction and ideality factor configuration to eliminate major sources of temperature measurement error.¹

An added feature to the EMC1043 is a function that automatically compares the two external temperature zones and reports the hotter of the two temperatures. Selectable conversion rates and standby mode support low-power operation. The temperature measurement ranges support two data ranges (and formats), -64°C to +127°C and -64°C to +191°C.

Applications

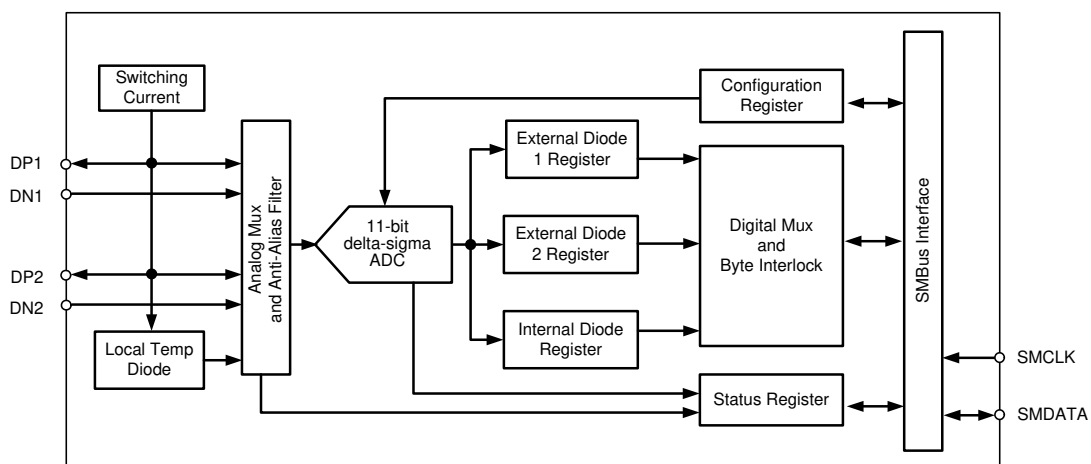
- Desktop and Notebook Computers
- Hardware Management
- Servers
- Embedded Applications

Features

- Supports two External Temperature Diodes
 - ±1°C Accuracy (40°C to 80°C)
 - 0.125°C Resolution
 - Ideality Factor Configuration
 - Accepts 2200pF Cap Across External Diodes for Noise Suppression
 - Optional Resistive Error Correction on External Diode 2
 - Resistance Error Correction (up to 100 Ohms)
 - Beta Compensation
- Internal Temperature Diode
 - ±3°C Accuracy (0°C to 85°C)
 - 0.125°C Resolution
- Low Power Operation
 - 4uA Standby Current
- 3.0V to 3.6V Supply
- Programmable Conversion Rate
- SMBus 2.0 Compliant
 - Four SMBus Address Available
- Reports Hotter of Two Diodes with Dual-core CPU

1. Patents pending

Simplified Block Diagram



ORDERING INFORMATION

| ORDERING NUMBER | PACKAGE | FEATURES | SMBUS ADDRESS |
|-------------------|-------------------------------------------------|-------------------------------------------------------------------------------------------------|---------------|
| EMC1043-1-ACZL-TR | 8 pinMSOP package (Lead Free ROHS compliant) | Two external diodes with REC and Beta Compensation and Hottest Of Comparison | 1001_100x |
| EMC1043-2-ACZL-TR | | | 1001_101x |
| EMC1043-3-ACZL-TR | | | 1001_000x |
| EMC1043-4-ACZL-TR | | | 1001_001x |
| EMC1043-5-ACZL-TR | | Two external diodes with REC. Beta Compensation on External Diode 1 only. Hottest of Comparison | 1001_100x |

Reel size is 4,000 pieces.

Evaluation Boards available upon request. (EVB-EMC1043, EVB-EMC1043C)

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Chapter 1 Pin Function

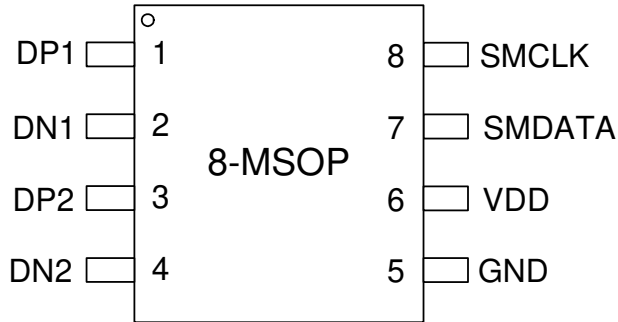


Figure 1.1 EMC1043 Pin Diagram

Table 1.1 EMC1043 Pin Description

| PIN | PIN NO. | DESCRIPTION |
|--------|---------|---------------------------------------------------------------------|
| DP1 | 1 | External Diode 1 Positive (anode) Connection |
| DN1 | 2 | External Diode 1 Negative (cathode) Connection |
| DP2 | 3 | External Diode 2 Positive (anode) Connection |
| DN2 | 4 | External Diode 2 Negative (cathode) Connection |
| GND | 5 | Ground |
| VDD | 6 | Supply Voltage |
| SMDATA | 7 | System Management Bus Data - bi-directional data, open drain output |
| SMCLK | 8 | System Management Bus Clock Input |

Chapter 2 Electrical Specifications

2.1 Absolute Maximum Ratings

Table 2.1 Absolute Maximum Ratings

| DESCRIPTION | RATING | UNIT |
|---------------------------------------------|--------------------------------|------|
| Supply Voltage V_{DD} | -0.3 to 5.0 | V |
| Voltage on SMDATA and SMCLK pins | -0.3 to 5.5 | V |
| Voltage on any other pin | -0.3 to $V_{DD}+0.3$ | V |
| Operating Temperature Range | -40 to 125 | °C |
| Storage Temperature Range | -55 to 150 | °C |
| Lead Temperature Range | Refer to JEDEC Spec. J-STD-020 | |
| Package Thermal Characteristics for MSOP-8 | | |
| Thermal Resistance T_{JA} (at 0 air flow) | 135.9 | °C/W |
| ESD Rating, All Pins Human Body Model | 2000 | V |

Note: Stresses above those listed could cause damage to the device. This is a stress rating only and functional operation of the device at any other condition above those indicated in the operation sections of this specification is not implied. When powering this device from laboratory or system power supplies, it is important that the Absolute Maximum Ratings not be exceeded or device failure can result. Some power supplies exhibit voltage spikes on their outputs when the AC power is switched on or off. In addition, voltage transients on the AC power line may appear on the DC output. If this possibility exists, it is suggested that a clamp circuit be used.

2.2 Electrical Specifications

Table 2.2 Electrical Characteristics

| $V_{DD}=3.0V$ to $3.6V$, $T_A = -20^{\circ}C$ to $+85^{\circ}C$, Typical values at $T_A = 27^{\circ}C$ unless otherwise noted | | | | | | |
|---------------------------------------------------------------------------------------------------------------------------------|------------|-----|---------|-----------|---------|----------------------------------------------------|
| PARAMETER | SYMBOL | MIN | TYP | MAX | UNITS | CONDITIONS |
| DC Power | | | | | | |
| Supply Voltage | V_{DD} | 3.0 | 3.3 | 3.6 | V | |
| Average Operating Current | I_{DD} | | 340 | 400 | μA | 4 conversions/s See Table 4.4 . |
| | I_{STBY} | | 2 | 4 | μA | Standby mode |
| Internal Temperature Monitor | | | | | | |
| Temperature Accuracy | | | ± 1 | ± 3 | °C | $-20^{\circ}C \leq T_A \leq 85^{\circ}C$ |
| | | | | ± 1.5 | °C | $0^{\circ}C < T_A \leq 85^{\circ}C$ |
| Temperature Resolution | | | 0.125 | | °C | |

Table 2.2 Electrical Characteristics (continued)

| V _{DD} =3.0V to 3.6V, T _A = -20°C to +85°C, Typical values at T _A = 27°C unless otherwise noted | | | | | | |
|--------------------------------------------------------------------------------------------------------------------------------|----------------------------------|------|-------|---------------------------------|----------------|------------------------------------------------------------------------------------------------|
| PARAMETER | SYMBOL | MIN | TYP | MAX | UNITS | CONDITIONS |
| External Temperature Monitor | | | | | | |
| Temperature Accuracy Remote Diode 40°C to 80°C Remote Diode -20°C to 125°C Remote Diode -64°C to 192°C | | | | ± 1 ± 3 ± 5 | °C °C °C | 15°C ≤ T _A ≤ 70°C -20°C ≤ T _A ≤ 85°C -20°C ≤ T _A ≤ 85°C |
| Temperature Resolution | | | 0.125 | | °C | |
| Filter Capacitor | C _{FILTER} | | | 2.2 | nF | Connected across external diode Note 2.2 |
| Voltage Tolerance | | | | | | |
| Voltage at pin (SMDATA,SMCLK) | V _{TOL} | -0.3 | | 5.5 | V | |
| SMBus Interface (SMDATA,SMCLK) | | | | | | |
| Input High Level | V _{IH} | 2.0 | | | V | |
| Input Low Level | V _{IL} | | | 0.8 | V | |
| Input High/Low Current | I _{IH} /I _{IL} | -1 | | 1 | μA | |
| Hysteresis | | | 500 | | mV | |
| Input Capacitance | | | 5 | | pF | |
| Output Low Sink Current | | 6 | | | mA | SMDATA = 0.6V |
| SMBus Timing | | | | | | |
| Clock Frequency | F _{SMB} | 10 | | 400 | kHz | |
| Spike Suppression | | | | 50 | ns | |
| Bus free time Start to Stop | T _{BUF} | 1.3 | | | μs | |
| Hold time Start | T _{HD:STA} | 0.6 | | | μs | |
| Setup time Start | T _{SU:STA} | 0.6 | | | μs | |
| Setup time Stop | T _{SU:STO} | 0.6 | | | μs | |
| Data Hold Time | T _{HD:DAT} | 0.3 | | | μs | |
| Data Setup Time | T _{SU:DAT} | 100 | | | ns | |
| Clock Low Period | T _{LOW} | 1.3 | | | μs | |
| Clock High Period | T _{HIGH} | 0.6 | | | μs | |
| Clock/Data Fall Time | T _F | * | | 300 | ns | *Min = 20+0.1C _b ns |
| Clock/Data Rise Time | T _R | * | | 300 Note 2.1 | ns | *Min = 20+0.1C _b ns |
| Capacitive Load (each bus line) | C _b | 0.6 | | 400 | pF | |

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- Note 2.1** 300nS rise time max is required for 400kHz bus operation. For lower clock frequencies, the maximum rise time is $(0.1/F_{SMB})+50nS$
- Note 2.2** See SMSC Applications for Application Notes and Guidelines when measuring GPU processor diodes and CPU processor diodes.

2.3 System Management Bus Interface Protocol

A host controller, such as an SMSC I/O controller, communicates with the EMC1043 via the two wire serial interface named SMBus. The SMBus interface is used to read and write registers in the EMC1043, which is a slave-only device. A detailed timing diagram is shown in [Figure 2.1](#).

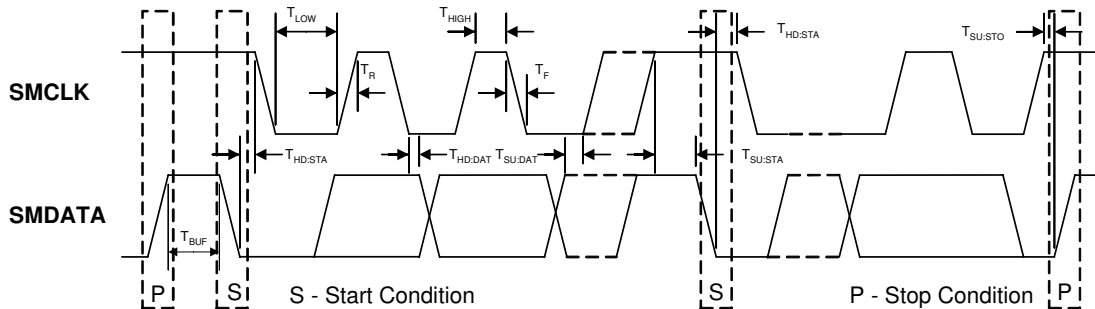


Figure 2.1 System Management Bus Timing Diagram

The EMC1043 implements a subset of the SMBus specification and supports Write Byte, Read Byte, Send Byte, and Receive Byte protocols as shown. In the tables that describe the protocol, the “gray” columns indicate that the slave is driving the bus.

All of the below protocols use the following convention:

| DATA SENT TO DEVICE | DATA SENT TO THE HOST |
|---------------------|-----------------------|
| # of bits sent | # of bits sent |

2.3.1 Write Byte

The Write Byte is used to write one byte of data to the registers as shown in [Table 2.3](#).

Table 2.3 Write Byte Protocol

| START | SLAVE ADDRESS | WR | ACK | COMMAND | ACK | DATA | ACK | STOP |
|-------|---------------|----|-----|---------|-----|------|-----|------|
| 1 | 7 | 1 | 1 | 8 | 1 | 8 | 1 | 1 |

2.3.2 Read Byte

The Read Byte protocol is used to read one byte of data from the registers as shown in [Table 2.4](#).

Table 2.4 Read Byte Protocol

| START | SLAVE ADDRESS | WR | ACK | COMMAND | ACK | START | SLAVE ADDRESS | RD | ACK | DATA | NACK | STOP |
|-------|---------------|----|-----|---------|-----|-------|---------------|----|-----|------|------|------|
| | | | | | | | | | | | | |

Table 2.4 Read Byte Protocol

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 1 | 1 | 8 | 1 | 1 | 7 | 1 | 1 | 8 | 1 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

2.3.3 Send Byte

The Send Byte protocol is used to set the Internal Address Register to the correct Address as shown in [Table 2.5](#). The Send Byte can be followed by the Receive Byte protocol described in [Table 2.6](#) to read data from the register. The send byte protocol cannot be used to write data - if data is to be written to a register then the write byte protocol must be used as described in [Section 2.3.1](#).

Table 2.5 Send Byte Protocol

| START | SLAVE ADDR | WR | ACK | REG. ADDR | ACK | STOP |
|-------|------------|----|-----|-----------|-----|------|
| 1 | 7 | 1 | 1 | 8 | 1 | 1 |

2.3.4 Receive Byte

The Receive Byte protocol is used to read data from a register when the internal register address pointer is known to be at the right location (e.g. set via Send Byte). This can be used for consecutive reads of the same register as shown in [Table 2.6](#).

Table 2.6 Receive Byte Protocol

| START | SLAVE ADDR | RD | ACK | REG. DATA | NACK | STOP |
|-------|------------|----|-----|-----------|------|------|
| 1 | 7 | 1 | 1 | 8 | 1 | 1 |

2.3.5 SMBus Timing Diagram

The Timing for the SMBus is shown in [Figure 2.1](#).

2.4 SMBus Addresses

The EMC1043 may be ordered with one of four slave addresses as shown in [Ordering Information](#). Attempting to communicate with the EMC1043 SMBus interface with an invalid slave address or invalid protocol results in no response from the device and does not affect its register contents. The EMC1043 supports stretching of the SMCLK signal by other devices on the SMBus but will not perform this operation itself.

2.5 SMBus Timeout

The EMC1043 includes an SMBus time-out feature. Following a 25 ms period of inactivity on the SMBus, the device will time-out and reset the SMBus interface.

Chapter 3 Product Description

The EMC1043 is an SMBus sensor that monitors three temperature zones for use in a personal computer or embedded environment. The part may be used as a companion to one of SMSC's broad line of SIO host devices to perform fan control and thermal management.

The EMC1043-1, EMC1043-2, EMC1043-3 and EMC1043-4 are designed specifically to work with a CPU that implements the thermal diode as a PNP substrate transistor with the collector connected to GND. A new feature called beta compensation automatically compensates for measurement error caused by beta variation in CPU thermal diodes as described in [Section 3.7](#).

Because the beta compensation circuit is designed to work with PNP substrate transistors, the EMC1043-1, EMC1043-2, EMC1043-3 and EMC1043-4 are not typically used with diode-connected transistors (such as the 2N3904) or CPUs that implement the thermal diode as a two-terminal diode (such as the AMD processor). However, the beta compensation feature may be disabled by configuring the appropriate register as described in [Section 4.8](#). For applications that measure a two-terminal thermal diode, refer to the EMC1063.

A typical system is shown in [Figure 3.1](#)

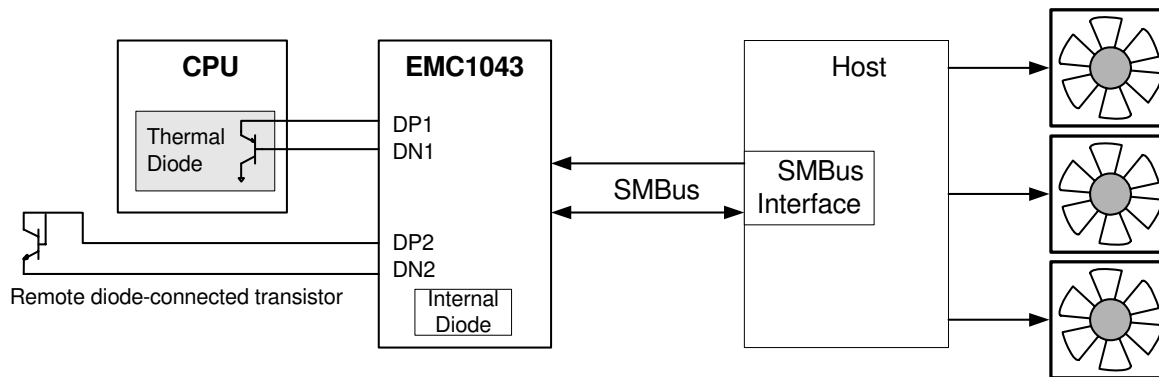


Figure 3.1 EMC1043 System Drawing

3.1 Power Modes

The EMC1043 has two power modes.

- Run Mode - In this mode, the temperature monitors are active and converting at the programmed conversion rate. The average power dissipation will depend on the conversion rate. When the EMC1043 is not actively converting a channel, it goes into a lower power wait state.
- Standby Mode (power-up default) - in this mode, the EMC1043 is put into a low power state. In the standby mode, temperature monitoring is disabled. The device will still respond to SMBus commands.

3.2 One Shot During Standby Mode

The EMC1043 supports a One-Shot command when it is in Standby Mode. Writing to the One-Shot register will cause the device to power up, perform 1 full set of temperature conversions, then return to Standby Mode.

3.3 Operation During Run Mode

When the device is active, there are two modes of operation available.

- Normal Mode (power-up default) - In this mode of operation, the EMC1043 continuously samples and updates all of its temperature channels.
- Hotter of Two Mode - In this mode, the EMC1043 continuously samples and then compares the two remote zones. The hotter of the two remote zones is loaded into the External Diode 2 Data Registers. In addition, the HOTTER bit in the Status register is set or cleared to indicate which external diode zone is hotter. If the two remote zones are exactly equal to each other, then the HOTTER bit is cleared (set to '0'), and the results of the two remote zones are stored in their respective registers.

3.3.1 Conversion Rates

The EMC1043 may be configured for different conversion rates based on the system requirements. The available rates are 1 full set of conversions per second to 16 full sets of conversions per second. The conversion rate is configured as described in [Section 4.4](#). The available conversion rates are shown in [Table 4.4](#).

3.3.2 Dynamic Averaging

The EMC1043 temperature channels support a new feature that measures the external diode channels for an extended time based on the selected conversion rate. This functionality can be disabled as described in [Section 4.5](#) for increased power savings at the lower conversion rates. When Dynamic Averaging is enabled, the device will automatically adjust the sampling and measurement time for both external diode channels. This allows the device to average 2x or 4x longer than the normal 11 bit operation while still maintaining the selected conversion rate. The benefits of Dynamic Averaging are improved noise rejection due to the longer integration time as well as less random variation on the temperature measurement.

The Dynamic Averaging applies when a One-Shot command is issued. The device will perform the desired averaging during the one-shot operation according to the selected conversion rate.

The Dynamic Averaging will affect the average supply current based on the chosen conversion rate as shown in [Table 3.1](#).

Table 3.1 Supply Current vs. Conversion Rate and ADC Averaging Factor

| CONVERSION RATE | ADC AVERAGING FACTOR | | |
|-----------------|-----------------------------------|-----------------------------------|------------------|
| | 4X (MAX_RES = 1) (DA_N = 0) | 2X (MAX_RES = 0) (DA_N = 0) | 1X (DA_N = 1) |
| 1 / sec | 190uA | 132uA | 105uA |
| 2 / sec | 315uA | 205uA | 150uA |
| 4 / sec | 580uA | 350uA | 235uA |
| 8 / sec | N/A | 640uA | 405uA |
| 16 / sec | N/A | N/A | 750uA |

3.4 Temperature Monitors

In general, thermal diode temperature measurements are based on the change in forward bias voltage of a diode when operated at two different currents. This ΔV_{BE} is then proportional to absolute temperature as shown in the following equation:

$$\Delta V_{BE} = V_{BE_HIGH} - V_{BE_LOW} = \frac{\eta k T}{q} \ln \left(\frac{I_{HIGH}}{I_{LOW}} \right)$$

where:

k = Boltzmann's constant

T = absolute temperature in Kelvin [1]

q = electron charge

η = diode ideality factor

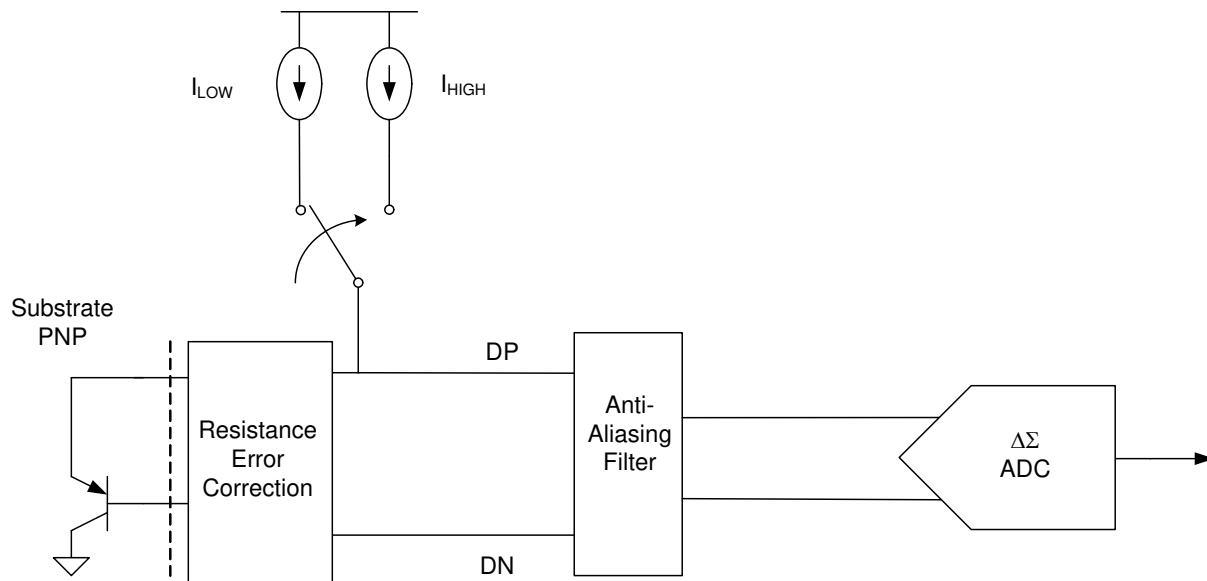


Figure 3.2 Block Diagram of Temperature Monitoring Circuit

Figure 3.2 shows a block diagram of the temperature measurement circuit. The negative terminal for the remote temperature diode, DN, is internally biased with a forward diode voltage referenced to ground.

The EMC1043-1, EMC1043-2, EMC1043-3 and EMC1043-4 are designed to work with the PNP substrate transistor in a CPU. The External Diode 2 channel in the EMC1043-5 has beta compensation disabled by default.

The external diodes in all versions of the EMC1043 are compatible with a broad range of thermal diodes that may be connected as shown in Figure 3.3 (see Section 4.8 for programming details when using diode-connected transistors as the external diodes).

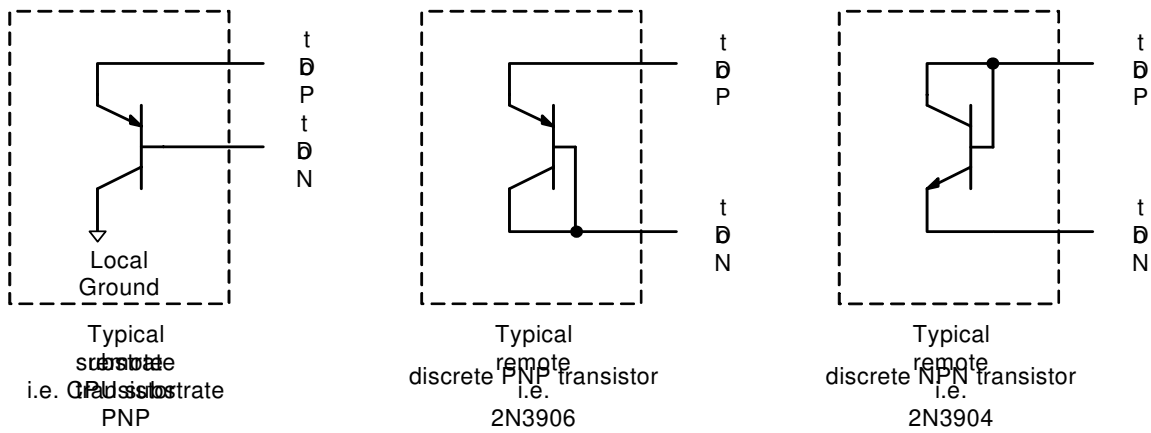


Figure 3.3 External Diode Configurations

3.5 Temperature Measurement Results and Data

Each temperature result for each zone is available in two byte wide data registers. As shown in [Section 4.1](#), the 11-bit format has the 8 most significant bits stored in the high byte register and the 3 least significant bits stored in the three MSB positions of the low byte register. The delta-sigma ADC may be operated with more than 11 bits of resolution for improved averaging as described in [Section 4.5](#), but the temperature result is reported at 11-bit resolution.

The temperature results for the two remote zones are also stored in extended format with a range from -64°C to $+191^{\circ}\text{C}$. The data format is a 2's complement number offset by 64°C as shown in [Section 4.2](#). The data for each of the remote zones in both legacy and extended format is stored in separate data registers so that both data formats are always available. [Table 3.2](#) shows the default and extended range formats.

Table 3.2 EMC1043 Temperature Data Format

| TEMPERATURE (°C) | RANGE -64°C TO 127°C | RANGE -64°C TO 191°C |
|------------------|----------------------|----------------------|
| | BINARY | OFFSET BINARY |
| Diode Fault | 100 0000 0000 | 100 0000 0000 |
| <= -64 | 110 0000 0000 | 100 0000 0000 |
| -63.875 | 110 0000 0001 | 100 0000 0001 |
| -63 | 110 0000 1000 | 100 0000 1000 |
| -1 | 111 1111 1000 | 101 1111 1000 |
| 0 | 000 0000 0000 | 110 0000 0000 |
| 0.125 | 000 0000 0001 | 110 0000 0001 |
| 1 | 000 0000 1000 | 110 0000 1000 |
| 64 | 010 0000 0000 | 000 0000 0000 |
| 65 | 010 0000 1000 | 000 0000 1000 |
| 127 | 011 1111 1000 | 001 1111 1000 |
| 127.875 | 011 1111 1111 | 001 1111 1111 |
| 128 | 011 1111 1111 | 010 0000 0000 |
| 191 | 011 1111 1111 | 011 1111 1000 |
| >= 191.875 | 011 1111 1111 | 011 1111 1111 |

3.6 Resistance Error Correction (REC)

Resistance error correction is an automatic feature that eliminates the need to characterize and compensate for series resistance in the external diode lines. The EMC1043 corrects for as much as 100 ohms of series resistance.

When using a temperature sensor that does not include resistance error correction, voltage developed across the parasitic resistance in the external diode path produces an error in the reported temperature. The error introduced by this resistance is approximately +0.7°C per ohm. Sources of series resistance are PCB trace resistance, on die (i.e. on the processor) metal resistance, bulk resistance in the base and emitter of the temperature transistor.

When monitoring the thermal diode of an AMD K8 processor, the Resistance Error Correction must be disabled for accurate temperature measurements. This is accomplished by clearing the REC bit in the configuration 2 register (see [Section 4.5](#)). Please see Application note “13.16 - Using the EMC1043 with AMD Processors” for more details.

3.7 Beta Compensation

The Beta Compensation function automatically eliminates temperature errors caused by beta variation in modern, low beta transistors used for monitoring processor temperatures. Changes in beta as differing currents are applied to temperature transistors can cause significant temperature errors in monitoring devices. As modern processor geometries shrink the trend is for transistor betas to decrease, which exacerbates temperature errors.

Discrete transistors, with collector connected to base to form a diode, are generally immune to these temperature errors because of high (>100) betas. A beta variation of 10% from low current to high current, when beta equals 100, induces approximately 0.12° error at 100°C. However for a low beta (1.0) substrate transistor used for processor temperature measurement, a beta variation of 10% from low to high current induces approximately 6.12° error at 100°C.

Because the Beta Compensation function is designed to be used with substrate PNP transistors only, this function should be disabled when using a diode-connected transistor (such as the 2N3904) or CPUs that implement the thermal diode as a two-terminal device. The Beta Compensation function is disabled by writing 07h to the Beta Configuration register

When measuring an AMD K8 processor, the Beta Compensation circuitry must be disabled. See [Section 4.8](#). Please see SMSC Application note “13.16 - Using the EMC1043 with AMD Processors” for more details.

3.8 Programmable Ideality Factor

The EMC1043 default is for a diode ideality factor of 1.008 which is common for a 2N3904 diode and for many processor transistors. When a diode or transistor is used that has a different ideality factor value than 1.008 a temperature error is induced that is a linear function of temperature. Previous solutions for this mismatch in ideality factor has been to supply a programmable offset to the temperature reading which corrects the error at a single temperature but causes a residual error at all other temperatures. The EMC1043 ideality factor register corrects this mismatch error at all temperatures (see [Section 4.7](#)).

APPLICATION NOTE: When monitoring a substrate transistor or CPU diode and beta compensation is enabled, the Ideality Factor should not be adjusted. Beta Compensation automatically corrects for most ideality errors.

3.9 Diode Faults

The EMC1043 detects a fault if the DP pin is left floating or is shorted to VDD. In the case of a diode fault, the corresponding status bit will be set and the output data will be set at 400h.

Chapter 4 Register Set and Description

The following registers are accessible through the SMBus Interface.

Table 4.1 EMC1043 Register Set

| REGISTER ADDRESS | | R/W | REGISTER NAME | SYMBOL | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | DEFAULT VALUE |
|------------------|-------|-----|------------------------------------------------|--------|------|------|-------|----|----|----|----|----|---------------|
| READ | WRITE | | | | | | | | | | | | |
| 00h | N/A | R | Internal Temperature High Byte - Legacy Format | INTHBL | Sign | 64 | 32 | 16 | 8 | 4 | 2 | 1 | 00h |
| 23h | N/A | R | Internal Temperature Low Byte - Legacy Format | INTLBL | 0.5 | 0.25 | 0.125 | | | | | | 00h |
| 01h | N/A | R | External Diode 1 High Byte - Legacy Format | ET1HBL | Sign | 64 | 32 | 16 | 8 | 4 | 2 | 1 | 00h |
| 10h | N/A | R | External Diode 1 Low Byte - Legacy Format | ET1LBL | 0.5 | 0.25 | 0.125 | | | | | | 00h |
| F8h | N/A | R | External Diode 2 High Byte - Legacy Format | ET2HBL | Sign | 64 | 32 | 16 | 8 | 4 | 2 | 1 | 00h |
| F9h | N/A | R | External Diode 2 Low Byte - Legacy Format | ET2LBL | 0.5 | 0.25 | 0.125 | | | | | | 00h |
| FAh | N/A | R | External Diode 1 High Byte - Extended Format | ET1HBE | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | 00h |
| FBh | N/A | R | External Diode 1 Low Byte - Extended Format | ET1LBE | 0.5 | 0.25 | 0.125 | | | | | | 00h |
| FCh | N/A | R | External Diode 2 High Byte - Extended Format | ET2HBE | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | 00h |

Table 4.1 EMC1043 Register Set (continued)

| REGISTER ADDRESS | | R/W | REGISTER NAME | SYMBOL | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | DEFAULT VALUE |
|--------------------|-------|-----|---------------------------------------------|--------|------------------------------------------------------------------------|----------|-------|--------|---------|-----------|------|-----|---------------|
| READ | WRITE | | | | | | | | | | | | |
| FDh | N/A | R | External Diode 2 Low Byte - Extended Format | ET2LBE | 0.5 | 0.25 | 0.125 | | | | | | 00h |
| Status and Control | | | | | | | | | | | | | |
| 02h | N/A | R | Status | STS | Busy | - | - | HOTTER | - | - | D2 | D1 | 00h |
| 03h | 09h | R/W | Configuration | CFG | - | ADC_STOP | - | - | - | CR<2:0> | | | 45h |
| 04h | 04h | R/W | Configuration 2 | CFG2 | - | - | - | - | MAX_RES | DA_n | COMP | REC | 09h |
| One Shot | | | | | | | | | | | | | |
| N/A | 0Fh | W | One Shot Conversion | Shot | The data written to this register is irrelevant and will not be stored | | | | | | | 00h | |
| Ideality | | | | | | | | | | | | | |
| 27h | 27h | R/W | External Diode 1 Ideality Correction Factor | IDCF1 | - | - | B5 | B4 | B3 | B2 | B1 | B0 | 12h (1.008) |
| 28h | 28h | R/W | External Diode 2 Ideality Correction Factor | IDCF2 | - | - | B5 | B4 | B3 | B2 | B1 | B0 | 12h (1.008) |
| 29h | 29h | R/W | External Diode 1 Beta Configuration | BCF1 | - | - | - | - | - | BETA<2:0> | | | 03h |

Table 4.1 EMC1043 Register Set (continued)

| REGISTER ADDRESS | | R/W | REGISTER NAME | SYMBOL | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | DEFAULT VALUE |
|------------------|-------|-----|-------------------------------------|--------|----|----|----|----|----|-----------|----|----|-------------------------|
| READ | WRITE | | | | | | | | | | | | |
| 2Ah | 2Ah | R/W | External Diode 2 Beta Configuration | BCF2 | - | - | - | - | - | BETA<2:0> | | | 03h (07h for EMC1043-5) |
| EDh | EDh | R | Product ID | PID | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0Ch (-1) |
| | | | | | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0Dh (-2) |
| | | | | | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0Eh (-3) |
| | | | | | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0Fh (-4) |
| | | | | | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 2Ch (-5) |
| FEh | FEh | R | Manufacturer ID | SMSC | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 5Dh |
| FFh | FFh | R | Revision Register | REV | - | - | - | - | 0 | 0 | 0 | 1 | 01h |

During Power on Reset (POR), the default values are stored in the registers. A POR is initiated when power is first applied to the part and the voltage on the VDD supply surpasses the POR level as specified in the electrical characteristics. Any reads to undefined registers will return 00h. Writes to undefined registers will not have an effect.

The EMC1043 uses an interlock mechanism that will update the Low byte of a particular monitor when the High Byte is read. This prevents changes in register content when the ADC updates between successive reads.

4.1 Legacy Temperature Data Registers (00h, 23h, 01h, 10h, F8h, F9h)

As shown in [Table 4.1](#), each temperature monitor has two data registers. The 11 bit temperature data is stored aligned to the left resulting in the High Byte containing temperature in 1°C steps and the Low Byte containing fractions of a degree.

4.2 Extended Format Temperature Registers (FAh-FDh)

The Extended Format Temperature Registers store only the external diode temperatures in the extended data format. This is because, due to the operating range limitations of the EMC1043, the internal temperature could not benefit from the extended temperature range. Like the Legacy data formatting, the data is stored in two registers per temperature channel.

4.3 Status Register - 02h

Table 4.2 Status Register

| ADDR | REGISTER | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | DEFAULT |
|------|----------|------|----|----|--------|----|----|----|----|---------|
| 02h | Status | Busy | - | - | HOTTER | - | - | D2 | D1 | 00h |

The Status Register is a read only register and returns the operational status of the part. External diode faults are indicated by bits 1 and 0. If either bit is set to '1', then a diode fault has occurred. When a diode fault occurs, the D1 or D2 status bit is set, but otherwise the data remains unchanged.

Bit 7 - Busy - indicates that the ADC is currently converting a temperature.

Bit 4 - HOTTER - during Hotter of Two mode, this bit indicates which of the external diode channels is hotter. If this bit is '0', then External Diode 1 is hotter or equal to External Diode 2. If this bit is '1', then External Diode 2 is hotter than External Diode 1. During normal operation, this bit will always read a '0'.

Bit 1 - D2 - indicates that a diode fault has occurred on External Diode 2.

Bit 0 - D1 - indicates that a diode fault has occurred on External Diode 1.

4.4 Configuration Register (03h Read, 09h Write)

Table 4.3 Configuration Register

| ADDR | REGISTER | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | DEFAULT |
|------------------------|----------|----|---------|----|----|----|---------|----|----|---------|
| 03h Read, 09h Write | Config | - | STANDBY | - | - | - | CR<2:0> | | | 45h |

The Configuration Register controls the basic functionality of the EMC1043. The bits are described below:

Bit 6 - STANDBY- controls the ADC conversions and power modes of the part.

- '0' - The device is in the run operating mode. The ADC is converting at the user-programmed conversion rate.
- '1' - (default) The device is in the standby operating mode (see [Section 3.1](#)).

Bit 2-0 - CR<2:0> - determines the conversion rate for the temperature monitoring per [Table 4.4](#).

Table 4.4 Conversion Rate

| CR<2:0> | | | CONVERSIONS / SECOND (CONVERSION TIME) |
|---------|---|---|-------------------------------------------|
| 2 | 1 | 0 | |
| 0 | 0 | 0 | Reserved |
| 0 | 0 | 1 | Reserved |
| 0 | 1 | 0 | Reserved |
| 0 | 1 | 1 | 1 Conversion / sec |
| 1 | 0 | 0 | 2 Conversions / sec |
| 1 | 0 | 1 | 4 Conversions / sec (default) |
| 1 | 1 | 0 | 8 Conversions / sec |
| 1 | 1 | 1 | 16 Conversions / sec |

4.5 Configuration 2 Register - (04h)

Table 4.5 Configuration 2 Register

| ADDR | REGISTER | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | DEFAULT |
|------|----------|----|----|----|----|---------|------|------|-----|---------|
| 04h | CFG2 | - | - | - | - | MAX_RES | DA_n | COMP | REC | 09h |

The Configuration 2 Register controls the basic functionality of the EMC1043 that is NOT compatible with the EMC1023.

Bit 3 - MAX_RES - controls the external diode conversion time during dynamic averaging. Although the dynamic averaging may be used to increase the ADC resolution, only 11 bits of data are available in the temperature registers.

- '0' - the dynamic averaging will set the ADC averaging factor at 1x when the conversion rate is set at 16 conversions per second and 2x at conversion rates lower than 16 per second.
- '1' (default) - the dynamic averaging will set the ADC averaging factor at 1x when the conversion rate is set at 16 conversions per second, 2x at 8 conversions / second and 4x at conversion rates lower than 8 per second.

Bit 2 - DA_n - controls the dynamic digital averaging circuitry. See [Section 3.3.2](#).

- '0' (default) - dynamic averaging is enabled. Depending on the selected conversion rate, the ADC averaging factor is increased for the external diodes.
- '1' - dynamic averaging is disabled. The ADC averaging factor will remain fixed at 1x for all conversion rates and will allow increased power savings at the slower conversion rates.

Bit 1 - COMP - configures the device to perform a comparison for the Hotter of Two mode (see [Section 3.3, "Operation During Run Mode," on page 12.](#))

- '0' (default) - the device is in normal mode
- '1' - the device is in Hotter of Two mode. In this mode, the two external diode channels are measured and compared against each other. The hotter of the two channels has its data loaded into the External Diode 2 Data Registers. The Internal Diode and External Diode 1 Data Registers remain unaffected.

Bit 0 - REC - controls the Resistance Error Correction circuitry

- '0' - The Resistance Error Correction circuitry is disabled.
- '1' (default) - The Resistance Error Correction circuitry is active and will automatically correct for up to 100 ohms of series resistance in the diode lines for both External Diode 1 and External Diode 2 channels.

4.6 One Shot Register - (0Fh)

Table 4.6 One Shot Registers

| ADDR | REGISTER | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | DEFAULT |
|------|---------------------|------------------------------------------------------------------------------------------------------|----|----|----|----|----|----|----|---------|
| 0Fh | One Shot Conversion | Writing to this register address initiates the one-shot. The data is not important and is not stored | | | | | | | | 00h |

The One Shot Register is an address place holder for the one-shot command. Writing to the address initiates the command. The data written is not important and is not stored. Reading from the one-shot registers will always return 00h.

4.7 Ideality Configuration Registers (27h - 28h)

Table 4.7 Ideality Configuration Registers

| ADDR | REGISTER | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | DEFAULT |
|------|------------------------------------|----|----|----|----|----|----|----|----|----------------|
| 27h | Diode 1 Ideality Correction Factor | - | - | B5 | B4 | B3 | B2 | B1 | B0 | 12h (1.008) |
| 28h | Diode 2 Ideality Correction Factor | - | - | B5 | B4 | B3 | B2 | B1 | B0 | 12h (1.008) |

The Ideality Configuration Registers store the ideality correction factor that is applied to each external diode.

The table below shows the ideality factor settings for the Ideality Configuration registers. Shading indicates power-up default. All codes that are not listed are reserved and should not be used.

Beta Compensation and Resistance Error Correction automatically correct for most diode ideality errors, therefore it is not recommended that these settings be updated without consulting SMSC.

Table 4.8 Ideality Factor Look Up Table

| SETTING | FACTOR | SETTING | FACTOR | SETTING | FACTOR |
|---------|--------|---------|--------|---------|--------|
| 001000 | 0.9951 | 011000 | 1.0159 | 101000 | 1.0377 |
| 001001 | 0.9964 | 011001 | 1.0173 | 101001 | 1.0391 |
| 001010 | 0.9976 | 011010 | 1.0186 | 101010 | 1.0404 |
| 001011 | 0.9989 | 011011 | 1.0199 | 101011 | 1.0418 |
| 001100 | 1.0002 | 011100 | 1.0213 | 101100 | 1.0432 |
| 001101 | 1.0015 | 011101 | 1.0226 | 101101 | 1.0446 |
| 001110 | 1.0028 | 011110 | 1.0240 | 101110 | 1.0460 |
| 001111 | 1.0041 | 011111 | 1.0253 | 101111 | 1.0475 |
| 010000 | 1.0054 | 100000 | 1.0267 | 110000 | 1.0489 |
| 010001 | 1.0067 | 100001 | 1.0280 | 110001 | 1.0503 |
| 010010 | 1.0080 | 100010 | 1.0294 | | |
| 010011 | 1.0093 | 100011 | 1.0308 | | |
| 010100 | 1.0106 | 100100 | 1.0321 | | |
| 010101 | 1.0119 | 100101 | 1.0335 | | |
| 010110 | 1.0133 | 100110 | 1.0349 | | |
| 010111 | 1.0146 | 100111 | 1.0363 | | |

For CPU substrate transistors that require the BJT transistor model, the ideality factor behaves slightly differently than for discrete diode-connected transistors. Refer to [Table 4.9](#) when using a CPU substrate transistor.

Table 4.9 Substrate Diode Ideality Factor Look-Up Table (BJT Model)

| SETTING | FACTOR | SETTING | FACTOR | SETTING | FACTOR |
|---------|--------|---------|--------|---------|--------|
| 001000 | 0.9869 | 011000 | 1.0079 | 101000 | 1.0291 |
| 001001 | 0.9882 | 011001 | 1.0092 | 101001 | 1.0304 |
| 001010 | 0.9895 | 011010 | 1.0105 | 101010 | 1.0317 |
| 001011 | 0.9908 | 011011 | 1.0120 | 101011 | 1.0330 |
| 001100 | 0.9921 | 011100 | 1.0132 | 101100 | 1.0343 |
| 001101 | 0.9934 | 011101 | 1.0146 | 101101 | 1.0356 |
| 001110 | 0.9947 | 011110 | 1.0159 | 101110 | 1.0369 |
| 001111 | 0.9960 | 011111 | 1.0173 | 101111 | 1.0382 |
| 010000 | 0.9973 | 100000 | 1.0187 | 110000 | 1.0395 |

Table 4.9 Substrate Diode Ideality Factor Look-Up Table (BJT Model) (continued)

| SETTING | FACTOR | SETTING | FACTOR | SETTING | FACTOR |
|---------|--------|---------|--------|---------|--------|
| 010001 | 0.9986 | 100001 | 1.0200 | 110001 | 1.0408 |
| 010010 | 1.0000 | 100010 | 1.0213 | | |
| 010011 | 1.0013 | 100011 | 1.0226 | | |
| 010100 | 1.0026 | 100100 | 1.0239 | | |
| 010101 | 1.0039 | 100101 | 1.0252 | | |
| 010110 | 1.0053 | 100110 | 1.0265 | | |
| 010111 | 1.0066 | 100111 | 1.0278 | | |

APPLICATION NOTE: When measuring a 65nm Intel CPUs, the Ideality Setting should be the default 12h. When measuring 45nm Intel CPUs, the Ideality Setting should be 15h.

4.8 Beta Configuration Registers (29h - 2Ah)

Table 4.10 Beta Configuration Registers

| ADDR | REGISTER | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | DEFAULT |
|------|----------------------------|----|----|----|----|----|-----------|----|----|----------------------------|
| 29h | Diode 1 Beta Configuration | - | - | - | - | - | BETA<2:0> | | | 03h |
| 2Ah | Diode 2 Beta Configuration | - | - | - | - | - | BETA<2:0> | | | 03h (07h for EMC1043-5) |

The Beta Configuration Registers have a factory programmed power-on default based on the beta of the PNP substrate transistor that is being monitored as the external diode. The default value of the Diode 2 Beta Configuration Register of EMC1043-5 is 07h (disabled).

The beta compensation circuit is able to compensate for beta variation within a given range. The beta configuration register is configured to the proper range to match the CPU to be monitored. The beta values should be set so that the minimum expected beta is not below the threshold indicated in [Table 4.11](#). Beta compensation is activated if the BETA<2:0> bits are set to any value other than 07h.

When using diode-connected transistors (such as the 2N3904) or CPUs that implement the thermal diode as a two-terminal diode, the Beta Configuration Register should be set to 07h.

Table 4.11 Beta Configuration Look Up Table

| BETA<2:0> | | | MINIMUM BETA |
|-----------|---|---|--------------|
| 2 | 1 | 0 | |
| 0 | 0 | 0 | 0.11 |
| 0 | 0 | 1 | 0.18 |
| 0 | 1 | 0 | 0.25 |

Table 4.11 Beta Configuration Look Up Table (continued)

| BETA<2:0> | | | MINIMUM BETA |
|-----------|---|---|----------------|
| 2 | 1 | 0 | |
| 0 | 1 | 1 | 0.33 (default) |
| 1 | 0 | 0 | 0.43 |
| 1 | 0 | 1 | 1.00 |
| 1 | 1 | 0 | 2.33 |
| 1 | 1 | 1 | Disabled |

4.9 Product ID Register (EDh)

Table 4.12 Product ID Register

| ADDR | REGISTER | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | DEFAULT |
|------|----------|----|----|----|----|----|----|----|----|----------------------------------------------------------|
| EDh | PID | 0 | 0 | X | 0 | 1 | 1 | X | X | 0Ch (-1) 0Dh (-2) 0Eh (-3) 0Fh (-4) 2Ch (-5) |

The Product ID Register holds the unique product ID for identifying SMSC EMC products. See [Table 4.1](#) for a list of the product ID number for each version of the EMC1043.

4.10 Manufacturer ID Register (FEh)

Table 4.13 Manufacturer ID Register

| ADDR | REGISTER | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | DEFAULT |
|------|----------|----|----|----|----|----|----|----|----|---------|
| FEh | SMSC | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 5Dh |

The Manufacturer ID register contains an 8 bit word that identifies the manufacturer of the EMC1043 (SMSC = 5Dh).

4.11 Revision Register (FFh)

Table 4.14 Revision Register

| ADDR | REGISTER | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | DEFAULT |
|------|----------|----|----|----|----|----|----|----|----|---------|
| FFh | REV | - | - | - | - | 0 | 0 | 0 | 1 | 01h |

The Revision register contains a 4 bit word that identifies the die revision.