# TCN75A

## 2-Wire Serial Temperature Sensor

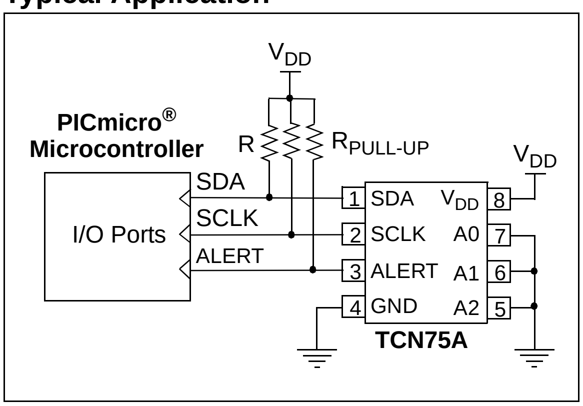
### Features

- Temperature-to-Digital Converter
- Accuracy with 12-bit Resolution:
  - ±0.5°C (typ.) at +25°C
  - ±3°C (max.) from +25°C to +100°C
- User-selectable Resolution: 9 – 12 bits
- Operating Voltage Range: 2.7V to 5.5V
- 2-wire Interface: $I^2C$™ Compatible
- Operating Current: 200 µA (typ.)
- Shutdown Current: 2 µA (max.)
- Power-saving One-shot Temperature Measurement
- Available Packages: MSOP-8, SOIC-8

### Typical Applications

- Personal Computers and Servers
- Hard Disk Drives and Other PC Peripherals
- Entertainment Systems
- Office Equipment
- Data Communication Equipment
- General-purpose Temperature Monitoring

### Typical Application




### Description

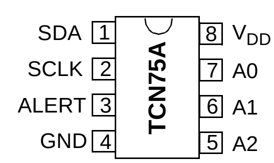
Microchip Technology Inc.'s TCN75A digital temperature sensor converts temperatures between -40°C and +125°C to a digital word, with ±1.5°C (typ.) accuracy.

The TCN75A product comes with user-programmable registers that provide flexibility for temperature-sensing applications. The register settings allow user-selectable, 9-bit to 12-bit temperature measurement resolution, configuration of the power-saving Shutdown and One-shot (single conversion on command while in Shutdown) modes and the specification of both temperature alert output and hysteresis limits. When the temperature changes beyond the specified limits, the TCN75A outputs an alert signal. The user has the option of setting the alert output signal polarity as an active-low or active-high comparator output for thermostat operation, or as temperature event interrupt output for microprocessor-based systems.

This sensor has an industry standard 2-wire, $I^2C$™ compatible serial interface, allowing up to eight devices to be controlled in a single serial bus. These features make the TCN75A ideal for low-cost, sophisticated multi-zone temperature-monitoring applications.

### Package Types

**8-Pin SOIC, MSOP**



# 1.0 ELECTRICAL CHARACTERISTICS

## Absolute Maximum Ratings †

$V_{DD}$ ........................................................................ 6.0V

Voltage at all Input/Output pins .... GND – 0.3V to 5.5V

Storage temperature ..........................-65°C to +150°C

Ambient temp. with power applied .....-55°C to +125°C

Junction Temperature ($T_J$)................................. 150°C

ESD protection on all pins (HBM:MM)....... (4 kV:400V)

Latch-up current at each pin ......................... ±200 mA

**†Notice:** Stresses above those listed under "Maximum ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

## DC CHARACTERISTICS

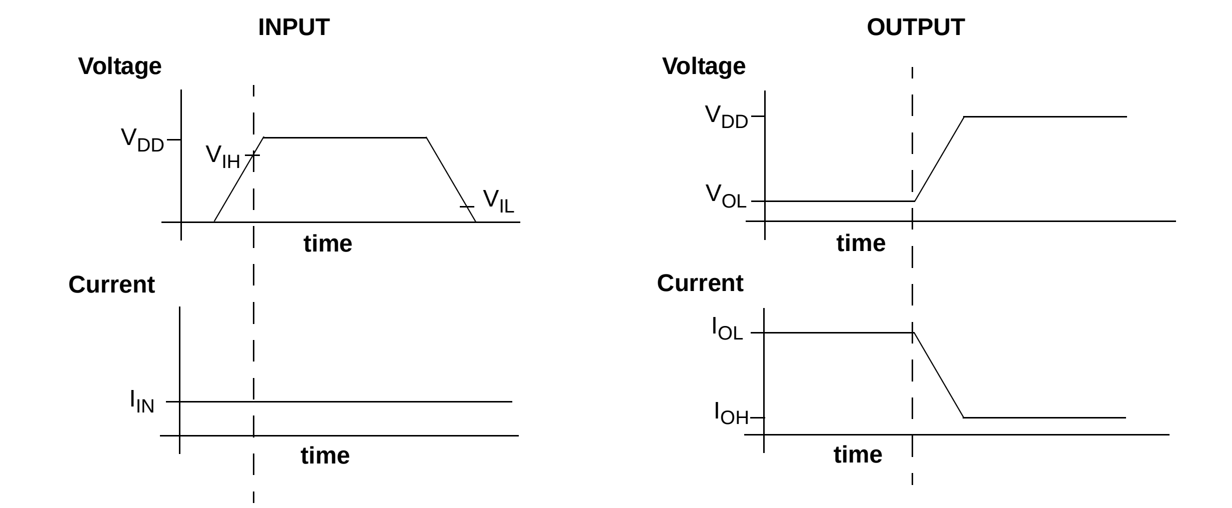
**Electrical Specifications:** Unless otherwise indicated, $V_{DD}$ = 2.7V to 5.5V, GND = Ground, and $T_A$ = -40°C to +125°C.

| Parameters | Sym | Min | Typ | Max | Unit | Conditions |
|---|---|---|---|---|---|---|
| **Power Supply** | | | | | | |
| Operating Voltage Range | $V_{DD}$ | 2.7 | — | 5.5 | V | |
| Operating Current | $I_{DD}$ | — | 200 | 500 | µA | Continuous operation |
| Shutdown Current | $I_{SHDN}$ | — | 0.1 | 2 | µA | Shutdown mode |
| Power-On Reset (POR) Threshold | $V_{POR}$ | — | 1.7 | — | V | $V_{DD}$ falling edge |
| **Temperature Sensor Accuracy** | | | | | | |
| Accuracy with 12-bit Resolution: | | | | | | |
| $T_A$ = +25°C | $T_{ACY}$ | — | ±0.5 | — | °C | $V_{DD}$ = 3.3V |
| +25°C < $T_A \le$ +100°C | $T_{ACY}$ | -3.0 | — | +3.0 | °C | $V_{DD}$ = 3.3V |
| -40°C < $T_A \le$ +125°C | $T_{ACY}$ | — | ±1.5 | — | °C | $V_{DD}$ = 3.3V |
| **Internal ΣΔ ADC** | | | | | | |
| Conversion Time: | | | | | | |
| 9-bit Resolution | $t_{CONV}$ | — | 30 | — | ms | 33 samples/sec (typ.) |
| 10-bit Resolution | $t_{CONV}$ | — | 60 | — | ms | 17 samples/sec (typ.) |
| 11-bit Resolution | $t_{CONV}$ | — | 120 | — | ms | 8 samples/sec (typ.) |
| 12-bit Resolution | $t_{CONV}$ | — | 240 | — | ms | 4 samples/sec (typ.) |
| **Alert Output (Open-drain)** | | | | | | |
| High-level Current | $I_{OH}$ | — | — | 1 | µA | $V_{OH}$ = 5V |
| Low-level Voltage | $V_{OL}$ | — | — | 0.4 | V | $I_{OL}$= 3 mA |
| **Thermal Response** | | | | | | |
| Response Time | $t_{RES}$ | — | 1.4 | — | s | Time to 63% (89°C)<br>27°C (air) to 125°C (oil bath) |

## DIGITAL INPUT/OUTPUT PIN CHARACTERISTICS

| Parameters | Sym | Min | Typ | Max | Units | Conditions |
|---|---|---|---|---|---|---|
| **Electrical Specifications:** Unless otherwise indicated, $V_{DD}$ = 2.7V to 5.5V, GND = Ground and $T_A$ = -40°C to +125°C. | | | | | | |
| **Serial Input/Output (SCLK, SDA, A0, A1, A2)** | | | | | | |
| **Input** | | | | | | |
| High-level Voltage | $V_{IH}$ | 0.7 $V_{DD}$ | — | — | V | |
| Low-level Voltage | $V_{IL}$ | — | — | 0.3 $V_{DD}$ | V | |
| Input Current | $I_{IN}$ | -1 | — | +1 | µA | |
| **Output (SDA)** | | | | | | |
| Low-level Voltage | $V_{OL}$ | — | — | 0.4 | V | $I_{OL}$= 3 mA |
| High-level Current | $I_{OH}$ | — | — | 1 | µA | $V_{OH}$ = 5V |
| Low-level Current | $I_{OL}$ | 6 | — | — | mA | $V_{OL}$ = 0.6V |
| Capacitance | $C_{IN}$ | — | 10 | — | pF | |
| **SDA and SCLK Inputs** | | | | | | |
| Hysteresis | $V_{HYST}$ | 0.05 $V_{DD}$ | — | — | V | |

### Graphical Symbol Description




## TEMPERATURE CHARACTERISTICS

| Parameters | Sym | Min | Typ | Max | Units | Conditions |
|---|---|---|---|---|---|---|
| **Electrical Specifications:** Unless otherwise indicated, $V_{DD}$ = +2.7V to +5.5V and GND = Ground. | | | | | | |
| **Temperature Ranges** | | | | | | |
| Specified Temperature Range | $T_A$ | -40 | — | +125 | °C | **Note 1** |
| Operating Temperature Range | $T_A$ | -40 | — | +125 | °C | |
| Storage Temperature Range | $T_A$ | -65 | — | +150 | °C | |
| **Thermal Package Resistances** | | | | | | |
| Thermal Resistance, 8L-SOIC | $\theta_{JA}$ | — | 163 | — | °C/W | |
| Thermal Resistance, 8L-MSOP | $\theta_{JA}$ | — | 206 | — | °C/W | |

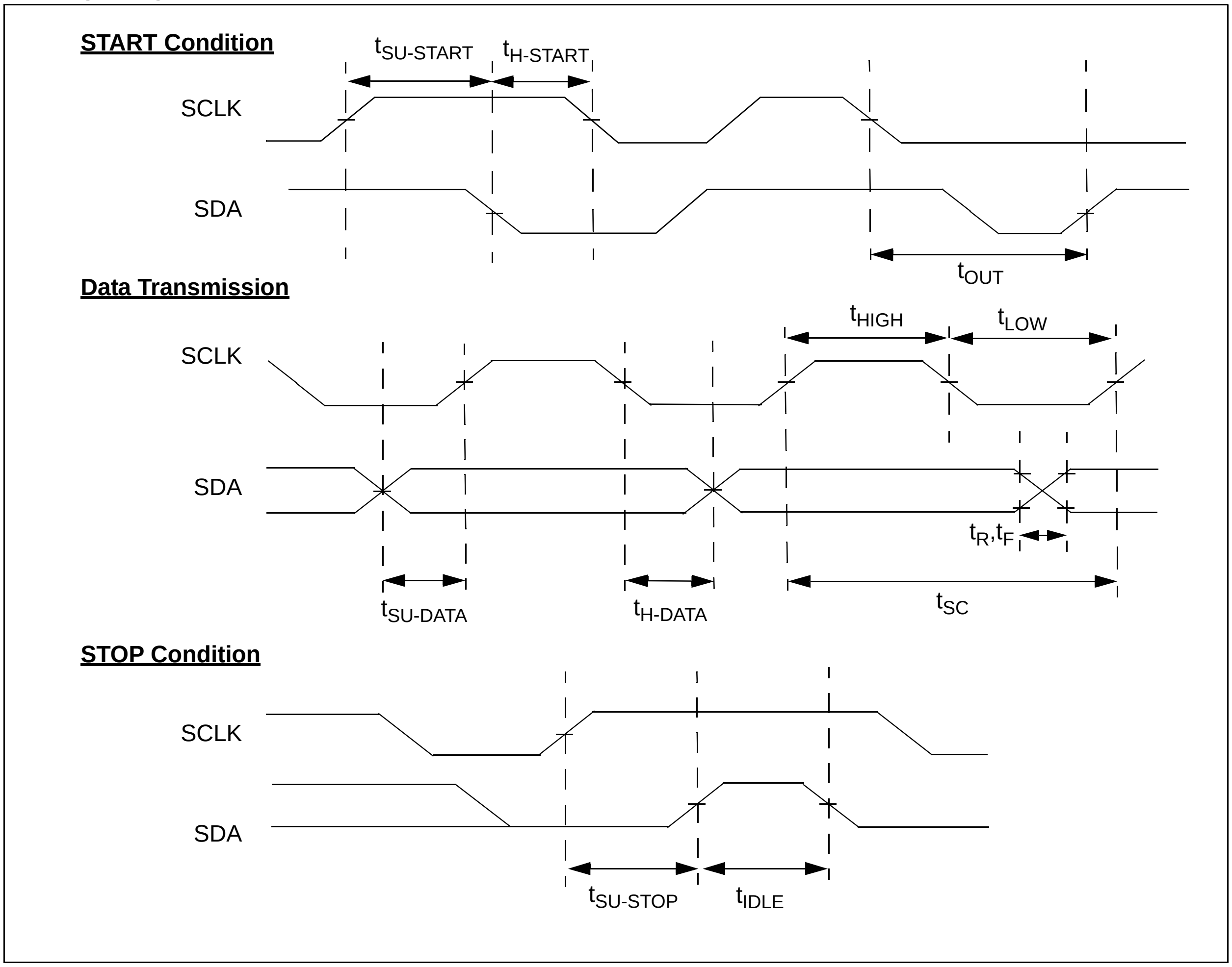
**Note 1:** Operation in this range must not cause $T_J$ to exceed Maximum Junction Temperature (+150°C).

## SERIAL INTERFACE TIMING SPECIFICATIONS

| **Electrical Specifications:** Unless otherwise indicated, $V_{DD}$ = 2.7V to 5.5V, GND = Ground, $T_A$ = -40°C to +125°C, $C_L$ = 80 pF and all limits measured to 50% point. | | | | | | |
|---|---|---|---|---|---|---|
| **Parameters** | **Sym** | **Min** | **Typ** | **Max** | **Units** | **Conditions** |
| **2-Wire I²C™ Compatible Interface** | | | | | | |
| Serial Port Frequency | $f_{SC}$ | 0 | — | 400 | kHz | |
| Clock Period | $t_{SC}$ | 2.5 | — | — | µs | |
| Low Clock | $t_{LOW}$ | 1.3 | — | — | µs | |
| High Clock | $t_{HIGH}$ | 0.6 | — | — | µs | |
| Rise Time | $t_R$ | 20 | — | 300 | ns | 10% to 90% of $V_{DD}$ (SCLK, SDA) |
| Fall Time | $t_F$ | 20 | — | 300 | ns | 90% to 10% of $V_{DD}$ (SCLK, SDA) |
| Data Setup Before SCLK High | $t_{SU-DATA}$ | 0.1 | — | — | µs | |
| Data Hold After SCLK Low | $t_{H-DATA}$ | 0 | — | — | µs | |
| START Condition Setup Time | $t_{SU-START}$ | 0.6 | — | — | µs | |
| START Condition Hold Time | $t_{H-START}$ | 0.6 | — | — | µs | |
| STOP Condition Setup Time | $t_{SU-STOP}$ | 0.6 | — | — | µs | |
| Bus Idle | $t_{IDLE}$ | 1.3 | — | — | µs | |

### Timing Diagram



## 2.0 TYPICAL PERFORMANCE CURVES

| | |
|---|---|
| **Note:** | The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range. |

**Note:** Unless otherwise noted: $V_{DD}$ = 2.7V to 5.5V.

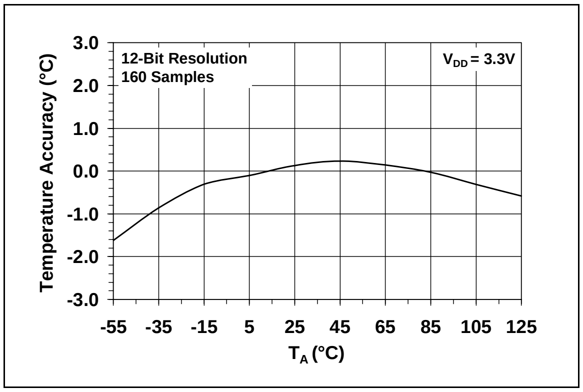



***FIGURE 2-1:*** *Average Temperature Accuracy vs. Ambient Temperature, $V_{DD}$ = 3.3V.*

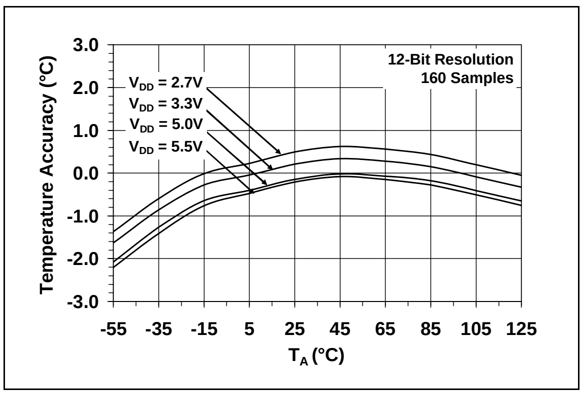



***FIGURE 2-2:*** *Average Temperature Accuracy vs. Ambient Temperature.*

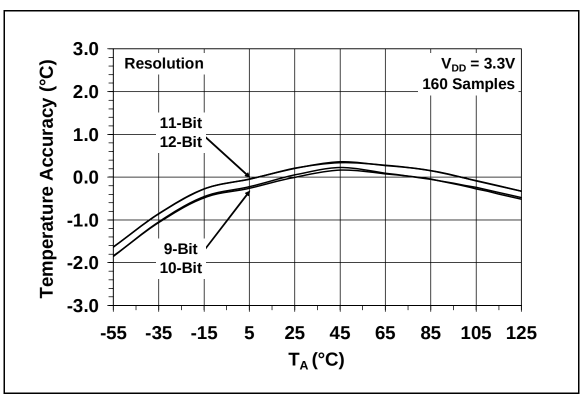



***FIGURE 2-3:*** *Average Temperature Accuracy vs. Ambient Temperature, $V_{DD}$ = 3.3V.*

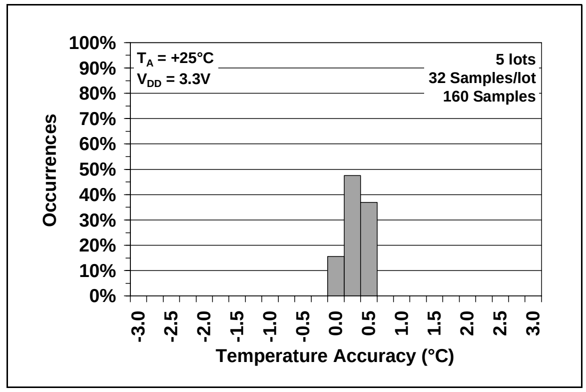



***FIGURE 2-4:*** *Temperature Accuracy Histogram, $T_A$ = +25°C.*

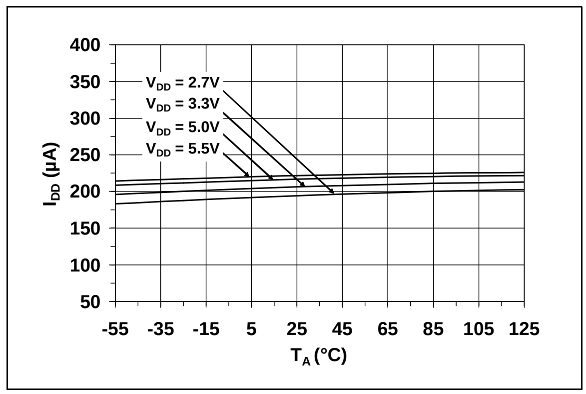



***FIGURE 2-5:*** *Supply Current vs. Ambient Temperature.*

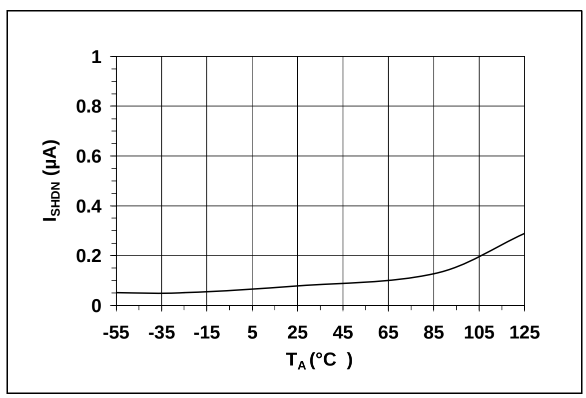



***FIGURE 2-6:*** *Shutdown Current vs. Ambient Temperature.*

**Note:** Unless otherwise noted: $V_{DD}$ = 2.7V to 5.5V.

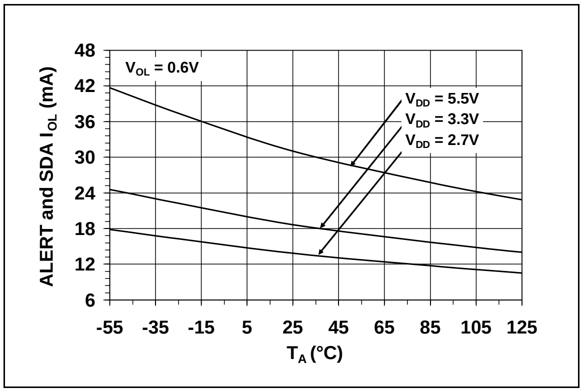



***FIGURE 2-7:*** *ALERT and SDA $I_{OL}$ vs. Ambient Temperature.*

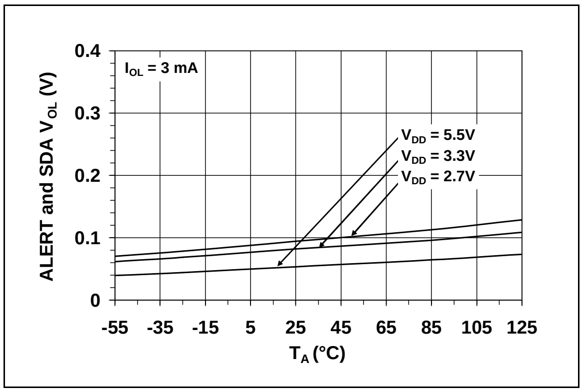



***FIGURE 2-8:*** *ALERT and SDA Output $V_{OL}$ vs. Ambient Temperature.*

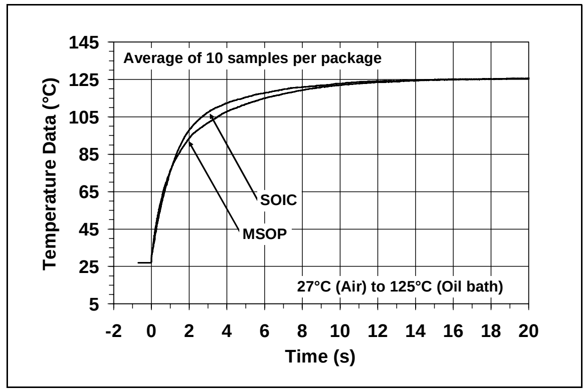



***FIGURE 2-9:*** *TCN75A Thermal Response vs. Time.*

## 3.0 PIN DESCRIPTION

The descriptions of the pins are listed in Table 3-1.

**TABLE 3-1: PIN FUNCTION TABLE**

| MSOP, SOIC | Symbol | Function |
|---|---|---|
| 1 | SDA | Bidirectional Serial Data |
| 2 | SCLK | Serial Clock Input |
| 3 | ALERT | Temperature Alert Output |
| 4 | GND | Ground |
| 5 | A2 | Address Select Pin (bit 2) |
| 6 | A1 | Address Select Pin (bit 1) |
| 7 | A0 | Address Select Pin (bit 0) |
| 8 | $V_{DD}$ | Power Supply Input |

### 3.1 Serial Data Pin (SDA)

SDA is a bidirectional input/output pin, used to serially transmit data to and from the host controller. This pin requires a pull-up resistor to output data.

### 3.2 Serial Clock Pin (SCLK)

SCLK is a clock input pin. All communication and timing is relative to the signal on this pin. The clock is generated by the host controller on the bus.

### 3.3 Power Supply Input ($V_{DD}$)

$V_{DD}$ is the power pin. The operating voltage, as specified in the DC electrical specification table, is applied on this pin.

### 3.4 Ground (GND)

GND is the system ground pin.

### 3.5 ALERT Output

The TCN75A's ALERT pin is an open-drain output. The device outputs an alert signal when the ambient temperature goes beyond the user-programmed temperature limit.

### 3.6 Address Pins (A2, A1, A0)

A2, A1 and A0 are device or slave address input pins.

The address pins are the Least Significant bits (LSb) of the device address bits. The Most Significant bits (MSb) (A6, A5, A4, A3) are factory-set to <1001>. This is illustrated in Table 3-2.

**TABLE 3-2: SLAVE ADDRESS**

| Device | A6 | A5 | A4 | A3 | A2 | A1 | A0 |
|---|---|---|---|---|---|---|---|
| TCN75A | 1 | 0 | 0 | 1 | X | X | X |

**Note:** User-selectable address is shown by X.

## 4.0 FUNCTIONAL DESCRIPTION

The TCN75A temperature sensor consists of a band-gap type temperature sensor, a ΣΔ Analog-to-Digital Converter (ADC), user-programmable registers and a 2-wire $I^2C$ protocol-compatible serial interface.

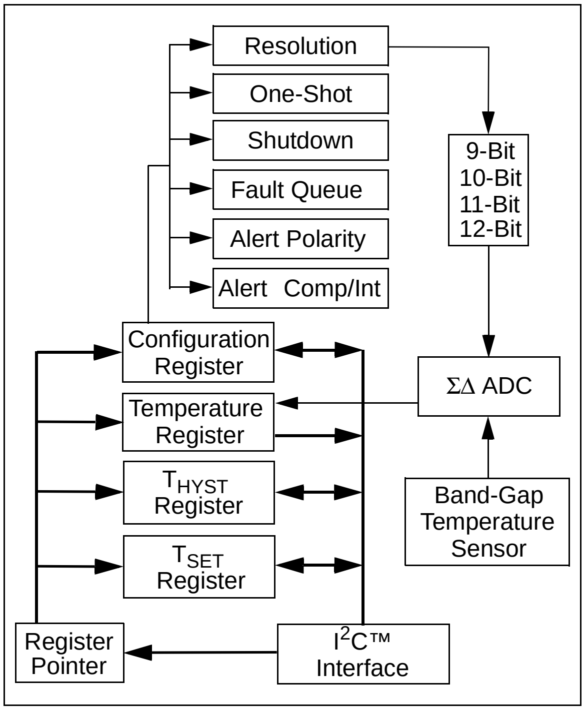



***FIGURE 4-1:*** *Functional Block Diagram.*

## 4.1 Temperature Sensor

The TCN75A uses the difference in the base-emitter voltage of a transistor while its collector current is changed from $IC_1$ to $IC_2$. With this method, the $\Delta V_{BE}$ depends only on the ratio of the two currents and the ambient temperature, as shown in Equation 4-1.

**EQUATION 4-1:**

$$\Delta V_{BE} = \left(\frac{kT}{q}\right) \times ln(IC_1/IC_2)$$

Where:

| | | |
|---|---|---|
| T | = | temperature in kelvin |
| $\Delta V_{BE}$ | = | change in diode base-emitter voltage |
| k | = | Boltzmann's constant |
| q | = | electron charge |
| $IC_1$ and $IC_2$ | = | currents with n:1 ratio |

## 4.2 ΣΔ Analog-to-Digital Converter

A sigma-delta ADC is used to convert $\Delta V_{BE}$ to a digital word that corresponds to the transistor temperature. The converter has an adjustable resolution from 9-bits (at 30 ms conversion time) to 12-bits (at 240 ms conversion time). Thus, it allows the user to make trade-offs between resolution and conversion time. Refer to **Section 4.3.4 "Sensor Configuration Register (CONFIG)"** and **Section 4.3.4.7 "ΣΔ ADC Resolution"** for details.

## 4.3 Registers

The TCN75A has four registers that are user-accessible. These registers are specified as the Ambient Temperature ($T_A$) register, the Temperature Limit-set ($T_{SET}$) register, the Temperature Hysteresis ($T_{HYST}$) register and device Configuration (CONFIG) register.

The Ambient Temperature register is a read-only register and is used to access the ambient temperature data. The data from the ADC is loaded in parallel in the register. The Temperature Limit-set and Temperature Hysteresis registers are read/write registers that provide user-programmable temperature limits. If the ambient temperature drifts beyond the programmed limits, the TCN75A outputs an alert signal using the ALERT pin (refer to **Section 4.3.4.3 “ALERT Output Configuration”**). The device Configuration register provides access for the user to configure the TCN75A’s various features. These registers are described in further detail in the following sections.

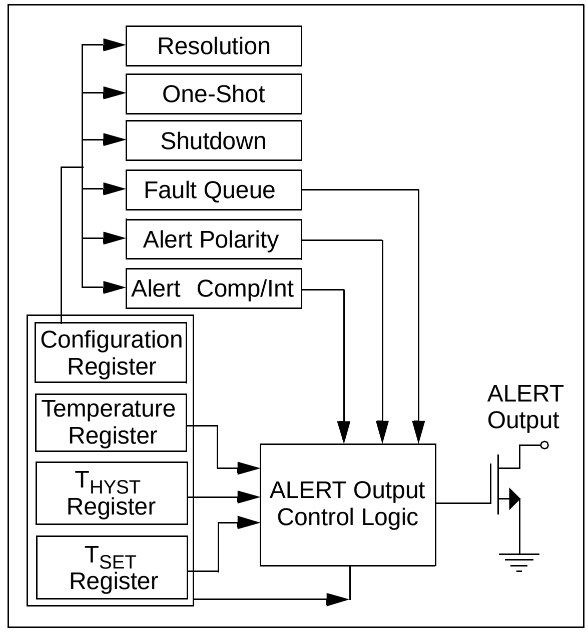



*FIGURE 4-2: Register Block Diagram.*

The registers are accessed by sending register pointers to the TCN75A using the serial interface. This is an 8-bit pointer. However, the two Least Significant bits (LSbs) are used as pointers and all other bits need to be cleared <0>. This device has additional registers that are reserved for test and calibration. If these registers are accessed, the device may not perform according to the specification. The pointer description is shown below.

**REGISTER 4-1: REGISTER POINTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | P1 | P0 |
| bit 7 | | | | | | | bit 0 |

bit 7-3 **Unimplemented:** Read as ‘0’

bit 2-0 **Pointer bits**

00 = Temperature register
01 = Configuration register
10 = Temperature Hysteresis register
11 = Temperature Limit-set register

| **Legend:** | | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as ‘0’ | |
| - n = Value at POR | ‘1’ = Bit is set | ‘0’ = Bit is cleared | x = Bit is unknown |

### 4.3.1 AMBIENT TEMPERATURE REGISTER ($T_A$)

The TCN75A has a 16-bit read-only Ambient Temperature register that contains 9-bit to 12-bit temperature data. This data is formatted in two's complement. The bit assignments, as well as the corresponding resolution, is shown in the register assignment below.

The refresh rate of this register depends on the selected ADC resolution. It takes 30 ms (typ.) for 9-bit data and 240 ms (typ.) for 12-bit data. Since this register is double-buffered, the user can read the register while the TCN75A performs analog-to-digital conversion in the background. The decimal code to ambient temperature conversion is shown in Equation 4-2:

**EQUATION 4-2:**

$$T_A = Code \times 2^{-4}$$

Where:

$T_A$ = Ambient Temperature (°C)

Code = TCN75A output in decimal (Table 4-1)

**REGISTER 4-2: AMBIENT TEMPERATURE REGISTER ($T_A$)**

**Upper Half:**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| Sign | $2^6$ °C/bit | $2^5$ °C/bit | $2^4$ °C/bit | $2^3$ °C/bit | $2^2$ °C/bit | $2^1$ °C/bit | $2^0$ °C/bit |
| bit 15 | | | | | | | bit 8 |

**Lower Half:**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| $2^{-1}$ °C/bit | $2^{-2}$ °C/bit | $2^{-3}$ °C/bit | $2^{-4}$ °C/bit | 0 | 0 | 0 | 0 |
| bit 7 | | | | | | | bit 0 |

**Note:** When the 9-bit, 10-bit or 11-bit resolutions are selected, bit 6, bit 7 or bit 8 will remain clear <0>, respectively.

| **Legend:** | | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| - n = Value at POR | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

**TABLE 4-1: CODE CONVERSION**

| Resolution | TCN75A Output (Binary) | Hexadecimal | Decimal | $T_A$ (°C) |
|---|---|---|---|---|
| **9-Bit** | 0111 1101 0uuu uuuu[(1)] | 0FA | 250 | +125 |
| | 0001 1001 0uuu uuuu | 032 | 50 | +25 |
| | 0000 0000 1uuu uuuu | 001 | 1 | +0.5 |
| **10-Bit** | 0111 1101 00uu uuuu | 1F4 | 500 | +125 |
| | 0001 1001 01uu uuuu | 065 | 101 | +25.25 |
| | 0000 0000 01uu uuuu | 001 | 1 | +0.25 |
| **11-Bit** | 0111 1101 000u uuuu | 3E8 | 1000 | +125 |
| | 0001 1001 011u uuuu | 0CB | 203 | +25.375 |
| | 0000 0000 001u uuuu | 001 | 1 | +0.125 |
| **12-Bit** | 0111 1101 0000 uuuu | 7D0 | 2000 | +125 |
| | 0001 1001 0111 uuuu | 197 | 407 | +25.4375 |
| | 0000 0000 0001 uuuu | 001 | 1 | +0.0625 |
| 0°C | 0000 0000 0000 uuuu | 000 | 0 | 0 |
| **12-Bit** | 1111 1111 1111 uuuu[(2)] | 001[(3)] | -1 | -0.0625 |
| | 1110 0110 1001 uuuu | 197 | -407 | -25.4375 |
| | 1100 1001 0000 uuuu | 370 | -880 | -55 |

**Note 1:** 'u' represents unused bits. The TCN75A clears <0> the unused bits.

**2:** This data is in two's complement format, which indicates ambient temperature below 0°C.

**3:** Negative temperature magnitude in hexadecimal. This conversion is accomplished by complimenting each binary bit and adding 1.

### 4.3.2 TEMPERATURE LIMIT-SET REGISTER ($T_{SET}$)

The TCN75A has a 16-bit read/write Temperature Limit-Set register ($T_{SET}$) which contains a 9-bit data in two's compliment format. This data represents a maximum temperature limit. If the ambient temperature exceeds this specified limit, the TCN75A asserts an alert output. (Refer to **Section 4.3.4.3 "ALERT Output Configuration"**).

This register uses the nine Most Significant bits (MSbs) and all other bits are don't cares.

The power-up default value of the $T_{SET}$ register is 80°C, or `<0 1010 0000>` in binary.

**REGISTER 4-3: TEMPERATURE LIMIT-SET REGISTER ($T_{SET}$)**

**Upper Half**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| Sign | $2^6$ °C/bit | $2^5$ °C/bit | $2^4$ °C/bit | $2^3$ °C/bit | $2^2$ °C/bit | $2^1$ °C/bit | $2^0$ °C/bit |
| bit 15 | | | | | | | bit 8 |

**Lower Half**

| R/W-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| $2^{-1}$ °C/bit | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| - n = Value at POR | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

### 4.3.3 TEMPERATURE HYSTERESIS REGISTER ($T_{HYST}$)

The TCN75A has a 16-bit read/write Temperature Hysteresis register that contains a 9-bit data in two's compliment format. This register is used to set a hysteresis for the $T_{SET}$ limit. Therefore, the data represents a minimum temperature limit. If the ambient temperature drifts below the specified limit, the TCN75A asserts an alert output (refer to **Section 4.3.4.3 "ALERT Output Configuration"**).

This register uses the nine Most Significant bits (MSbs) and all other bits are don't cares.

The power-up default value of $T_{HYST}$ register is 75°C, or `<0 1001 0110>` in binary.

**REGISTER 4-4: TEMPERATURE HYSTERESIS REGISTER ($T_{HYST}$)**

**Upper Half:**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| Sign | $2^6$ °C/bit | $2^5$ °C/bit | $2^4$ °C/bit | $2^3$ °C/bit | $2^2$ °C/bit | $2^1$ °C/bit | $2^0$ °C/bit |
| bit 15 | | | | | | | bit 8 |

**Lower Half:**

| R/W-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| $2^{-1}$ °C/bit | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| - n = Value at POR | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

### 4.3.4 SENSOR CONFIGURATION REGISTER (CONFIG)

The TCN75A has an 8-bit read/write Configuration register that allows the user to select the different features. These features include shutdown, ALERT output select as comparator or interrupt output, ALERT output polarity, fault queue cycle, temperature measurement resolution and One-shot mode (single conversion while in shutdown). These functions are described in detail in the following sections.

**REGISTER 4-5: CONFIGURATION REGISTER (CONFIG)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| One-Shot | Resolution | | Fault Queue | | ALERT Polarity | COMP/INT | Shut-down |
| bit 7 | | | | | | | bit 0 |

bit 7 **ONE-SHOT bit**
1 = Enabled
0 = Disabled (Power-up default)

bit 5-6 **ΣΔ ADC RESOLUTION bits**
00 = 9 bit (Power-up default)
01 = 10 bit
10 = 11 bit
11 = 12 bit

bit 3-4 **FAULT QUEUE bits**
00 = 1 (Power-up default)
01 = 2
10 = 4
11 = 6

bit 2 **ALERT POLARITY bit**
1 = Active-high
0 = Active-low (Power-up default)

bit 1 **COMP/INT bit**
1 = Interrupt mode
0 = Comparator mode (Power-up default)

bit 0 **SHUTDOWN bit**
1 = Enable
0 = Disable (Power-up default)

| **Legend:** | | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| - n = Value at POR | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

#### 4.3.4.1 Shutdown Mode

The Shutdown mode disables all power-consuming activities (including temperature sampling operations) while leaving the serial interface active. The device consumes 2 µA (max.) in this mode. It remains in this mode until the Configuration register is updated to enable continuous conversion or until power is recycled.

In Shutdown mode, the CONFIG, $T_A$, $T_{SET}$ and $T_{HYST}$ registers can be read or written to; however, the serial bus activity will increase the shutdown current.

#### 4.3.4.2 One-Shot Mode

The TCN75A can also be used in a One-shot mode that can be selected using bit 7 of the CONFIG register. The One-shot mode performs a single temperature measurement and returns to Shutdown mode. This mode is especially useful for low-power applications where temperature is measured upon command from a controller. For example, a 9-bit $T_A$ in One-shot mode consumes 200 µA (typ.) for 30 ms and 0.1 µA (typ.) during shutdown.

To access this feature, the device needs to initially be in Shutdown mode. This is done by sending a byte to the CONFIG register with bit 0 set <`1`> and bit 7 cleared <`0`>. Once the device is in Shutdown mode, the CONFIG register needs to be written to again, with bit 0 and bit 7 set <`1`>. This begins the single conversion cycle of $t_{CONV}$, 30ms for 9-bit data. Once the conversion is completed, $T_A$ is updated and bit 7 of CONFIG becomes cleared <`0`> by the TCN75A.

**TABLE 4-6: SHUTDOWN AND ONE-SHOT MODE DESCRIPTION**

| Operational Mode | One-Shot (Bit 7) | Shutdown (Bit 0) |
|---|---|---|
| Continuous Conversion | 0 | 0 |
| Shutdown | 0 | 1 |
| Continuous Conversion (One-shot is ignored) | 1 | 0 |
| One-shot | 1 | 1 |

**Note:** The shutdown command <`01`> needs to be programmed before sending a one-shot command <`11`>.

#### 4.3.4.3 ALERT Output Configuration

The ALERT output can be configured as either a comparator output or as Interrupt Output mode using bit 1 of CONFIG. The polarity can also be specified as an active-high or active-low using bit 2 of CONFIG. The following sections describe each output mode, while Figure 4-3 gives a graphical description.

#### 4.3.4.4 Comparator Mode

In Comparator mode, the ALERT output is asserted when $T_A$ is greater than $T_{SET}$. The pin remains active until $T_A$ is lower than $T_{HYST}$. The Comparator mode is useful for thermostat-type applications, such as turning on a cooling fan or triggering a system shutdown when the temperature exceeds a safe operating range.

In Comparator mode, if the device enters the Shutdown mode with asserted ALERT output, the output remains active during shutdown. The device must be operating in continuous conversion, with $T_A$ below $T_{HYST}$, for the ALERT output to be deasserted.

#### 4.3.4.5 Interrupt Mode

In Interrupt mode, the ALERT output is asserted when $T_A$ is greater than $T_{SET}$. However, the output is deasserted when the user performs a read from any register. This mode is designed for interrupt-driven, microcontroller-based systems. The microcontroller receiving the interrupt will have to acknowledge the interrupt by reading any register from the TCN75A. This will clear the interrupt and the ALERT pin will become deasserted. When $T_A$ drifts below $T_{HYST}$, the TCN75A outputs another interrupt and the controller needs to read a register to deassert the ALERT output. Shutting down the device will also reset, or deassert, the ALERT output.

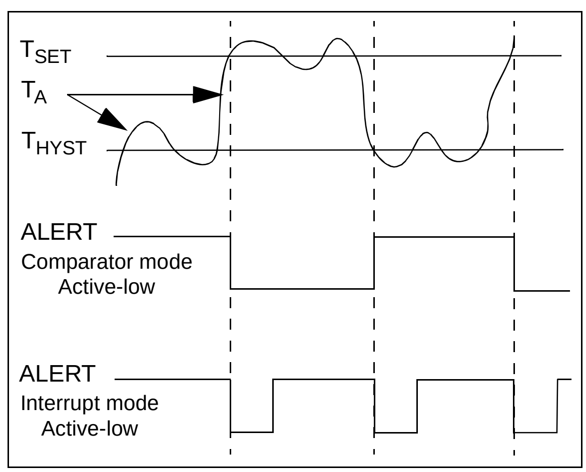



***FIGURE 4-3:*** *Alert Output.*

#### 4.3.4.6 Fault Queue

The fault queue feature can be used as a filter to lessen the probability of spurious activation of the ALERT pin. $T_A$ must remain above $T_{SET}$ for the consecutive number of conversion cycles selected using the Fault Queue bits. Bit 3 and bit 4 of CONFIG can be used to select up to six fault queue cycles. For example, if six fault queues are selected, $T_A$ must be greater than $T_{SET}$ for six consecutive conversions before ALERT is asserted as a comparator or an interrupt output.

This queue setting also applies for $T_{HYST}$. If six fault queues are selected,$T_A$ must remain below $T_{HYST}$ for six consecutive conversions before ALERT is deasserted (Comparator mode) or before another interrupt is asserted (Interrupt mode).

#### 4.3.4.7 ΣΔ ADC Resolution

The TCN75A provides access to select the ADC resolution from 9-bit to 12-bit using bit 6 and bit 5 of the CONFIG register. The user can gain better insight into the trends and characteristics of the ambient temperature by using a finer resolution. Increasing the resolution also reduces the quantization error. Figure 2-4 shows accuracy versus resolution.

Table 4-1 shows the $T_A$ register conversion time for the corresponding resolution.

**TABLE 4-1: RESOLUTION AND CONVERSION TIME**

| Bits | Resolution °C/bit (typ.) | $t_{CONV}$ (typ.) |
|---|---|---|
| 9 | 0.5 | 30 ms |
| 10 | 0.25 | 60 ms |
| 11 | 0.125 | 120 ms |
| 12 | 0.0625 | 240 ms |

## 4.4 Summary of Power-up Condition

The TCN75A has an internal Power-on Reset (POR) circuit. If the power supply voltage $V_{DD}$ glitches down to the 1.7V (typ.) threshold, the device resets the registers to the power-up default settings.

Table 4-2 shows the power-up default summary.

**TABLE 4-2: POWER-UP DEFAULTS**

| Register | Data (Hex) | Power-up Defaults |
|---|---|---|
| $T_A$ | 0000 | 0°C |
| $T_{SET}$ | A000 | 80°C |
| $T_{HYST}$ | 9600 | 75°C |
| Pointer | 00 | Temperature register |
| CONFIG | 00 | Continuous Conversion<br>Comparator mode<br>Active-low Output<br>Fault Queue 1<br>9-bit Resolution |

At power-up, the TCN75A has an inherent 2 ms (typ.) power-up delay before updating the registers with default values and start a conversion cycle. This delay reduces register corruption due to unsettled power. After power-up, it takes $t_{CONV}$ for the TCN75A to update the $T_A$ register with valid temperature data.

# 5.0 SERIAL COMMUNICATION

## 5.1 2-Wire I²C™ Compatible Interface

The TCN75A serial clock input (SCLK) and the bidirectional Serial Data (SDA) line form a 2-wire bidirectional serial port for communication.

The following bus protocol has been defined:

**TABLE 5-1: SERIAL BUS CONVENTIONS**

| Term | Description |
|---|---|
| Transmitter | Device sending data to the bus |
| Receiver | Device receiving data from the bus |
| Master | The device that controls the serial bus, typically a microcontroller |
| Slave | The device addressed by the master, such as the TCN75A |
| START | A unique signal from master to initiate serial interface with a slave |
| STOP | A unique signal from the master to terminate serial interface from a slave |
| Read/Write | A read or write to the TCN75A registers |
| ACK | A receiver Acknowledges (ACK) the reception of each byte by polling the bus |
| NAK | A receiver Not-Acknowledges (NAK) or releases the bus to show End-of-Data (EOD) |
| Busy | Communication is not possible because the bus is in use |
| Not Busy | The bus is in the idle state, both SDA and SCLK remain high |
| Data Valid | SDA must remain stable before SCLK becomes high in order for a data bit to be considered valid. During normal data transfers, SDA only changes state while SCLK is low. |

### 5.1.1 DATA TRANSFER

Data transfers are initiated by a START condition, followed by a 7-bit device address and a 1-bit read/write. Acknowledge (ACK) from slave confirms the reception of each byte. Each access must be terminated by a STOP condition.

Data transfer may be initiated when the bus is in idle.

### 5.1.2 MASTER/SLAVE

The bus is controlled by a master device (typically a microcontroller) that controls the bus access and generates the START and STOP conditions. The TCN75A is a slave device and does not control other devices in the bus. Both master and slave devices can operate as either transmitter or receiver. However, the master device determines which mode is activated.

### 5.1.3 START/STOP CONDITION

A high-to-low transition of the SDA line (while SCLK is high) is the START condition. All data transfers must be preceded by a START condition from the master. If a START condition is generated during data transfer, the TCN75A resets and accepts the new START condition.

A low-to-high transition of the SDA line (while SCLK is high) is the STOP condition. All data transfers must be ended by a STOP condition from the master. If a STOP condition is introduced during data transmission, the TCN75A releases the bus.

### 5.1.4 ADDRESS BYTE

Following the START condition, the host must transmit the address byte to the TCN75A. The address for the TCN75A is <1001,A2,A1,A0> in binary, where the A0, A1 and A2 bits are set externally by connecting the corresponding pins to $V_{DD}$ <1> or GND <0>. The 7-bit address transmitted in the serial bit stream must match the selected address for the TCN75A to respond with an ACK.

Bit 8 in the address byte is a read/write bit. Setting this bit to '1' commands a read operation, while '0' commands a write operation.

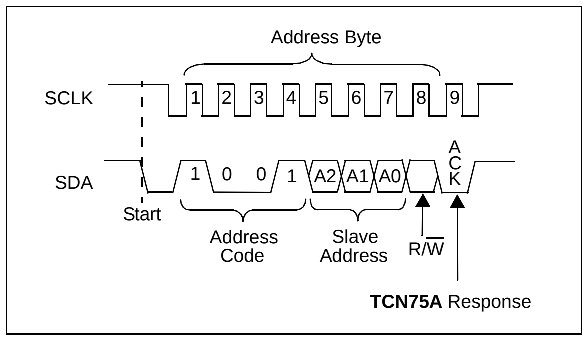



*FIGURE 5-1: Device Addressing.*

### 5.1.5 DATA VALID

After the start condition, each bit of data in transmission needs to be settled for time specified by $t_{SU\text{-}DATA}$ before SCLK toggles from low-to-high (refer to the Serial Interface Timing Specification).

### 5.1.6 ACKNOWLEDGE (ACK)

Each receiving device, when addressed, is obliged to generate an acknowledge bit after the reception of each byte. The master device must generate an extra clock pulse for ACK to be recognized.

The acknowledging device has to pull down the SDA line for $t_{SU\text{-}DATA}$ before the low-to-high transition of SCLK from the Master and remains pulled down for $t_{H\text{-}DATA}$ after high-to-low transition of SCLK.

During read, the master must signal an End-of-Data (EOD) to the slave by not generating an ACK bit once the last bit has been clocked out of the slave. In this case, the slave will leave the data line released to enable the master to generate the STOP condition.

## 5.2 Graphical Representation of the TCN75A Serial Protocols

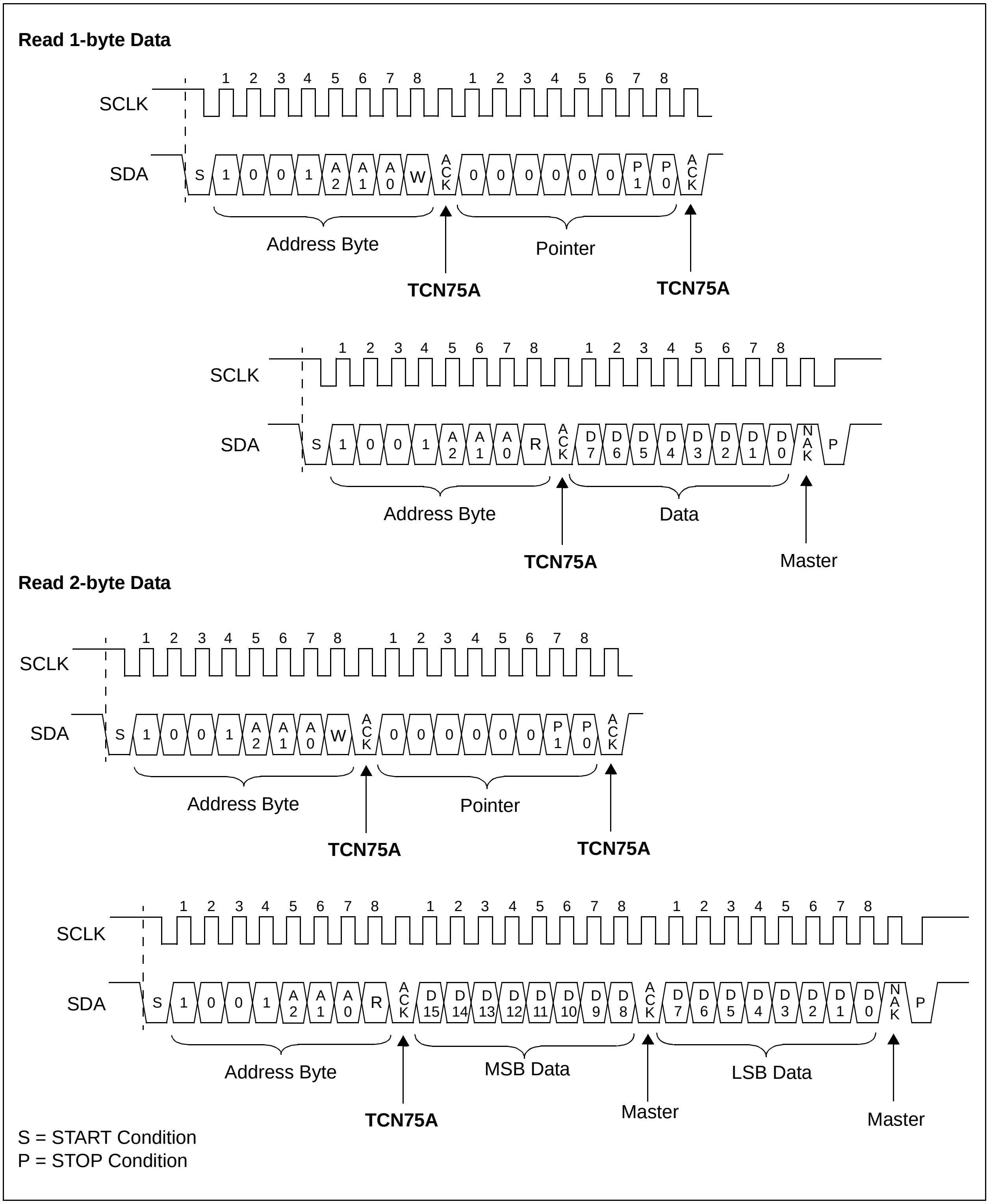



***FIGURE 5-2:*** *Read 1-byte and 2-byte data from a register.*

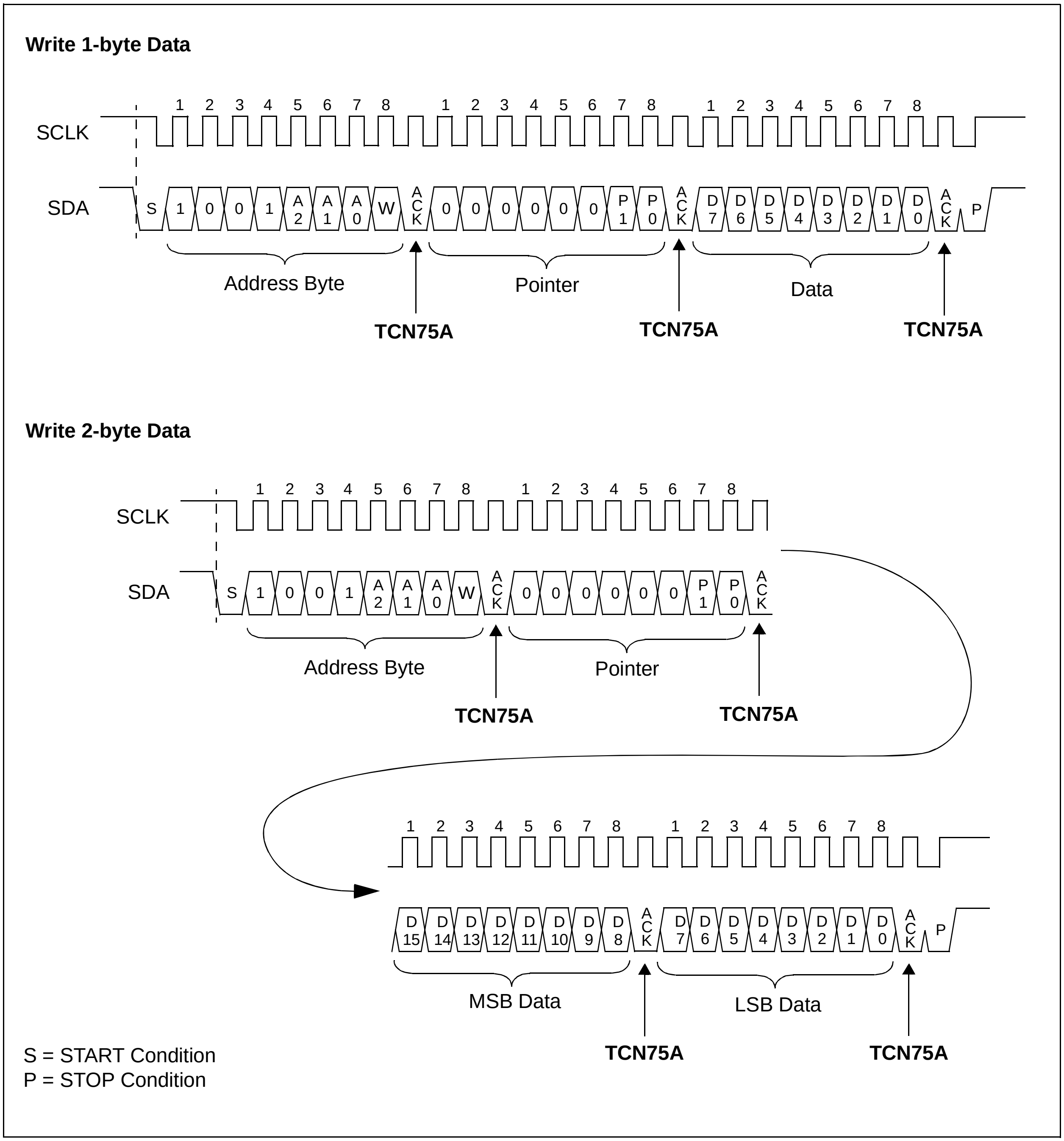
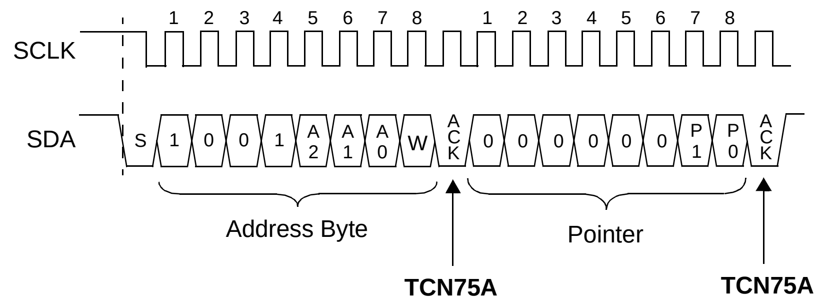
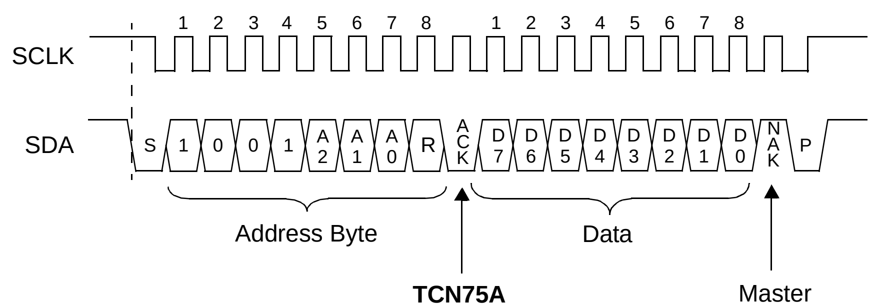



***FIGURE 5-3:*** *Write 1-byte and 2-byte data from a register.*

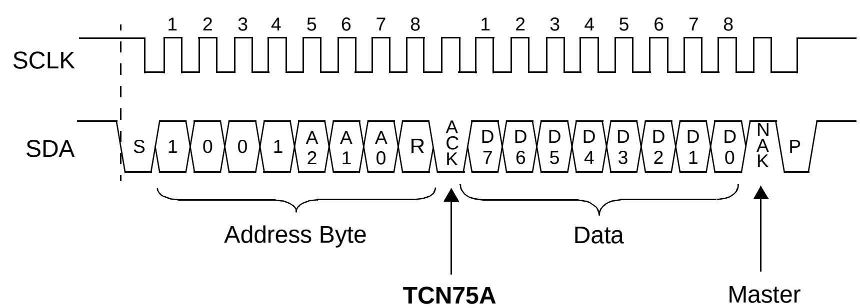
**Register Pointer Setting for Continuous Reception**




**Receive 1-byte Data**



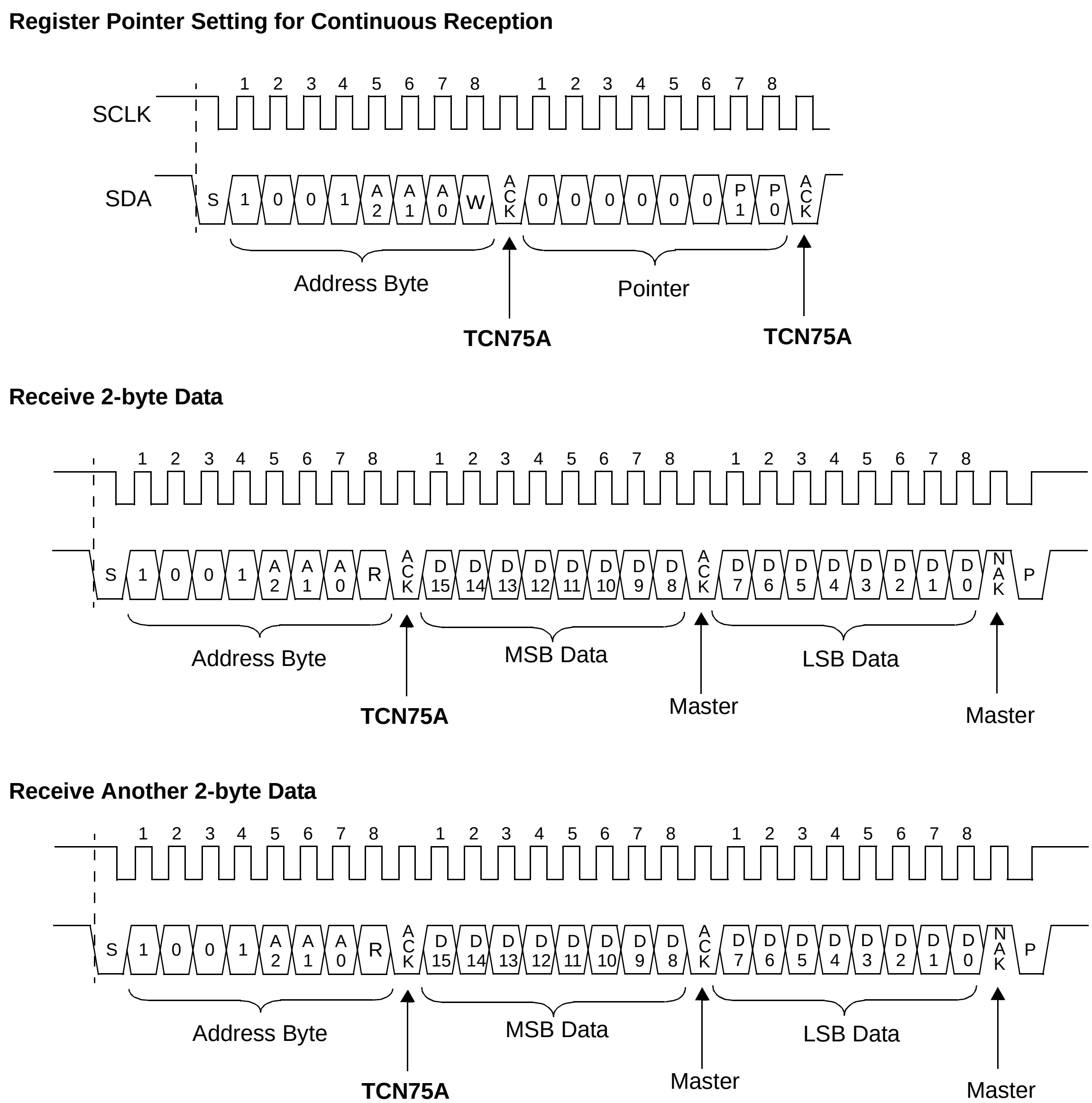

**Receive Another 1-byte Data**




**Note:** User can continue to receive 1-byte data indefinitely from a previously set register pointer.

S = START Condition
P = STOP Condition

***FIGURE 5-4:*** *Receive 1-byte data from previously set pointer.*




**Note:** User can continue to receive 2-byte data indefinitely from a previously set register pointer.

S = START Condition
P = STOP Condition

***FIGURE 5-5:*** *Receive 2-byte data from previously set pointer.*

# 6.0 APPLICATIONS INFORMATION

## 6.1 Connecting to the Serial Bus

The SDA and SCLK serial interface are open-drain pins that require pull-up resistors. This configuration is shown in Figure 6-1.

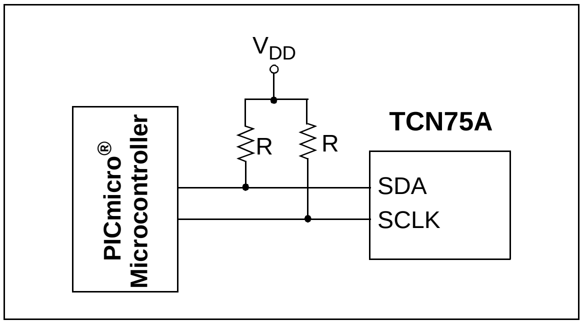



***FIGURE 6-1:*** *Pull-up Resistors On Serial Interface.*

The TCN75A is designed to meet 0.4V (max.) voltage drop at 3 mA of current. This allows the TCN75A to drive lower values of pull-up resistors and higher bus capacitance. In this application, all devices on the bus must meet the same pull-down current requirements.

## 6.2 Typical Application

Microchip provides several microcontroller product lines with Master Synchronous Serial Port Modules (MSSP) that include the $I^2C$ interface mode. This module implements all master and slave functions and simplifies the firmware development overhead. Figure 6-2 shows a typical application using the PIC16F737 as a master to control other Microchip slave products, such as EEPROM, fan speed controllers and the TCN75A temperature sensor connected to the bus.

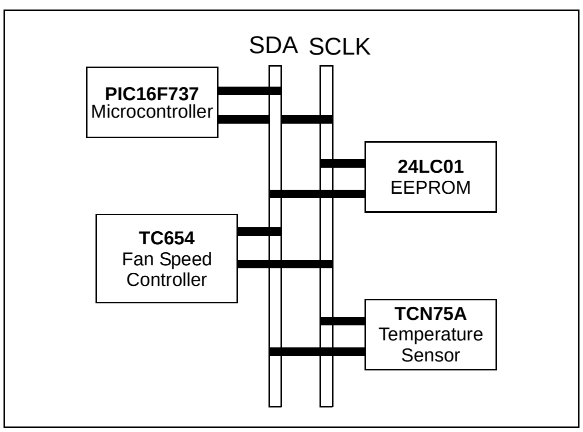



***FIGURE 6-2:*** *Multiple Devices on $I^2C$™ Bus*

The ALERT output can be wire-ORed with a number of other open-drain devices. In such applications, the output needs to be programmed as an active-low output. Most systems will require pull-up resistors for this configuration.

## 6.3 Layout Considerations

The TCN75A does not require any additional components besides the master controller in order to measure temperature. However, it is recommended that a decoupling capacitor of 0.1 µF to 1 µF be used between the $V_{DD}$ and GND pins. A high-frequency ceramic capacitor is recommended. It is necessary for the capacitor to be located as close as possible to the power pins in order to provide effective noise protection.

## 6.4 Thermal Considerations

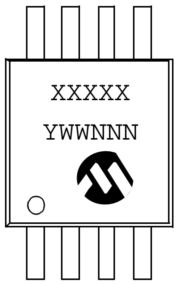
The TCN75A measures temperature by monitoring the voltage of a diode located in the die. A low-impedance thermal path between the die and the Printed Circuit Board (PCB) is provided by the pins. Therefore, the TCN75A effectively monitors the temperature of the PCB. However, the thermal path for the ambient air is not as efficient because the plastic device package functions as a thermal insulator.

A potential for self-heating errors can exist if the TCN75A SDA and SCLK communication lines are heavily loaded with pull-ups. Typically, the self-heating error is negligible because of the relatively small current consumption of the TCN75A. However, in order to maximize the temperature accuracy, the SDA and SCLK pins need to be lightly loaded.

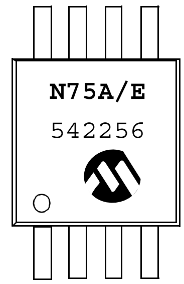
# 7.0 PACKAGING INFORMATION

## 7.1 Package Marking Information

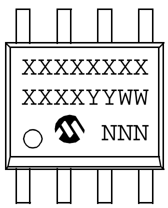
8-Lead MSOP



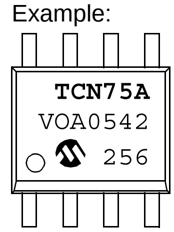

Example:




8-Lead SOIC (150 mil)



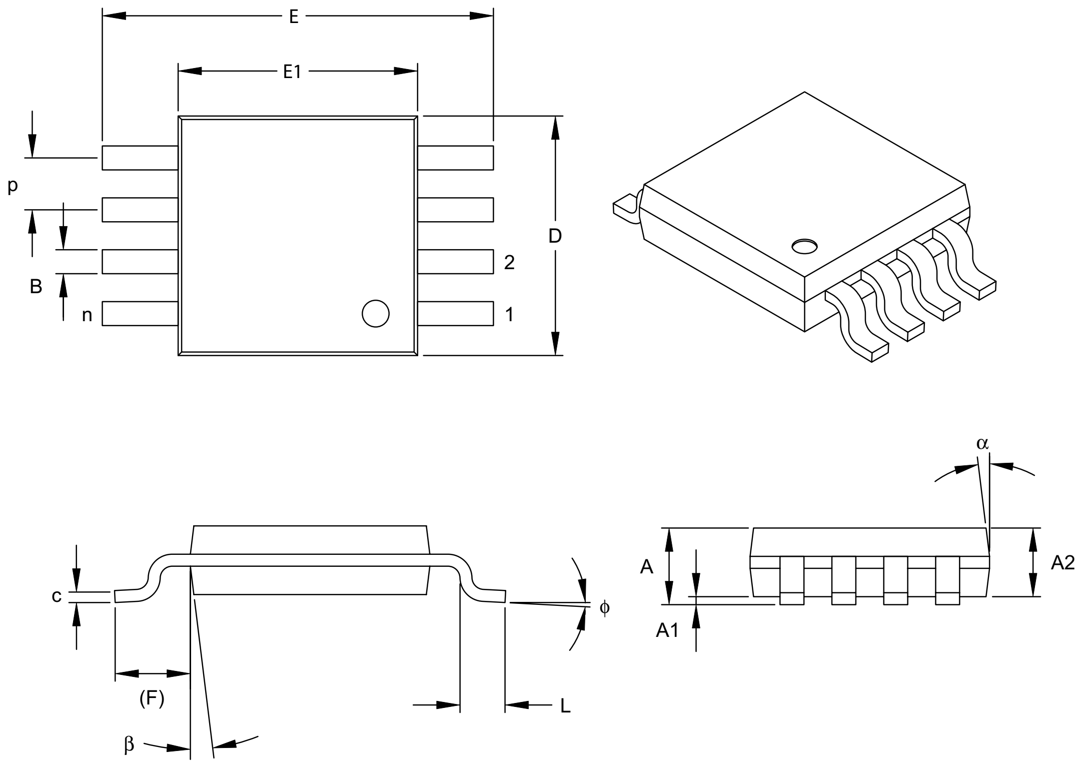

Example:




| | | |
|---|---|---|
| **Legend:** | XX...X | Customer-specific information |
| | Y | Year code (last digit of calendar year) |
| | YY | Year code (last 2 digits of calendar year) |
| | WW | Week code (week of January 1 is week ‘01’) |
| | NNN | Alphanumeric traceability code |
| | e3 | Pb-free JEDEC designator for Matte Tin (Sn) |
| | ***** | This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package. |

**Note**: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

## 8-Lead Plastic Micro Small Outline Package (UA) (MSOP)




| Units | | INCHES | | | MILLIMETERS* | | |
|---|---|---|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX | MIN | NOM | MAX |
| Number of Pins | n | | 8 | | | 8 | |
| Pitch | p | | .026 BSC | | | 0.65 BSC | |
| Overall Height | A | - | - | .043 | - | - | 1.10 |
| Molded Package Thickness | A2 | .030 | .033 | .037 | 0.75 | 0.85 | 0.95 |
| Standoff | A1 | .000 | - | .006 | 0.00 | - | 0.15 |
| Overall Width | E | | .193 TYP. | | | 4.90 BSC | |
| Molded Package Width | E1 | | .118 BSC | | | 3.00 BSC | |
| Overall Length | D | | .118 BSC | | | 3.00 BSC | |
| Foot Length | L | .016 | .024 | .031 | 0.40 | 0.60 | 0.80 |
| Footprint (Reference) | F | | .037 REF | | | 0.95 REF | |
| Foot Angle | φ | 0° | - | 8° | 0° | - | 8° |
| Lead Thickness | c | .003 | .006 | .009 | 0.08 | - | 0.23 |
| Lead Width | B | .009 | .012 | .016 | 0.22 | - | 0.40 |
| Mold Draft Angle Top | α | 5° | - | 15° | 5° | - | 15° |
| Mold Draft Angle Bottom | β | 5° | - | 15° | 5° | - | 15° |

*Controlling Parameter

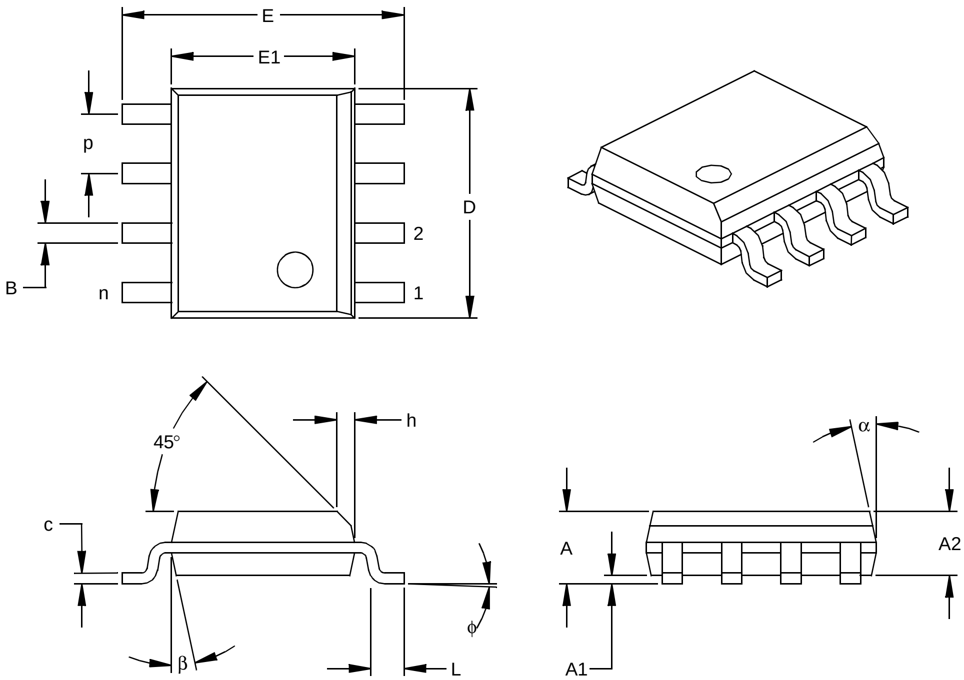
Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: MO-187

Drawing No. C04-111

## 8-Lead Plastic Small Outline (OA) – Narrow, 150 mil Body (SOIC)




| Units | | INCHES* | | | MILLIMETERS | | |
|---|---|---|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX | MIN | NOM | MAX |
| Number of Pins | n | | 8 | | | 8 | |
| Pitch | p | | .050 | | | 1.27 | |
| Overall Height | A | .053 | .061 | .069 | 1.35 | 1.55 | 1.75 |
| Molded Package Thickness | A2 | .052 | .056 | .061 | 1.32 | 1.42 | 1.55 |
| Standoff § | A1 | .004 | .007 | .010 | 0.10 | 0.18 | 0.25 |
| Overall Width | E | .228 | .237 | .244 | 5.79 | 6.02 | 6.20 |
| Molded Package Width | E1 | .146 | .154 | .157 | 3.71 | 3.91 | 3.99 |
| Overall Length | D | .189 | .193 | .197 | 4.80 | 4.90 | 5.00 |
| Chamfer Distance | h | .010 | .015 | .020 | 0.25 | 0.38 | 0.51 |
| Foot Length | L | .019 | .025 | .030 | 0.48 | 0.62 | 0.76 |
| Foot Angle | φ | 0 | 4 | 8 | 0 | 4 | 8 |
| Lead Thickness | c | .008 | .009 | .010 | 0.20 | 0.23 | 0.25 |
| Lead Width | B | .013 | .017 | .020 | 0.33 | 0.42 | 0.51 |
| Mold Draft Angle Top | α | 0 | 12 | 15 | 0 | 12 | 15 |
| Mold Draft Angle Bottom | β | 0 | 12 | 15 | 0 | 12 | 15 |

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010” (0.254mm) per side.
JEDEC Equivalent: MS-012
Drawing No. C04-057

## APPENDIX A: REVISION HISTORY

### Revision A (January 2005)

- Original release of this document.

**NOTES:**

## PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

| PART NO. | X | /XX |
|---|---|---|
| Device | Temperature Range | Package |

| | | |
|---|---|---|
| Device: | TCN75A: | Temperature Sensor |
| Temperature Range: | V = | -40°C to +125°C |
| Package: | OA = | Plastic SOIC, (150 mil Body), 8-lead |
| | UA = | Plastic Micro Small Outline (MSOP), 8-lead |

**Examples:**

a) TCN75AVOA 8LD SOIC package.
b) TCN75AVUA 8LD MSOP package.

**NOTES:**

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