TB066

Temperature Sensor Backgrounder

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INTRODUCTION

History has shown that consumers have an almost insatiable appetite for even greater computing horsepower. If you're old enough to remember, the mere thought of cryptic DOS software programs creeping along on your 286 platform just 16 years ago forces an almost irrepressible grin. However, as greater computing horsepower became available, our needs grew in direct proportion: the more capable the system, the more it could perform, and the more we depended on it. With this dependence came even greater demands for portability to match the life style of our highly mobile society. System manufacturers quickly realized that their next generation of equipment must be faster, more versatile and smaller. But increasing performance while reducing system size is a paradox in and of itself and creates other problems.

Increasing system performance requires both advanced digital chip architectures and faster system clock rates. More advanced architectures result in a greater amount of circuitry on-chip. Higher system clock rates cause chips to run hotter (primarily because of energy losses from parasitic circuit effects). As a result, thermal problems arise from a larger amount of circuitry on each chip running considerably faster (and therefore hotter) than ever before. This problem is exacerbated by the small physical space in which modern systems are packaged (e.g. notebook form factor). Since the heat cannot be removed quickly, careful thermal management techniques must be incorporated into every modern system design.

THEN AND NOW

Removing heat from the system was once a "hammer and chisel" exercise: the average system was packaged in an aluminum enclosure with lots of surface area for adequate heat sinking. Even if that wasn't enough, a finned heat sink or muffin fan could be added to increase the effective heatsink area. The system designer paid only moderate attention to thermal design and always knew he could brute force heatsink area in most cases. There was also plenty of air space in most systems, so airflow was free and unrestricted. Compare this to the present day notebook computer where the designer has neither the luxury of a large heatsink surface area, nor the "wide open spaces" of uncluttered circuit assemblies. If that's not enough, the designer now also has to contend with CPU chips that get hot enough to vaporize water during normal operation (though not recommended). Thermal management in systems of this kind is a far departure from that of the past. It's a delicate science where attention must be paid to thermal issues throughout all mechanical and electrical design. System temperature design points must be carefully picked and thermal balance designed with the precision and skill of a watchmaker. Thermal response of these systems are profiled during acceptance testing to assure they meet the design criteria. In addition, system thermal safeguards (insurance policies) are installed to prevent against thermal runaway in the event the system is placed in a hot environment, or suffers a catastrophic malfunction. Among these safeguards are special temperature sensing components collectively referred to as Temperature Sensors.

ENTER THE TEMPERATURE SENSOR

Early Temperature Sensors were electromechanical devices consisting of a switch composed of two dissimilar metals. Each metal had a different rate of expansion with temperature. When heat was applied, the difference in expansion rates caused an unbalanced force to be generated causing the switch to open. As the switch cooled off, the forces equalized and the switch closed. This approach was both crude and unreliable because continuous temperature cycling caused the metal switch to fatigue and ultimately break resulting in sensor failure. However, because there were no viable alternatives, use of this technology was wide spread. In later years, several companies offered simple solid state temperature sensors that relied on the electrical changes of materials with increasing temperature. These devices (among them: thermistors, RTDs and simple semiconductor temperature sensors) were superior to their electromechanical predecessors. However, they required external circuitry to linearize and translate the voltage or current outputs into electronic signals usable in the system. The board space consumed by the added circuitry and the added cost of manual calibration made these solutions less attractive to the design community at large. It wasn't until the last decade that semiconductor manufacturers began to combine solid state temperature sensing and application-specific peripheral circuitry into a single device, thus, providing a total system solution in a single small package. Temperature Sensors of this type are commonly referred to as Smart Temperature Sensors.

SMART TEMPERATURE SENSOR MARKET

The Smart Temperature Sensor's ability to translate a measured temperature into an electronic signal directly usable by the system has fueled their popularity. Today, application-optimized Smart Temperature Sensors are used across a wide range of applications. They safeguard expensive CPU chips in high performance computers, protect the output drivers of linear power amplifiers and perform a wide variety of cooling system control and other thermal protection and management functions. Smart Temperature Sensors with linear outputs (i.e. those that produce a voltage, current or digital code directly proportional to measured temperature) are used as sensing elements in process control equipment, laboratory instruments and other direct measurement applications. They offer the intrinsic benefits of small size, reliable and accurate operation, minimum external components and low installed cost. Most Smart Temperature Sensors are supplied in packages so small that they can be mounted in proximity of the devices they protect. This combination of features has fueled an explosive growth of these devices into the market.

THE TC623 SMART TEMPERATURE SENSOR

Recent mandates calling for more power efficient, "green" PCs have caused many of the power-saving techniques learned in developing notebook computers to be applied to desktop computers as well. Among these techniques is the reduction of system power dissipation by lowering power supply voltage from 5V to 3.3V. This helps to reduce the amount of heat generated by the system, increases system power efficiency and helps to extend operating time in battery-powered systems. Although newer processors, like the Pentium®, run at 3.3V, they still get hot enough to require careful thermal design and system safeguards, even in desktop PC applications.

The internals of modern desktop and notebook PCs have specific thermal profiles over normal system operating conditions. That is, the temperatures of the internal components will rise only so high because the thermal characteristics of the system are "fixed" by the system design itself. Thermal safeguards are installed by the system designer only to warn the system when temperatures exceed the thermal design. This can be caused by a malfunction or by operating the system at too high an ambient temperature. The TC623 is a Smart Temperature Sensor designed specifically to warn the system of an impending thermal overload situation.

The TC623 consists of a user-programmable temperature detector and built-in temperature sensor in a 0.150 wide, 8-pin surface mount package (see Figure 1). It is specifically designed to operate at power supply voltages as low as 2.7V for easy hookup to state-of-the-art CPU power supplies. Its small size and low operating voltage capability allows the TC623 to be mounted under (or near) the system CPU chip, the hottest component in the system (Figure 2). In some cases, a second TC623 is mounted on the motherboard to measure the internal ambient temperature of the system.

The TC623 furnishes three digital outputs: LOW LIMIT, HIGH LIMIT and CONTROL. The LOW LIMIT and HIGH LIMIT outputs become active when measured temperature exceeds the temperature trip points determined by the resistors on the LOW SET and HIGH SET inputs. The CONTROL output provides the correct logic for driving a cooling fan. It becomes active when temperature equals the HIGH SET value and inactive when temperature reaches the LOW SET value (Figure 3). In actual use, the TC623 is used as a temperature monitor in a holistic thermal protection scheme. Its outputs are connected to a microcontroller, ASIC or other piece of control logic dedicated to responding to an active output from the TC623. An example of a typical thermal safeguard design using the TC623 might go like this: assume a desktop computer having a normal CPU operating temperature of 65°C and a maximum allowable CPU temperature of 85°C. The TC623 is installed in close physical contact with the CPU chip (see Figure 2).

The TC623 LOW SET input is programmed at a trip point temperature of 70°C (5°C above normal) and the HIGH SET input for a trip point of 80°C (5°C below maximum). Under normal operating conditions, the CPU operating temperature never exceeds 70°C and the TC623 outputs remain off. Now assume the user relocates his computer to a very tight location with inadequate airflow for cooling. The internal temperature of the computer begins rising and the CPU temperature increases. When CPU temperature reaches 70°C, the TC623 LOW LIMIT becomes active and the system responds by reducing the CPU clock speed, thereby lowering power dissipation and reducing the rate of temperature increase. If temperature continues to rise, more aggressive steps must be taken. When the CPU temperature reaches the HIGH SET setting of 80°C, the HIGH LIMIT and CONTROL outputs both become active. The CONTROL output starts a CPU cooling fan while the HIGH LIMIT output reduces CPU clock speed even further. At this point, the system might notify the user that his system is running over temperature. If the HIGH LIMIT output persists after a given time interval, a very serious problem is indicated and the system might respond by powering down all but the DRAM (to save the user's work).

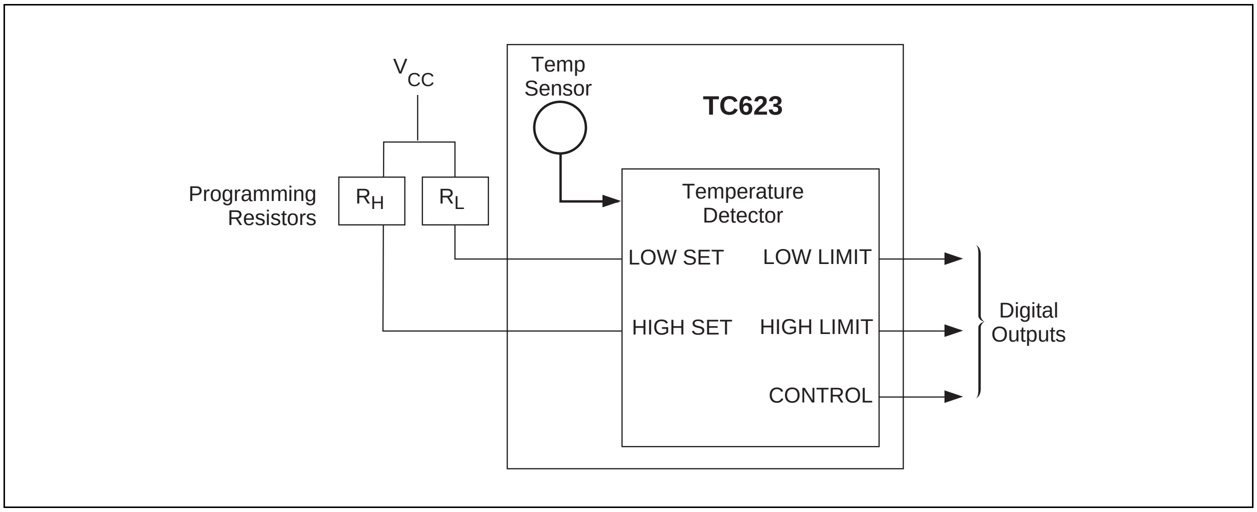

FIGURE 1: *TC623 Smart Temperature Sensor*

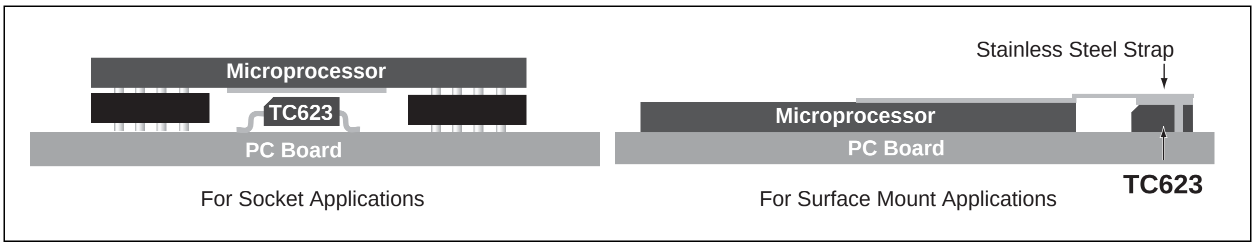

FIGURE 2: *TC623 Direct PC Board Mounting*

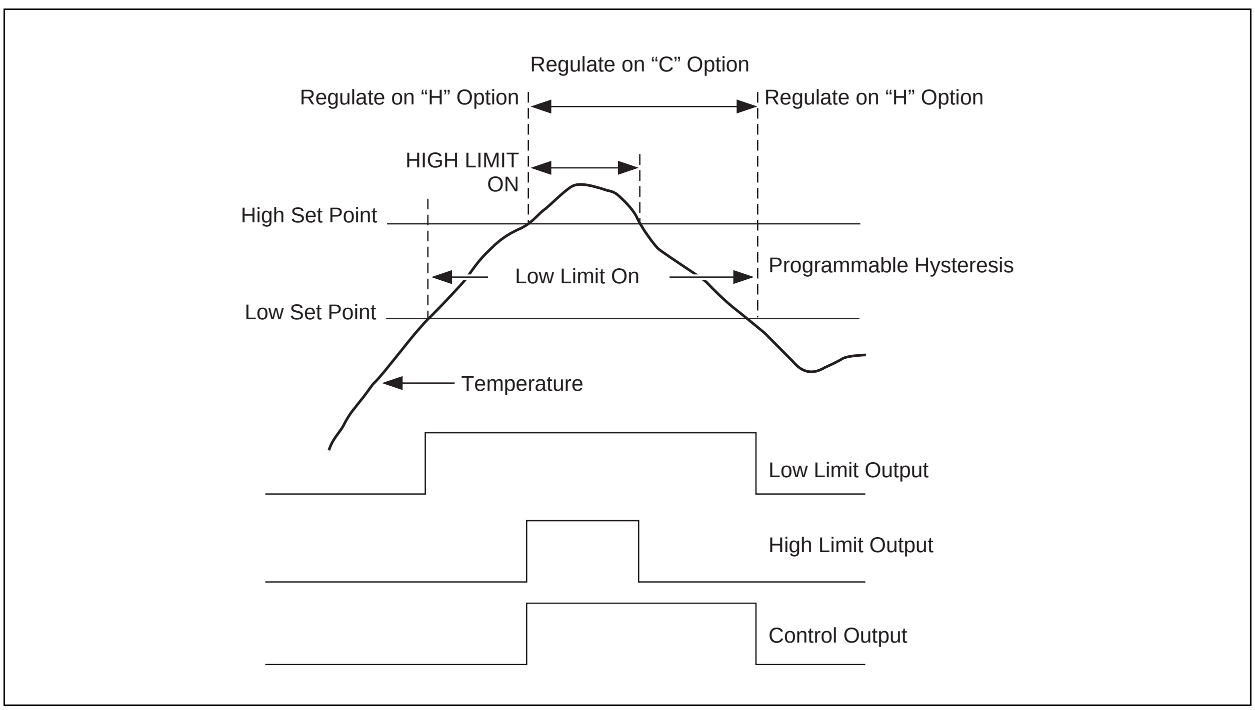

FIGURE 3: *Using resistors, the TC623 can be set to give an output from 0°C to 125°C*

SUMMARY

To satisfy demand for smaller, more powerful PCs, system designers have aggressively reduced enclosures and designed in faster processors. However, all that power stuffed into cramped quarters produces heat that threatens not only the processor, but also the entire system.

Microchip's Smart Temperature Sensors are low cost devices that safequard against this problem. For more information on effective thermal management products, contact your nearest Microchip sales office listed on the back of this publication or visit our website at www.microchip.com.

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