AN13.19

Resistance Error Correction

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INTRODUCTION

This application note describes the Resistance Error Correction feature available on many Microchip temperature sensor devices.

OVERVIEW

The information presented will show system designers that the Resistance Error Correction (REC) feature removes the need to compensate for series resistance in the thermal diode connection. Figure 1 shows a typical system and the remote diode-connected transistor could be a central processing unit (CPU) thermal diode or a discrete transistor located where the temperature must be measured.

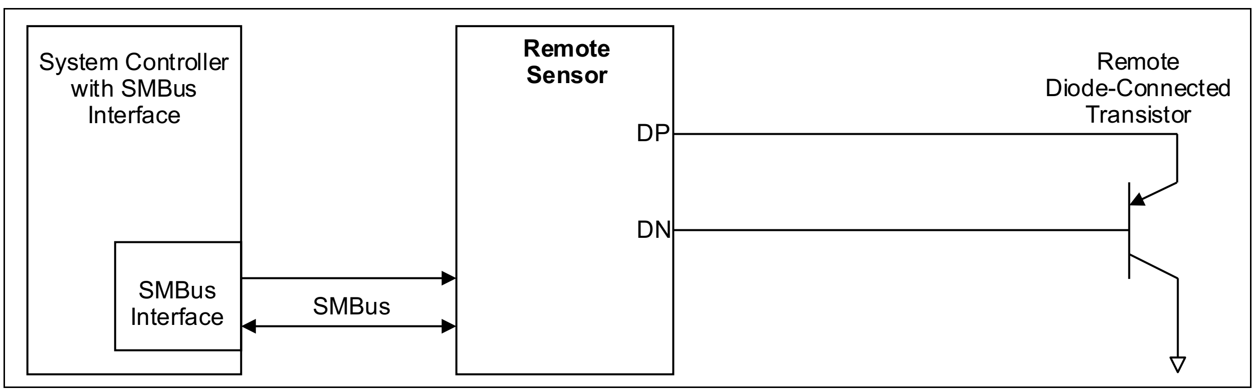

FIGURE 1: *Block Diagram of Typical Temperature Sensing System.*

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POSITIVE TEMPERATURE OFFSET RESULTING FROM SERIES RESISTANCE

Review of Temperature Sensing Method

A typical temperature sensor forces two fixed currents (I_{F1} and I_{F2}) into the thermal diode to measure temperature, as shown in Figure 2 below. The forward bias voltage (V_F) of the diode is measured as each of the two fixed currents is sourced into the diode. In Figure 2, the value of V_F measured at the DP/DN pins inside the chip is equivalent to the value of V_{BE} at the remote diode-connected transistor.

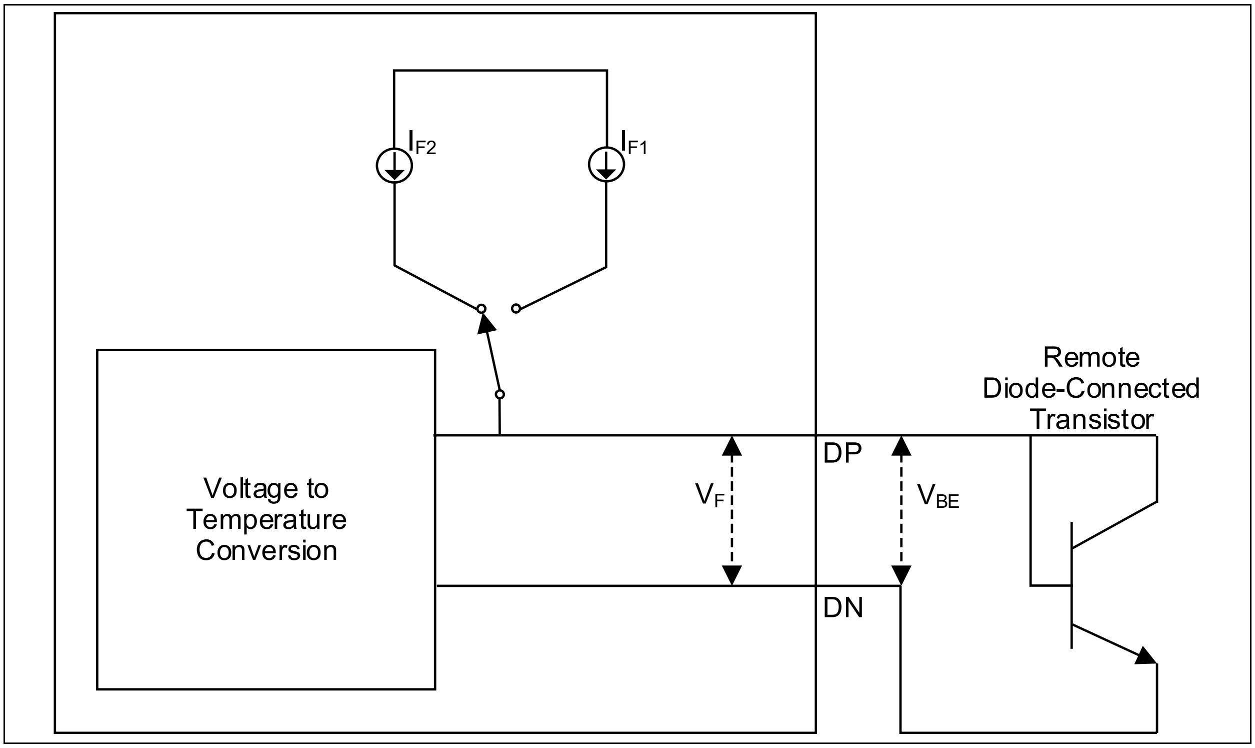

FIGURE 2: *Two Current Sources.*

The difference between the two values of V_F ($V_{F2} – V_{F1} = \Delta V_{BE}$) is used to determine the temperature, as shown in Equation 1.

EQUATION 1:

$$V_{F2} - V_{F1} = \eta \frac{kT}{q}\left[ln\left(\frac{I_{F2}}{I_{F1}}\right)\right]$$

Where:

k = Boltzmann's constant

T = Absolute temperature in Kelvin

q = Electron charge

η = Diode ideality factor

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Figure 3 shows that the relationship of $V_{F2} - V_{F1}$ to temperature is linear. In this plot, the Ideality Factor (η) is assumed to be 1.000 and the I_{F2}/I_{F1} ratio is 17. The value of $V_{F2} - V_{F1}$ will change to 244 μV when the temperature changes from 25°C to 26°C or from 100°C to 101°C.

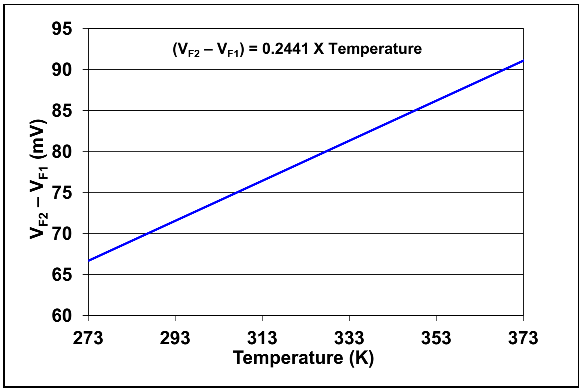

FIGURE 3: *$V_{F2} - V_{F1}$ vs. Temperature.*

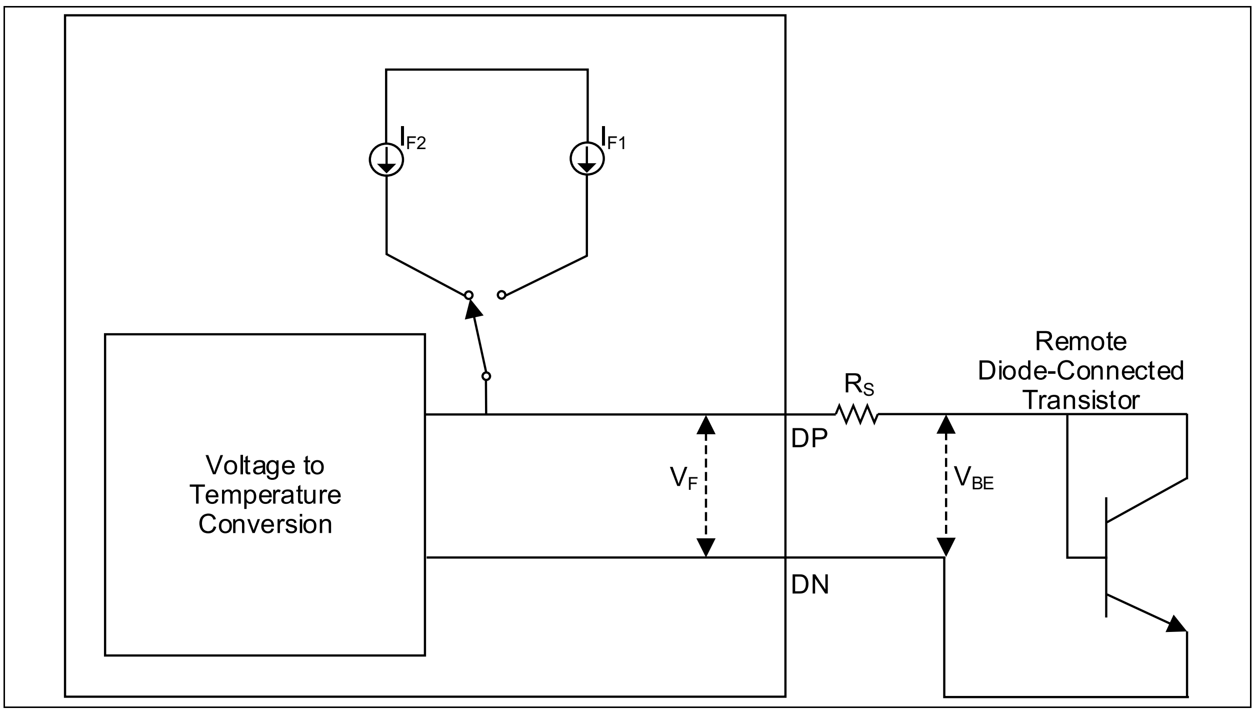

FIGURE 4: *Block Diagram of Temperature Monitoring Circuit.*

Positive Temperature Offset Resulting from Series Resistance

In the real world, series resistance will be present in the path from the DP pin to the actual junction of the diode and back to the DN pin of the temperature sensor. Sources of series resistance include package leads, Printed Circuit Board (PCB) traces, other forms of interconnect and the physical structure of the remote diode itself. In Figure 4, all these sources of series resistance are combined and shown as R_S.

When series resistance is present in the system, the V_F value measured at the DP/DN pins inside the chip is no longer equivalent to the value of V_{BE}. The V_F value with series resistance is shown in Equation 2.

EQUATION 2:

$$V_F = V_{BE} + (I_F \times R_S)$$

This R_S term will always induce a positive temperature measurement offset error. The reported temperature will be higher than the actual amount by the value obtained using Equation 3.

EQUATION 3:

$$T_{OFFSET} = \frac{q}{\eta k} \frac{(I_{F2} - I_{F1})R_S}{ln\left(\frac{I_{F2}}{I_{F1}}\right)}$$

This means that a system could be operating at an acceptable temperature but the sensor would report that it is beyond critical temperature because of the series resistance.

Example with Series Resistance

This example provides insight into the effects of series resistance on the detected temperature. Assume a value of I_{F1} = 10 µA and I_{F2} = 170 µA. A typical value of series resistance from a CPU data sheet is 3Ω.

EQUATION 4:

$$(I_{F2} - I_{F1})R_S = (170\ \mu A - 10\ \mu A) \times 3\Omega = 480\ \mu V$$

For an I_F ratio of 17, a 1° change in temperature equates to a 244 mV change in the $V_{F2} - V_{F1}$ term.

EQUATION 5:

$$\frac{480\ \mu V}{244\ \mu V} = 1.96$$

This series resistance term results in approximately a 2° error to the "real" temperature.

The remote thermal diode is often connected to the temperature sensor using PCB traces. Figure 5 shows typical values of series resistance for PCB traces at room temperature.

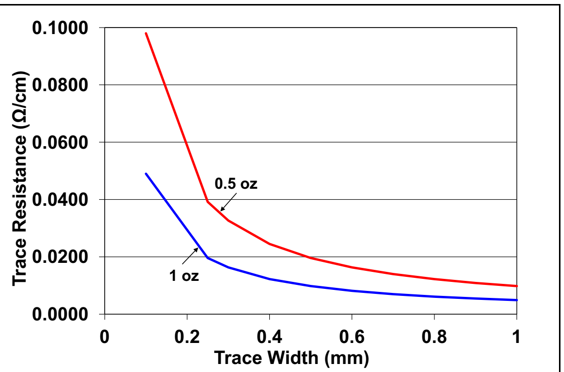

FIGURE 5: *Trace Resistance vs. Trace Width (at T = 25°C).*

In some systems, it may be practical to compensate for the error caused by series resistance by subtracting a constant offset value. However, this would require calculating a new offset value for each system because the total amount of series resistance added by the PCB traces will change depending on the physical properties of the board and on the dimensions of the traces. Moreover, changing the offset value often requires changing firmware that would otherwise not require a change. In addition, Figure 6 shows that the series resistance of PCB traces also changes over temperature.

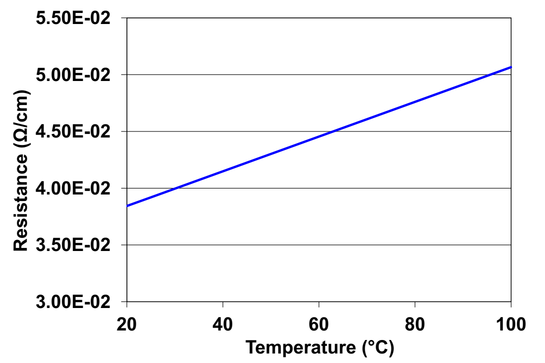

FIGURE 6: *Trace Resistance vs. Temperature (250 µm Traces, 0.5 oz Copper Plating).*

As the temperature of the PCB traces increases from 20°C to 60°C, the series resistance changes by approximately 32%. These small error terms should not be overlooked when designing systems with ±1°C accuracy components. The desired way to handle series resistance is to design with a Microchip temperature sensor that incorporates automatic resistance error correction.

Resistance Error Correction

Microchip temperature sensor devices that include resistance error correction implement in the analog front end of the chip. Resistance Error Correction is an automatic feature that eliminates the need to characterize and compensate for the series resistance. The REC feature corrects for as much as 100Ω of series resistance.

CONCLUSION

In conclusion, using a Microchip temperature sensor with REC capabilities automatically eliminates temperature errors induced by the series resistance that is present in all systems.

Microchip supplies a family of temperature sensors for a variety of applications. Several enhanced features, such as beta compensation and ideality configuration, are available. In addition, some devices are designed to work specifically with CPU thermal diodes. Please consult your Microchip representative or www.microchip.com for additional information.

REFERENCES

- Microchip Application Note 10.14 – *"Using Temperature Sensing Diodes with Remote Thermal Sensors"* (DS00001839)

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