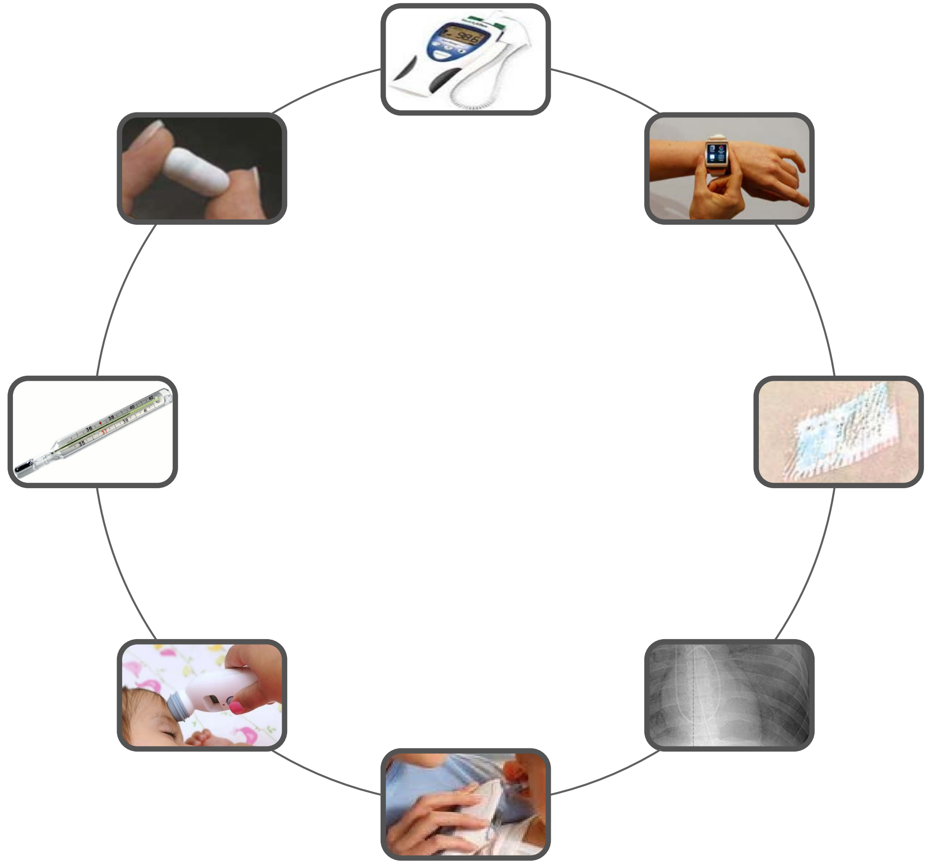
Learn How to Measure Body Temperature Accurately and Cost Effectively

Emmy Denton

Temperature Sensor Applications
Texas Instruments

March 17, 2015



Analog Temperature Sensors

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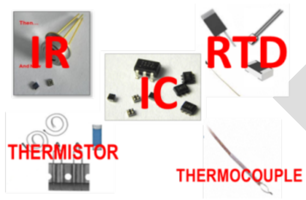
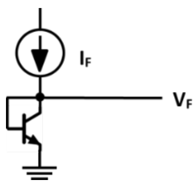
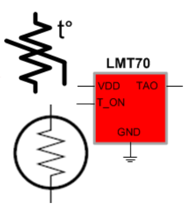


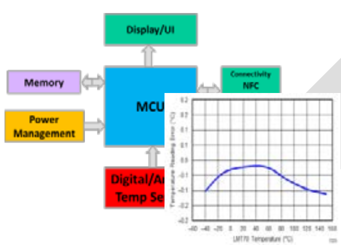
Overview and challenges of thermometry solutions



Principles behind IC temperature sensors

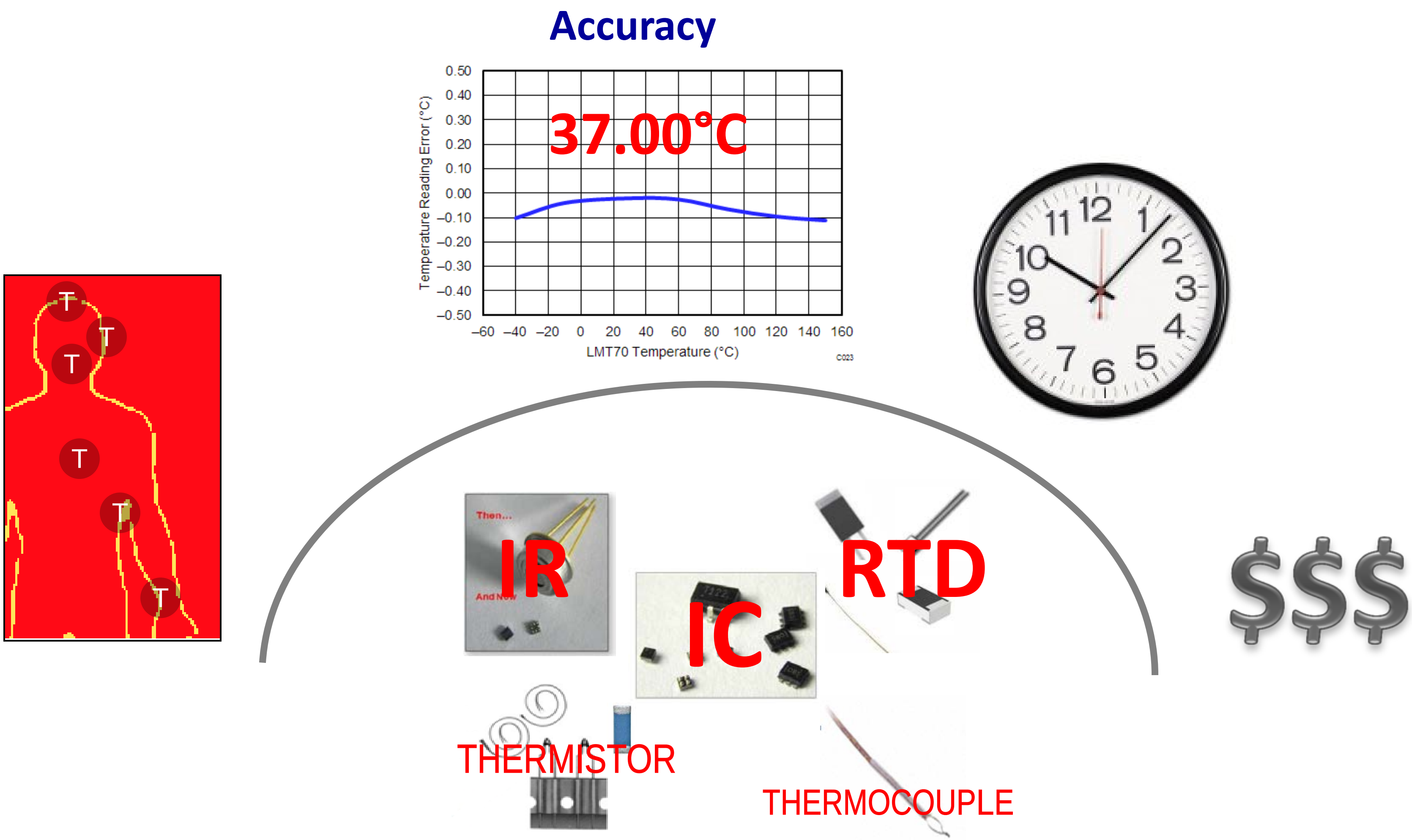


Comparison of different types of sensors

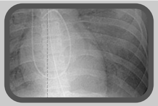
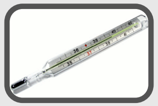
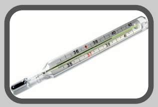
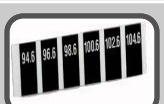


System implementation using IC temperature sensor

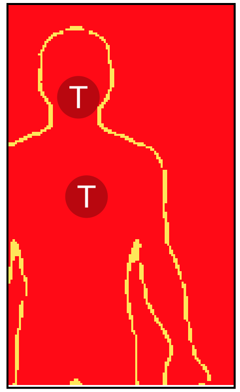
There are several technical challenges for measuring body temperature

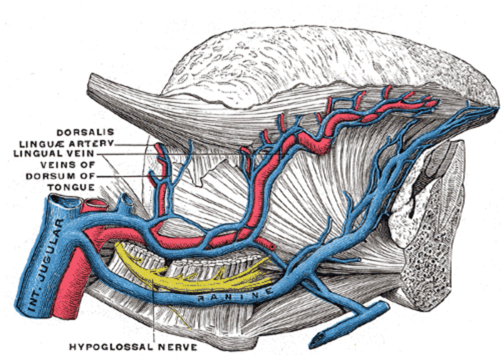


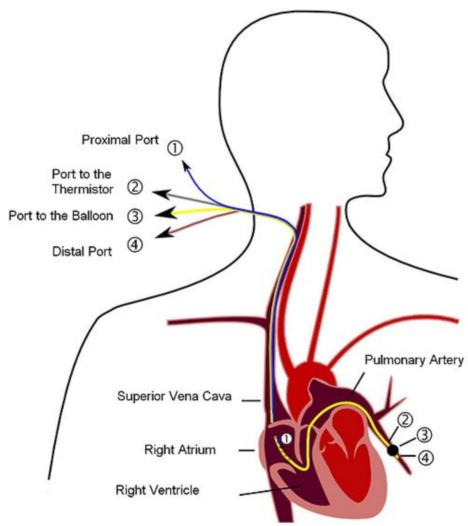
There are a variety of body locations that have been used

Locations		Target Accuracy	Application
	Pulmonary artery catheter	“Golden Standard”	Critically ill – blood flow
	Sublingual	0.1C	Home/hospital
	Rectal	0.1C	Home/hospital
	Superficial temporal artery	0.1C	Home/hospital
	Ear (ympanic)	0.2C	Home/hospital
	Telemetry pill (Intestinal)	0.1C	Athletics (heat stress)
	Wrist	0.5C	Fitness
	Axillary (armpit)	0.5C	Home
	Forehead (NFC or LCD sticker)	1C	Child/infant dispensable home

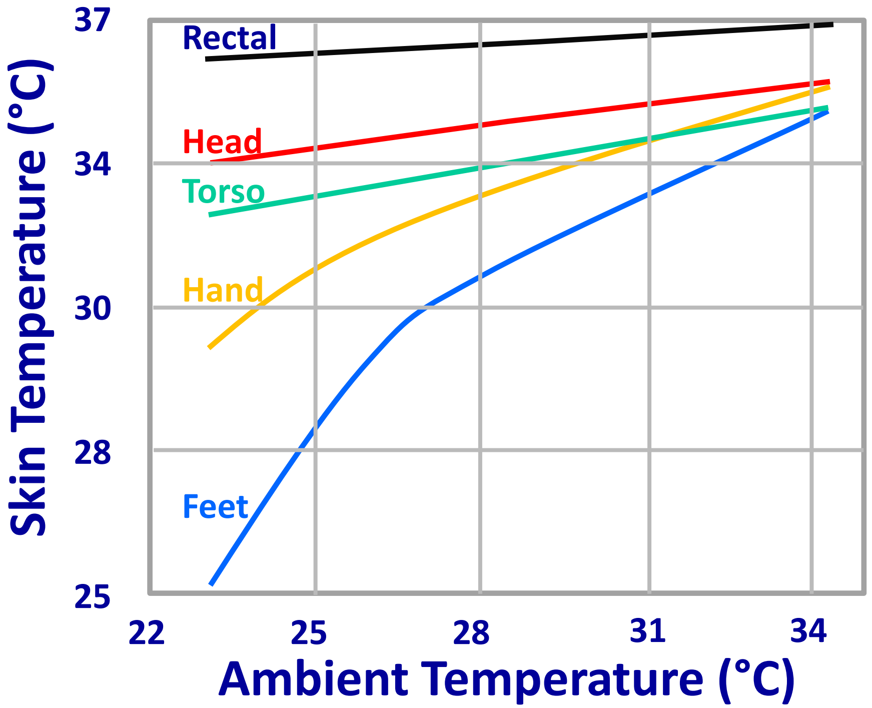
Most accurate sensing methods are internal to the body or in a body cavity

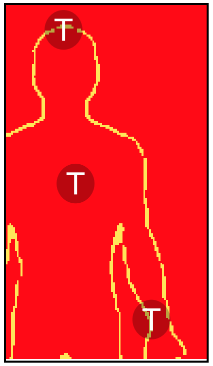






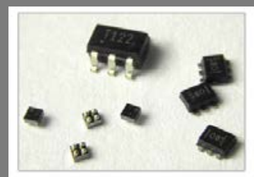
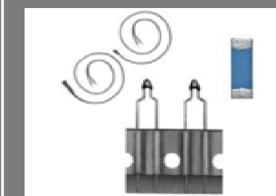
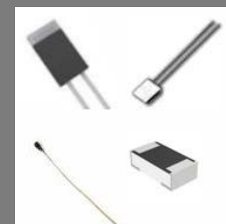
Skin temperature - How many sensors do you actually need to measure core temperature?



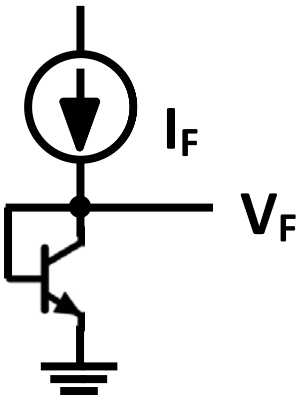


You regulate your core temperature by modulating your skin temperature through sweat and blood perfusion.

Complicating the matter further, there are a variety of temperature sensor types

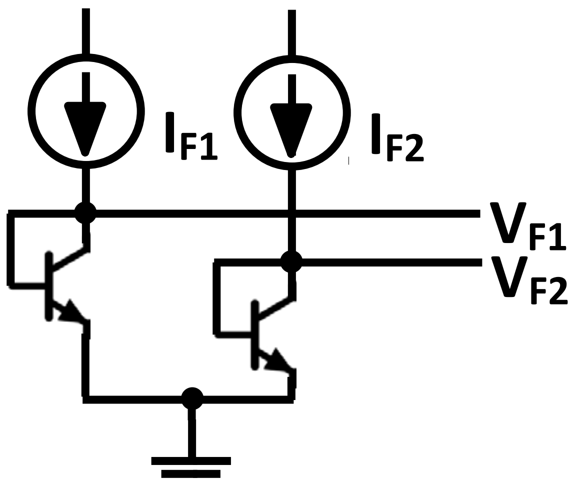
Criteria	Temp Sense IC 	Thermistor 	RTD 	Thermocouple 	IR Temp Sensor 
Temp Range	-55°C to +150°C	-100°C to +500°C	-240°C to 700°C	-267°C to **+2316°C**	-100°C to +500°C
Accuracy	**Meets requirements**	**Depends on calibration**	**Meets requirements**	**Depends on cold junction compensation**	**Depends on calibration**
Linearity	**Best**	Least	Better	Better	Better
Sensitivity	Better	**Best**	Less	Least	Less
Circuit Simplicity	**Simplest**	Simpler	Complex	Complex	Simple to Complex
Power	**Lowest**	Low	High	High	Medium
Cost	**$**	**$-$$$**	$$$	$$	$$

The principles behind IC temperature sensors are simply based on the temperature coefficient of a base emitter junction forward voltage drop



$$V_F = \frac{kT}{q} \ln\left(\frac{I_F}{I_S}\right)$$

Slope ≈ -2mV/°C

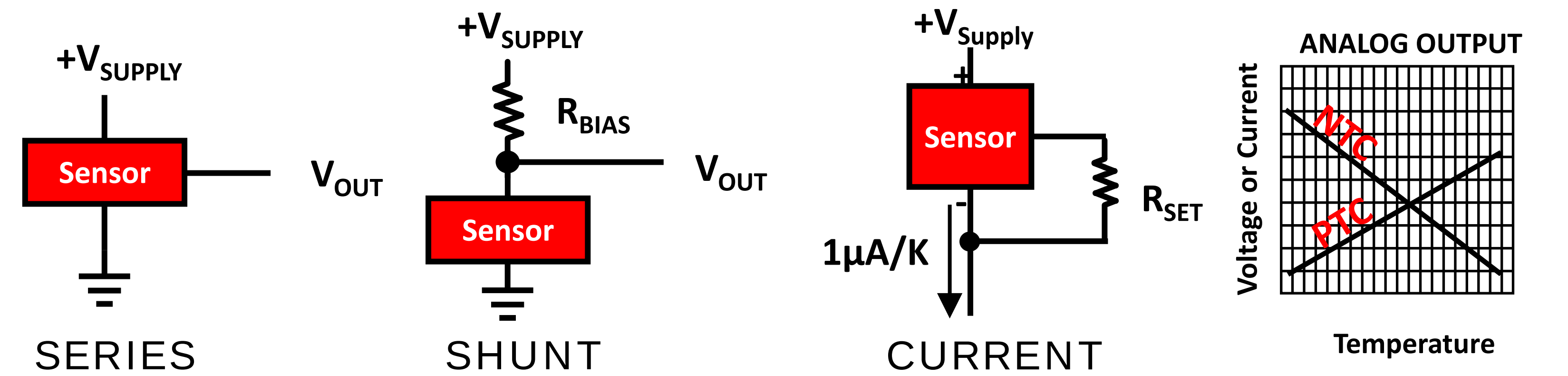


$$V_{F1} - V_{F2} = \frac{kT}{q} \ln \frac{J1}{J2}$$

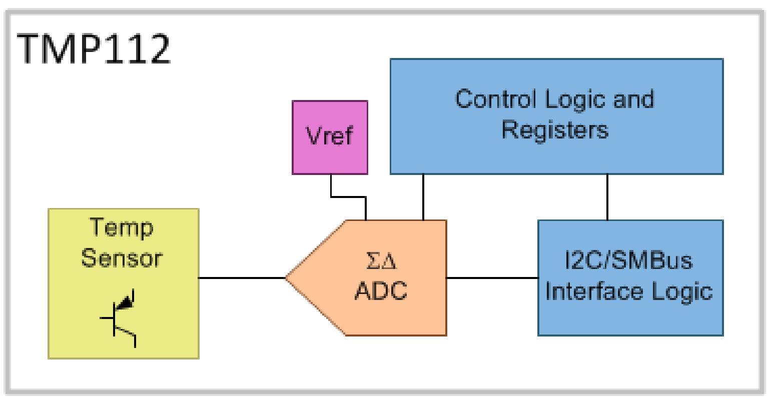
Slope ≈ 240 µV/°C
Compensates for Is

Types of IC temperature sensors include simple analog to more complex digital that simplify system design

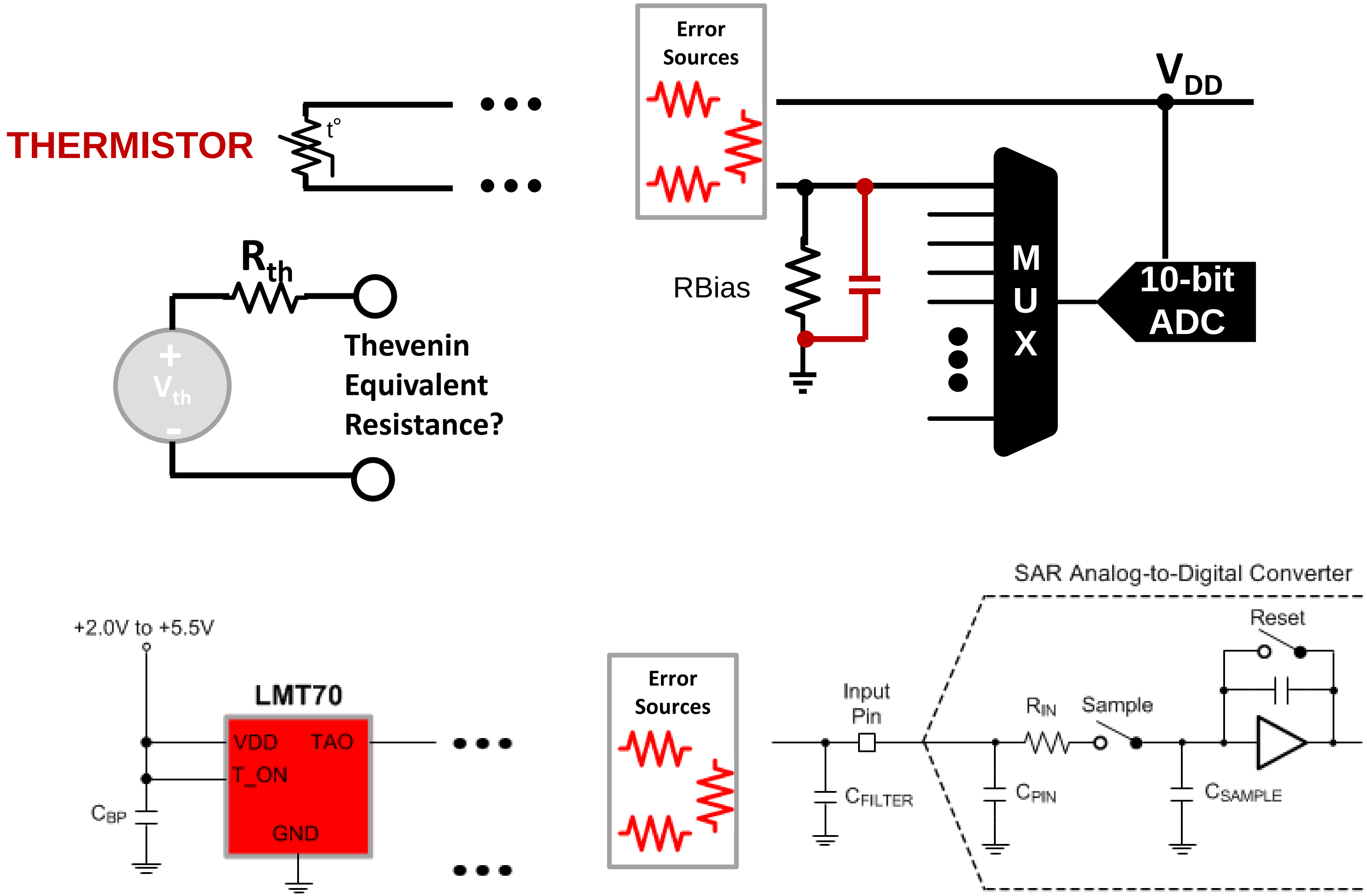
Analog Output



Digital Output



Challenges of output impedance

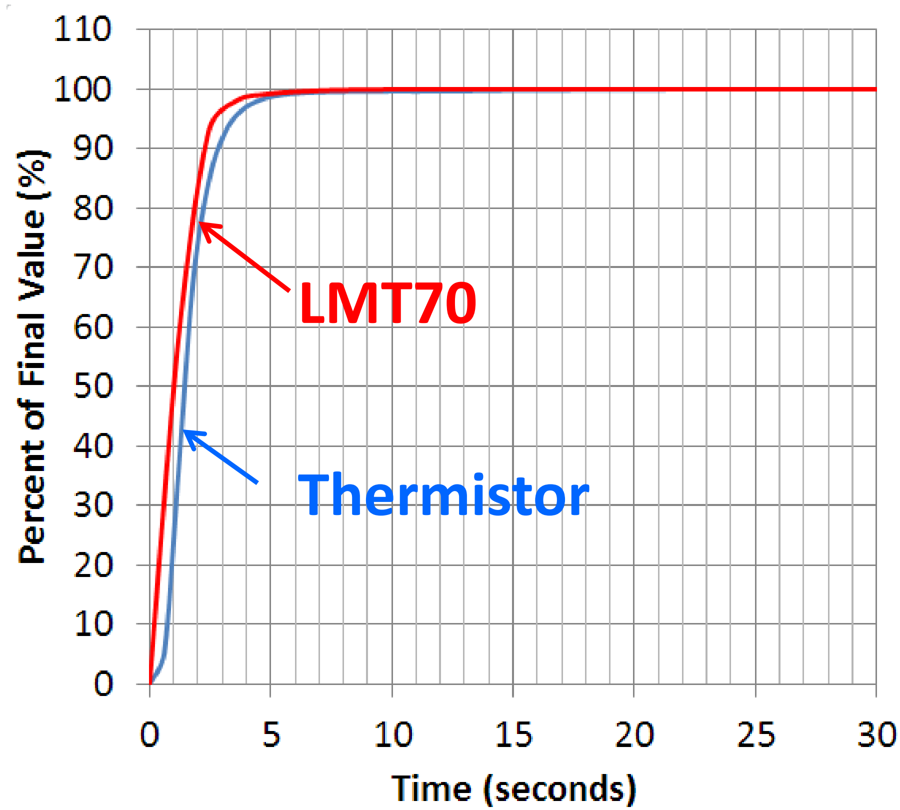


Response time of an IC temperature sensor is slightly better than a thermistor

Stainless Steel Probe Assembly

LMT70
DSBGA 4-bump
(0.8mm x 0.8mm)

Thermistor vs LMT70



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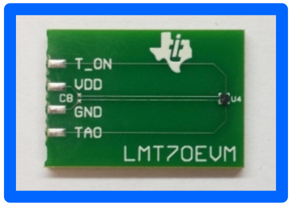
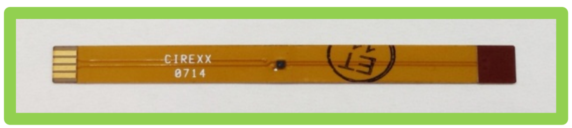
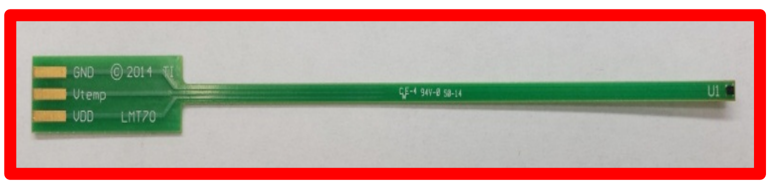
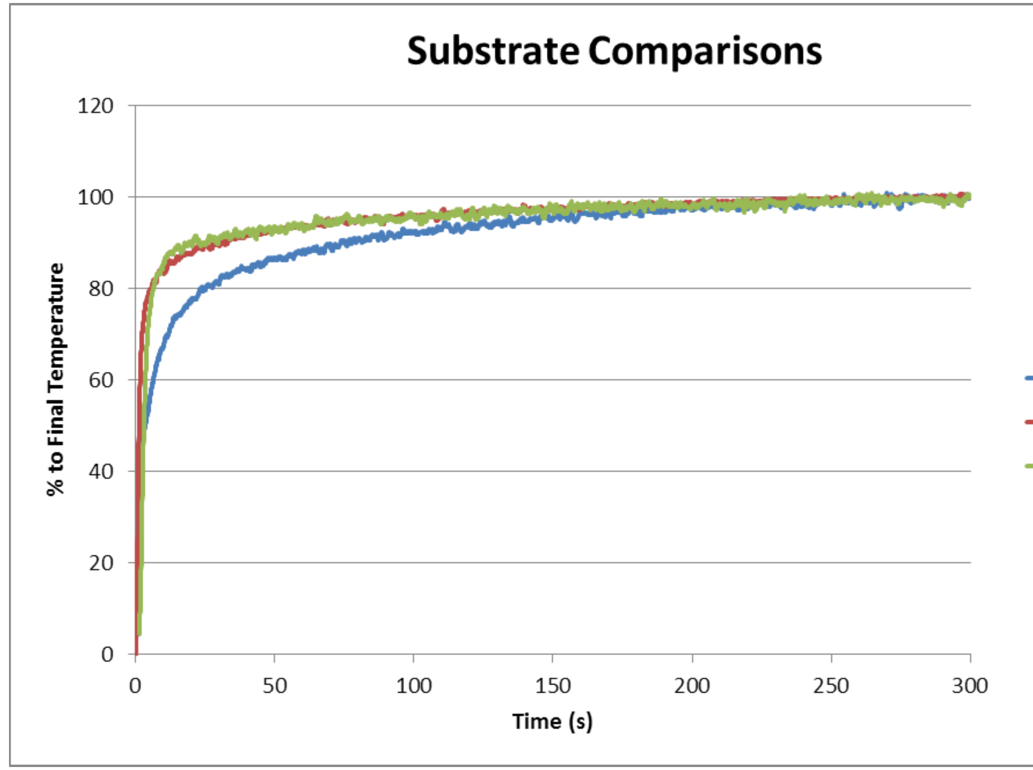
PCB material and layout can affect thermal response time



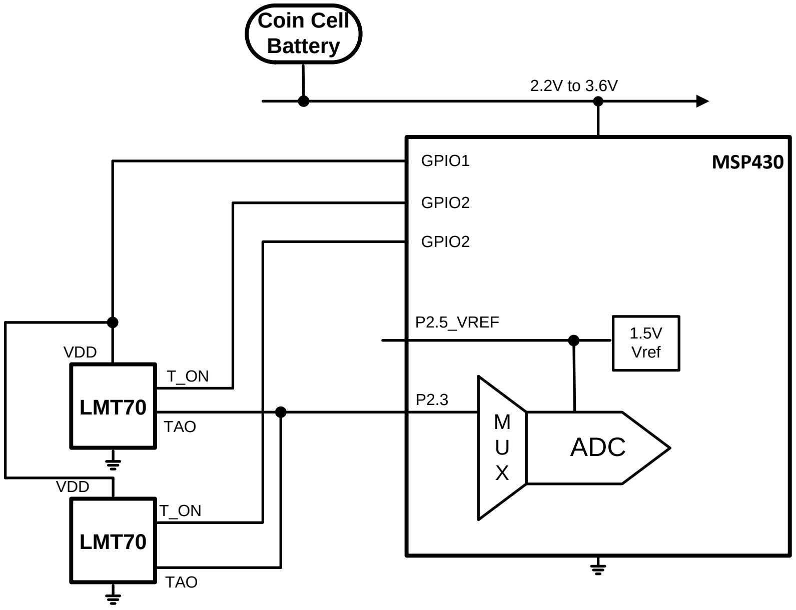




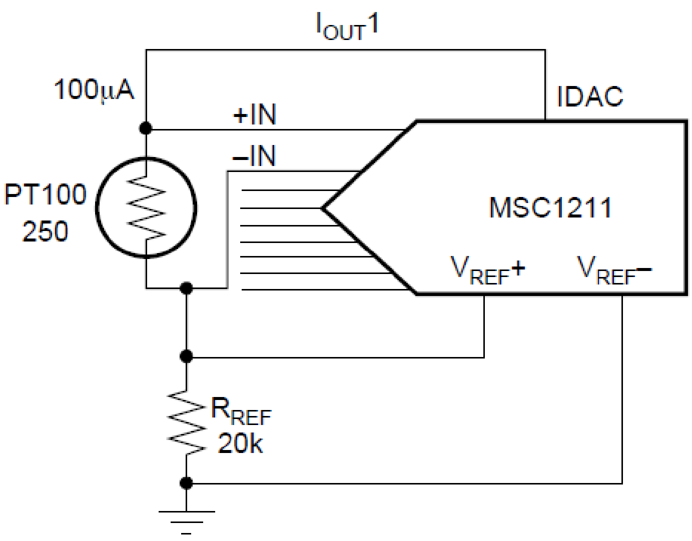


LMT70 requires less processor resources or analog signal processing than RTDs or thermistors

LMT70 is a single ended measurement

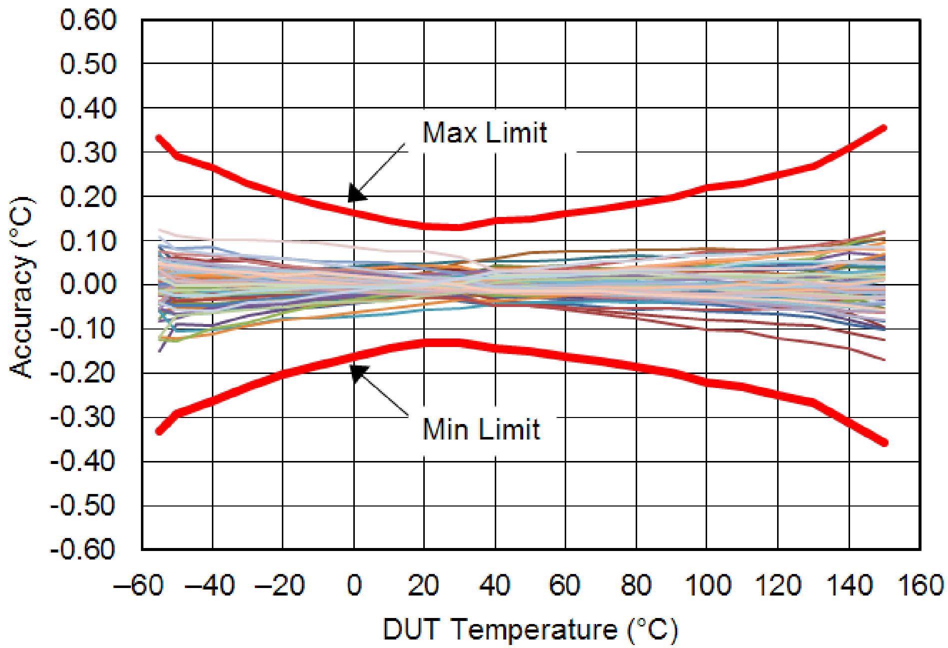


RTD requires differential measurement with 3 or 4 wire kelvin connections

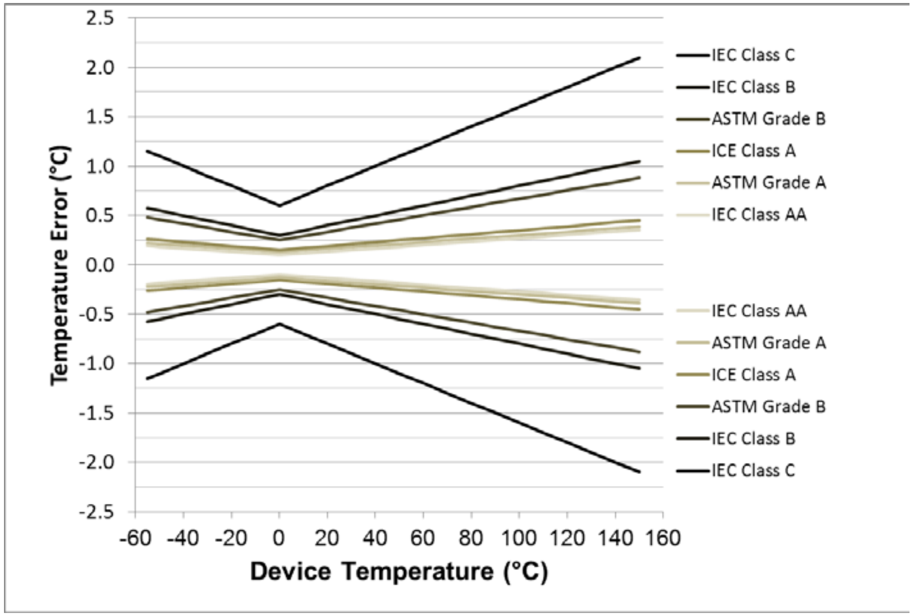


LMT70 has excellent accuracy over a wide range of -55°C to +150°C

LMT70 accuracy using LUT linear interpolation

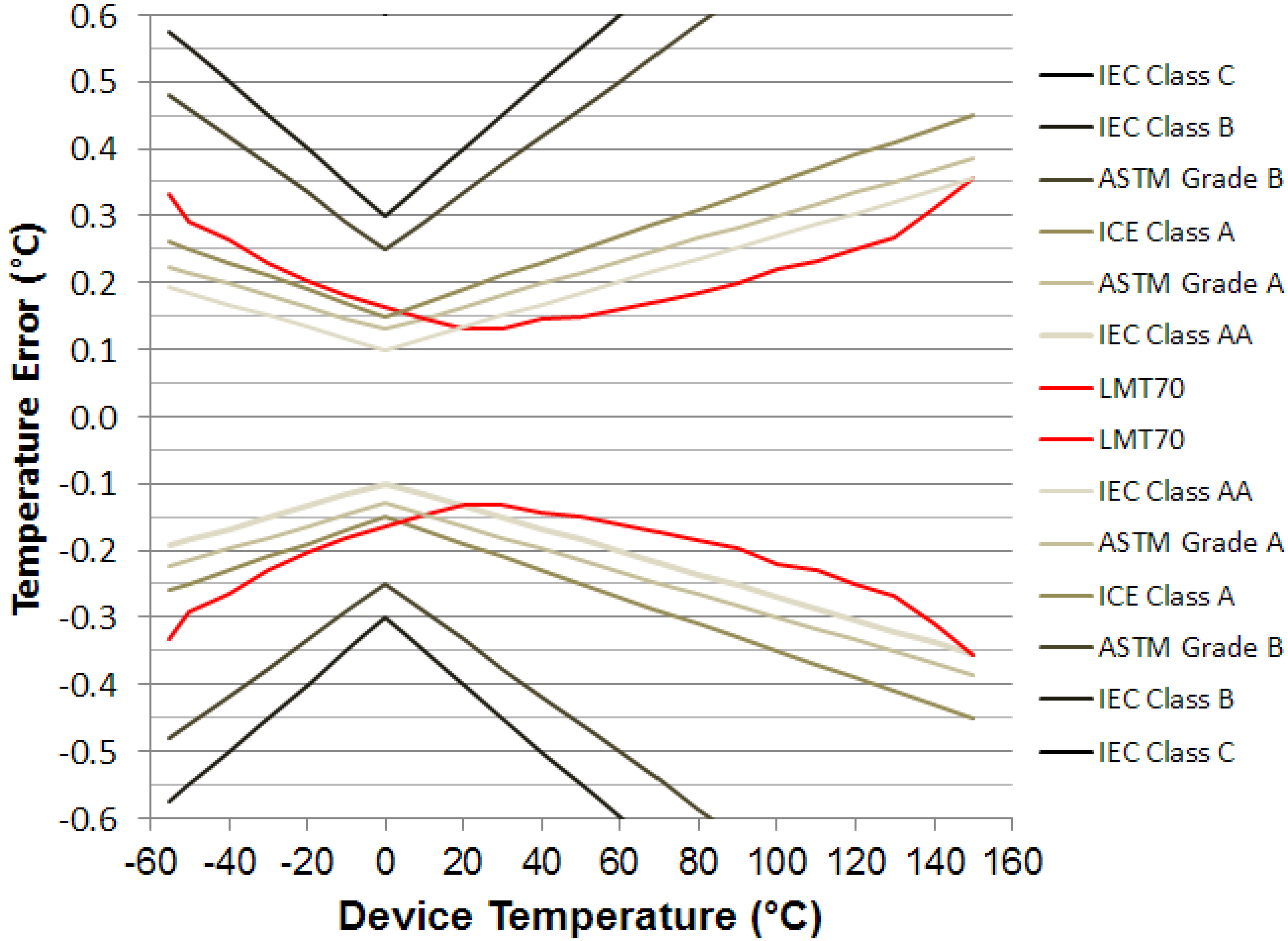


RTD accuracy curves

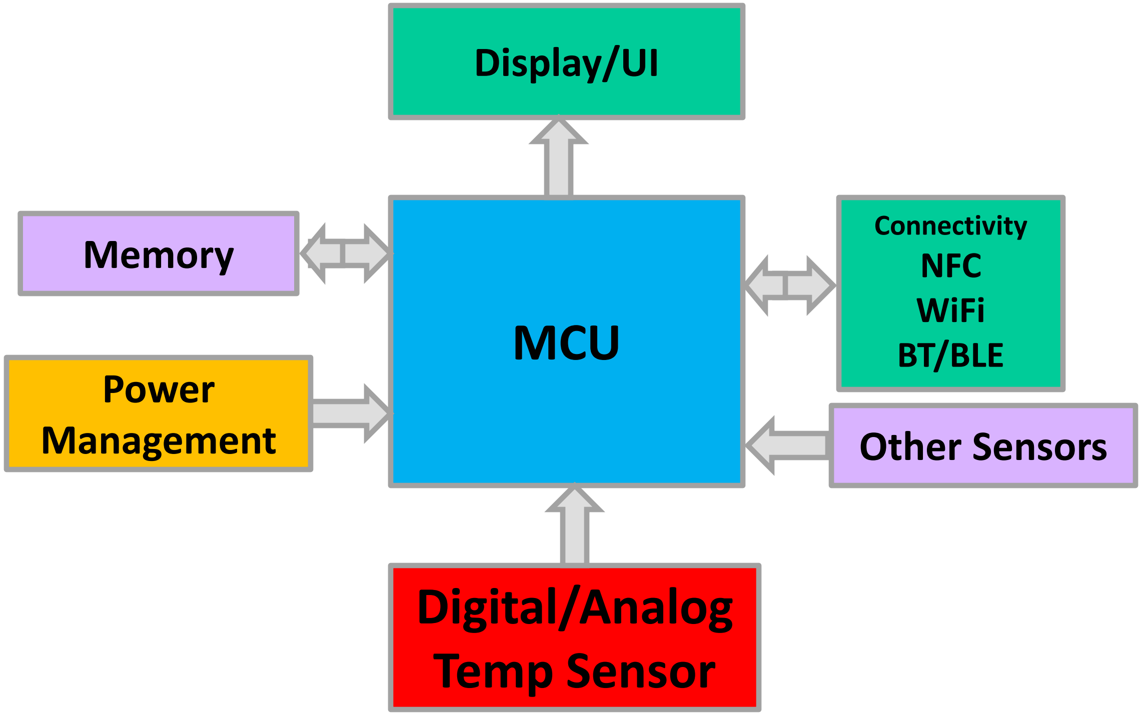


Meets 0.36°C over wide range!

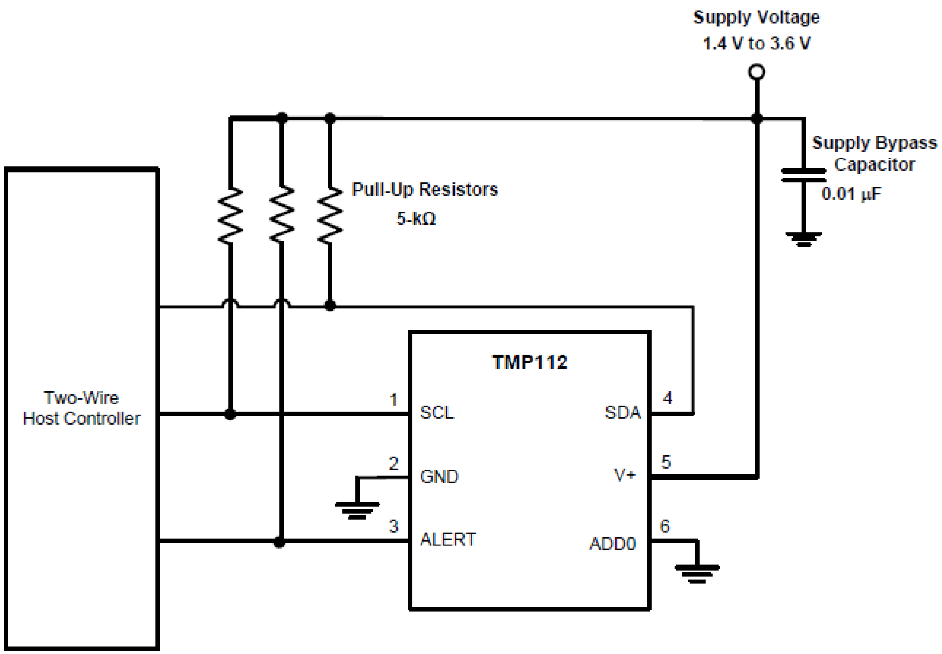
LMT70 beats IEC Class AA RTDs from 10°C to 150°C



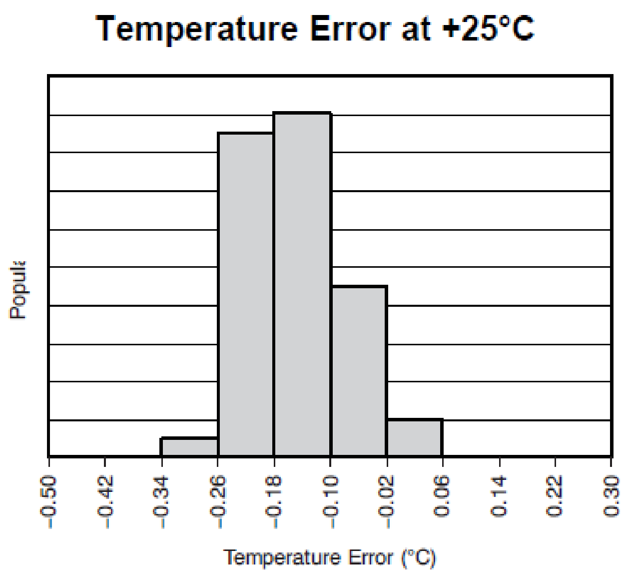
What is the system implementation using a semiconductor temperature sensor?



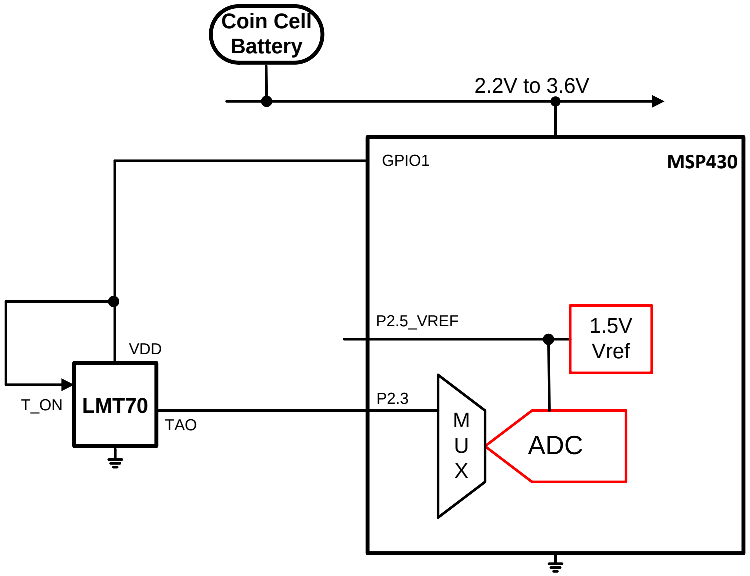
Use a digital sensor if your MCU excludes an ADC that provides the necessary performance

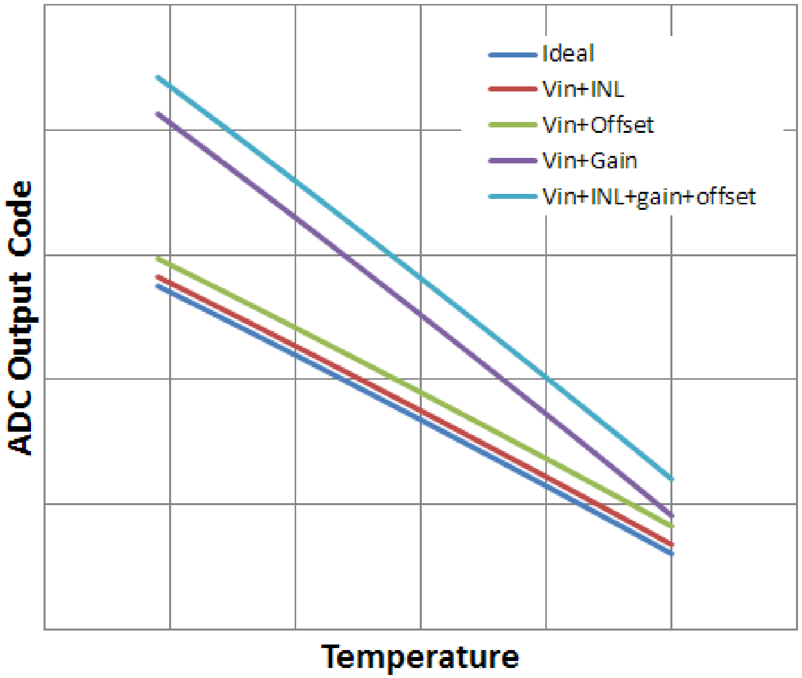


1.6mm x 1.2mm

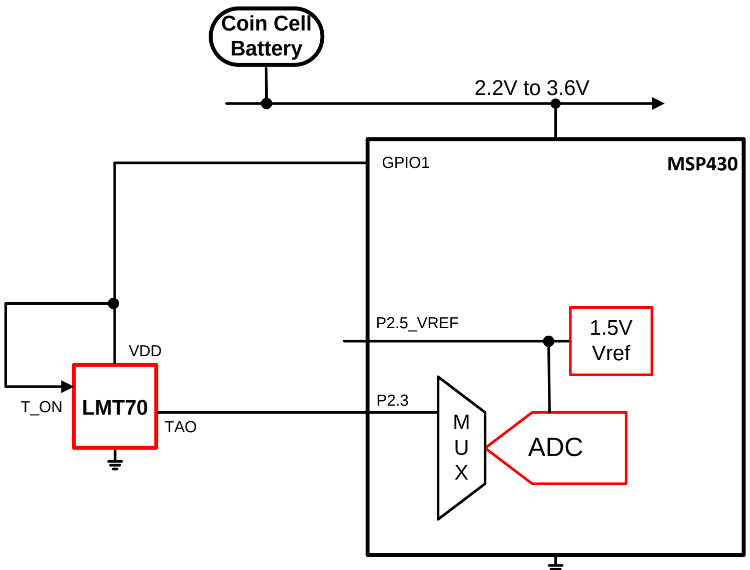


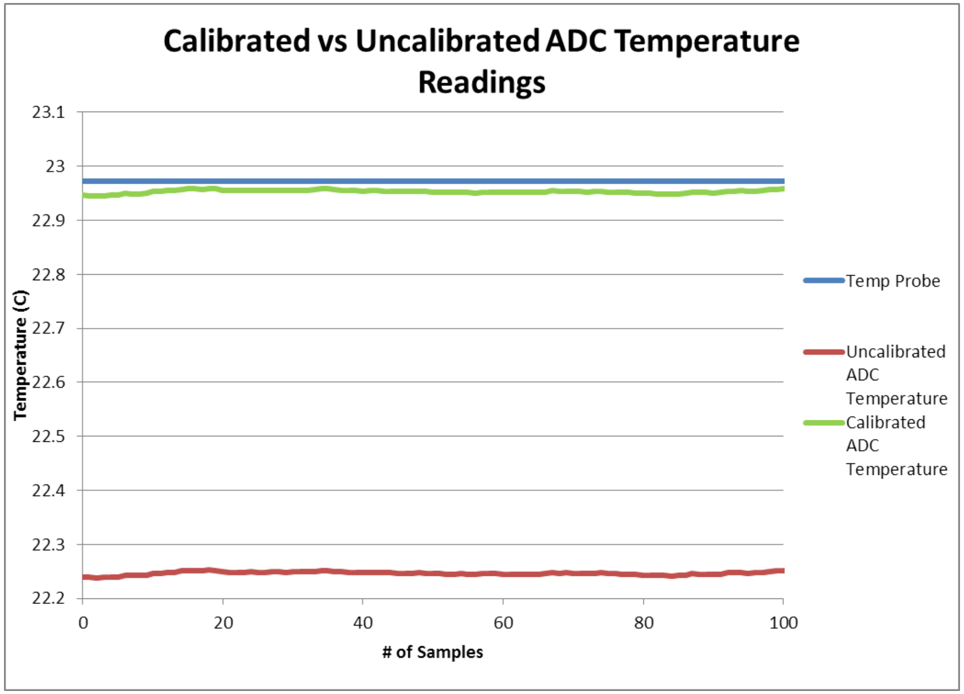
ADC error sources include INL, DNL, offset and gain error



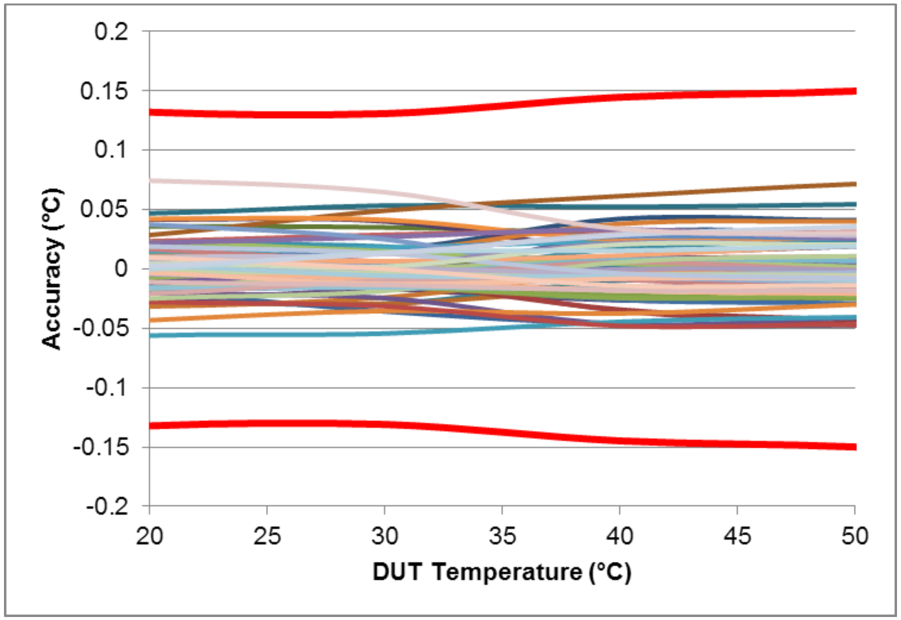


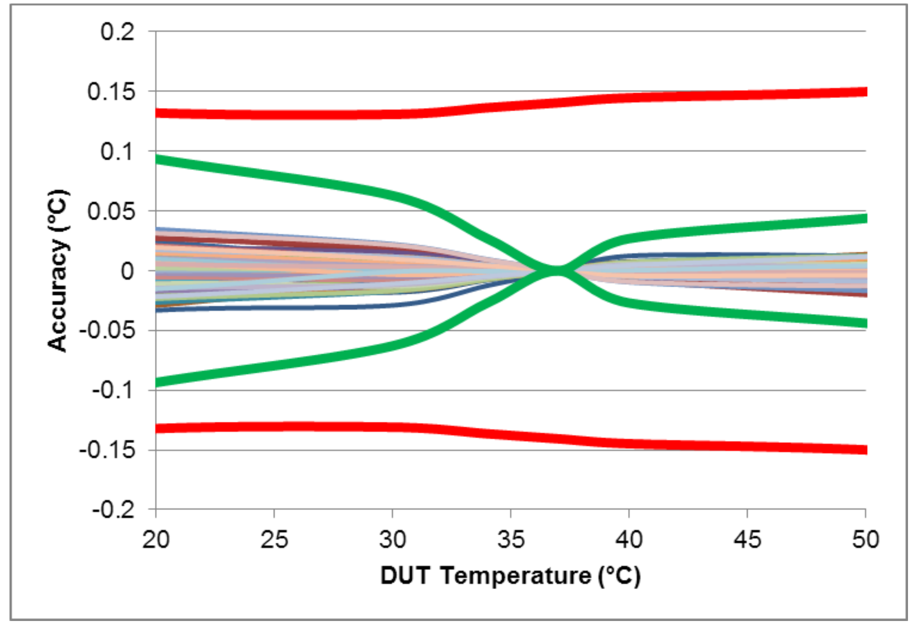
ADC error sources can be calibrated using calibration methods





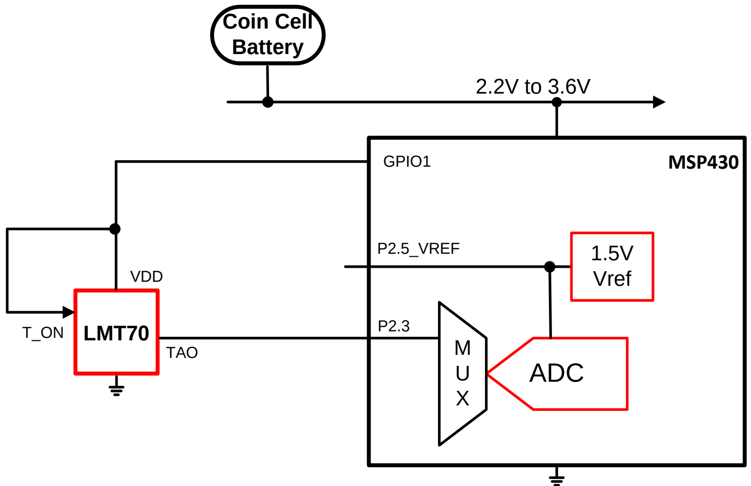
Over a narrow temperature range you can improve the LMT70's accuracy using a single point calibration

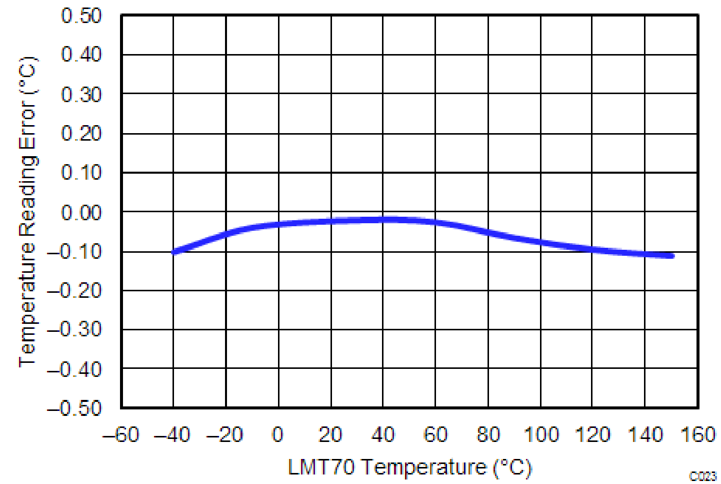




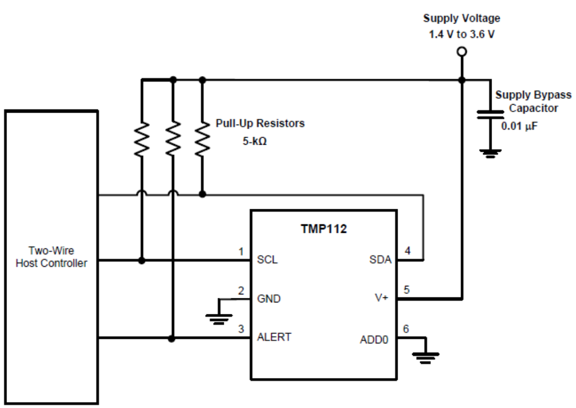
Analog or digital temperature sensors provide an answer for varying system resources and accuracy requirements

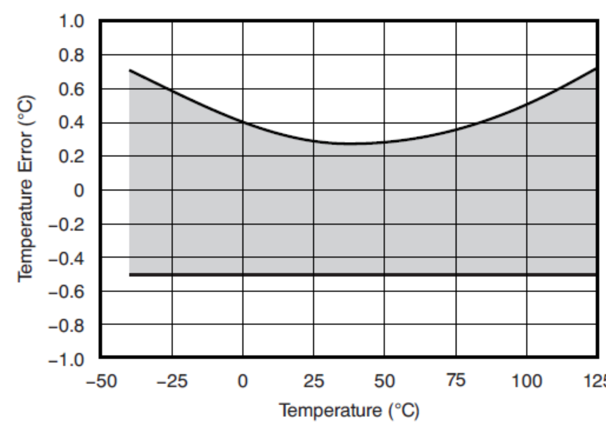
±0.1°C accuracy over an ultra-wide temperature range using analog sensor and integrated 12-bit ADC



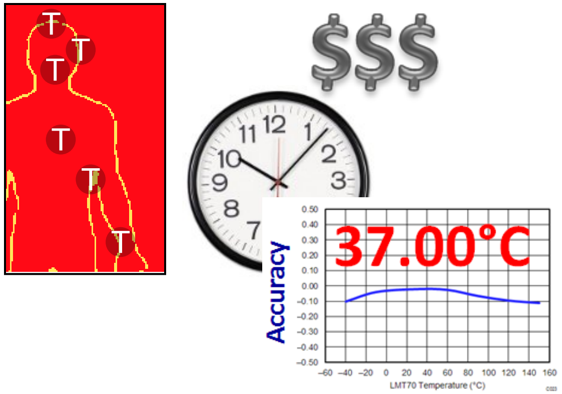


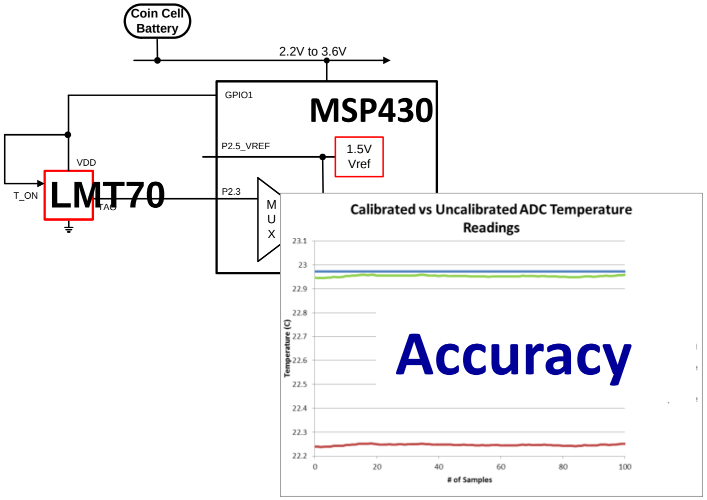
High-accuracy, low-power, digital temperature sensor with SMBus™ and two-wire serial interface in SOT563





Technical challenges and IC solutions for measuring body temperature accurately and cost effectively





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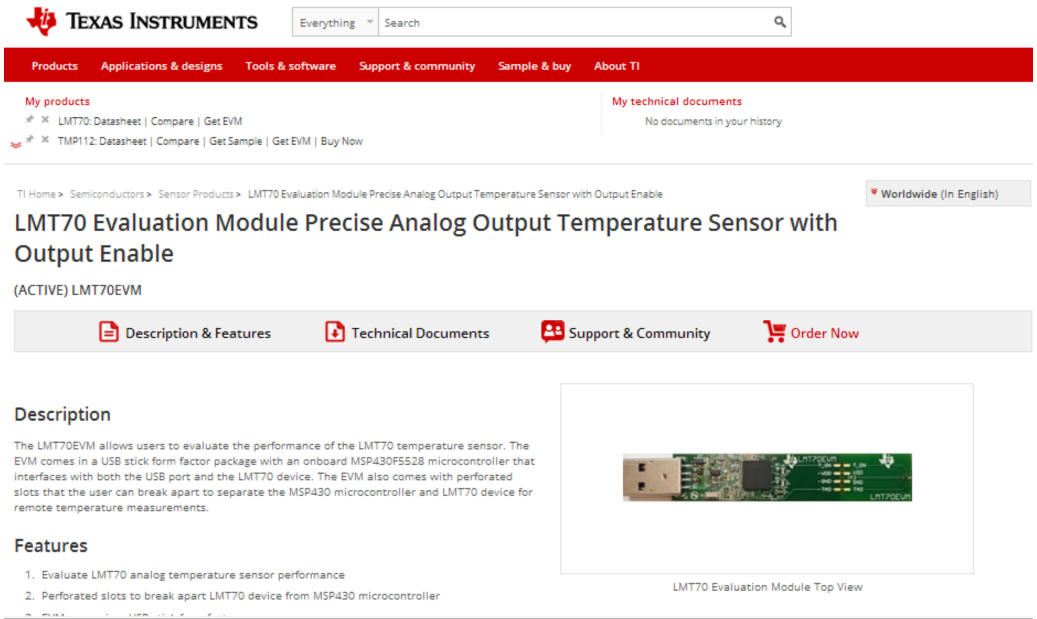
Order a new LMT70 evaluation board and check out its ±0.1°C accuracy

ti.com/tool/lmt70evm



www.ti.com/sensing

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