Universidad de Valparaíso
CHILE

Transductores térmicos

Mediciones Biomédicas 2024
Ingeniería Civil Biomédica

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Tipos de transductores

Resistivos

Capacitivos

Piezoeléctricos

Inductivos/magnéticos

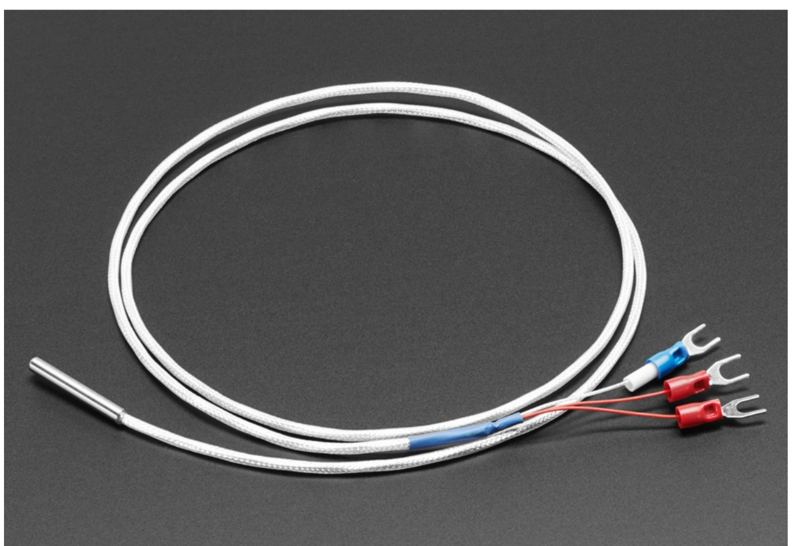
Térmicos

Radiación/ópticos

Electroquímicos (Cap. 4)

Efecto termorresistivo

- La resistividad de materiales conductores y semiconductores varía con los cambios de temperatura.
- Estos materiales pueden ser usados en circuitos para medir la temperatura.
- De ahí surgen los **RTD: Resistance Temperature Detector.**
- Se construyen en ciertos materiales metálicos: Platino (predominante), Nickel y Cobre.



Platinum RTD Sensor - PT100 - 3 Wire 1 meter long

PRODUCT ID: 3290

$11.95

IN STOCK

1 ADD TO CART

Also include 1 x Adafruit PT100 RTD Temperature Sensor Amplifier - MAX31865 ($14.95)

QTY	DISCOUNT
1-9	$11.95
10-99	$10.76
100+	$9.56

ADD TO WISHLIST

RTD

- La relación resistencia temperatura tiene la forma:

  $$R = R_0(1 + \alpha\Delta T)$$

  donde

  R_0 es la resistencia a un valor de temperatura de referencia T_0,

  α es el coeficiente de temperatura para T_0 (temperature coefficient of resistance, TCR) y

  ΔT es la diferencia de temperatura en relación a T_0.

- Para la mayoría de los metales α es una función de la temperatura, pero para efectos prácticos ésta puede ser considerada constante.

- Es deseable tener un alto coeficiente α.

RTD

- En particular, la resistencia del Platino puede aproximarse mediante:

  $R_t = R_0(1+ At + Bt^2)$, 0<t<640 ºC

  $R_t = R_0(1+At+Bt^2+C(t-100)t^3)$, -240<t<0 ºC

  donde

  - $A=3.96847\times 10^{-3}$,
  - $B=-5.847\times 10^{-7}$,
  - $C=-4.22\times 10^{-12}$.

- Note que B y C son relativamente pequeños en relación a A.

RTD

- La tolerancia de la resistencia y el coeficiente de temperatura define la relación resistencia-temperatura de un sensor RTD.

- A medida que la tolerancia del elemento es más elevada:
  - Mayor desviación de la curva R-T nominal.
  - Mayor variación entre distintos RTDs (difícil reemplazo).

RTD

- Existen dos estándares para RTDs de platino: el europeo (DIN o IEC) que es predominante y el de USA.
- El estándar DIN/IEC 60751:
  - R_0 = 100 Ω para T_0 = 0 ºC y
  - A = 0.00385 Ω/Ω/°C para temperaturas en el rango 0-100°C.
- Hay dos tolerancias de resistencias especificadas en el estándar DIN/IEC 60751:

  Clase A: ±(0.15 + 0.002*t)°C o 100.00 ± 0.06 Ω para 0ºC.

  Clase B: ±(0.3 + 0.005*t)°C o 100.00 ± 0.12 Ω para 0ºC.

RTD

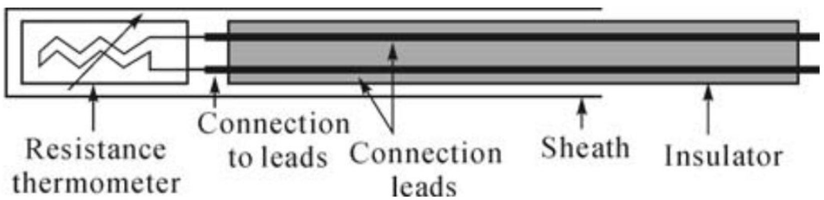
- El cobre también se usa como un RTD.
  - Posee resistividad baja en relación al platino.
  - Esto implica sensores de mayor tamaño.
  - Son atractivos por su bajo costo y linealidad.
  - Límite superior de temperatura es app. 150 ºC.
- La relación resistencia temperatura puede ser aproximada mediante:

$$R_t = R_0(1 + At + Bt^2 + Ct^3), \qquad -50 < t < 150\ ºC$$

donde

- $A = 4.28899 \times 10^{-3}$,
- $B = -2.133 \times 10^{-7}$,
- $C = -1.233 \times 10^{-9}$.

RTD



<u>Sheaths:</u>

T < 250 ºC

PVC, PTFE.

T > 250 ºC

Fibra de vidrio, cerámica.

Select the Right RTD Sensor

- RTD Finder
- Surface Measurement RTD Elements
- Quick Disconnect RTD Probes
- RTD Elements with Lead Wires Attached
- Extruder RTD Probes
- Precision and Specialized RTD Probes

Learn more about RTDs

- RTD Transmitter Calibration
- RTDs for Monitoring Air Duct Temperature
- Preventing Vibration Damage to RTDs

Support

- Manuals
- Tech Reference
- **Live Online Help**

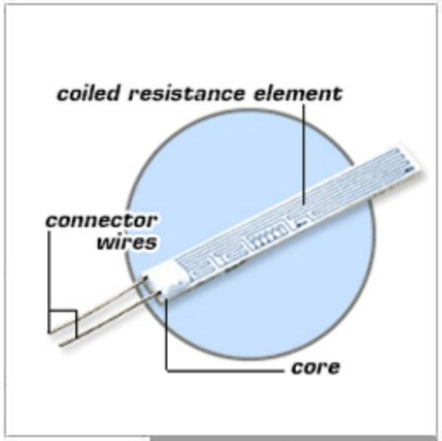
RTD Sensors

Introduction to Resistance Temperature Detectors

RTDs - or **Resistance Temperature Detectors** - are temperature sensors that contain a resistor that changes resistance value as its temperature changes. They have been used for many years to measure temperature in laboratory and industrial processes, and have developed a reputation for accuracy, repeatability, and stability.

Most RTD elements consist of a length of fine coiled wire wrapped around a ceramic or glass core. The element is usually quite fragile, so it is often placed inside a sheathed probe to protect it. The RTD element is made from a pure material whose resistance at various temperatures has been documented. The material has a predictable change in resistance as the temperature changes; it is this predictable change that is used to determine temperature.

This page will help you better understand RTDs, but you can also speak to our application engineers at anytime if you have any special measurement challenges.



Typical RTD Design

Learn more about RTDs

- *What elements make an RTD Probe?*
- *Common Resistance Materials for RTDs*
- *Benefits of Using an RTD*

Choose the right RTD

- *Resistance Temperature Detector Elements*
- *Resistance Temperature Detector Surface Elements*
- *Resistance Temperature Detector Probes*

RTD Applications & FAQ

- *RTDs for Water Temperature Measurement*
- *RTDs for Air and Gas Temperature Measurement*
- *Why use an RTD instead of a thermocouple or thermistor sensor?*
- *RTD Glossary & Definitions*
- *Popular RTD Models*

RTD Elements
The RTD element is the simplest form of RTD. It consists of a piece of wire wrapped around a ceramic or glass core. Because of their compact size, RTD elements are commonly used when space is very limited.

RTD Surface Elements
A surface element is a special type of RTD element. It is designed to be as thin as possible thus providing good contact for temperature measurement of flat surfaces.

RTD Probes
The RTD probe is the most rugged form of RTD. A probe consists of an RTD element mounted inside a metal tube, also known as a sheath. The sheath protects the element from the environment. OMEGA offers a wide variety of probes in various configurations.

General Purpose RTD (PT100) Probes with No Transition Junction Between Leads and Sheath

PR-10

$72.00 **PR-10-2-100-1/4-6-E**

PLACE ORDER

Be the first to review this product

WRITE A REVIEW

RoHS BY PART#

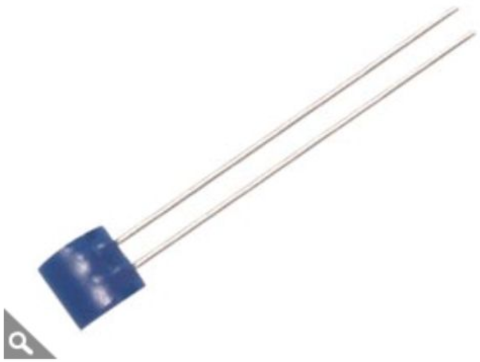
- Temperature Range -200 to 600°C
- Three Lead Configuration Standard
- Two Black Leads Connected to Same Side of RTD Element
- Leads Terminate with 3 Stripped Wires
- Alpha = .00385 Standard
- Accuracy: Class A Per IEC 60751
- 6, 12, 18, and 24 inch Probe Lengths Standard
- R_o = 100Ω @ 0°C

OPTIONS
- Shrink Tubing Strain Relief at End of Sheath
- Two and Four Lead Configurations
- PFA Coating of Probe
- Stainless Steel Overbraid for 3/16" and 1/4" diameter probes
- Alpha = .00392
- Non-Standard Probe Lengths
- Other Values of R_o

Temperature Sensors and Instruments - View related products

RTD Elements: OMEGAFILM® Flat Profile Thin Film Platinum with Ceramic Base and Glass Coating

F2020 Series



See All Models Below

PLACE ORDER

Be the first to review this product

WRITE A REVIEW

RoHS BY PART#

- Flat, Small Profile Thin Film RTD Element
- Specification DIN EN 60751 (According to IEC 60751)
- Temperature Range -50 to 500°C (-58 to 932°F) Depending on Accuracy Class (See Table Below)
- Temperature Coefficient α = 0.00385Ω/Ω/°C Nominal
- 100, 500 and 1000 Ohm Configurations
- Class A, B and 1/3 B (Also Known as Class AA) Tolerances
- Long Term Stability: Max. Ro Drift Not Greater Than the Class Tolerance After 1000 Hours in Air at Maximum Temperature Specified for Class.
- Vibration Resistance at Least 40 g Acceleration at 10 to 2000 Hz
- Shock Resistance at 100 g Acceleration with 8ms Half Sine Wave
- Insulation Resistance >10Mohms at 20°C: >1Mohms at 500°C
- Self Heating Does Not Exceed 25% of the Tolerance Value When Powered at the Maximum Specified Operating Current (1 milliamp for 100Ω, 0.7milliamp for 500Ω and 0.3 milliamp for 1000Ω Elements)
- Response Time Water Current (v=0.4 m/s) $t_{0.5}$ = 0.2 s; $t_{0.9}$ = 0.4 s Air Stream (v = 1 m/s) $t_{0.5}$ = 3.0 s; $t_{0.9}$ = 9.0 s
- Platinum Clad Nickel Wire Leads 10 L x 0.2 mm D (0.39 x 0.008")

RTD (PT100) Probes, Elements and Assemblies - View related products

Glass Wire Wound Platinum RTD Elements - Class B

1PT100G, 2PT100G

Glass Wire Wound Platinum RTD Elements - Class B

See All Models Below

PLACE ORDER

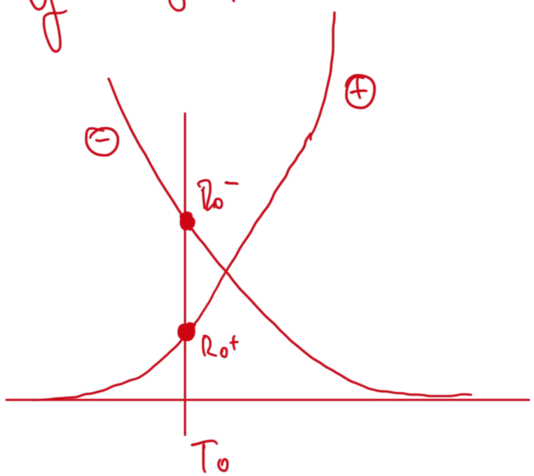
Be the first to review this product

WRITE A REVIEW

- Suitable for Low or very High Temperatures
- Tolerant of Thermal Shocks
- Good Vibration Resistance
- Alpha = 0.00385

RTD (PT100) Probes, Elements and Assemblies - View related products

Termistores son otro ejemplo. Están fabricados con materiales semiconductores y son inherentemente no lineales



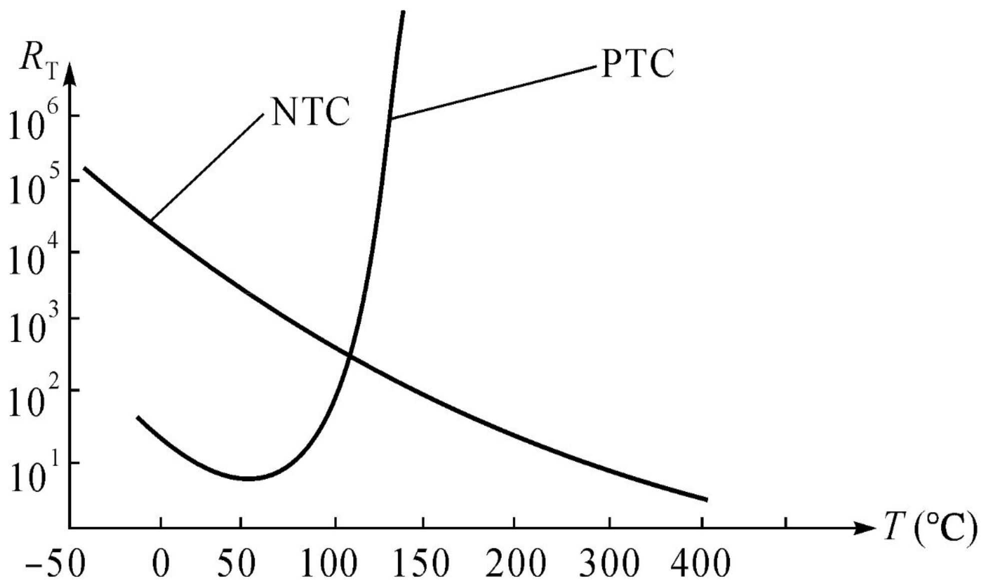
La curva temperatura / resistencia se aproxima:

$$R = R_0 e^{\beta (T^{-1} - T_0^{-1})}$$

R: es la resistencia a temperatura T (en °K).
T: es la temperatura en (°K)
R_0: es la resistencia a alguna temperatura de referencia T_0 (°K).
β: coeficiente de temperatura en (°K).

Termistores

- Materiales usados son semiconductores.
- Respuesta a temperaturas más precisas, pero en un espectro limitado de temperaturas (en relación a los RTDs).
- Dos clases (dependiendo del signo del coeficiente de temperatura): PTC - NTC



PTC (positive temperature coefficient)

Cerámico policristalino dopado conteniendo titanio de bario (BaTiO3) y otros componentes.

NTC (negative temperature coefficient)

Semiconductores, mezclas de óxidos Mn, Co, Ni, Cu y Zn.

Termistores

- Resistividad 0.1-100 Ωm
- Pequeños, app. 0.5 mm
- Alta sensibilidad -3-5%
- Estabilidad a largo plazo (+- 0.2% de la resistencia nominal por año).
- Relación resistencia-temperatura:

  $$R_t = R_0 \exp(\beta(T_0 - T)/TT_0)$$

  β es una constante que depende del material 2500-5000K.

  T_0 es una temperatura de referencia.
- Sensibilidad:

  $$\alpha = dR_t/dT$$

Termistores

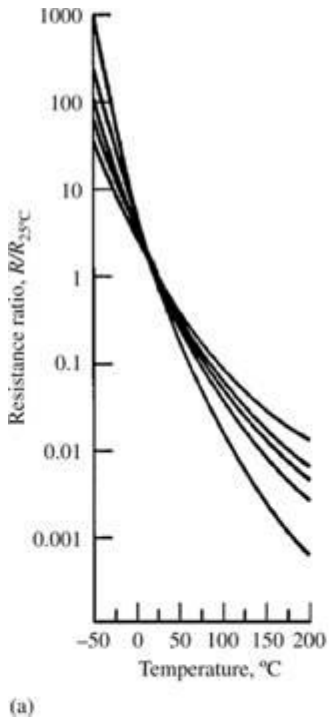
NTC: 10K ±1% @ 25°C **PTC: 1K ±1% @ 25°C**

STANDARD THERMISTOR RESISTANCE CHARACTERISTICS

Temperature	NTC sensor Resistance K		PTC sensor Resistance	
ºC	Min	Max	Min	Max
-50	314.70	344.40	500.9	536.2
-40	181.10	195.90	545.1	579.4
-30	107.50	115.10	597.4	630.6
-20	65.80	69.74	656.9	688.7
-10	41.43	43.50	720.4	750.4
0	26.74	27.83	788.1	815.7
10	17.67	18.24	859.8	884.7
20	11.95	12.23	935.8	957.1
25	9.90	10.10	975.0	995.0
30	8.21	8.41	1012.9	1035.2
40	5.73	5.92	1091.4	1118.5
50	4.08	4.24	1173.5	1205.8
60	2.95	3.09	1259.2	1297.1
70	2.17	2.28	1348.5	1392.2
80	1.62	1.71	1441.4	1491.3
90	1.22	1.30	1537.9	1594.4
100	0.94	1.00	1638.0	1701.4
110	0.72	0.78	1741.0	1813.0
120	-	-	1847.4	1928.8
130	-	-	1957.4	2048.6
140	-	-	2046.1	2146.4
150	-	-	2146.0	2256.1

Termistores

- Los parámetros principales de un termistor son:
  - Resistencia nominal R_0 a 25ºC.
  - Coeficiente de temperatura β generalmente a 20-25 ºC.
  - Factor de disipación H, medida de la tasa de pérdida de potencia.
  - Capacidad de calor específica C, medida de la energía calórica requerida para incrementar la resistencia en la unidad.
  - Constante de tiempo r.
  - Error puede ser 500 veces inferior que un RTD.



Ver ejercicio y solución en el Classroom

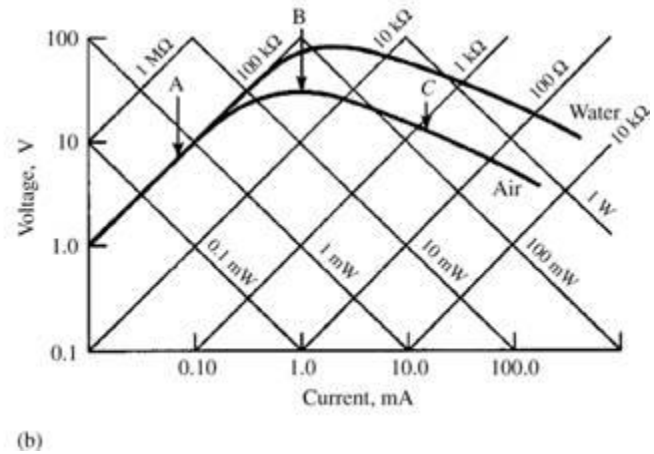


Figure 2.15 (a) Typical thermistor zero-power resistance ratio-temperature characteristics for various materials, (b) Thermistor voltage-versus-current characteristic for a thermistor in air and water. The diagonal lines with a positive slope give linear resistance values and show the degree of thermistor linearity at low currents. The intersection of the thermistor curves and the diagonal lines with negative slope give the device power dissipation. Point *A* is the maximal current value for no appreciable self-heat. Point *B* is the peak voltage. Point *C* is the maximal safe continuous current in air. [Part (b) is from *Thermistor Manual*, EMC-6, © 1974, Fenwal Electronics, Framingham, MA; used by permission.]

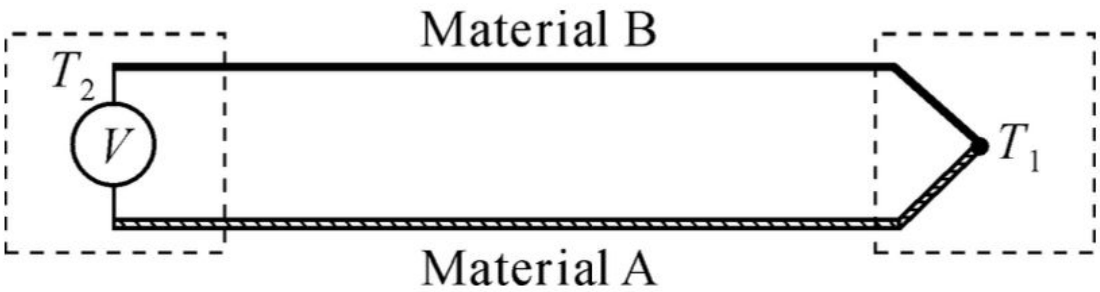
Termocuplas

- Fáciles de fabricar, baratos, intercambiables.

++ Respuesta rápida (constante de tiempo de app. 1ms), pequeños (diámetro de 12 μm), estabilidad a largo plazo.

-- Baja sensibilidad y necesidad de referencia.

- Su principio de operación es el llamado **efecto termoeléctrico (efecto Seebeck).**
  - Se produce una diferencia de potencial entre dos materiales conductores diferentes (metales o semiconductores) en respuesta a la temperatura.
  - Esto causa una corriente si éstos están conectados a un circuito.



T_1, temperatura en el punto de medición.
T_2, temperatura en el punto de referencia.

Termocuplas

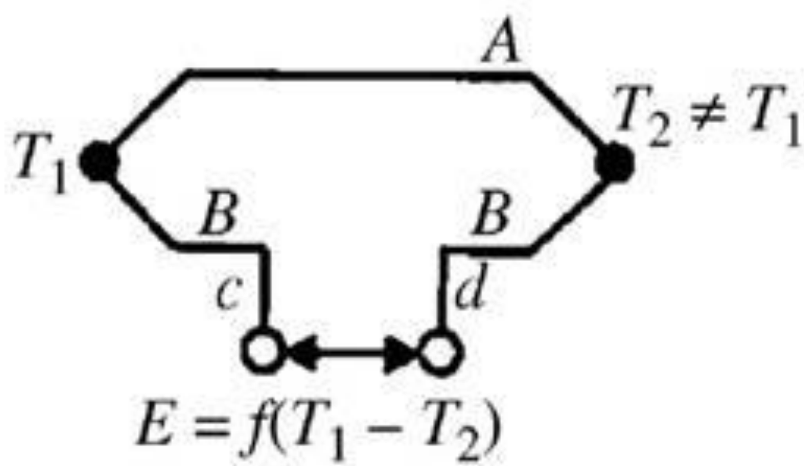
Voltaje de Seebeck:

$$E = a\Delta T + 0.5b\Delta T^2 + \ldots$$

a y b deben ser calibrados/estimados empíricamente.

donde ΔT es la diferencia de temperatura entre dos metales $\Delta T = T_1 - T_0$.

- T_0 es la temperatura de referencia (conocida) que típicamente se deja en 0 ºC.
- T_1 es la temperatura del mensurando.



Termocuplas

- Sensibilidad termoeléctrica:

$$\alpha = dE/dT = a + bT + \ldots$$

- Note que la sensibilidad varía con la temperatura.
- Sensibilidad de termocuplas comunes varía entre 6.5 – 80 μV / ºC a 20ºC, con exactitudes alrededor de ¼ % - 1%.
- **Cuando la exactitud importa:** ajuste la temperatura de referencia (ver diapositiva siguiente).
- **Para mejorar la sensibilidad:** conectar varias termocuplas en serie (con la misma temperatura de referencia) – esta configuración se llama termopila.
- Combinaciones en paralelo de termocuplas sirven para medir la **temperatura promedio**.

Termocuplas

Materials	Relative Seebeck coefficient at 25 °C [μV/°C]	Relative Seebeck coefficient at 0 °C [μV/°C]
Copper/constantan	40.9	38.7
Iron/constantan	51.7	50.4
Chromel/alumel	40.6	39.4
Chromel/constantan	60.9	58.7
Platinum (10%)/rhodium–platinum	6.0	7.3
Platinum (13%)/rhodium–platinum	6.0	5.3
Silver/palladium	10	
Constantan/tungsten	42.1	
Silicon/aluminum	446	
Carbon/silicon carbide	170	

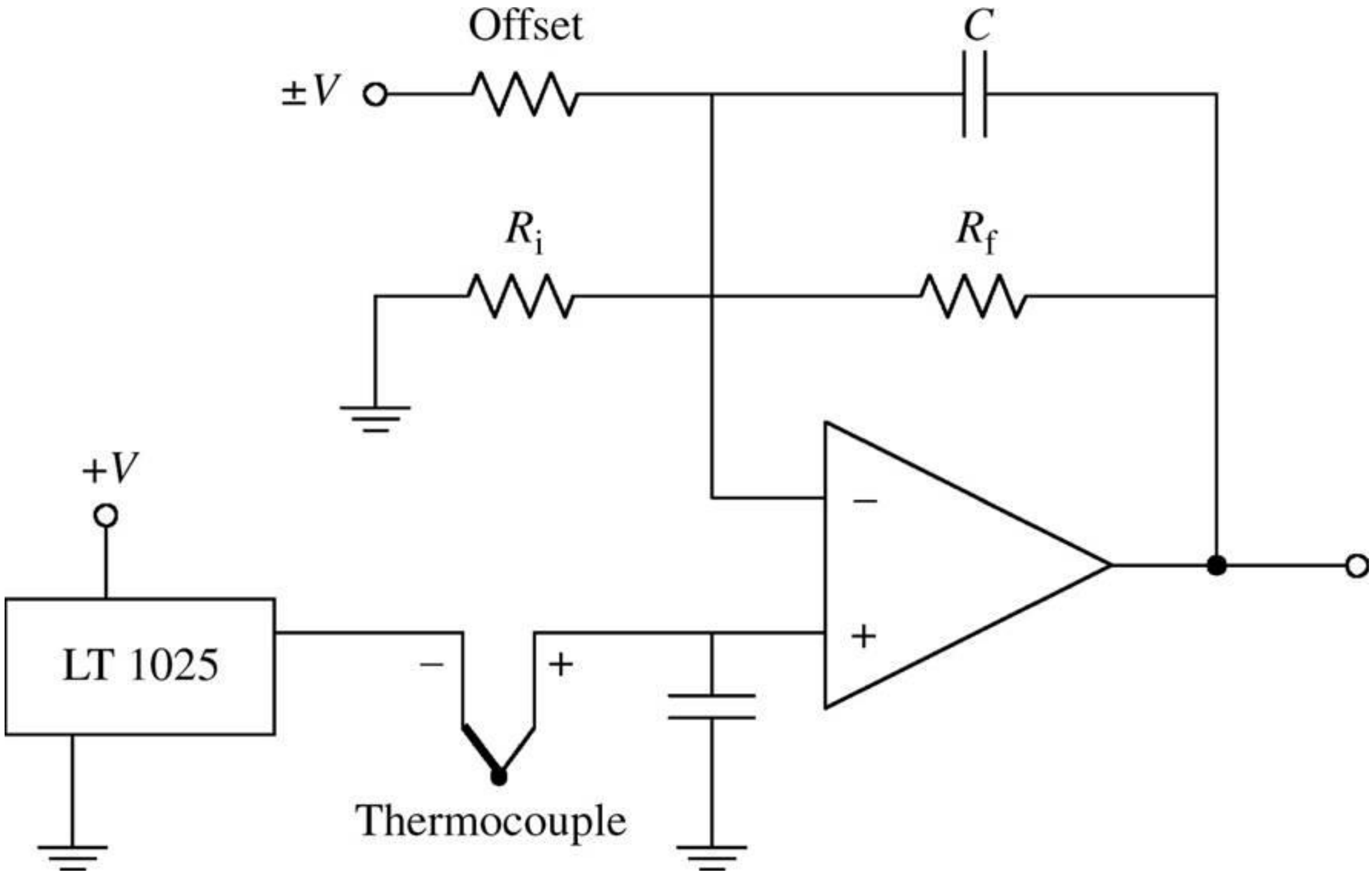
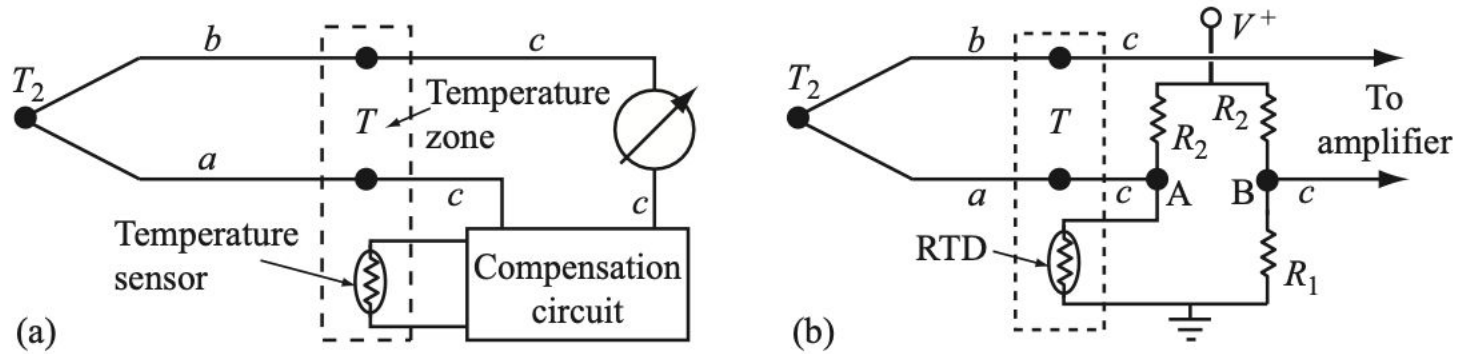


Figure 2.14 The LT1025 electronic cold junction and the hot junction of the thermocouple yield a voltage that is amplified by an inverting amplifier.

Termocuplas



$E = a_{ba}T2 – a_{ba}T + V_{compensacion}$

El voltaje de compensación (V_{ab}) se selecciona de manera tal que la salida del circuito de medición sea $E = a_{ba}T2$, por lo tanto, se debe garantizar que:

$$a_{ba}T = V_{compensación}$$

Considere una termocupla compuesta por la unión de cromel–alumel y un RTD de platino para el circuito de compensación. El RTD tiene una resistencia de 100 Ω a 0 °C y A=0.00385.

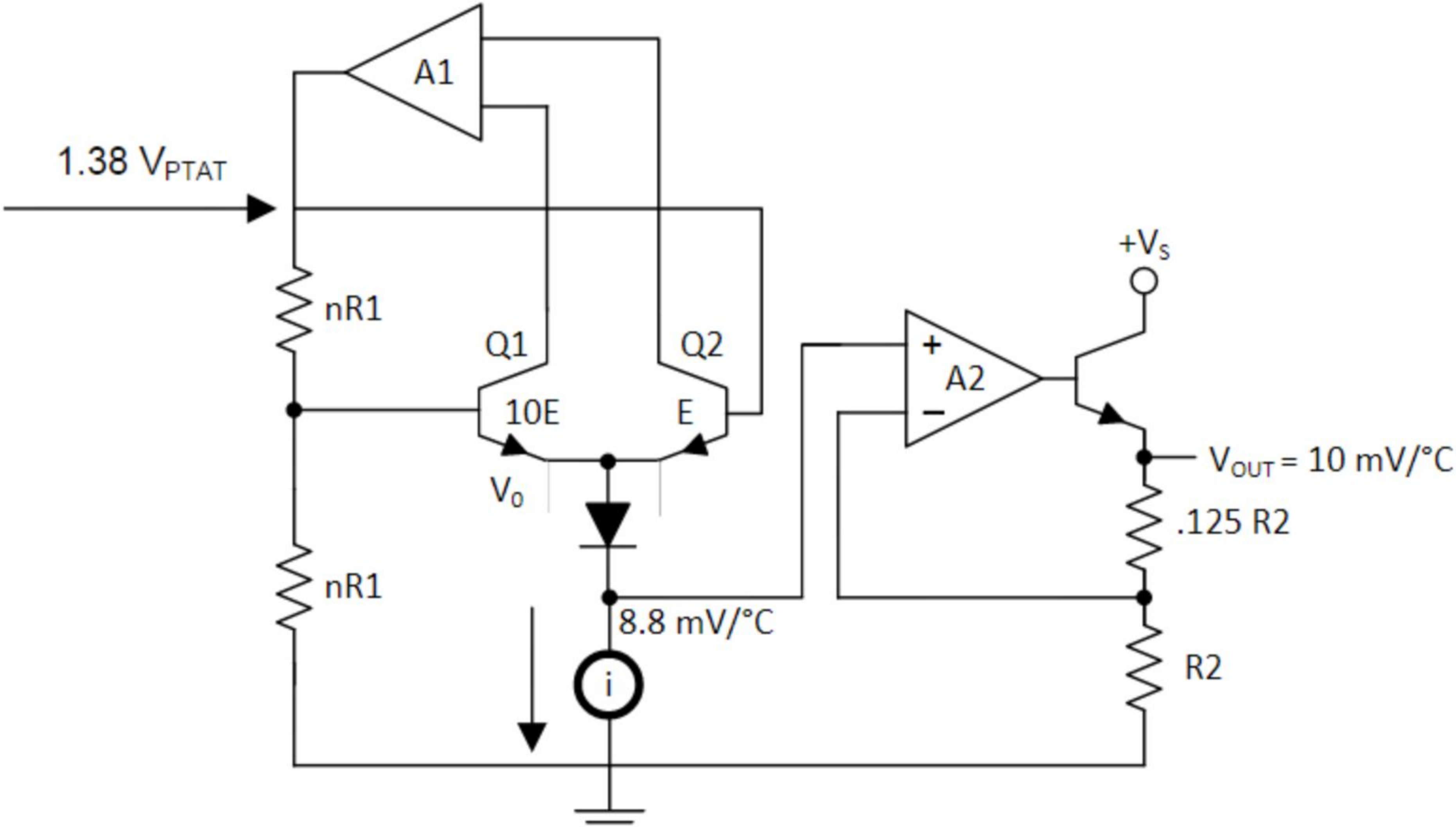
1. Dada una fuente de 10V, calcule R2 requerida para esta termocupla. Seleccione R1 = R_{RTD} a 0°C. Recuerde que el voltaje de compensación debe ser igual a $a_{ba}T$.
2. Calcule el error de medición de temperatura a 45°C, cuando T = 27°C.

Ver la solución en el Classroom

Sensores de temperatura integrados.

- Corriente o voltaje de salida proporcional a la temperatura.
  - Voltaje: AD22100, AD22103, LM35/135/235/335.
  - Corriente: AD590, AD592, TMP17, LM134/234/334.
- Semiconductores.
- Bajo costo, tamaño reducido.
- Alta sensibilidad y linealidad.
- Respuesta rápida.
- -50 – 150 ºC.

Sensores de temperatura integrados.



Sensores de temperatura integrados.

- La fabricación de estos sensores se basa en el mismo principio de los transistores bipolares.
- V_{BE} varía linealmente con la temperatura a medida que I_c se mantiene constante.

$$V_{BE}(I_c) = \frac{kT}{q} \ln\left(\frac{I_c}{I_s}\right)$$

donde

I_c es la corrientes de colector.
I_s es la corriente de saturación.
T es la temperatura del mensurando.
k es la constante de Boltzman (1.3807×10^{-23} J/K).
q es la carga del electrón (1.6022×10^{-19} C).

Sensores de temperatura integrados.

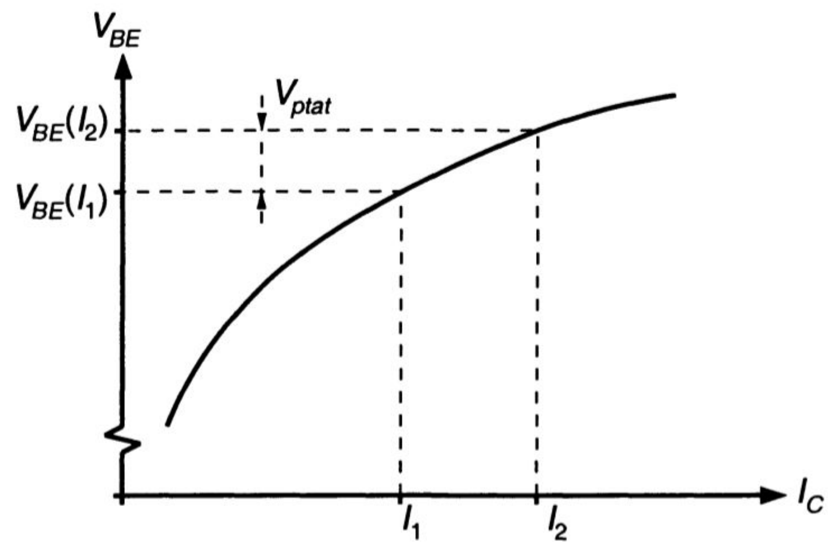


Fig. 1-2 *I_C-V_{BE} characteristic of a bipolar transistor, which can be used to make a temperature sensor that is almost perfectly Proportional To Absolute Temperature (PTAT).*

$$V_{BE}(I_1) = \frac{kT}{q} \ln\left(\frac{I_1}{I_s}\right)$$

$$V_{BE}(I_2) = \frac{kT}{q} \ln\left(\frac{I_2}{I_s}\right)$$

$$\begin{aligned} V_{\mathrm{PTAT}} = V_{BE}(I_2) - V_{BE}(I_1) &= \frac{kT}{q} \ln\left(\frac{I_2}{I_s}\right) - \frac{kT}{q} \ln\left(\frac{I_1}{I_s}\right) \\ &= \frac{kT}{q} \ln\left(\frac{I_2}{I_1}\right) \end{aligned}$$

In English

Alert me

LM35 (ACTIVE)

±0.5°C Temperature Sensor with Analog Output with 30V Capability

LM35 Precision Centigrade Temperature Sensors (Rev. G)

Description & parametrics | Online datasheet | Technical documents | Tools & software | Order Now | Compare | Quality & packaging | Support & training

Description | Features | Parametrics | Diagrams | Related end equipment | Companion products

Description

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly-proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to

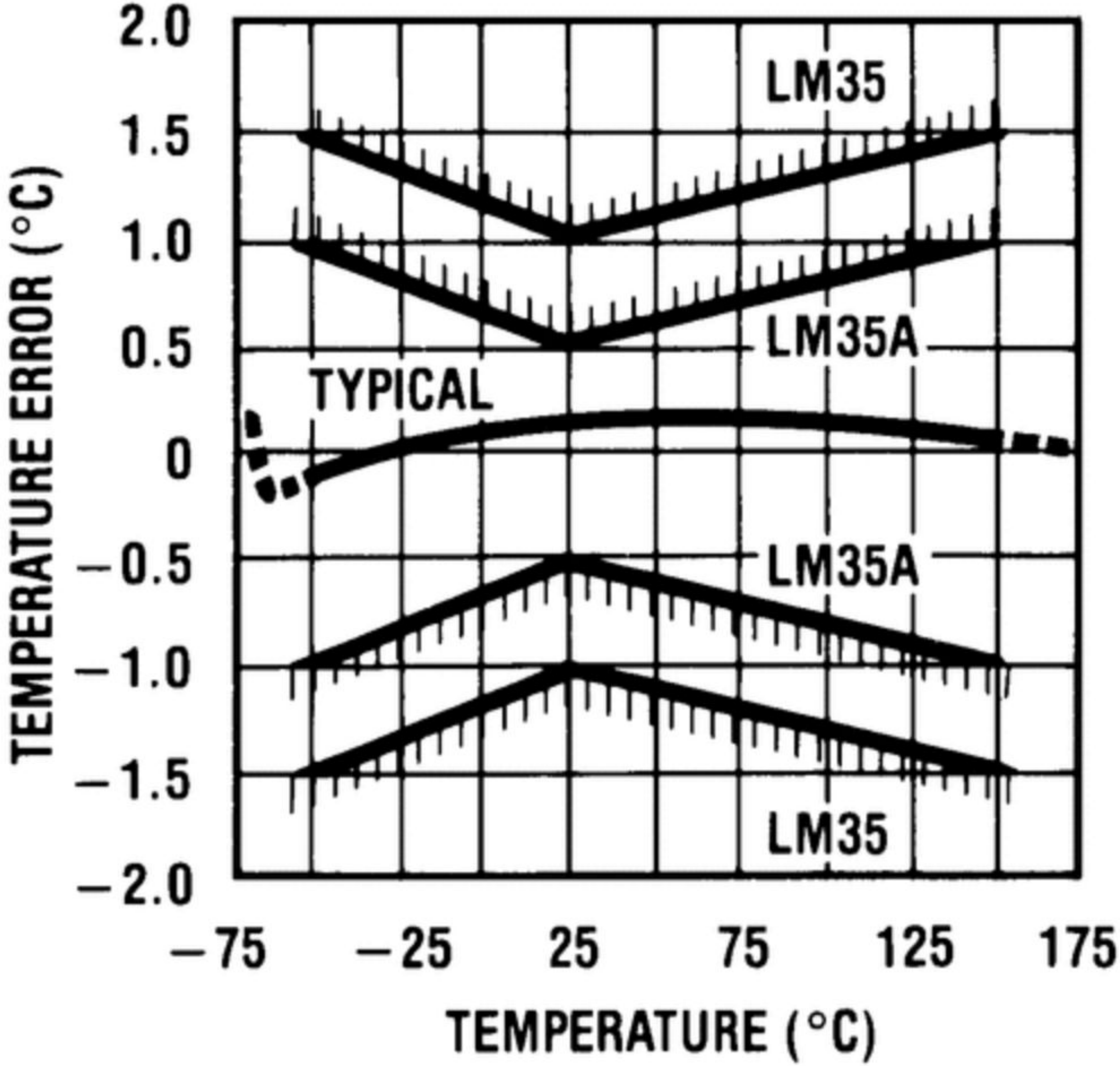
Features

- Calibrated Directly in Celsius (Centigrade)
- Linear + 10-mV/°C Scale Factor
- 0.5°C Ensured Accuracy (at 25°C)
- Rated for Full −55°C to 150°C Range
- Suitable for Remote Applications

Parametrics

Compare all products in Temperature Sensor

	LM35	LM135	LM135A	LM235
Interface	Analog Output	Analog Output	Analog Output	Analog Output
Operating Temperature Range (C)	-40 to 110 -55 to 150 0 to 100 0 to 70	-55 to 150	-55 to 150	-40 to 125
Local Sensor Accuracy (Max) (+/- C)	0.5	3	1	3
Supply Voltage (Min) (V)	4	5	5	5
Supply Voltage (Max) (V)	30			
Rating	Catalog	Catalog	Catalog	Catalog
Package Group	SOIC TO-220 TO-92 TO	TO	TO	TO
Package Size: mm2:W x L (PKG)	3TO-92: 19 mm2: 3.68 x 5.2(TO-92) 3TO: 22 mm2: 4.699 x 4.699(TO) 8SOIC: 29 mm2: 6 x 4.9(SOIC)	3TO: 22 mm2: 4.699 x 4.699(TO)	3TO: 22 mm2: 4.699 x 4.699(TO)	3TO: 22 mm2: 4.699 x 4.699(TO)



2.0
1.5
1.0
0.5
0
−0.5
−1.0
−1.5
−2.0
LM35
LM35A
TYPICAL
LM35A
LM35
−75
−25
25
75
125
175
TEMPERATURE ERROR (°C)
TEMPERATURE (°C)

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Development and testing of a wearable Integrated Thermometer sensor for skin contact thermography

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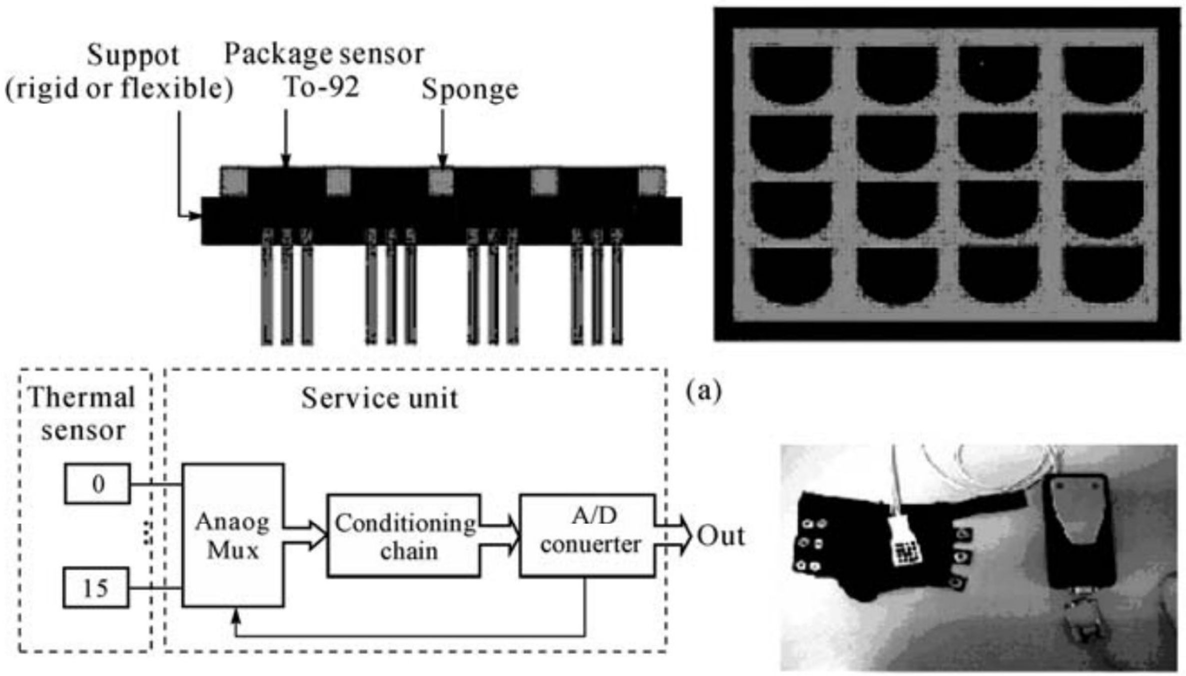
Received 2 December 2005; received in revised form 2 June 2006; accepted 11 July 2006

Monitoreo continuo de cancer de mama



(b) (c)

A wearable integrated thermometer sensor: (a) The 3D design of the integrated thermometer; (b) Block diagram of the device; (c) Details of the integrated thermometer, the elastic bandage and the service unit

Multiple-Sensor Micro-system for Pulmonary Function Diagnostics for COPD and Asthma Patients[1]

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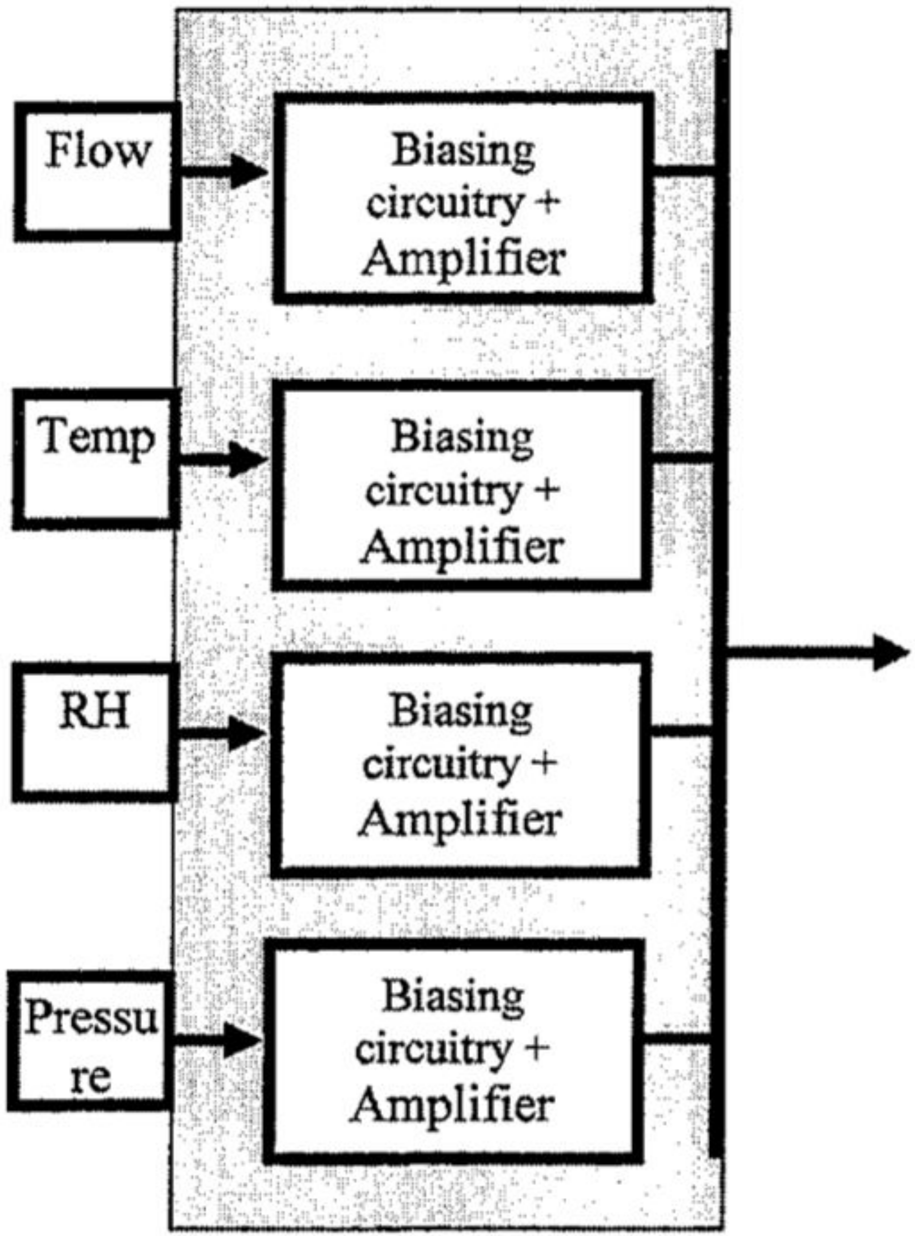

Fig. 2 *A functional diagram of the Multiple sensor micro-system for pulmonary diagnostic measurements.*

Sensor modality shifting in IoT deployment: measuring non-temperature data using temperature sensors

Luke Russell[1], *Student Member, IEEE*, Rafik Goubran[1,3], *Fellow, IEEE*,
Felix Kwamena[1], and Frank Knoefel, *MD*[1,2,3]

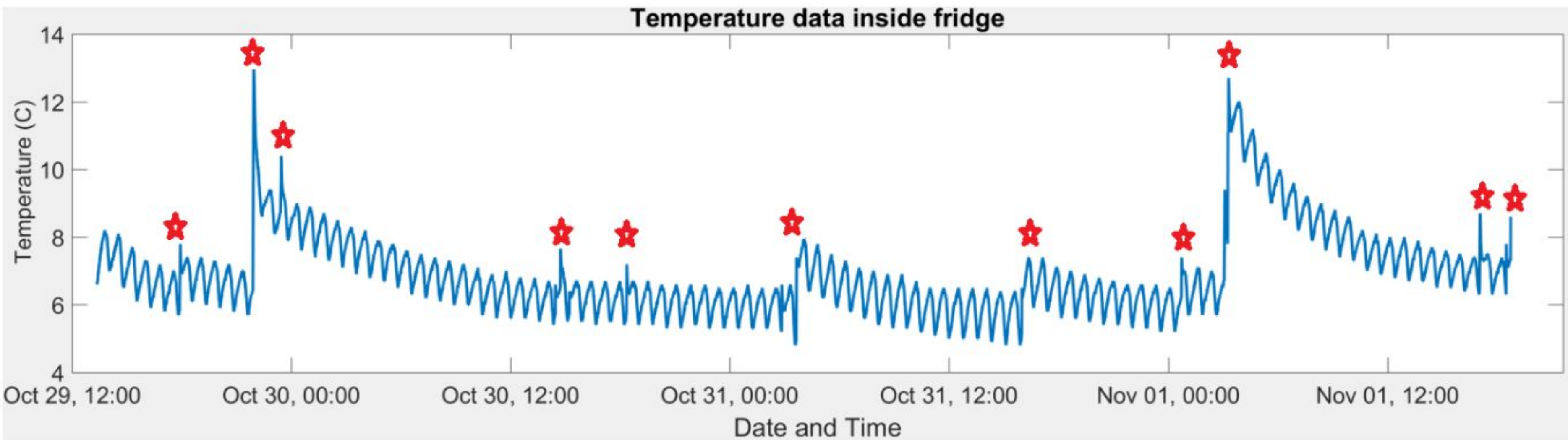

Figure 2. Internal fridge temperature. Selected door open events are highlighted with stars.

Autonomous smartwatch with flexible sensors for accurate and continuous mapping of skin temperature

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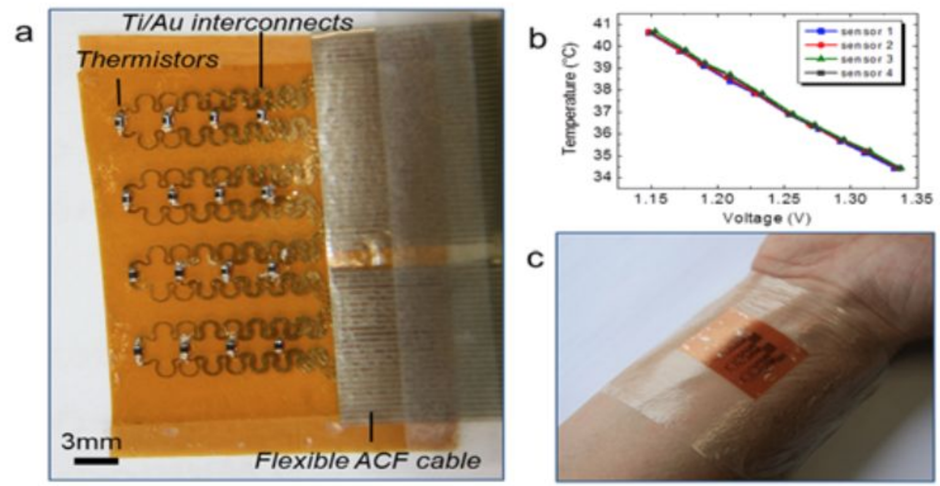

Fig. 3. **a.** Commercially available NTC thermistors are mounted on top of a 75µm Kapton foil, and connected through Ti/Au micro patterned traces to form an array of 16 temperature sensors; **b.** Calibration curves for 4 representative sensors which shows linear temperature-voltage response; **c.** The sensors are mounted on the wrist by using a Tegaderm tape to achieve a robust and compliant contact with the skin.