Semiconductor Sensors:

Ch5: Temperatures Sensors Cont.

Lecturer: Dr. Navid Alaei-Sheini
Assistant Professor of Electrical Enginnering
Shahid Chamran University of Ahvaz

جبرانسازی نقطه سرد در ترموکوپل

روش ۱: استفاده از یک حسگر اضافی

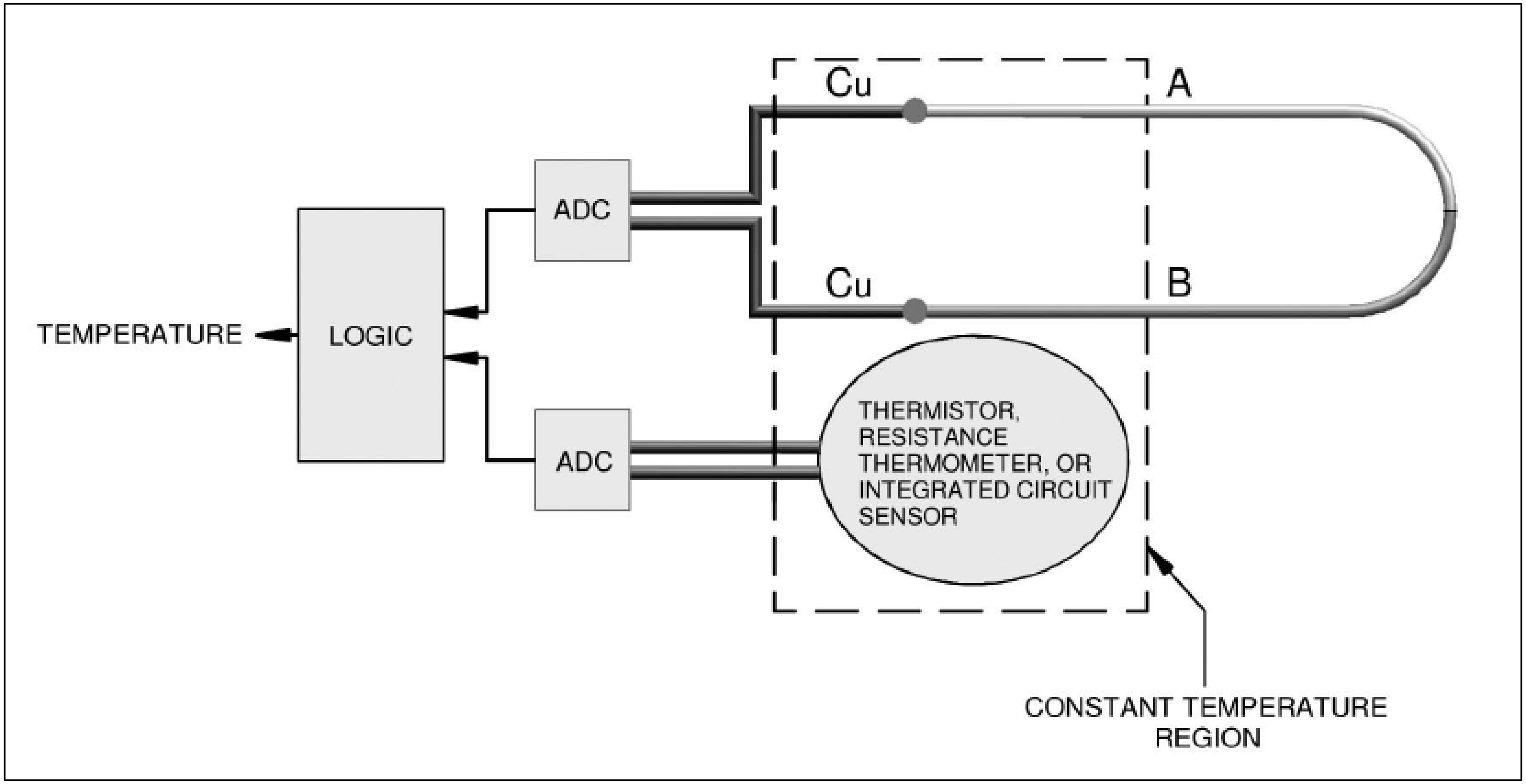


Figure 3-3. Computational Reference Junction Compensation

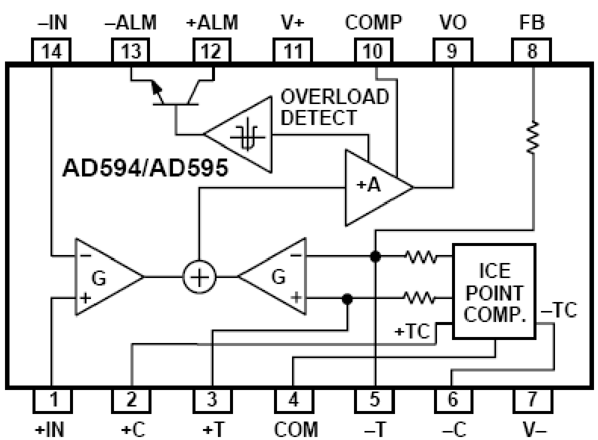
جبرانسازی نقطه سرد در ترموکوپل

روش ۲: استفاده از مدارهای مجتمع خاص

Monolithic Thermocouple Amplifiers with Cold Junction Compensation

AD594/AD595

FEATURES
- Pretrimmed for Type J (AD594) or Type K (AD595) Thermocouples
- Can Be Used with Type T Thermocouple Inputs
- Low Impedance Voltage Output: 10 mV/°C
- Built-In Ice Point Compensation
- Wide Power Supply Range: +5 V to ±15 V
- Low Power: <1 mW typical
- Thermocouple Failure Alarm
- Laser Wafer Trimmed to 1°C Calibration Accuracy
- Setpoint Mode Operation
- Self-Contained Celsius Thermometer Operation
- High Impedance Differential Input
- Side-Brazed DIP or Low Cost Cerdip



The temperature sensitivity of silicon integrated circuit transistors is quite predictable and repeatable. This sensitivity is exploited in the AD594/AD595 to produce a temperature related voltage to compensate the reference of “cold” junction of a thermocouple as shown in Figure 16.

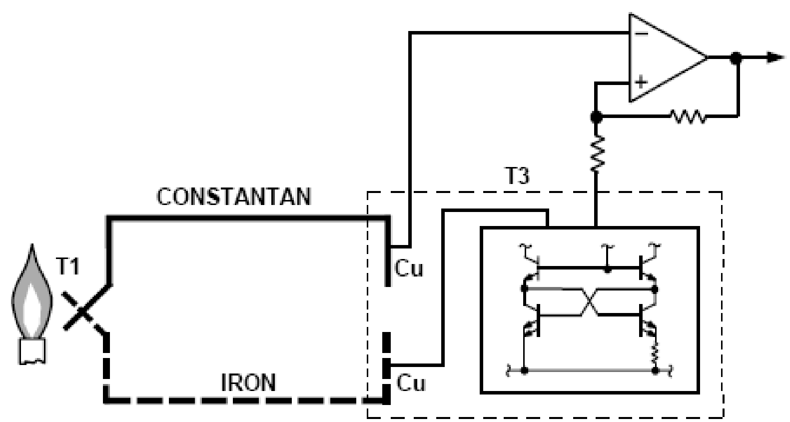


Figure 16. Connecting Isothermal Junctions

T. W. Kerlin and M. Johnson. *Practical thermocouple thermometry*. Instrument Society of America, 1999.

استفاده از مدارهای مجتمع AD594/AD595

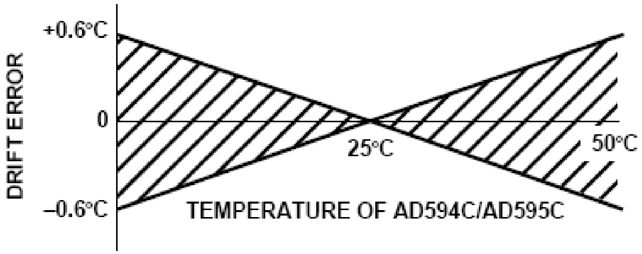


Figure 8. Drift Error vs. Temperature

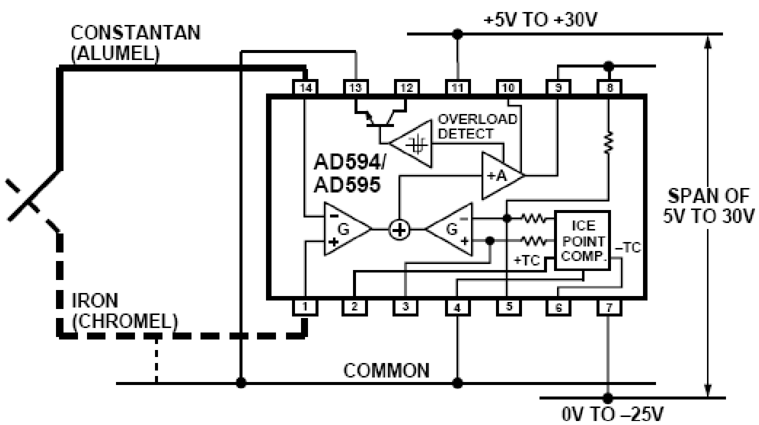


Figure 2. Dual Supply Operation

Table I. Output Voltage vs. Thermocouple Temperature (Ambient +25°C, V_S = –5 V, +15 V)

Thermocouple Temperature °C	Type J Voltage mV	AD594 Output mV	Type K Voltage mV	AD595 Output mV
–200	–7.890	–1523	–5.891	–1454
–180	–7.402	–1428	–5.550	–1370
–160	–6.821	–1316	–5.141	–1269
–140	–6.159	–1188	–4.669	–1152
–120	–5.426	–1046	–4.138	–1021
–100	–4.632	–893	–3.553	–876
–80	–3.785	–729	–2.920	–719
–60	–2.892	–556	–2.243	–552
–40	–1.960	–376	–1.527	–375
–20	–.995	–189	–.777	–189
–10	–.501	–94	–.392	–94
0	0	3.1	0	2.7
10	.507	101	.397	101
20	1.019	200	.798	200
25	1.277	250	1.000	250
30	1.536	300	1.203	300
40	2.058	401	1.611	401
50	2.585	503	2.022	503
60	3.115	606	2.436	605
80	4.186	813	3.266	810
100	5.268	1022	4.095	1015
120	[illegible]	1233	[illegible]	[illegible]

استفاده از مدارهای مجتمع AD594/AD595

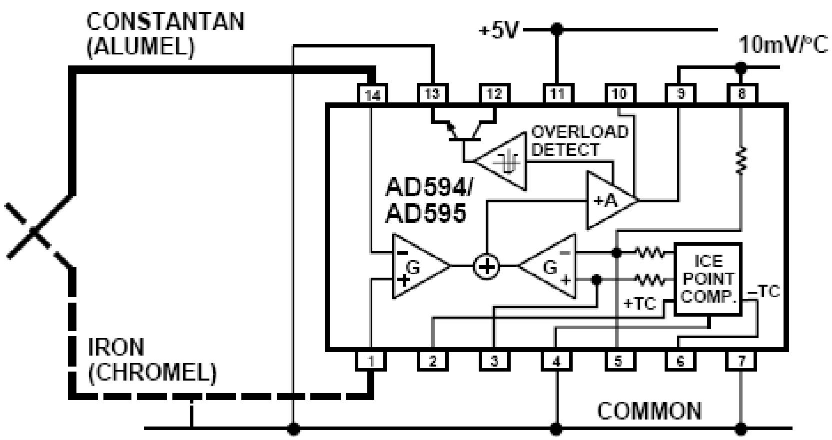


Figure 1. Basic Connection, Single Supply Operation

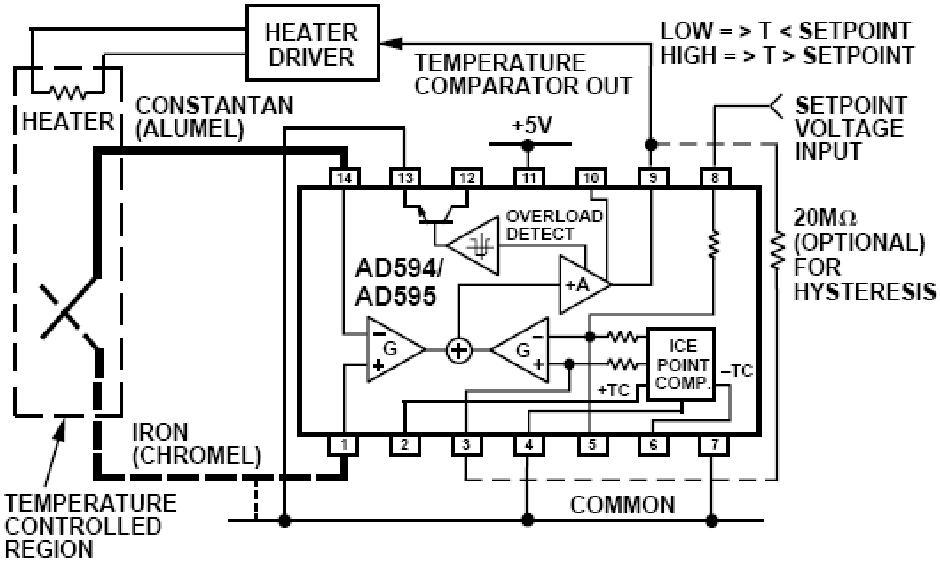
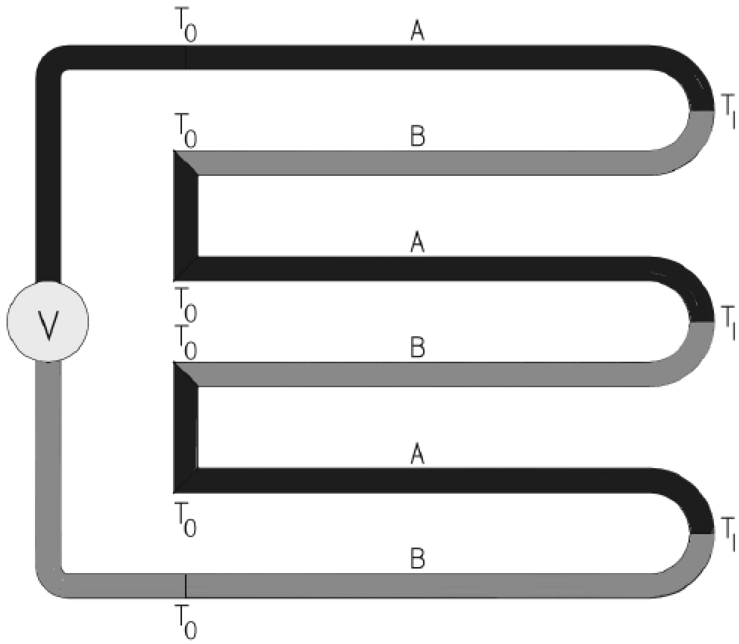


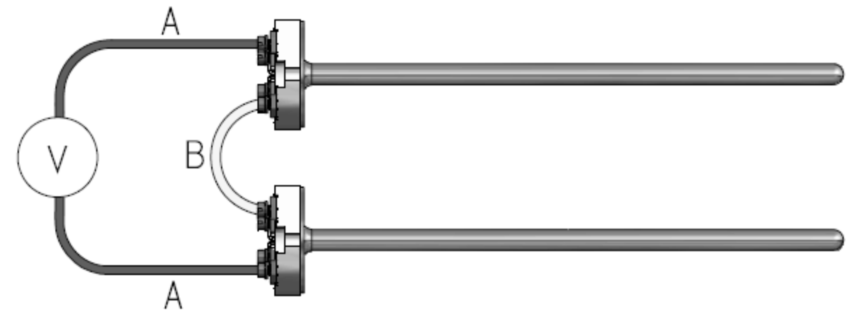
Figure 9. Setpoint Controller

Hysteresis can be introduced by injecting a current into the positive input of the feedback amplifier when the output is toggled high. With an AD594 about 200 nA into the +T terminal provides 1°C of hysteresis.



Thermocouples Wired in Series

This configuration, called a *thermopile*, may be used to obtain a larger signal than would be obtained with the normal single thermocouple arrangement.



Two Thermocouples Configured for Differential Measurements

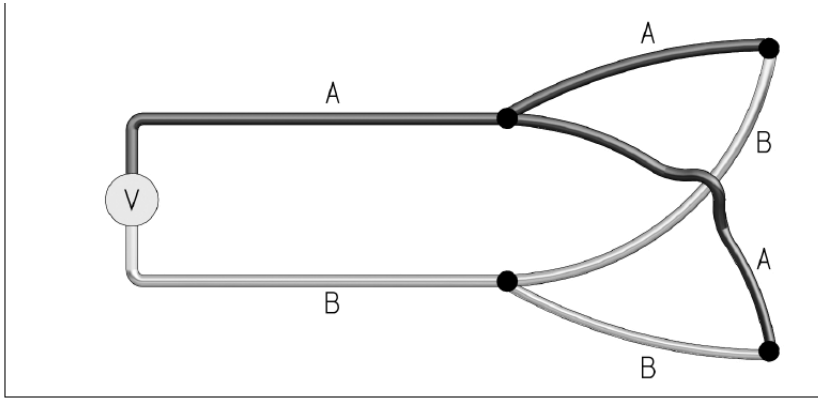


Figure 2-12. Thermocouples Wired in Parallel

$$E_T = \frac{\sum_1}{\sum_1 + \sum_2 + \ldots \sum_n} E_1 + \frac{\sum_{1_2}}{\sum_1 + \sum_2 + \ldots \sum_n} E_2 + \ldots$$

where

E_T	=	total emf from the circuit
Σ_i	=	$1/R_i$ = electrical conductance of thermocouple I
E_i	=	emf from thermcouple I

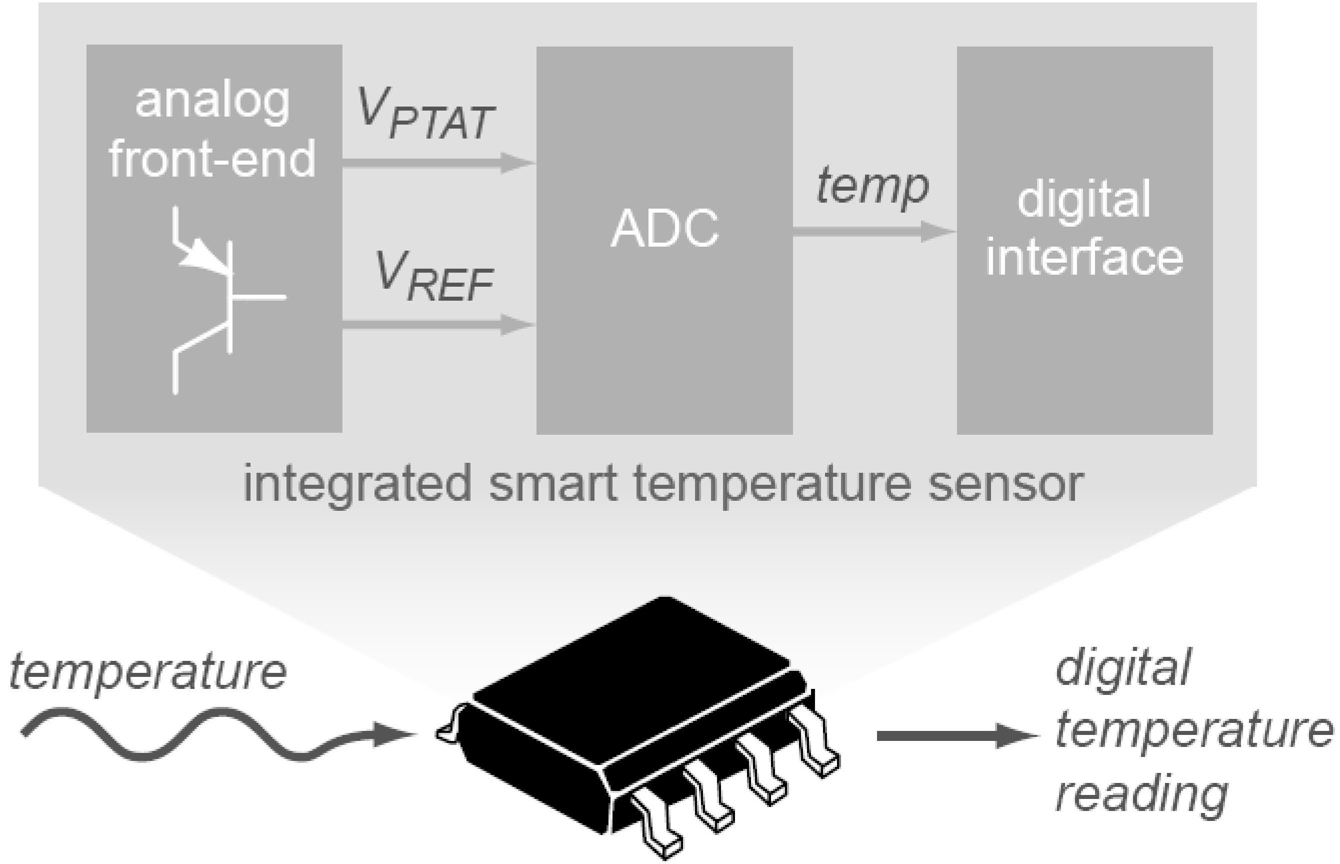
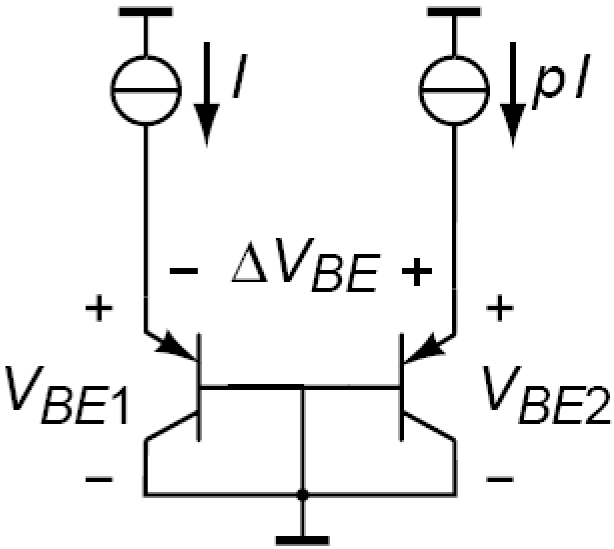
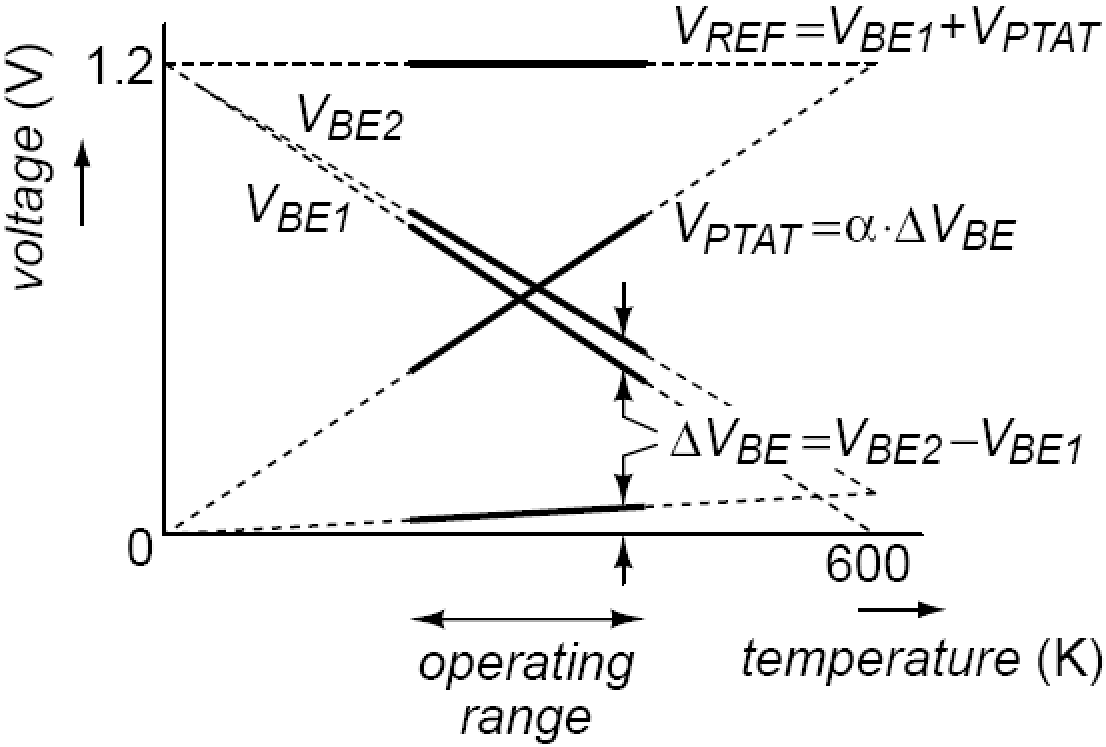


Figure 1.1. Block diagram of an integrated smart temperature sensor.





Proportional to Absolute Temperature (PTAT)

M. Pertijs and J. Huijsing. “Precision temperature sensors in CMOS technology.” Springer Science & Business Media, 2006.

If an external voltage V is applied to a p-n junction, the balance between the drift and diffusion currents is disturbed:

$$n_{p-side} = n_{p0} \exp\left(\frac{qV}{kT}\right),$$

$$p_{n-side} = p_{n0} \exp\left(\frac{qV}{kT}\right)$$

$$n_{po} = \frac{n_i^2}{N_a}, \quad p_{no} = \frac{n_i^2}{N_d},$$

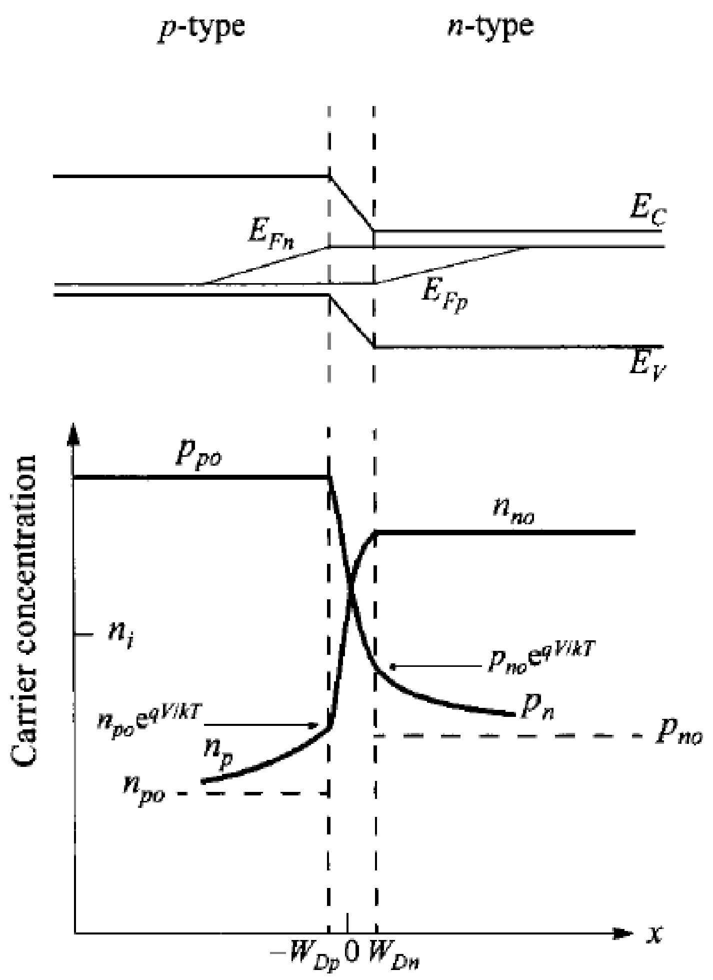
$$I_D = \frac{qAD_n(n_{p-side} - n_{p0})}{L_n} + \frac{qAD_p(p_{n-side} - p_{n0})}{L_p}$$

$$I_D = I_S\left(\exp\left(\frac{qV}{kT}\right) - 1\right)$$

$$I_S = \frac{qAD_n n_{p0}}{L_n} + \frac{qAD_p p_{n0}}{L_p}.$$

For forward-bias voltages $V \gg kT/q$,

$$V = \frac{kT}{q} \ln\left(\frac{I}{I_S}\right)$$



S.M Sze and K. Neg, “Physics of semiconductors”, 2006.

حسگر دمای مدار مجتمع

For forward-bias voltages $V \gg kT/q$,

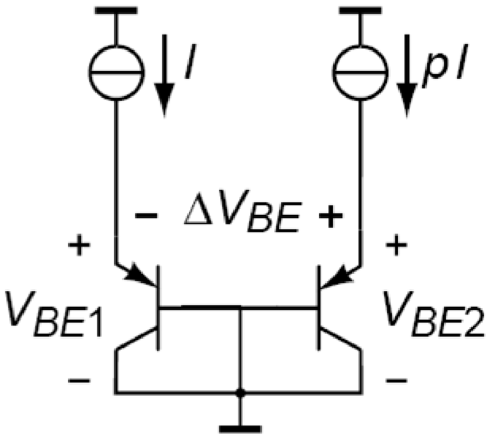
$$V = \frac{kT}{q} \ln\left(\frac{I}{I_S}\right)$$

If two bias currents I_1 and $I_2 = pI_1$ are successively applied to a diode,

$$V_2 - V_1 = \frac{kT}{q} \ln\left(\frac{pI_1}{I_S}\right) - \frac{kT}{q} \ln\left(\frac{I_1}{I_S}\right) = \frac{kT}{q} \ln p.$$

↓

اختلاف ولتاژهای بیس-امیترها نسبت به دما، خطی است.



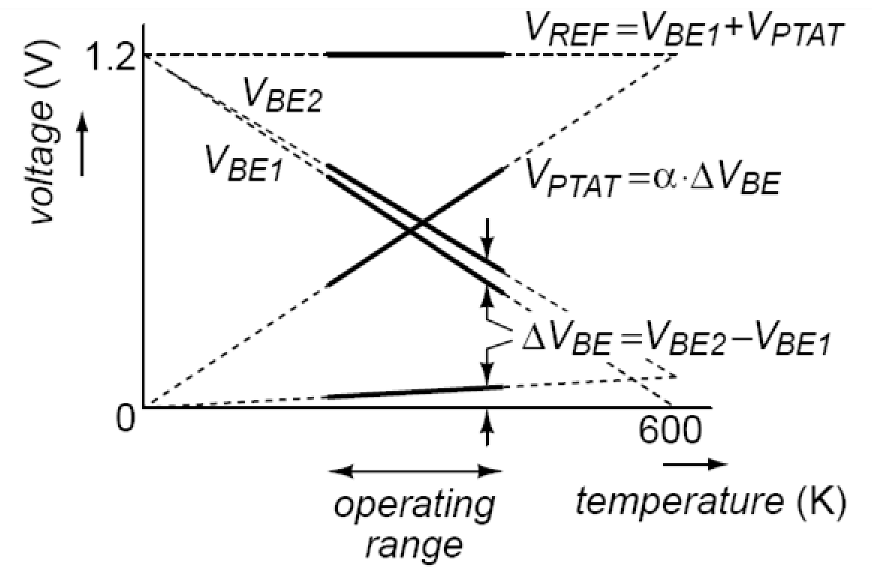


Table 7.6. Accuracy comparison of smart temperature sensors.

Reference	Inaccuracy	Range
LM75 [1]	±2.0 °C	−25 °C to 100 °C
	±3.0 °C	−55 °C to 125 °C
LM92 [17]	±0.33 °C	at 30 °C
	±1.5 °C	−25 °C to 150 °C
DS1626 [18],	±0.5 °C	0 °C to 70 °C
	±2.0 °C	−55 °C to 125 °C
ADT7301 [19]	±1.0 °C	0 °C to 70 °C
	±3.0 °C	−40 °C to 125 °C
SMT160-30 [20]	±0.7 °C	−30 °C to 100 °C
	±1.2 °C	−45 °C to 130 °C

M. Pertijs and J. Huijsing. “Precision temperature sensors in CMOS technology.” Springer Science & Business Media, 2006.