

2. SENZORI TEMPERATURE

- **Temperatura** je fizička veličina koja predstavlja stepen zagrejanosti sredine-tela (energetsko stanje medijuma).
- Temperatura je **intezivna (aktivna) veličina** koja nema svojstvo *aditivnosti* (prilikom deljenja tela svaki deo zadržava temperaturu tog tela).
- Ne može se izgraditi deljitelj ili sabirač.

$$T = f(x, y, z, t)$$

- U gasnoj ili tečnoj sredini, merenje može biti izvršeno u bilo kojoj tački.
- U slučaju čvrstih tela, merenja su uglavnom vezana za površinu tela.

- Podela senzora (po principu rada)
 - Ekspanzioni senzori temperature
 - Otpornički senzori temperature
 - Metalni otpornički senzori (*RTD*)
 - Poluprovodnički otpornički senzori (*Termistori: NTC i PTC*)
 - Termoelementi
- Senzori (po načinu rada) :
 - Kontaktni senzori temperature
 - Beskontaktni senzori temperature
 - (*na osnovu zračenja – pirometri, toplotne kamere*)

1 Temperature measuring points in the motor vehicle

Measuring point	Temperature range °C
Intake/charge air	-40 to 170
External environment	-40 to 60
Interior	-20 to 80
Exhaust air/heating system	-20 to 60
Evaporator (air-conditioning system)	-10 to 50
Cooling water	-40 to 130
Engine oil	-40 to 170
Battery	-40 to 100
Fuel	-40 to 120
Tire air	-40 to 120
Exhaust gas	100 to 1,000
Brake caliper	-40 to 2,000

Metalni otpornički senzori temperature

1 Methods for resistance/voltage conversion

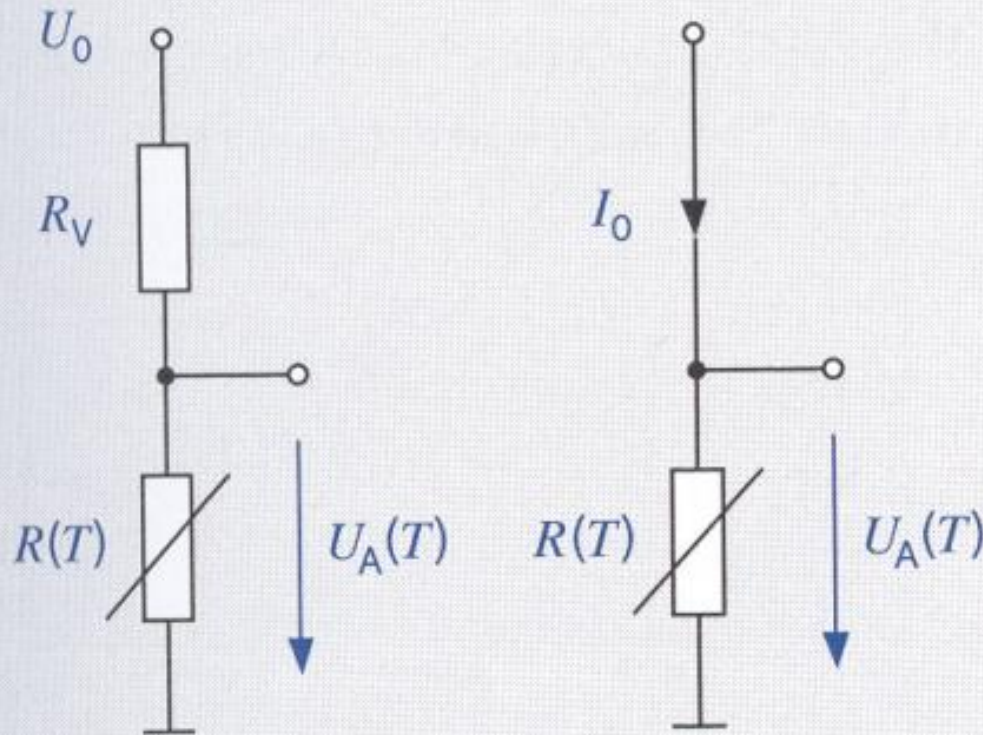


Fig. 1

- I_0 Current supply
- U_0 Supply voltage
- R_V Temperature-independent series resistor
- $R(T)$ Temperature-dependent measuring resistor
- $U_A(T)$ Output voltage

$$U(T) = U_0 \cdot \frac{R(T)}{R(T) + R_V}$$

$$U(T) = I_0 \cdot R(T)$$

$$R_V \approx R(T_0)$$

2 Calibration of a resistor to its setpoint value

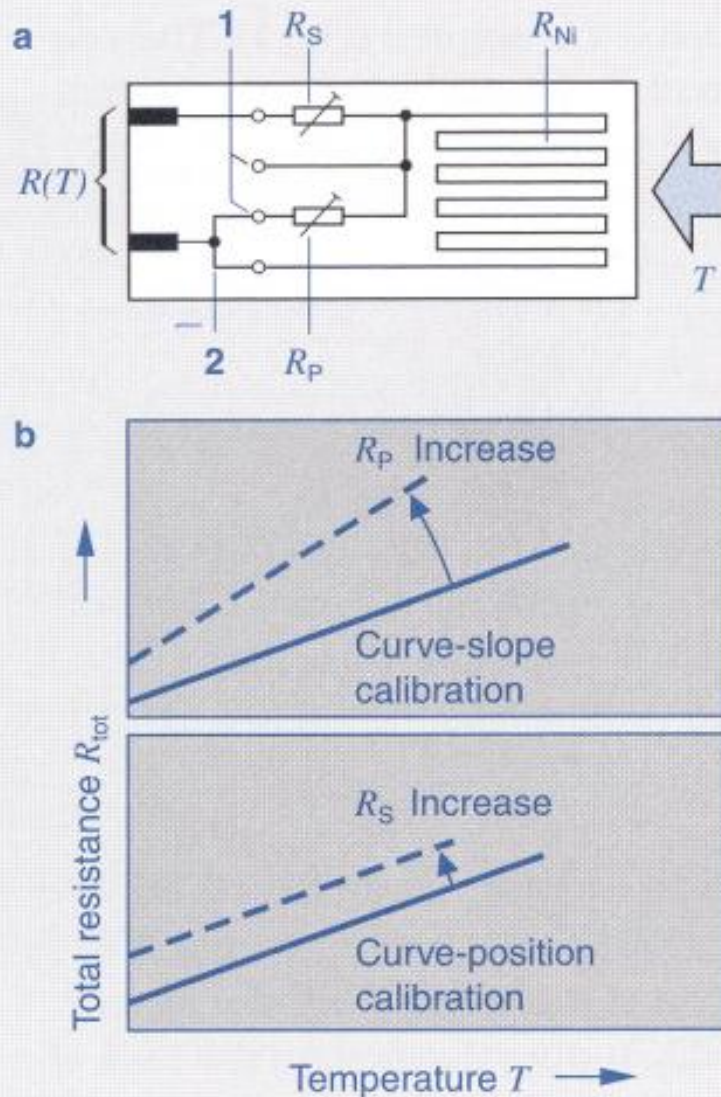


Fig. 2

a Resistance sensor

b Characteristic curves

1 Auxiliary contacts

2 Bridge

R_{Ni} Nickel-film resistor

$R_{tot}(T)$ Total resistance referred to temperature T

R_P Adjustable parallel resistor

R_S Adjustable series resistor

Poluprovodnički otpornički senzori temperature

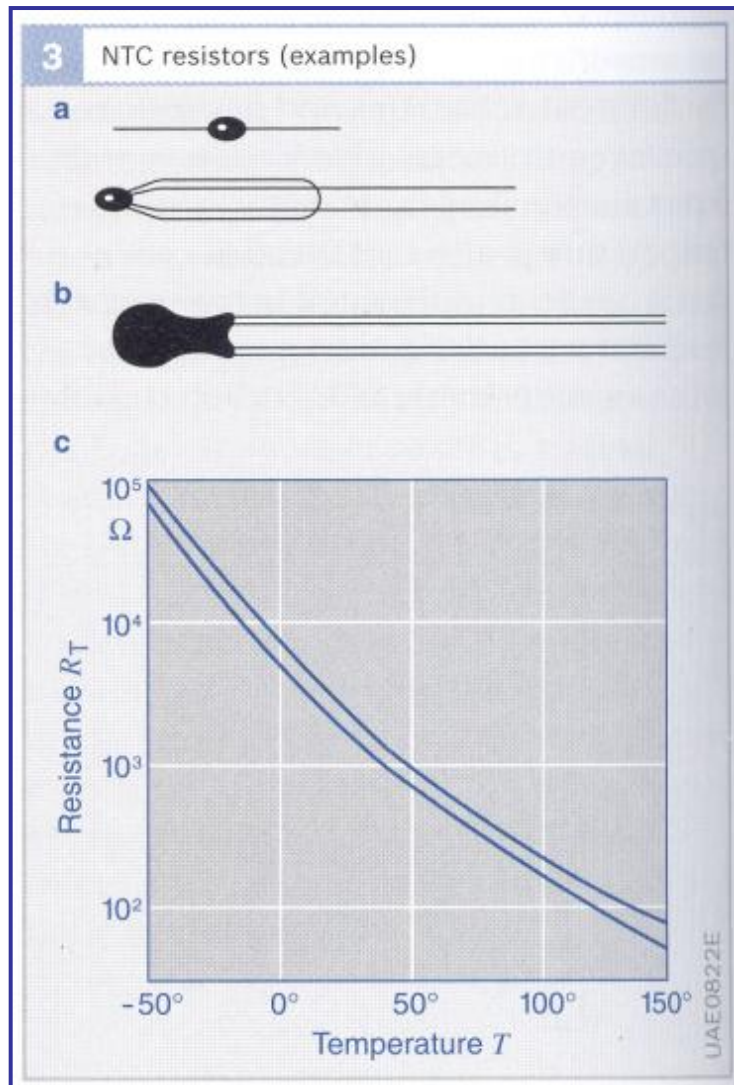


Fig. 3

- a Pearl form
- b Disk form
- c Characteristic curve with limits of variation

$$R(T) = R_0 \cdot e^{B \cdot \left(\frac{1}{T} - \frac{1}{T_0} \right)}$$

Where $R_0 = R(T_0)$,
 $B = 2,000$ to $5,000$ K = const,
 T absolute temperature

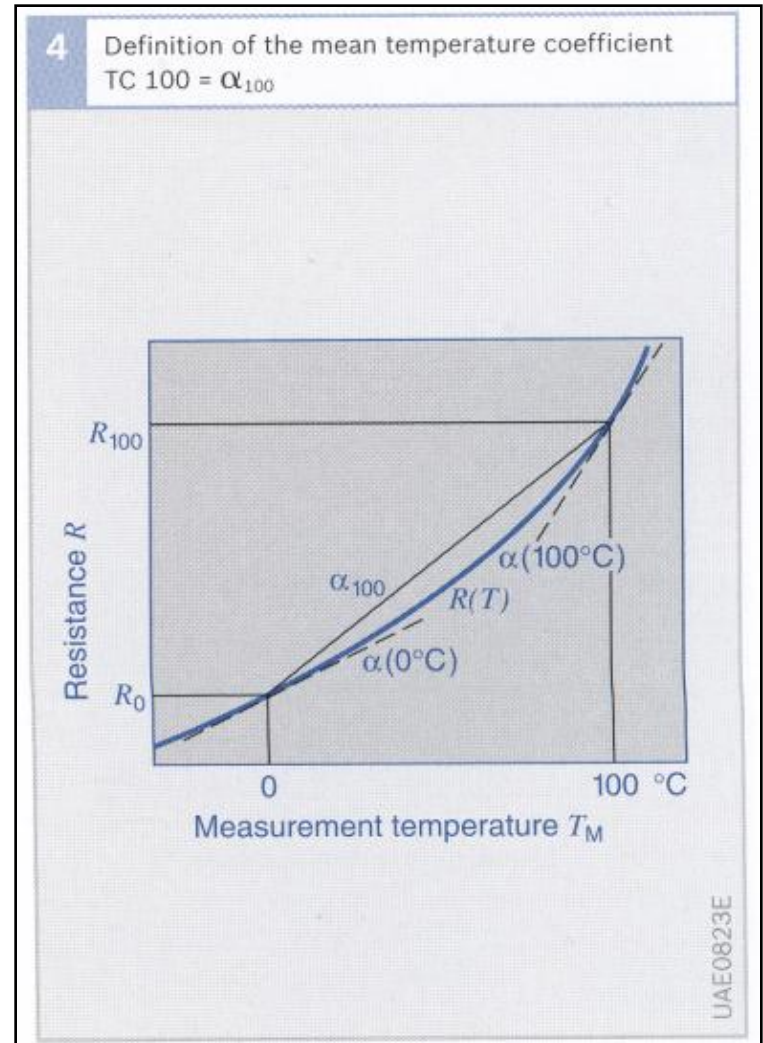
$$TC = -B/T^2$$

PTC metalni otpornički senzori u tehnici tankog filma

$$R(T) = R_0 (1 + \alpha \cdot \Delta T + \beta \cdot \Delta T^2 + \dots)$$

where $\Delta T = T - T_0$ and
 $T_0 = 20^\circ\text{C}$ (reference temperature),
 α linear temperature coefficient (TC),
 β square temperature coefficient.

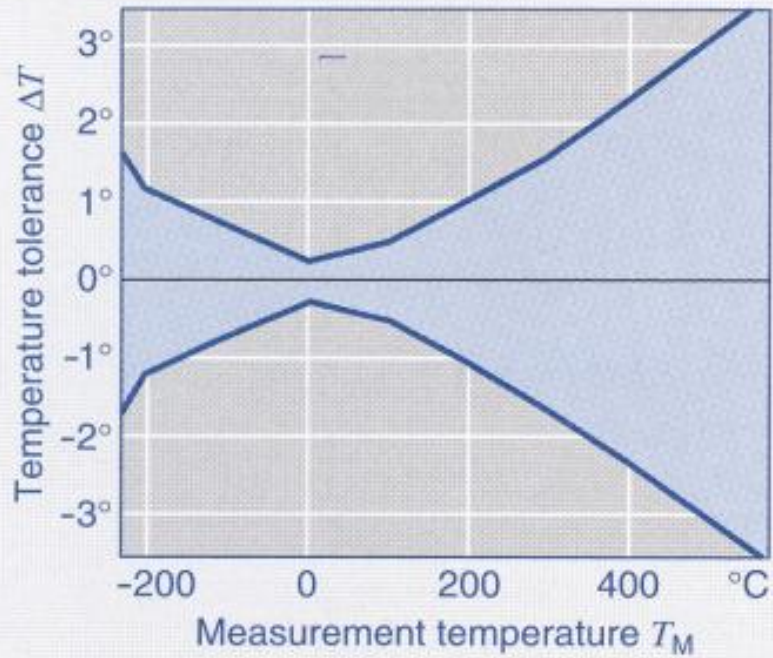
$$\text{Where } TC\ 100 = \frac{R(100^\circ\text{C}) - R(0^\circ\text{C})}{R(0^\circ\text{C}) \cdot 100\text{K}}$$



2 Temperature coefficient TC 100

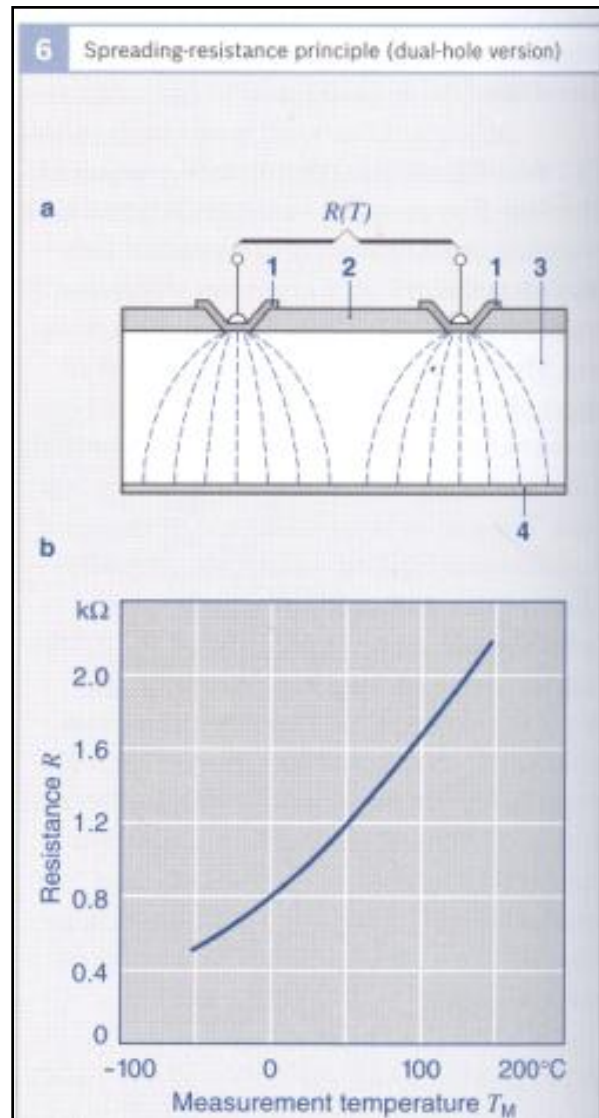
Sensor material	TC 100 $10^{-3}/K$	Characteris- tic curve	Measuring range
Nickel (Ni)	5.1	slightly progressive	-60 to 320
Copper (Cu)	4.1	slightly progressive	-50 to 200
Platinum (Pt)	3.5	slightly degressive	-220 to 850

5 Pt resistor (tolerance diagram)



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Monokristalni poluprovodnički otpornički senzori temperature (PTC)



- $TC = 7,73 \cdot 10^{-3}/K$ (duplo veći nego Pt otpornik)
- Merni opseg do $+150^{\circ}C$
(specijalne verzije do $+300^{\circ}C$, Sl. 7)

Fig. 6

- a** Design
- b** Characteristic curve
- 1 Contacts
- 2 Passivation (Nitride, oxide)
- 3 Si substrate
- 4 Counter-electrode without connection
- $R(T)$ Temperature-dependent resistor

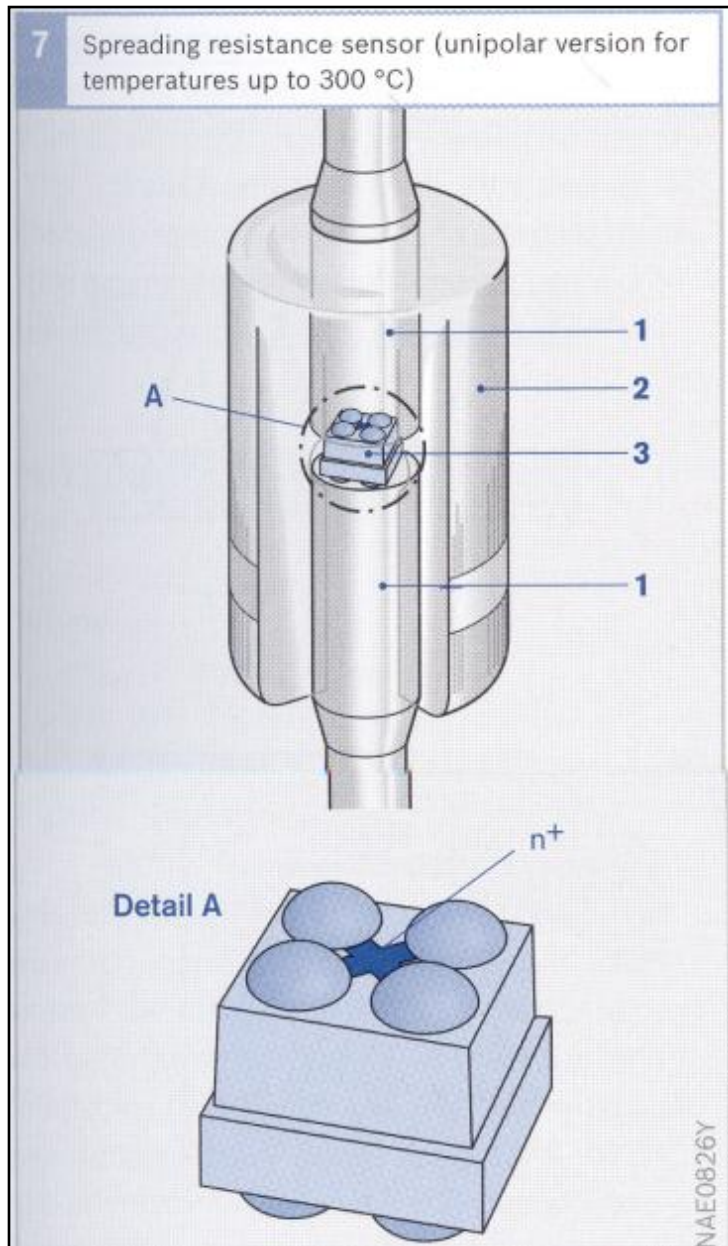
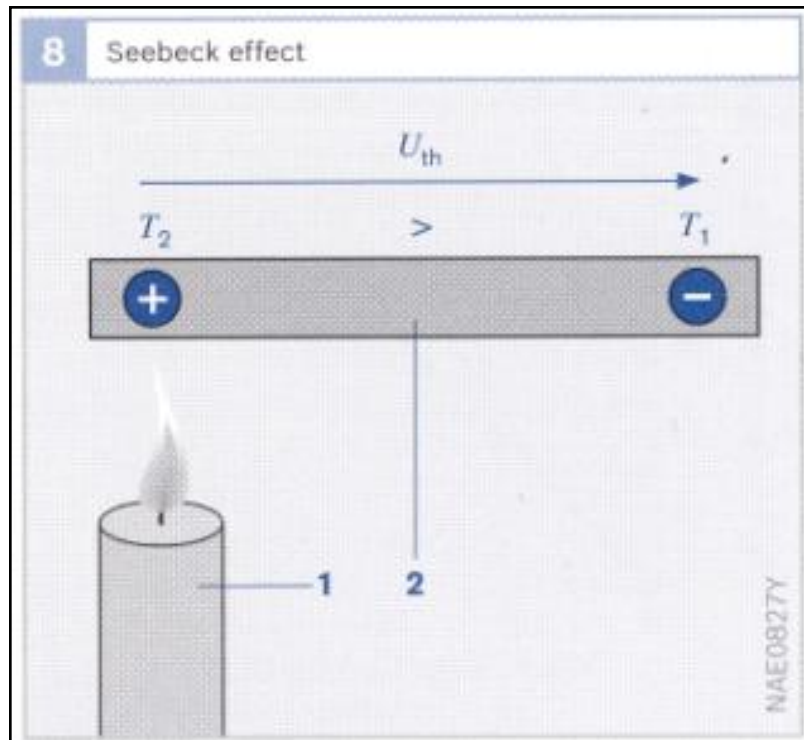


Fig. 7

- 1 Metal wire
- 2 Glass
- 3 Si crystal

Termoelementi



3 Thermoelectric voltage U_{th} of a number of metals

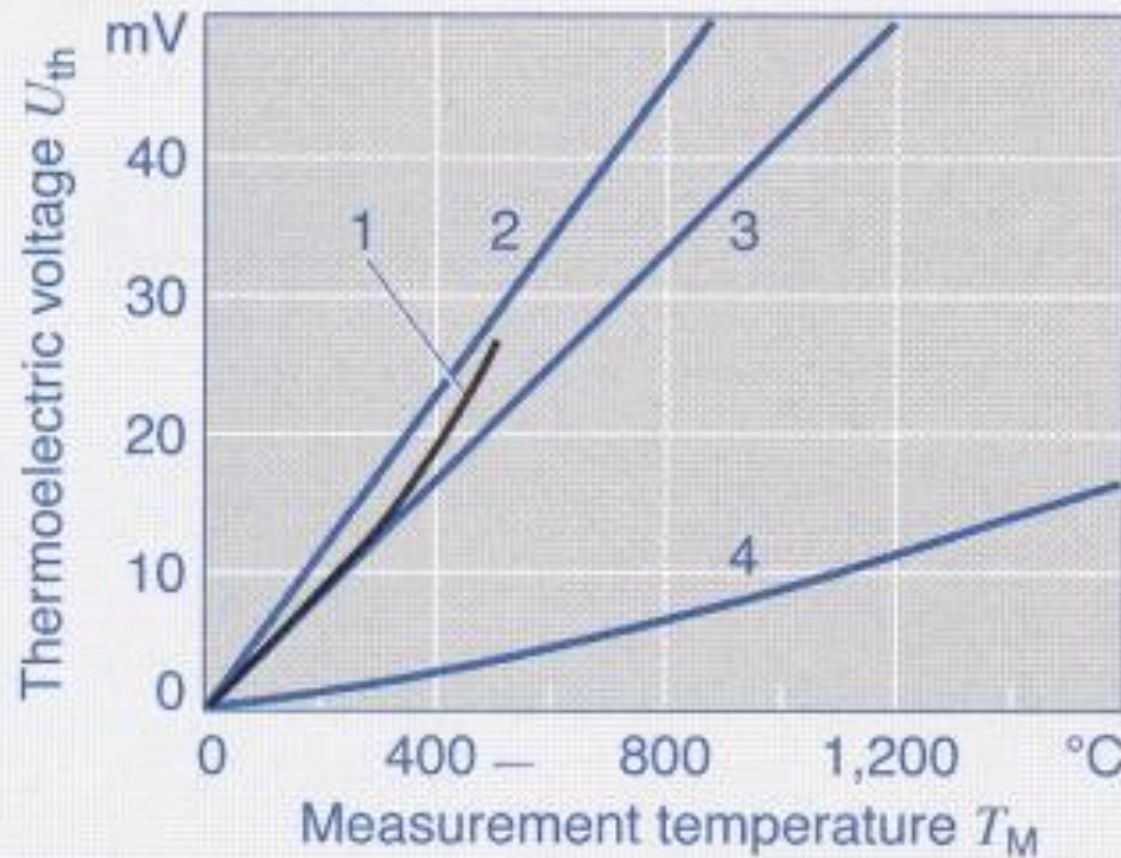
Material	Thermoelectric voltage U_{th} mV/100 °C
Constantan	-3.40
Nickel	-1.90
Paladium	-0.28
Platinum	0.00
Copper	+0.75
Manganite	+0.60
Iron	+1.88
Silicon	+44.80

Fig. 8

$$U_{th} = c (T_2 - T_1) = c \Delta T,$$

- 1 Heat source
- 2 Metallic conductor
- + High,
- low thermal velocity
of the electrons
- T_2 High temperature
- T_1 Low temperature
- U_{th} Thermoelectric
voltage

9 Common thermocouples (characteristic curves)



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Fig. 9

- 1 Copper/Constantan
- 2 Iron/Constantan
- 3 Nickel-chromium/Nickel
- 4 Platinum rhodium/Platinum

10 Thermocouple measuring set-up

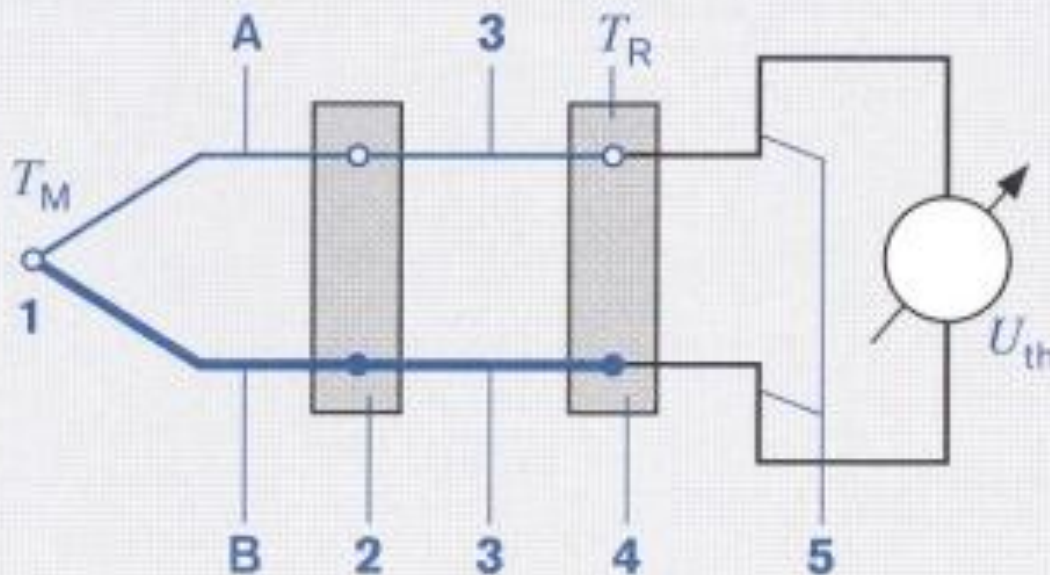
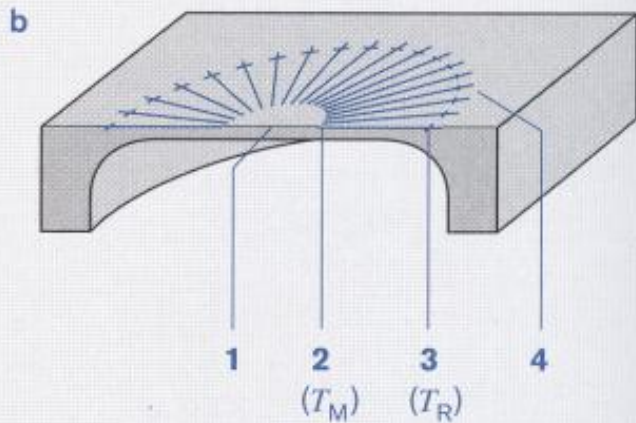
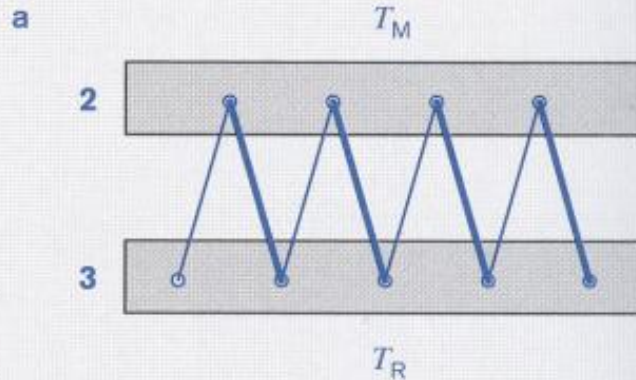


Fig. 10

- A/B Material pair (thermocouple legs)
- 1 Measuring point (electrically conductive junction)
- 2 Connection head
- 3 Compensating cable
- 4 Reference point
- 5 Connection cable (Cu)
- T_M Measurement temperature
- T_R Reference temperature
- U_{th} Thermoelectric voltage

- **Termoelektrični efekat** (Zebekov termoelektrični efekat) je pojava da kroz kolo od dva provodnika, napravljena od različitih materijala, čiji su krajevi na različitim temperaturama teče **termoelektrična struja**.
- To je termoelektrično kolo, koje se uobičajeno još naziva **termoelement (termopar)**

11 Thermocouples connected in series



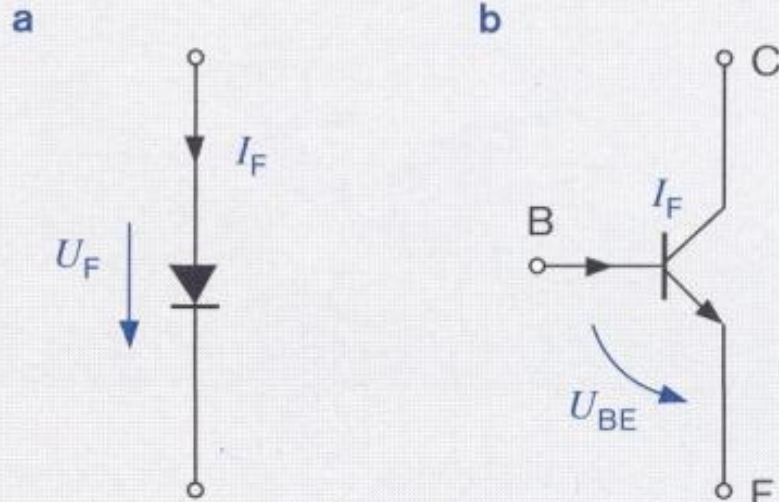
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Fig. 11

- a Principle of the thermopile
- b Example of application
- 1 Sensitive surface
- 2 "Hot" junctions at the measurement temperature T_M
- 3 "Cold" junctions at the reference temperature T_R
- 4 Thermopile

Dioda i tranzistor kao senzori temperature

12 Semiconductor depletion layers



$$U_F(T) = \frac{k \cdot T}{q} \cdot \ln \left(\frac{I_F}{I_{sat}} + 1 \right) \quad (10)$$

Where:

$I_{sat} = I_{sat}(T)$ and $I_F = \text{constant}$,

$q = 1.6 \cdot 10^{-19} \text{ C}$ (elementary charge),

$k = 1.88 \cdot 10^{-23} \text{ JK}^{-1}$ (Boltzmann's constant),

T absolute temperature.

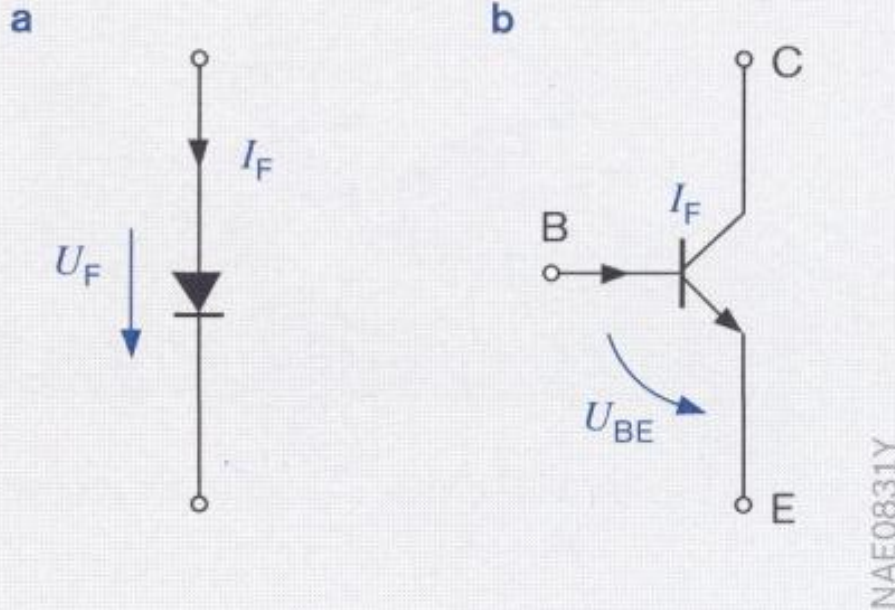
- Direktna struja I_F i inverzna struja zasićenja diode I_S menjaju se sa promenom temperature, ali su male za praktičnu primenu.
- $U_F(T)$ pri $I_F = \text{const}$ - **nelinearno**
- Merni opseg od -50°C do $+150^\circ \text{C}$ može se aproksimirati sa:

$$U_F(T) = k_1 - k_2 T$$

gde je: $k_1 = U_F(0) = 1,27 \text{ V}$, $k_2 = 2-3 \text{ mV/}^\circ \text{C}$

Dioda i tranzistor kao senzori temperature

12 Semiconductor depletion layers



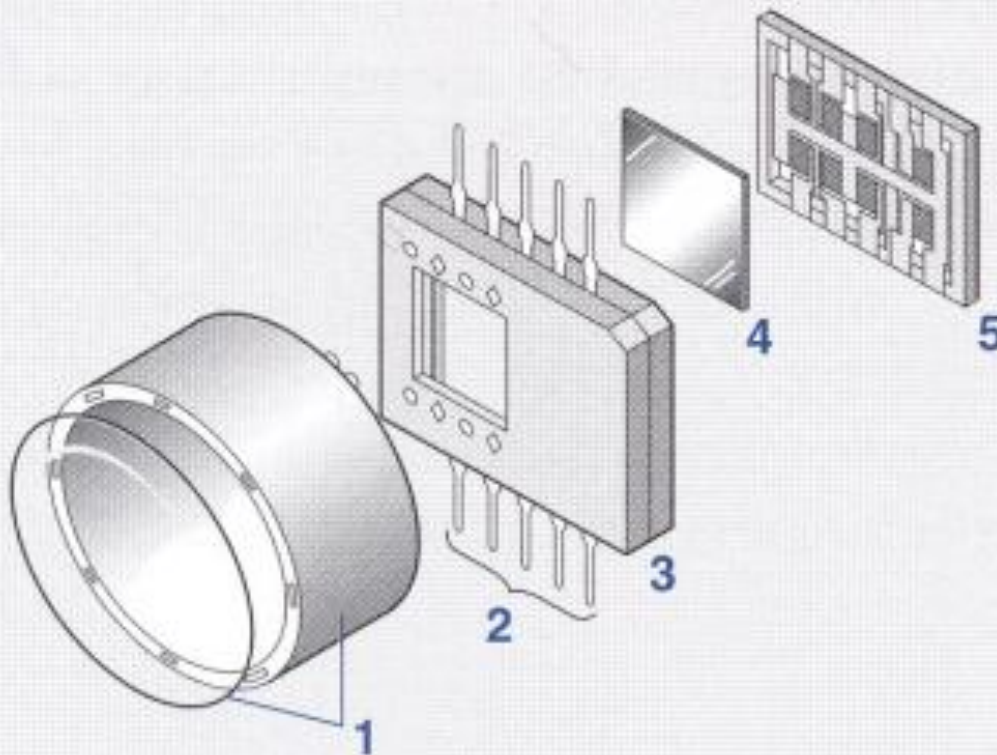
- Porast temperature utiče na smanjivanje inverzne struje kroz spoj kolektor-baza I_{CB0} , kao kod pn spoja diode.
- udvostručuju se za porast od $10\text{ }^{\circ}\text{C}$ i TC ima visoke vrednosti, ali su struje vrlo male $1\text{ }\mu\text{A}$ (Si) i $100\text{ }\mu\text{A}$ (Ge) i teško ih je meriti.
- Veću primeni za merenje temper. ima $U_{BE}(T)$ pri $I_F=I_C=const$ (nelinearno)
- Merni opseg od $-270\text{ }^{\circ}\text{C}$ do $+200\text{ }^{\circ}\text{C}$ može se aproksimirati sa:

$$U_{BE}(T) = k_1 - k_2 T$$

gde je: $k_1 = U_{BE}(0) = 1,27\text{V}$, $k_2 = 2\text{-}3\text{mV}/^{\circ}\text{C}$

Beskontaktni senzori: senzori termičkog zračenja

13 Prototype of a bolometric sensor array for automotive applications



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Fig. 13

- 1 Lens housing with lens
- 2 Connections
- 3 Infrared detector housing
- 4 Infrared window
- 5 Detector

14 Pyrometric sensor produced using micromechanical techniques, with thermopile pick-off.

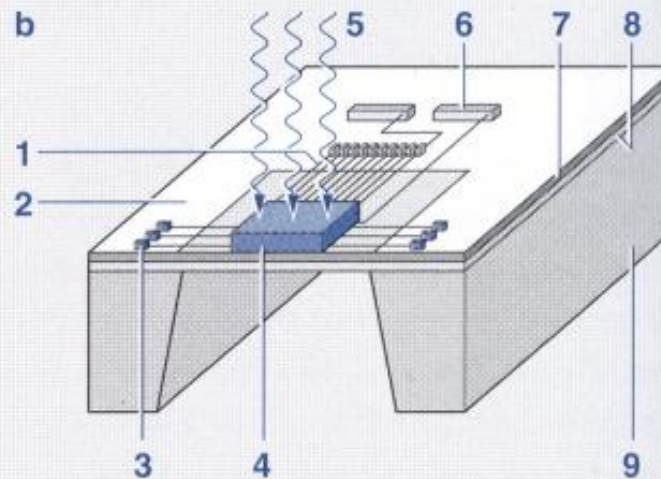
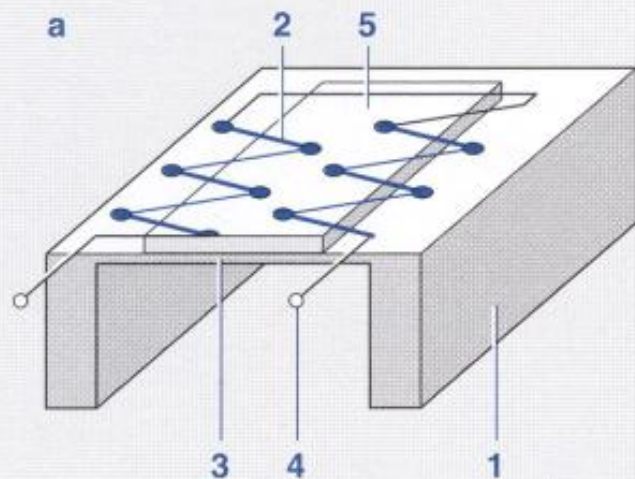


Fig. 14

- a Principle of the measuring cell
- 1 Silicon chip
 - 2 Thermocouples connected in series (e.g. Al/poly-Si)
 - 3 SiN diaphragm
 - 4 Thermopile terminals
 - 5 Absorber layer
- b Sensor type
- 1 Thermocouple
 - 2 "Cold" junction
 - 3 Diaphragm
 - 4 Absorber
 - 5 Heat radiation
 - 6 Electrical connection
 - 7 Si_3N_4 layer
 - 8 SiO_2 layer
 - 9 Heat sink

15 Thermal image analysis

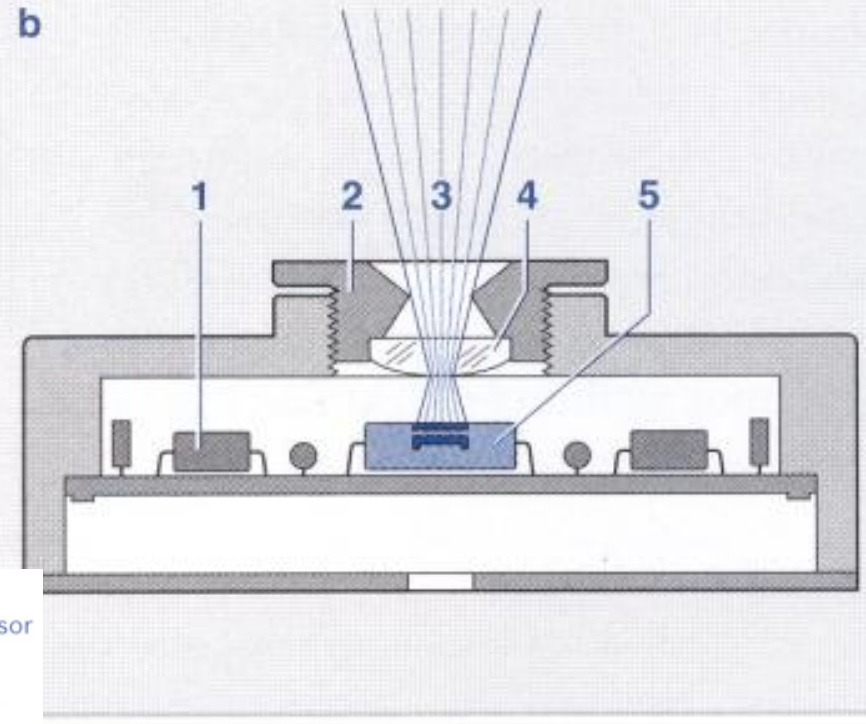
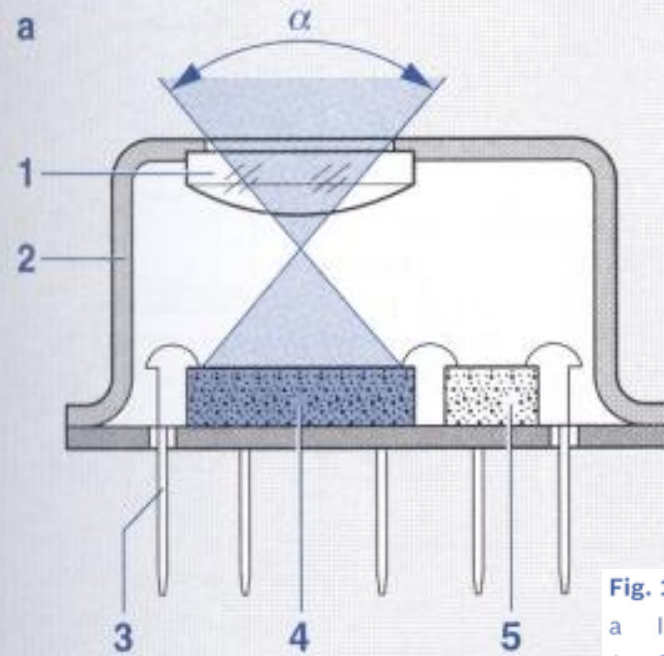


Fig. 15

- a IR imaging sensor
- 1 Silicon IR lens
- 2 TO5 housing
- 3 Terminal posts
- 4 Sensor chip
- 5 Evaluation ASIC
- α Viewing angle

- b Simple IR camera
- 1 Electronics
- 2 Lens system
- 3 Camera's field of view
- 4 Si IR lens
- 5 Sensor array

16 Micromechanical thermopile array

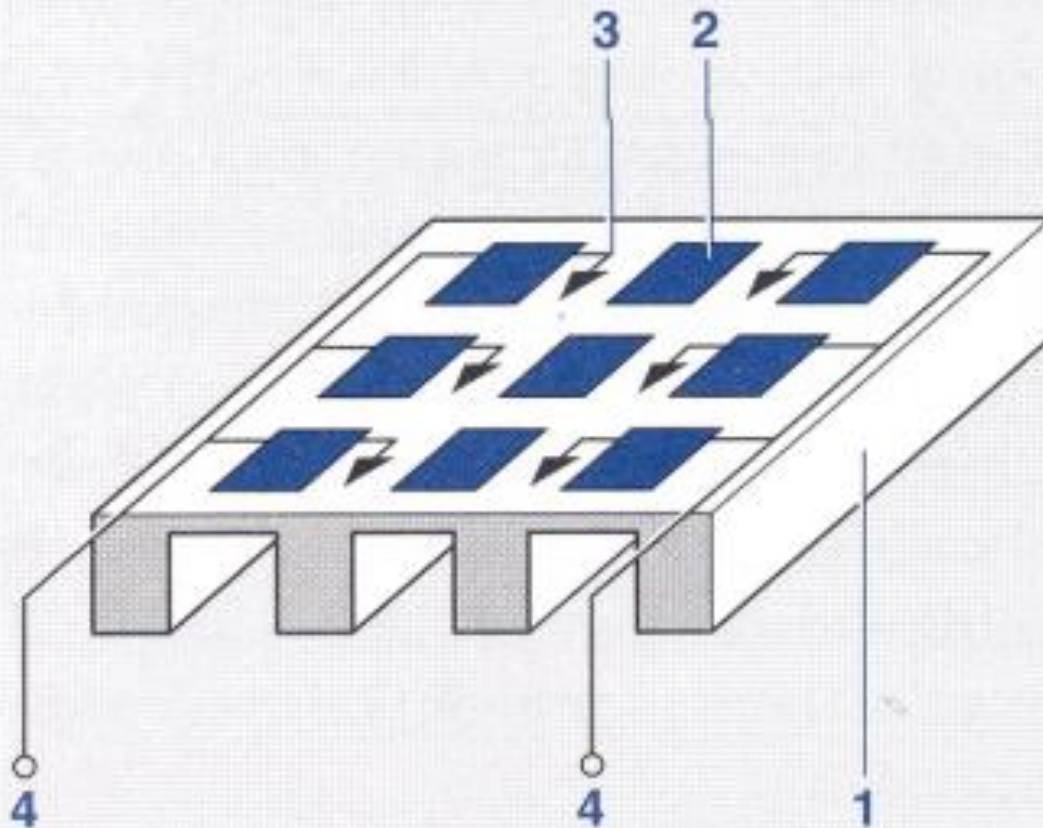
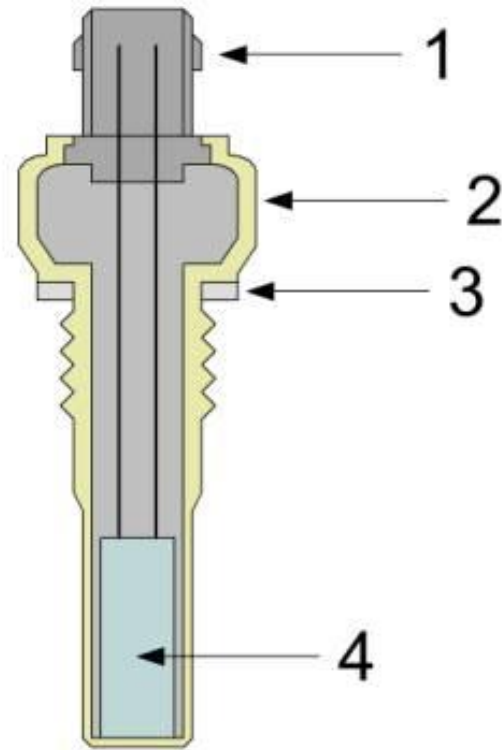


Fig. 16

- 1 Silicon chip
- 2 Pixel
- 3, 4 Pixel connections

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Primer: Senzor temperature rashladne tečnosti (ECT)



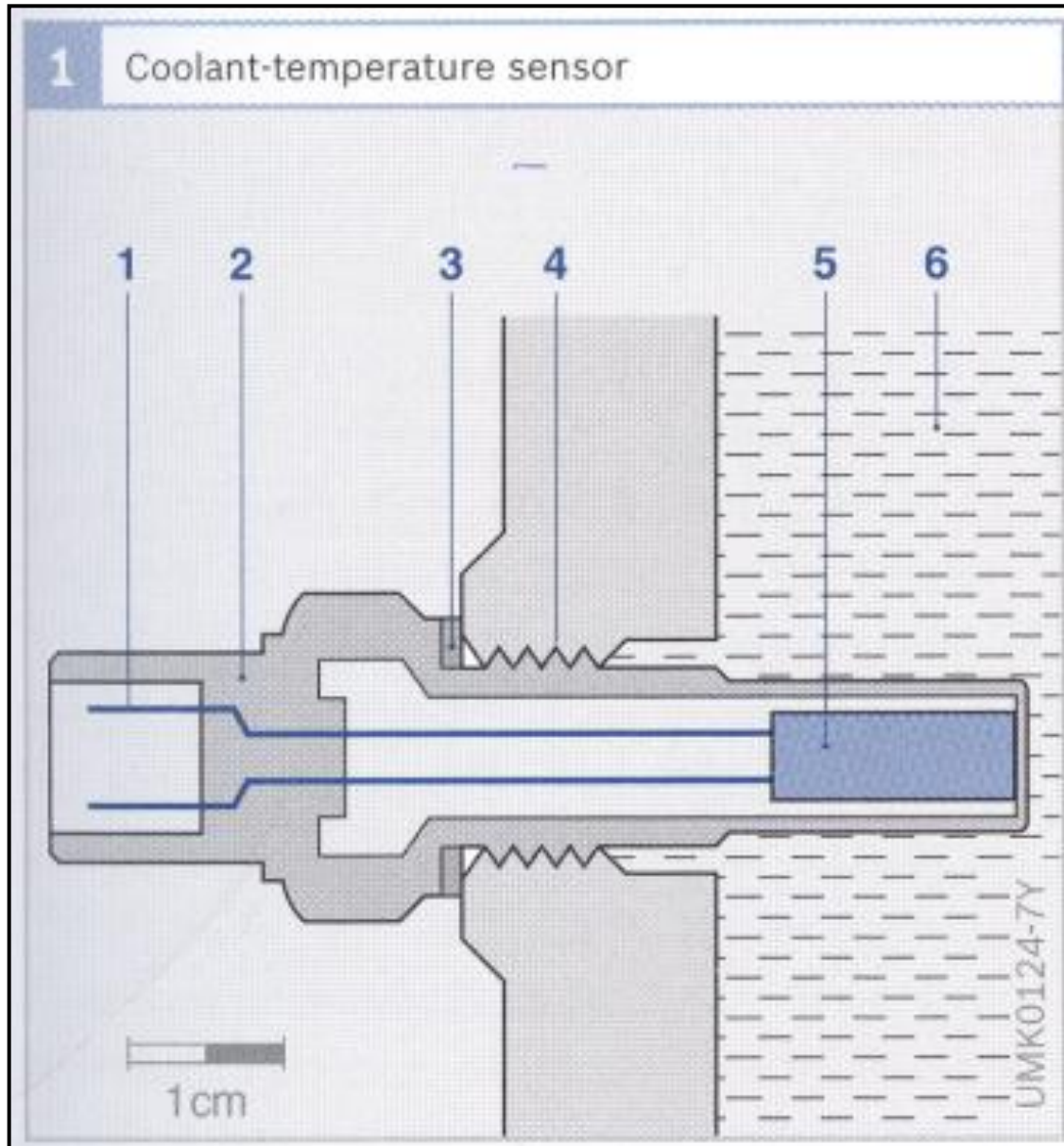
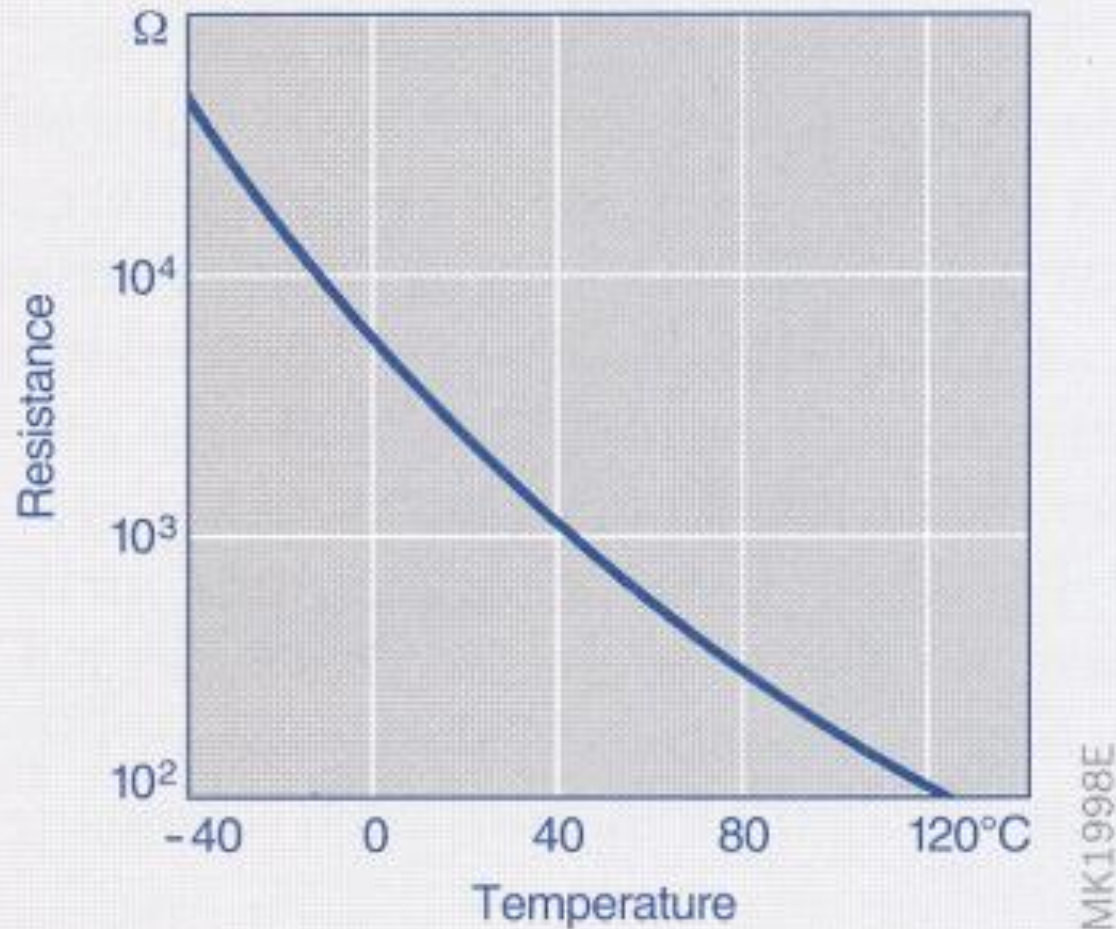


Fig. 1

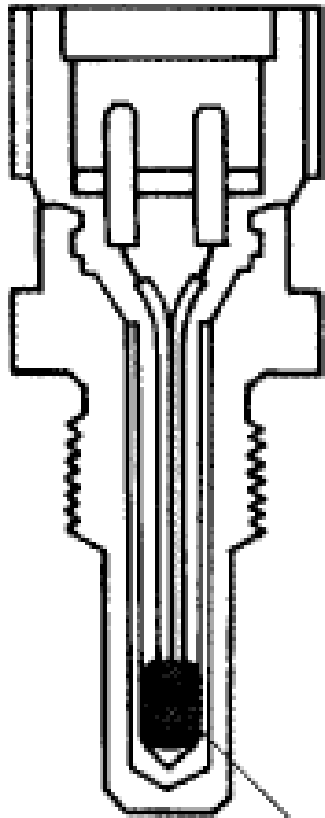
- 1 Electrical connection
- 2 Housing
- 3 Sealing ring
- 4 Thread
- 5 Measuring shunt
- 6 Coolant

2

NTC temperature sensor: characteristic curve

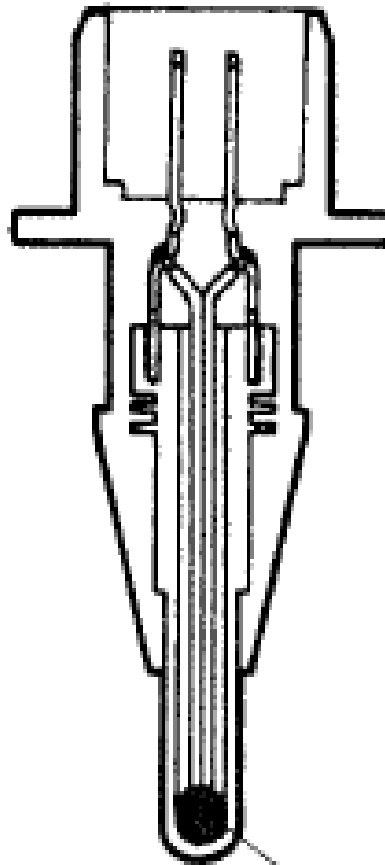


ECT



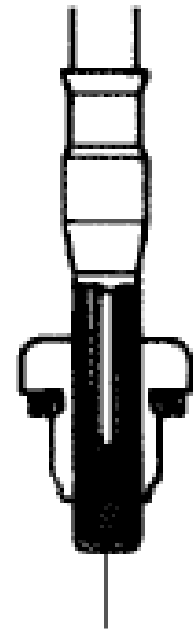
Thermistor

IAT

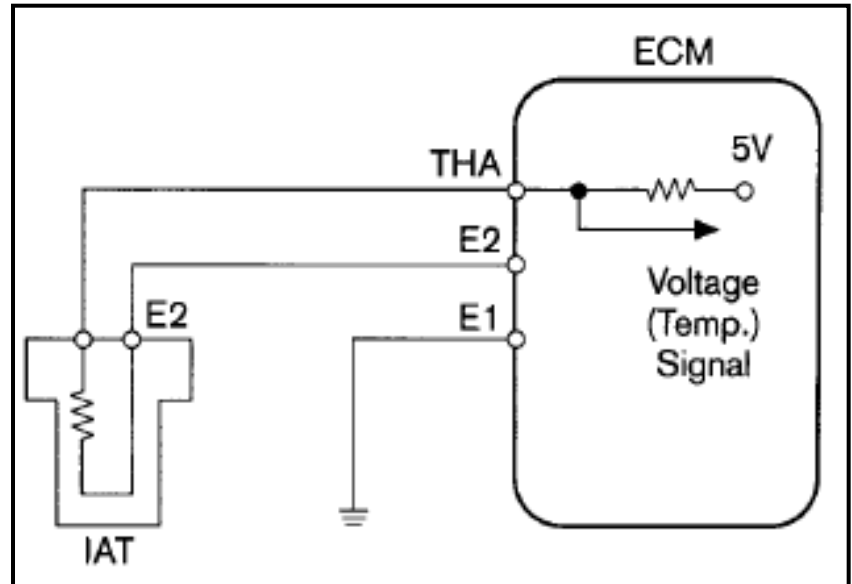
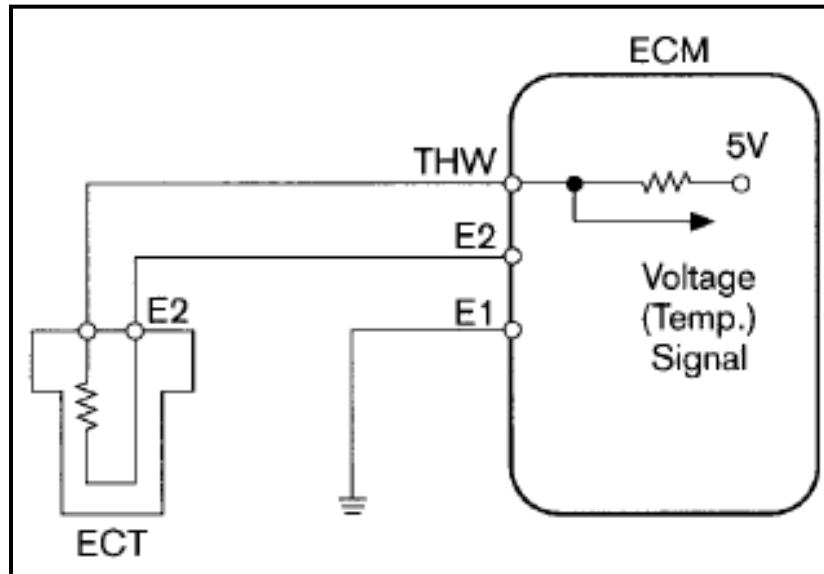


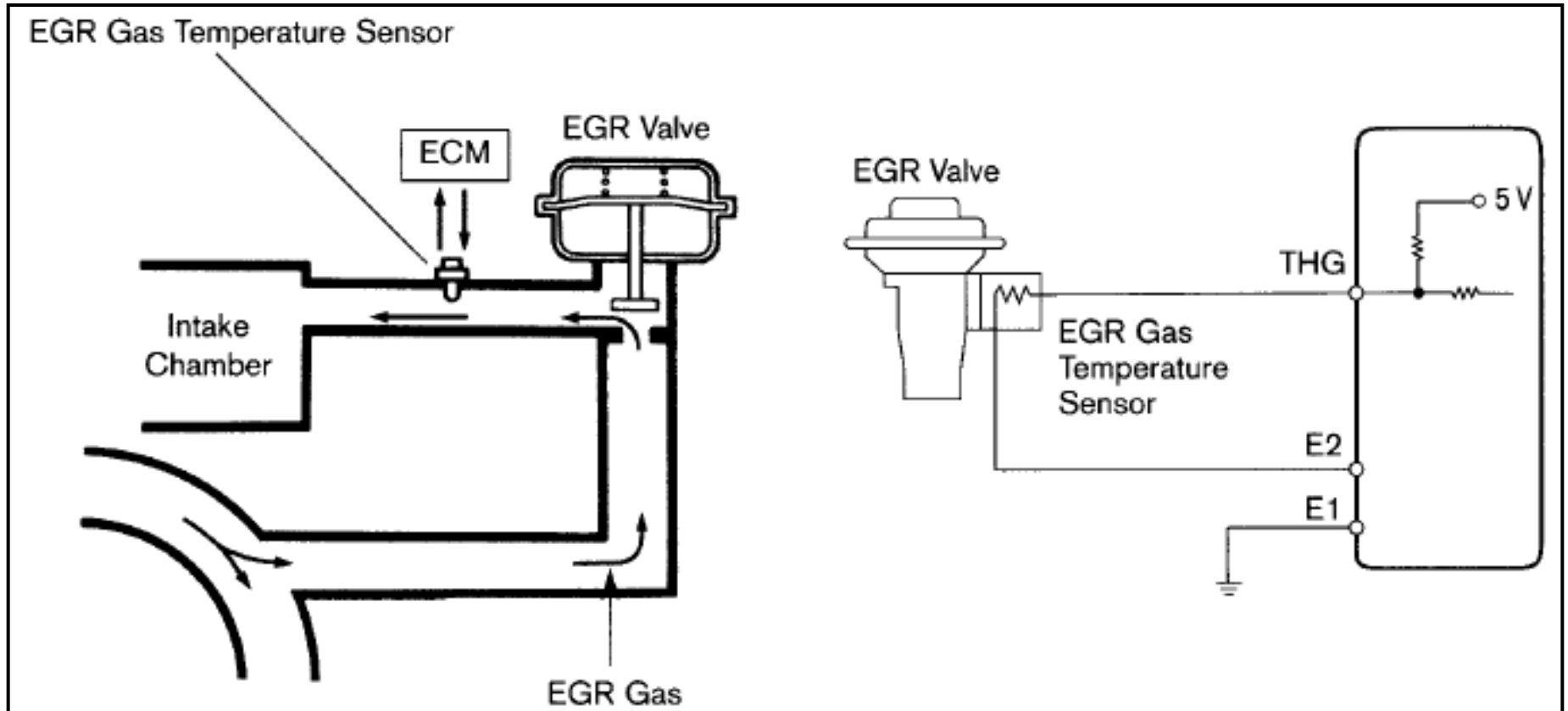
Thermistor

EGR Temperature
Sensor

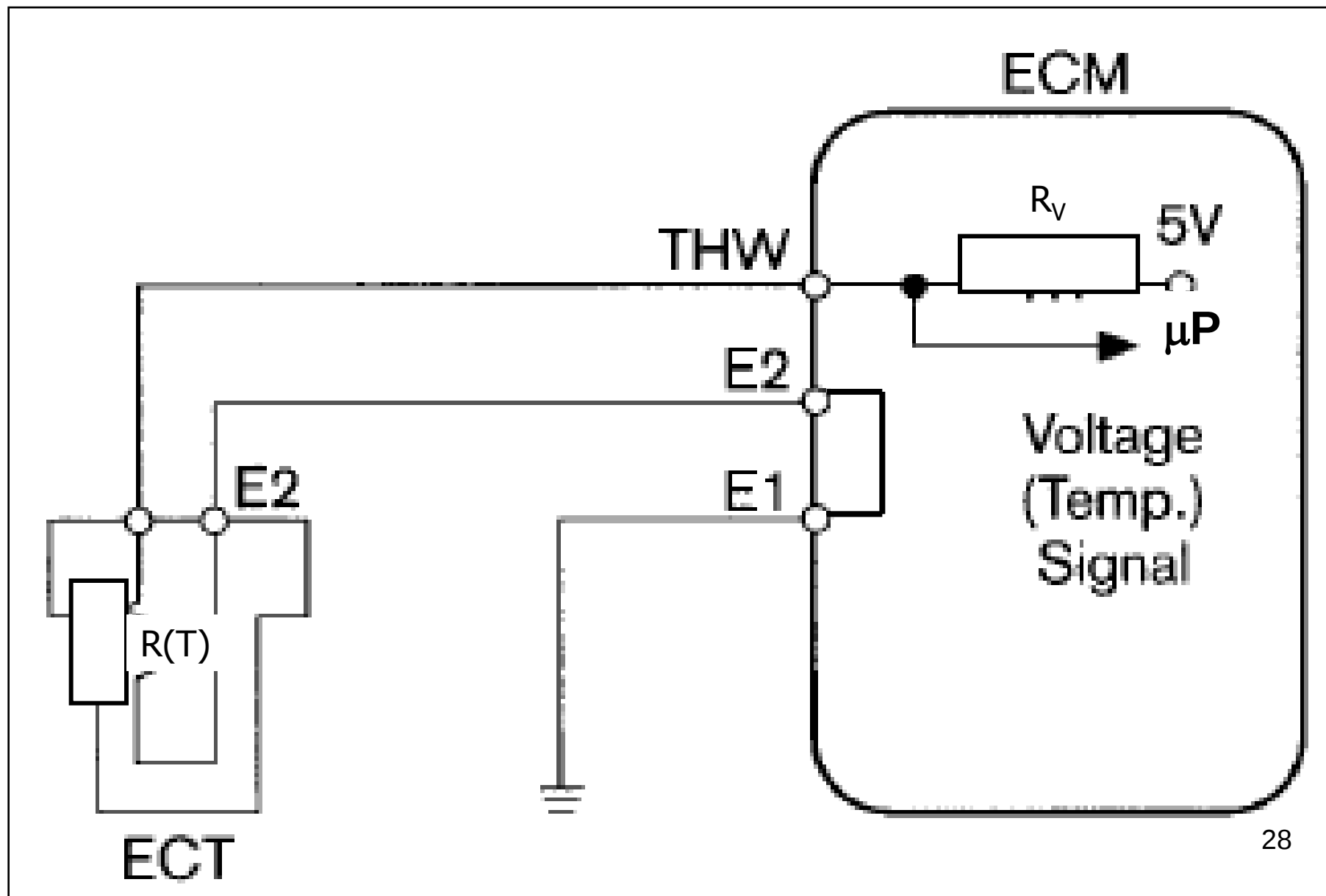


Thermistor





Šema senzora temperature rashladne tečnosti i ECU

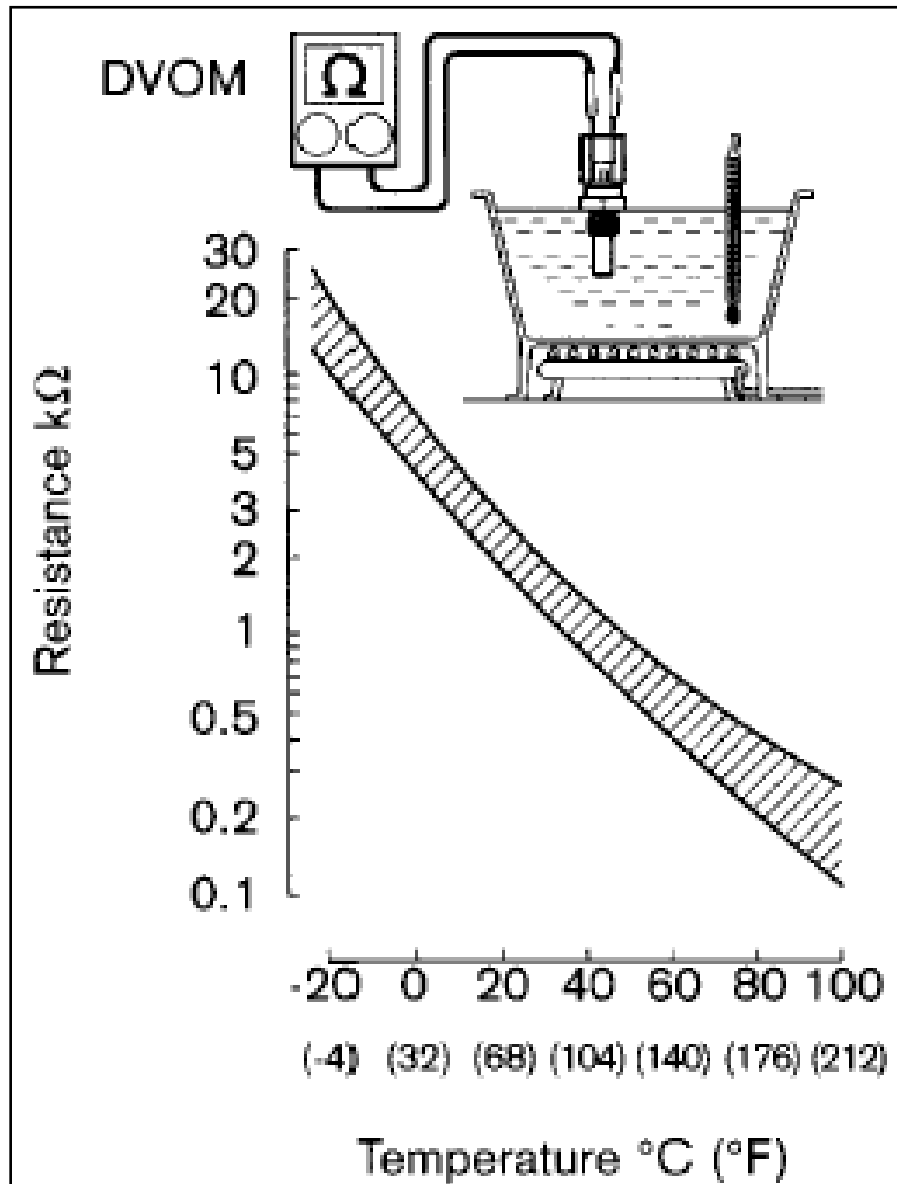


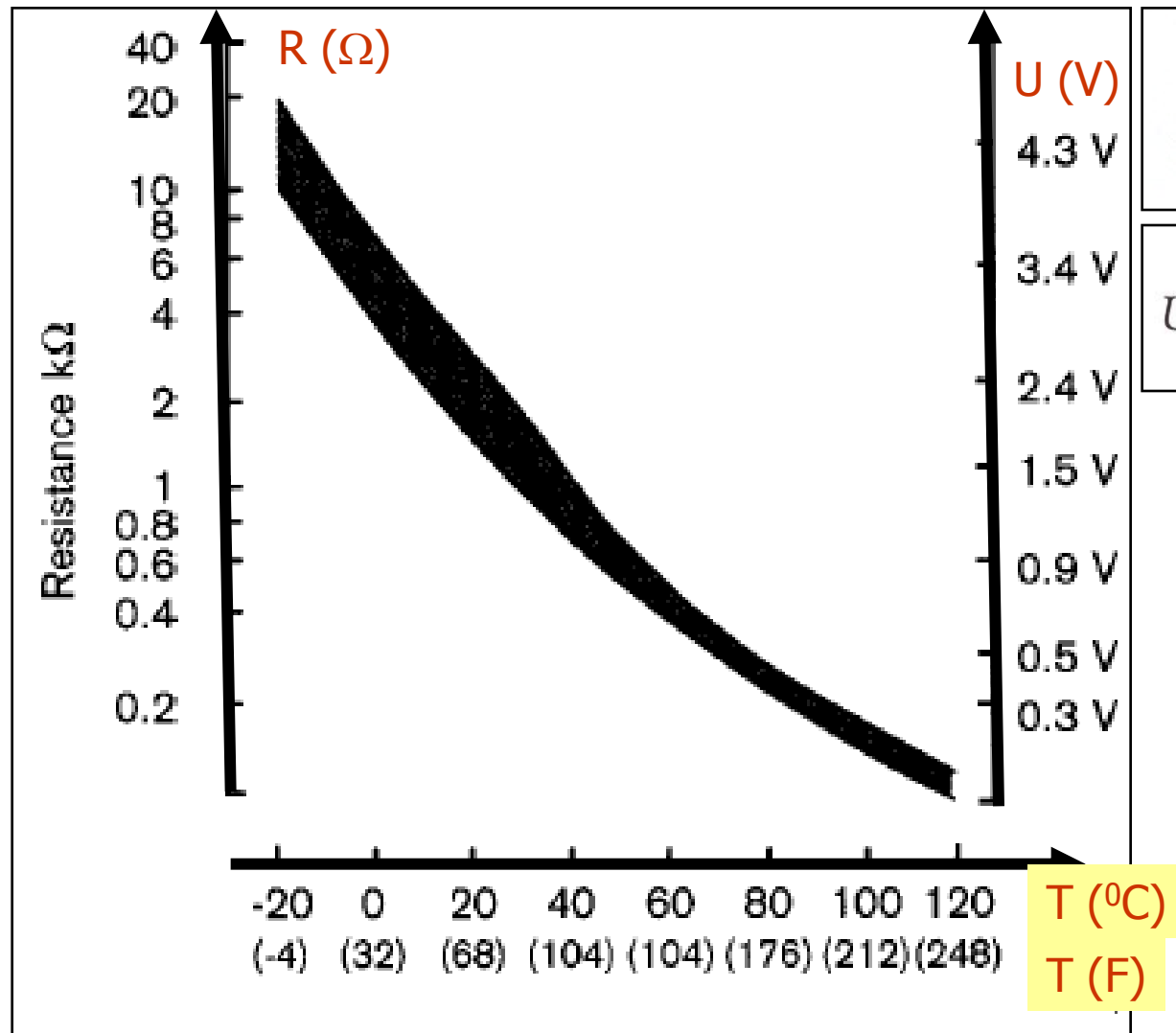
Ispitivanje ispravnosti senzora temperature

Ispitivanje ispravnosti senzora temperature (ECT, IAT ili EGR sistema) svodi se na iste procedure:

- provera promene otpornosti senzora,
- provera napona napajanja,
- proverana prekid strujnog kola i
- provera kratkog spoja u kolu senzora

Provera promene otpornosti senzora temperature

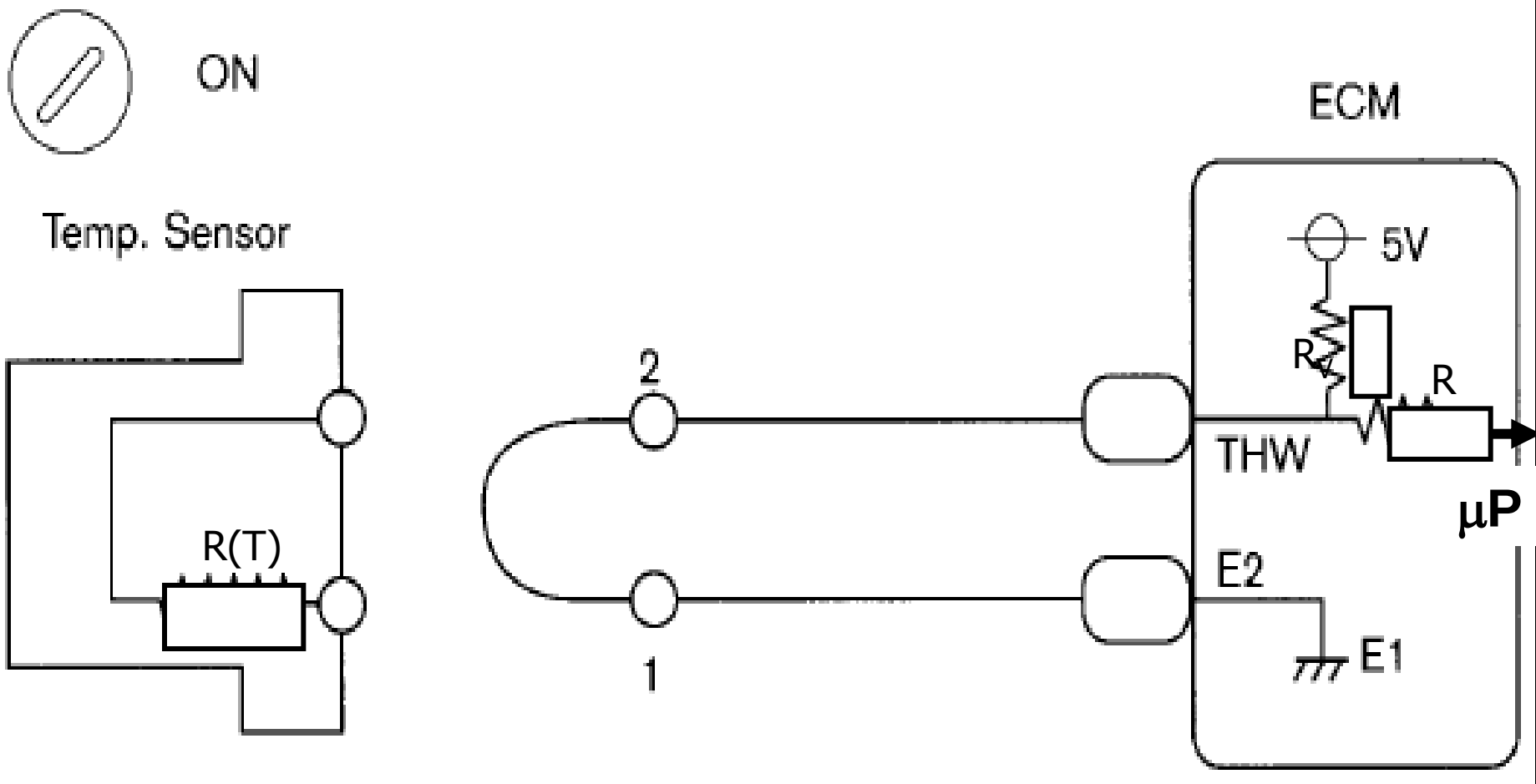




$$R_V \approx R(T_0)$$

$$U(T) = U_0 \cdot \frac{R(T)}{R(T) + R_V}$$

Ispitivanje ispravnosti rada senzora kratkim spajanjem na konektoru

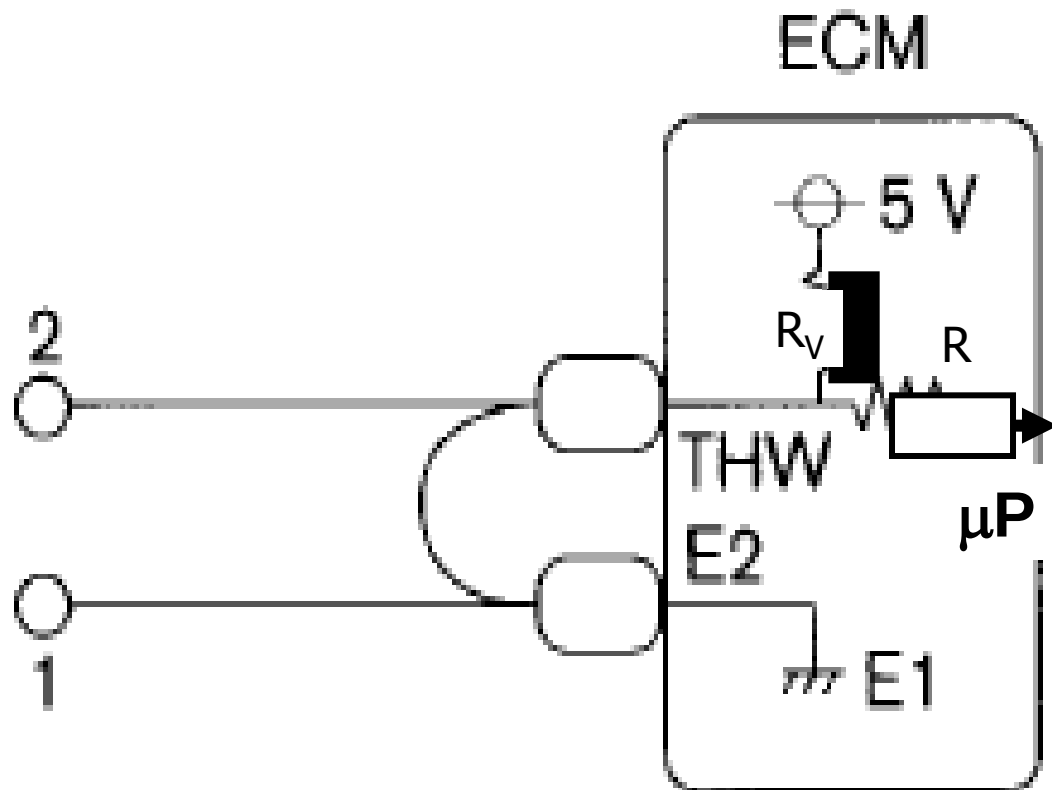
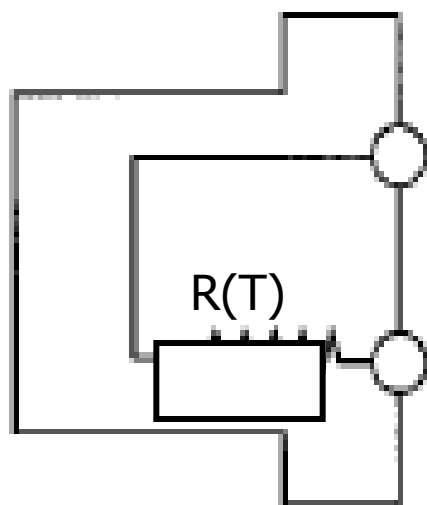


Ispitivanje ispravnosti rada senzora kratkim spajanjem na pinovima ECM



ON

Engine Coolant
Temp. Sensor



Ispitivanje ispravnosti rada senzora odspajanjem senzora



Engine Coolant
Temp. Sensor

