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

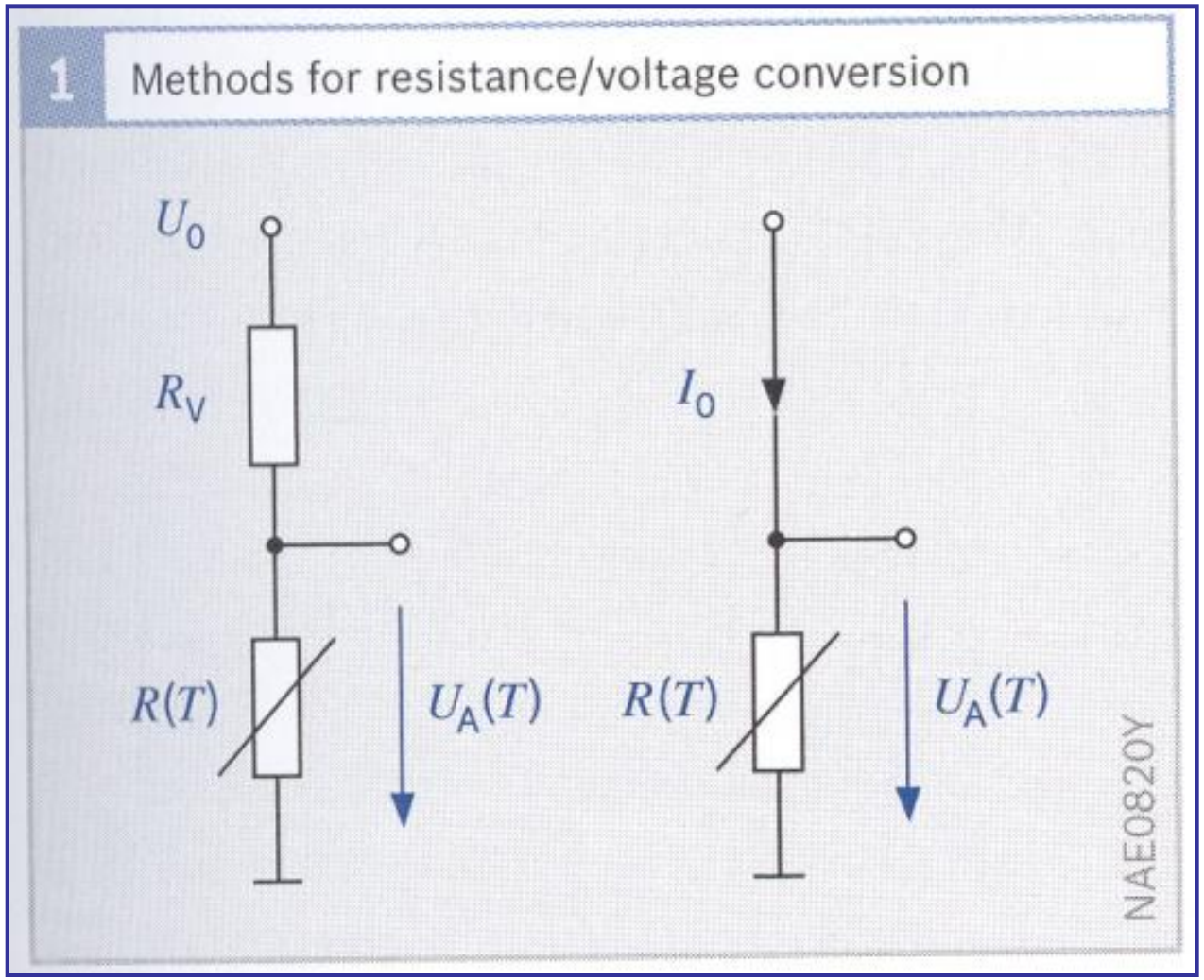


Fig. 1

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

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

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

$$R_V \approx R\,(T_0)$$

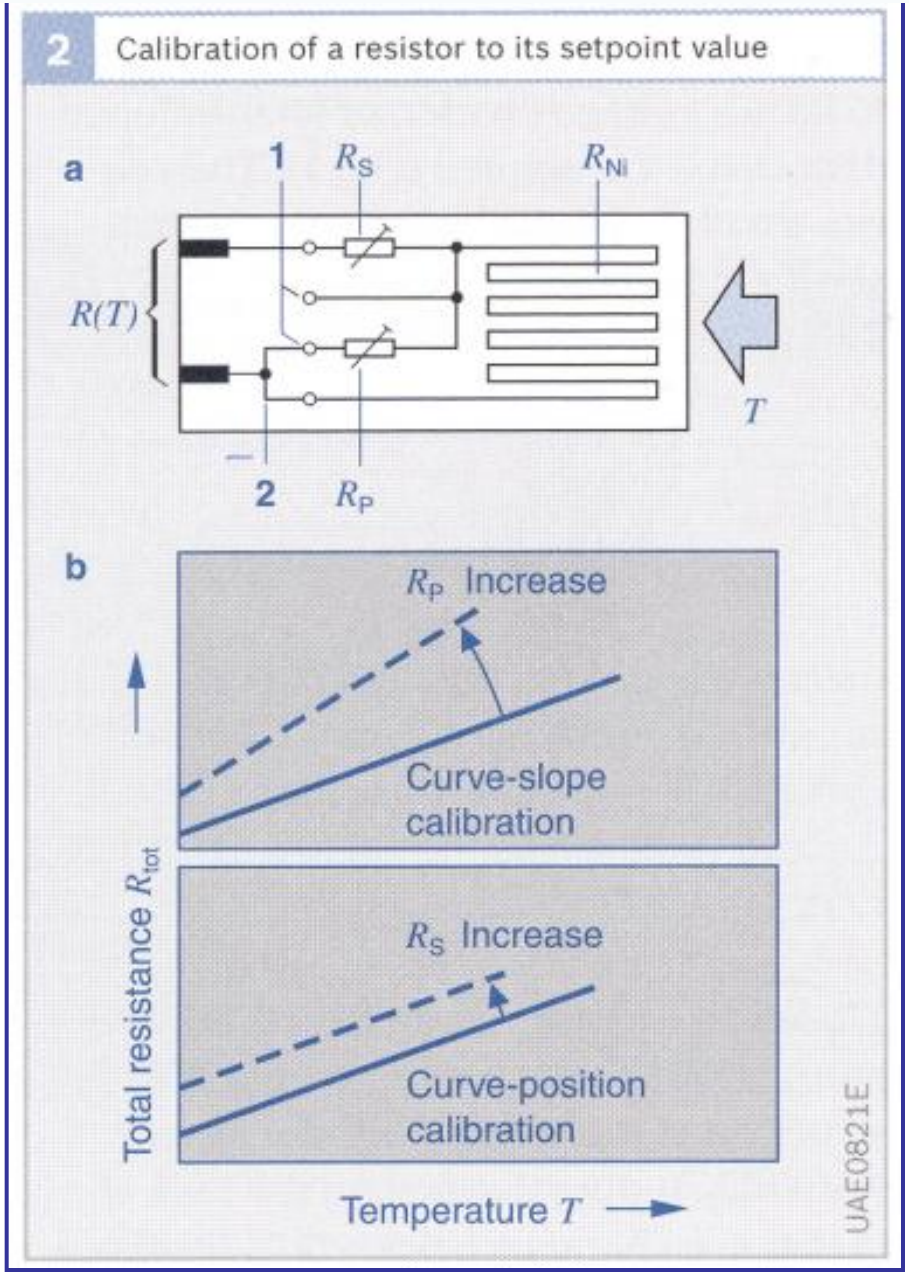


Fig. 2

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

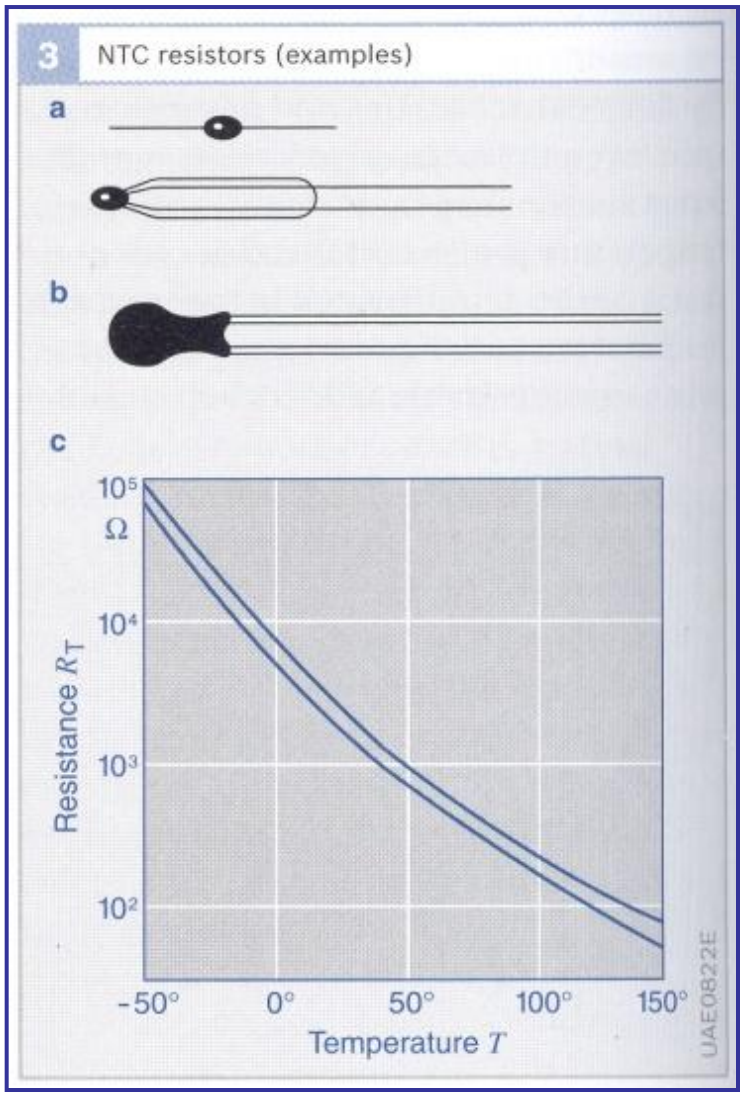


Fig. 3
a Pearl form
b Disk form
c Characteristic curve with limits of variation

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

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

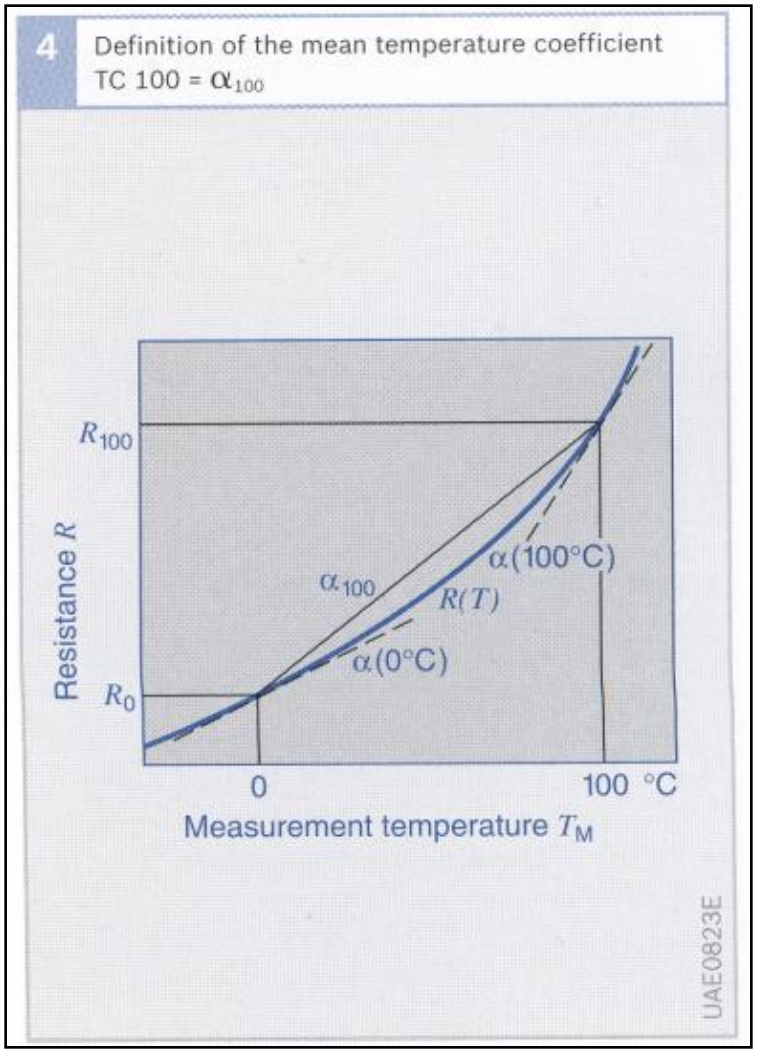
$$TC = -B/T^2$$

PTC metalni otpornički senzori u tehnici tankog filma

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

where $\Delta T = T - T_0$ and
$T_0 = 20\ °C$ (reference temperature),
α linear temperature coefficient (TC),
β square temperature coefficient.

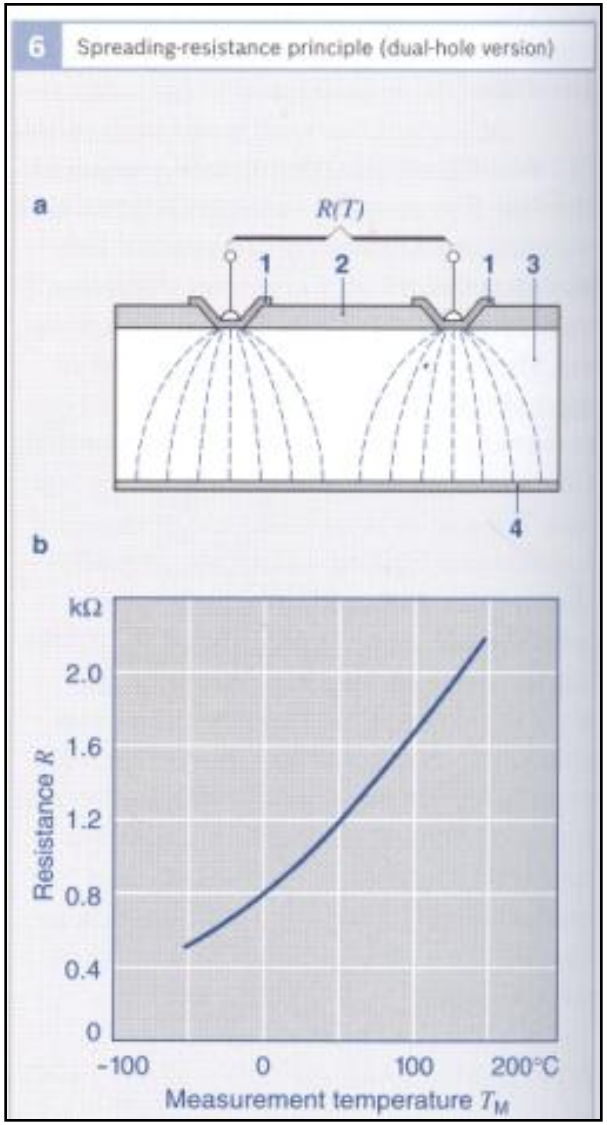
$$\text{Where } TC\ 100 = \frac{R(100°C) - R(0°C)}{R(0°C) \cdot 100K}$$



2 Temperature coefficient TC 100

Sensor material	TC 100 $10^{-3}/K$	Characteristic 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

Monokristalni poluprovodnički otpornički senzori temperature (PTC)



- TC = 7,73 *10-3/K (duplo veći nego Pt otpornik)
- Merni opseg do +150ºC
  (specijalnre verzije do +300ºC, 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

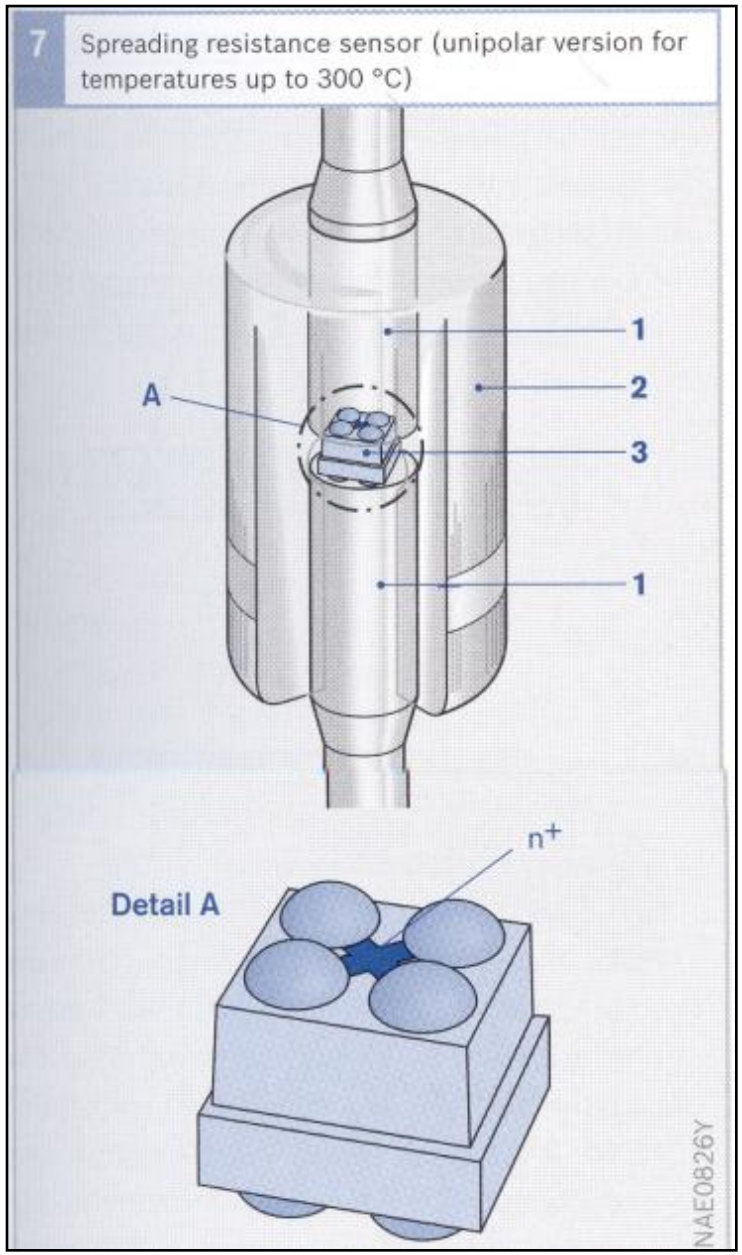


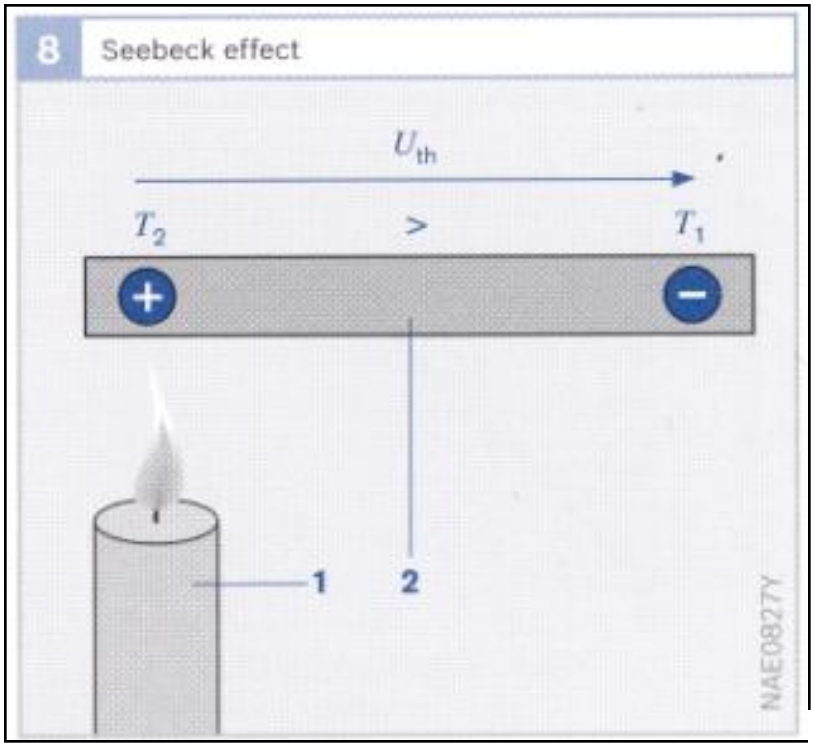
Fig. 7

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

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

Fig. 8

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

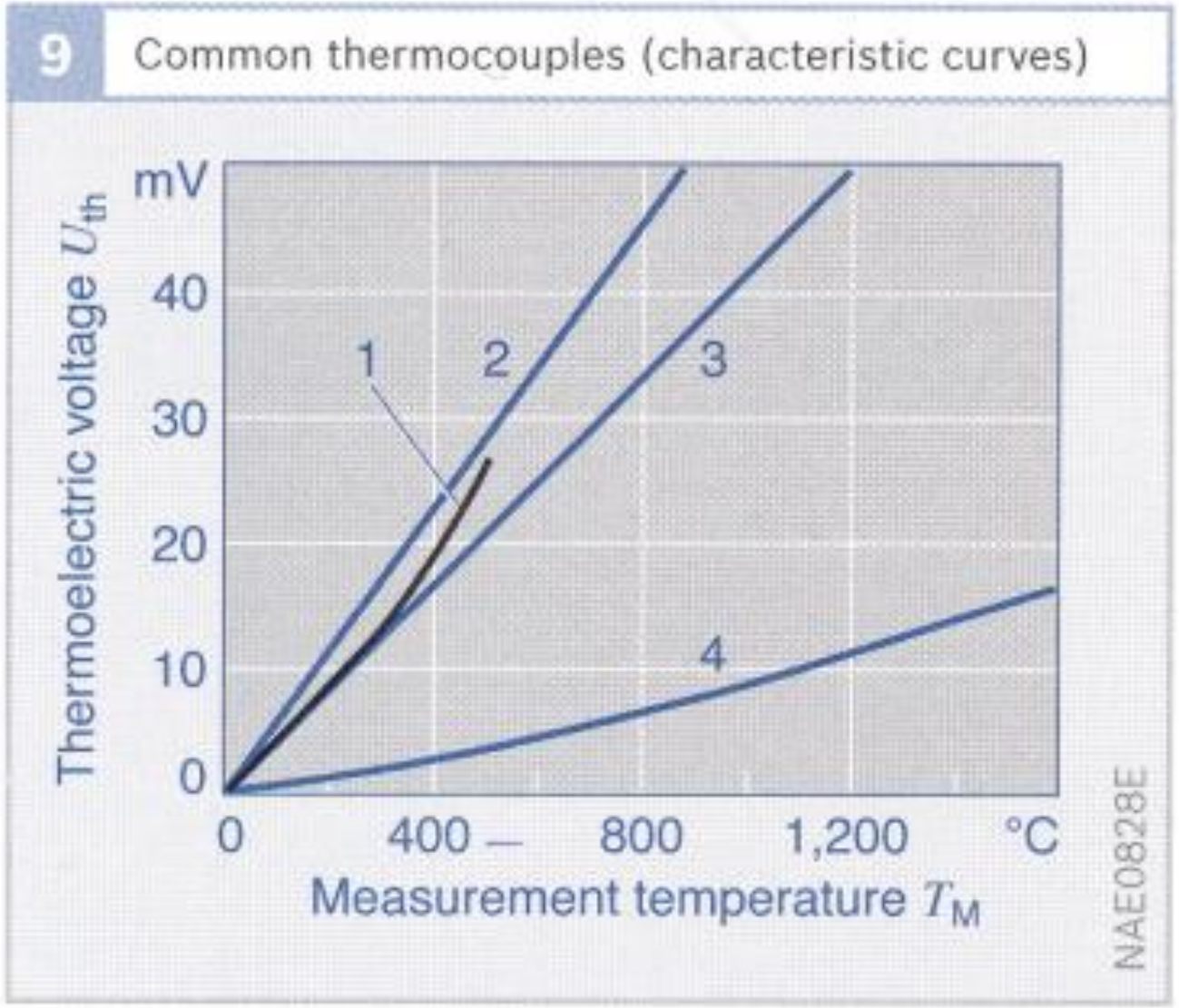


Fig. 9

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

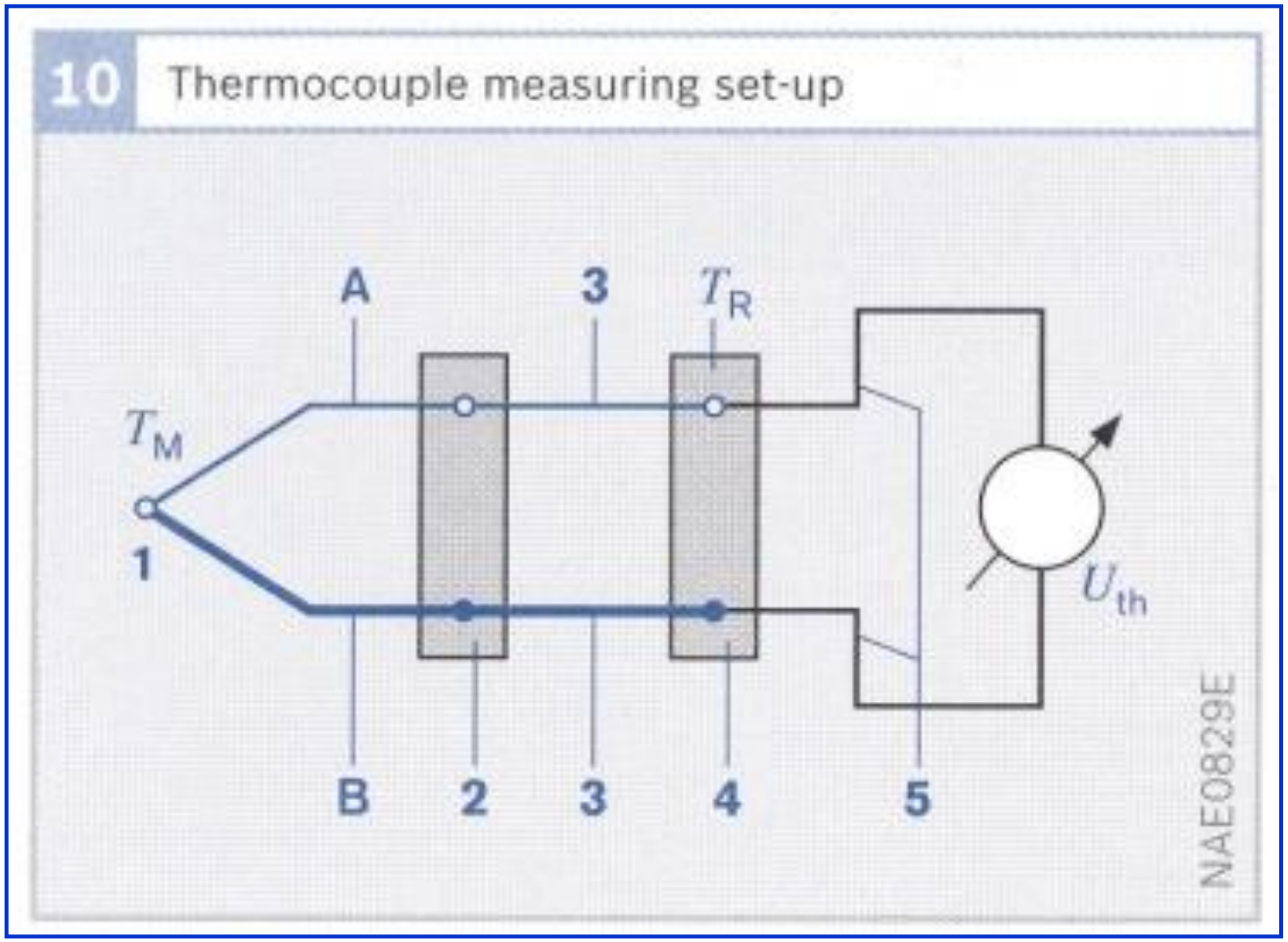


Fig. 10
A/B Material pair (thermocouple legs)
1 Measuring point (electrically conductive junction)
2 Connection head
3 Compensating cable
4 Reference point
5 Connection cable (Cu)
T_M Measurement temperature
T_R Reference temperature
U_{th} Thermoelectric voltage

- **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 termoelektično kolo, koje se uobičajeno još naziva **termoelement (termopar)**

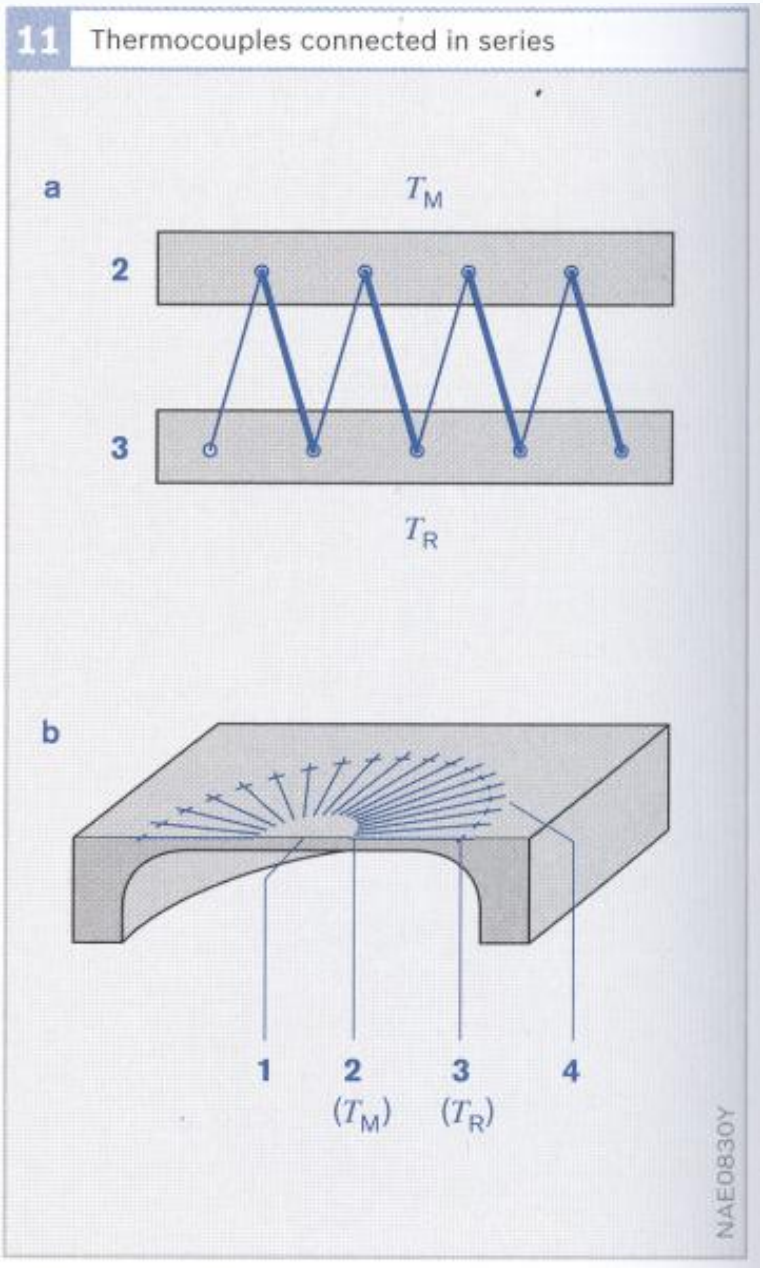


Fig. 11

a Principle of the thermopile

b Example of application

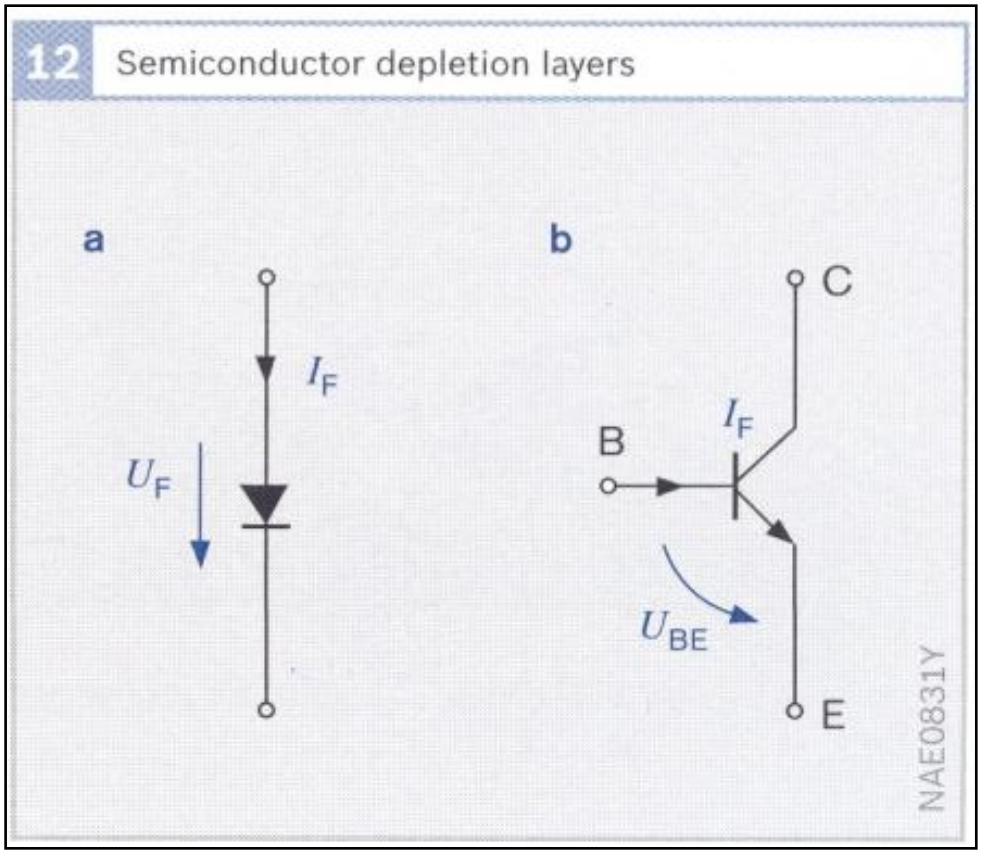
1 Sensitive surface

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



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

Where:

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

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

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

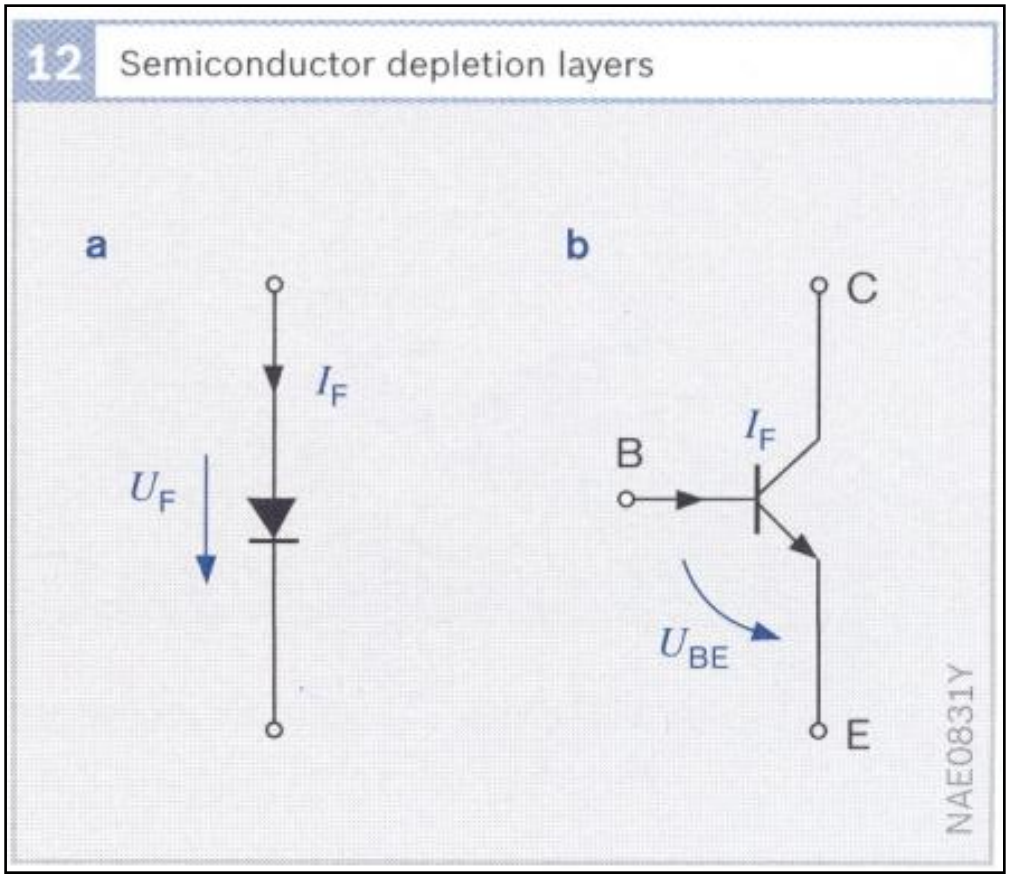
T absolute temperature.

- 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=*const* - nelinearno
- Merni opseg od -50 ºC do +150ºC može se aproksimirati sa:

$U_F(T)=k_1-k_2T$

gde je: $k_1=U_F(0)$=1,27V, k_2=*2-3* mV/ ºC

Dioda i tranzistor kao senzori temperature



- Porast temperature utiče na smanjivanje iverzne struje kroz spoj kolektor-baza $I_{CB0,}$ kao kod *pn* spoja diode.
- udvostručuju se za porast od 10 ºC i TC ima visoke vrednosti, ali su struje vrlo male 1 μA (Si) i 100 μA (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 ºC do +200ºC može se aproksimirati sa:

  $U_{BE}(T)=k_1-k_2T$

  gde je: $k_1=U_{BE}(0)$=1,27V, k_2=2-3mV/ ºC

Beskontaktni senzori: senzori termičkog zračenja

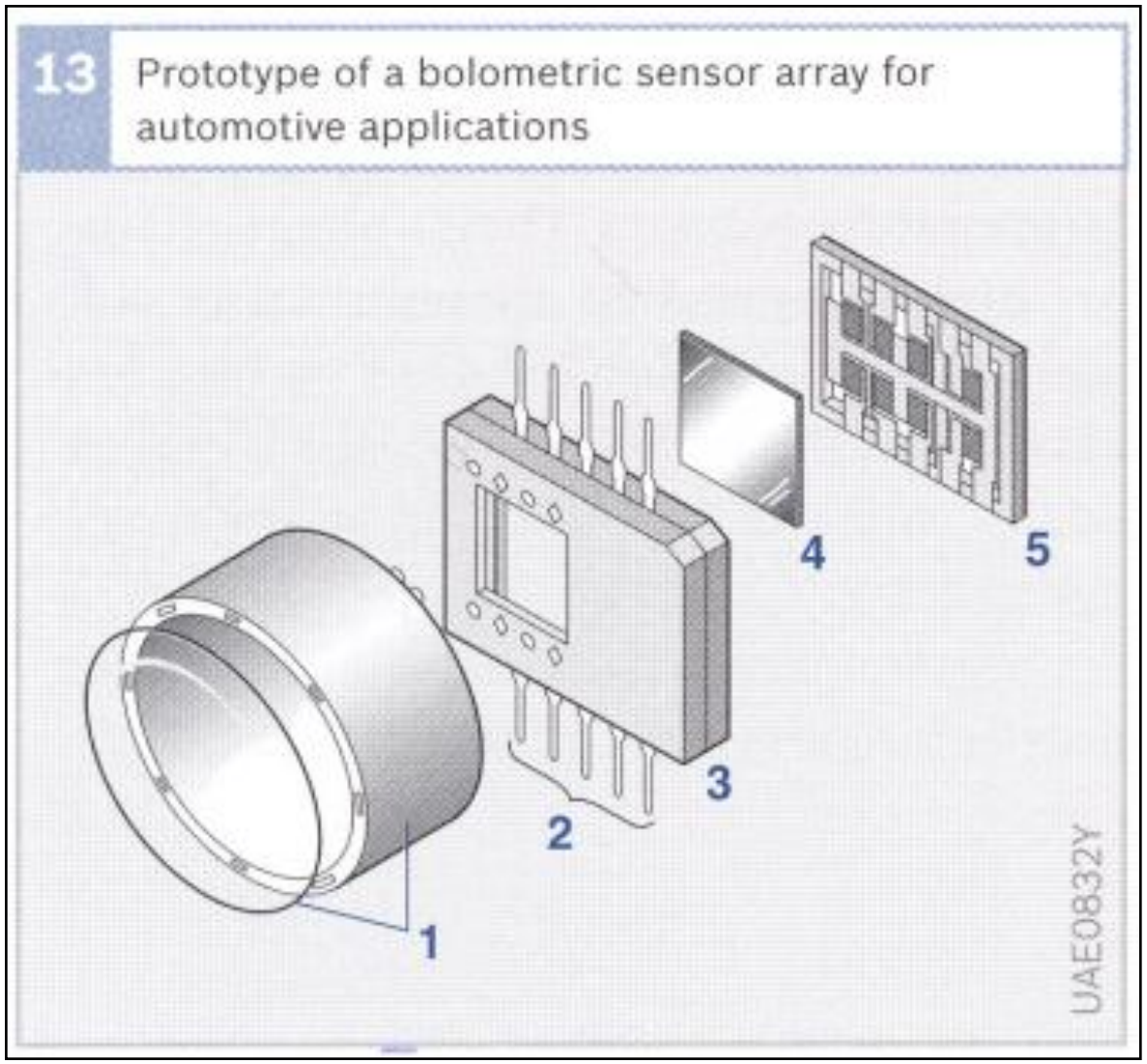


Fig. 13

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.

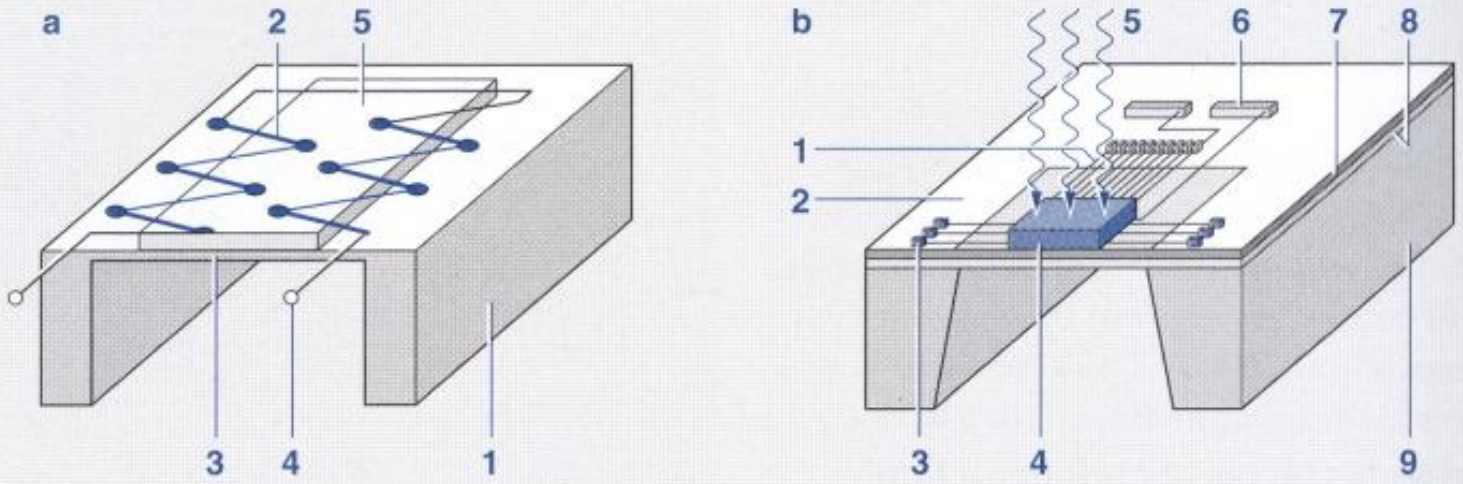


Fig. 14

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

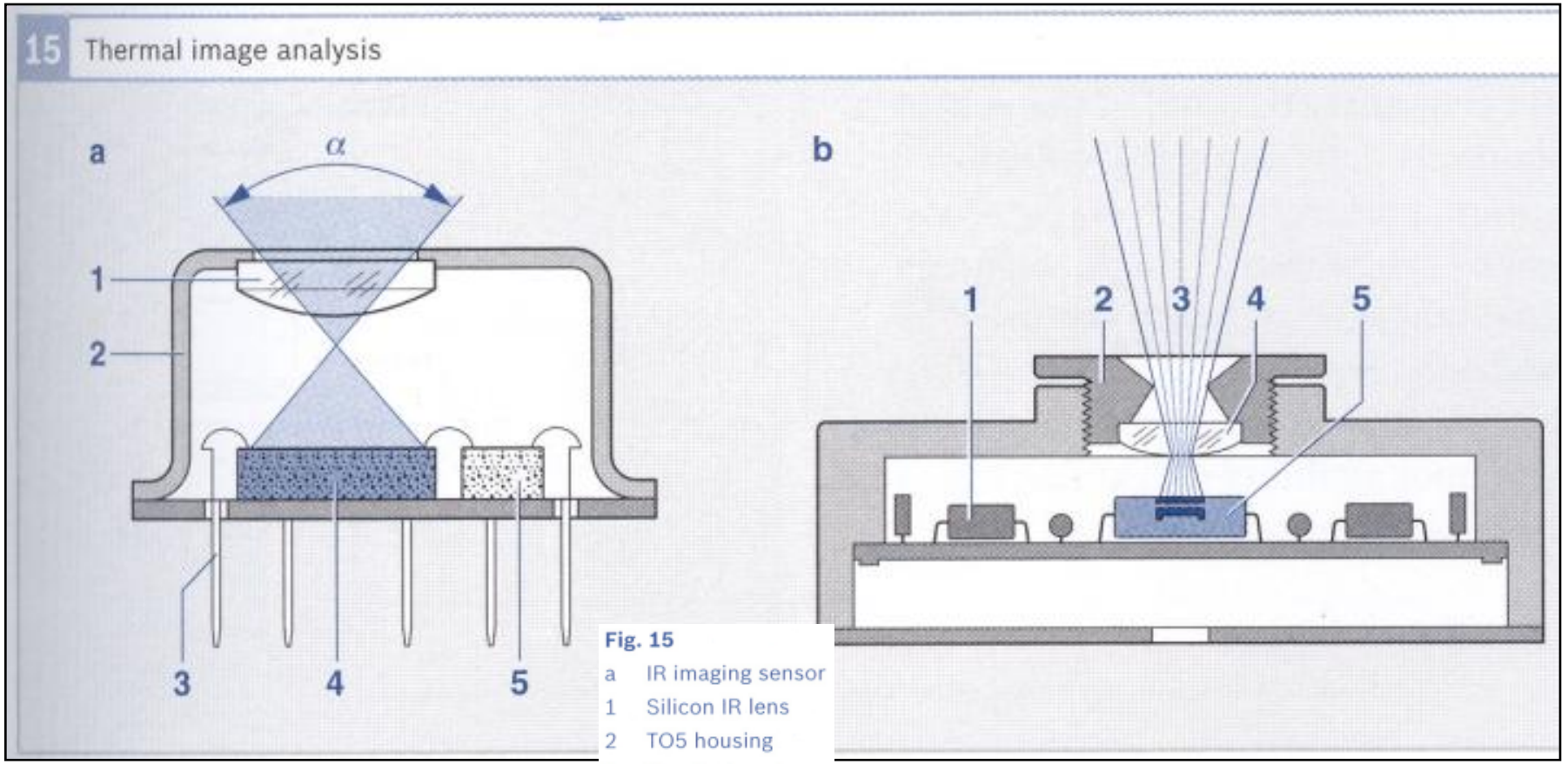


Fig. 15

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

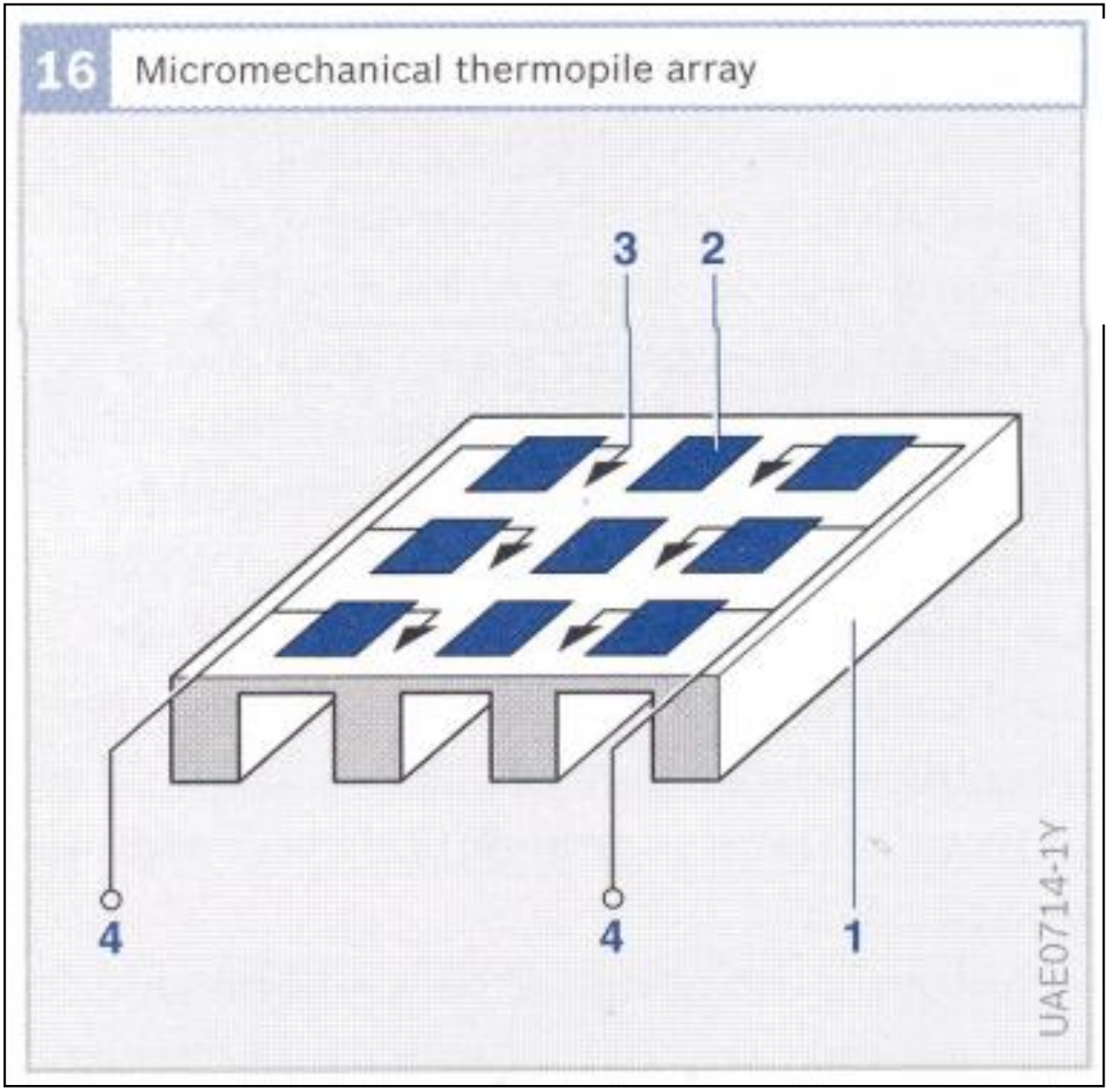


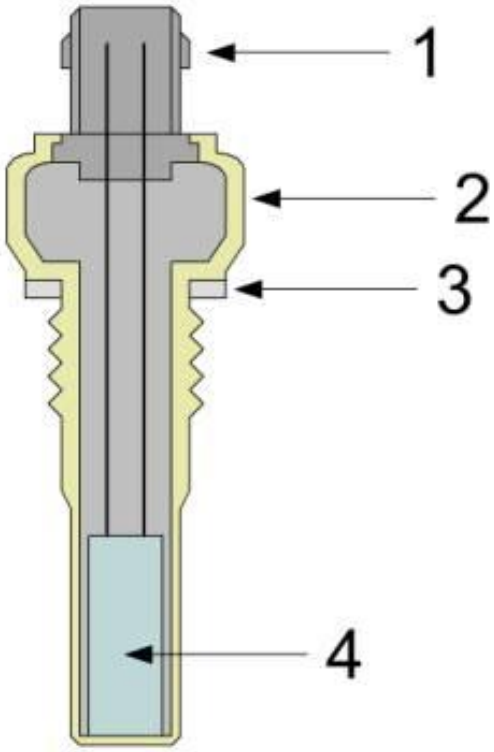
Fig. 16

1 Silicon chip

2 Pixel

3, 4 Pixel connections

Primer: Senzor temperature rashladne tečnosti (ECT)



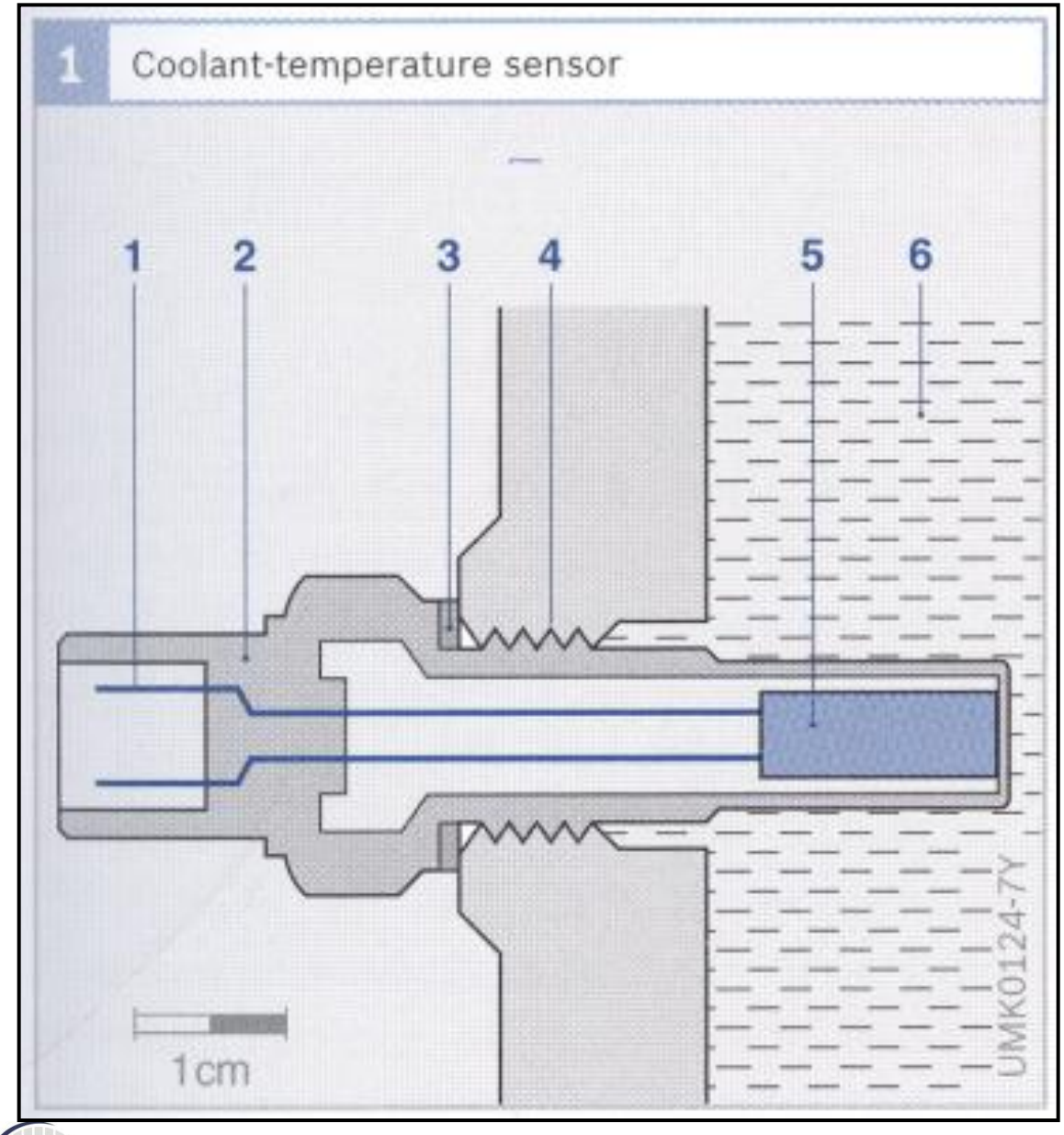
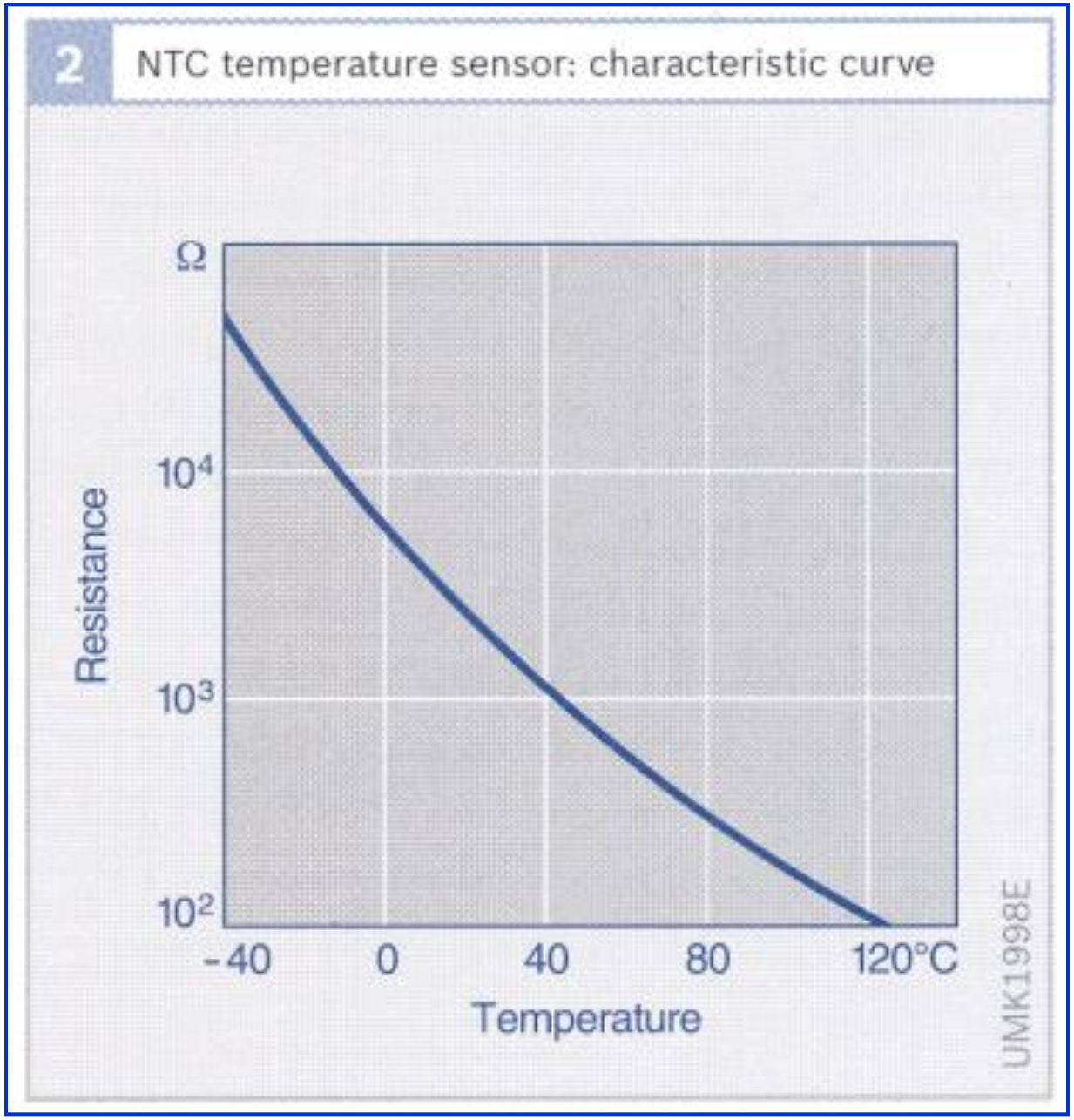
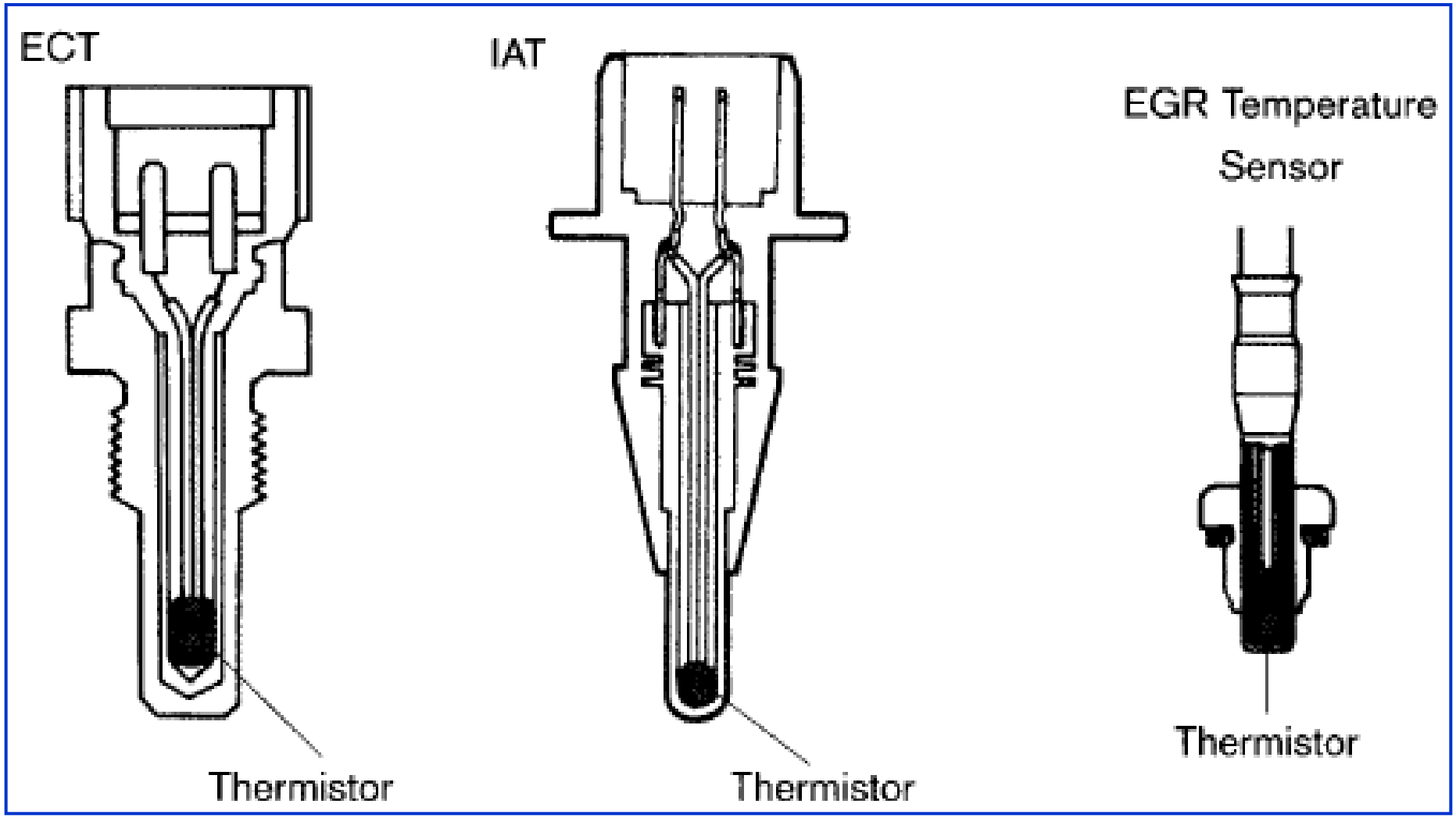
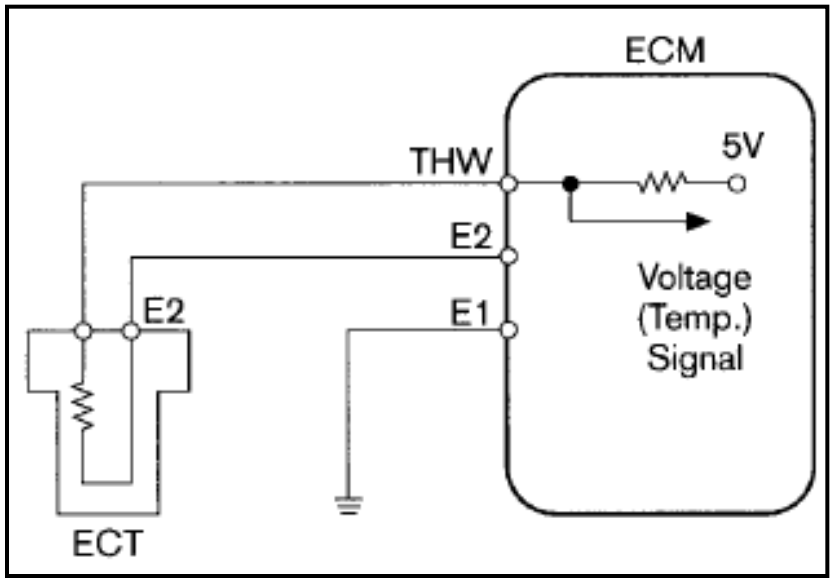


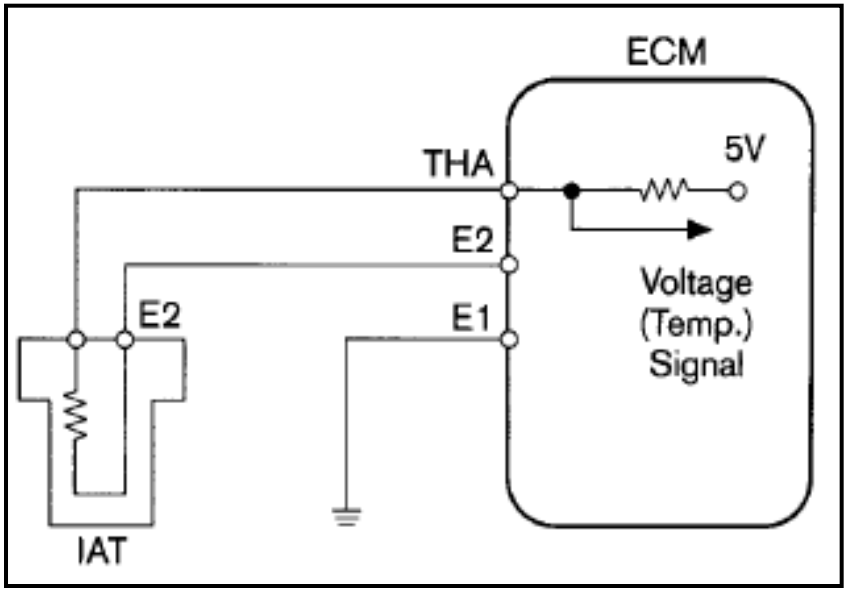
Fig. 1

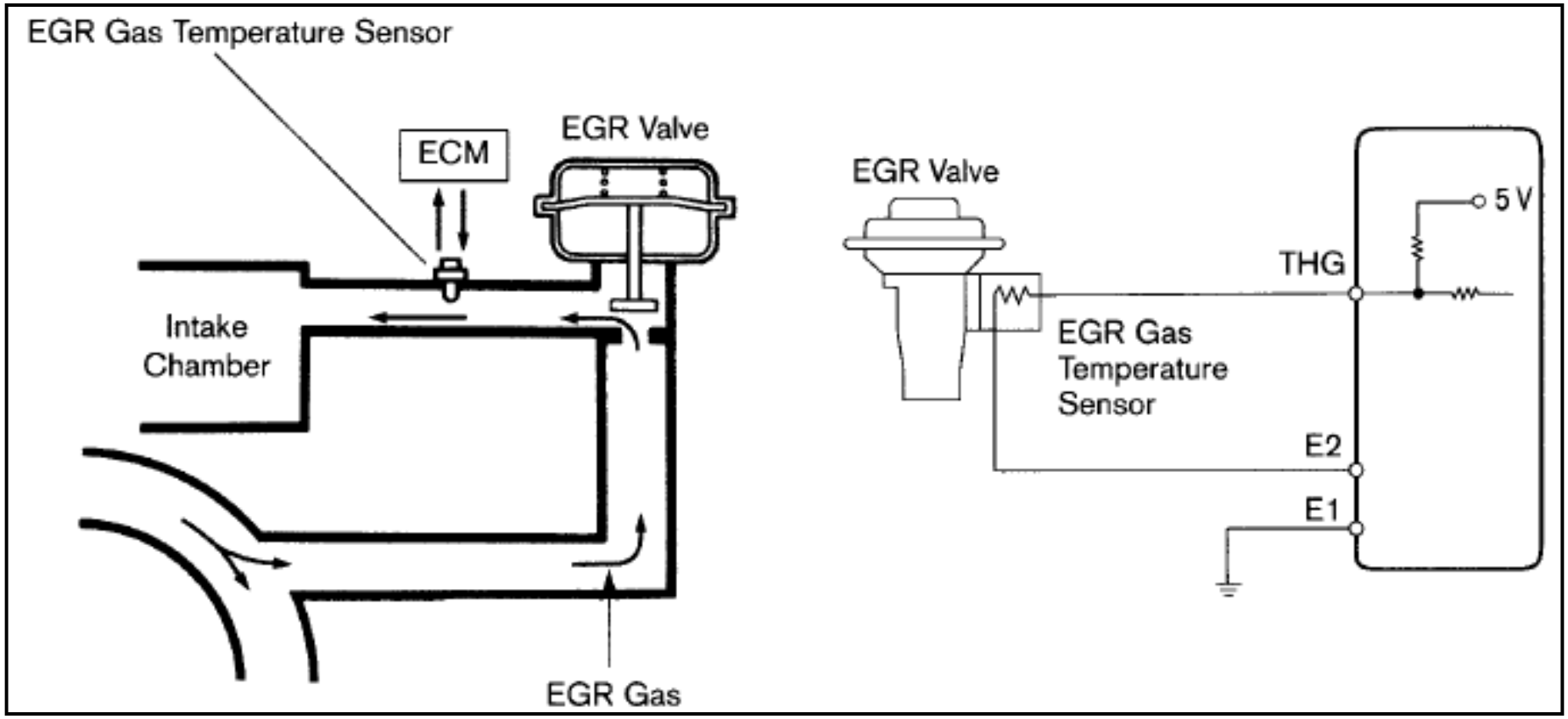
1 Electrical connection
2 Housing
3 Sealing ring
4 Thread
5 Measuring shunt
6 Coolant


2
NTC temperature sensor: characteristic curve
Ω
10^4
10^3
10^2
Resistance
-40
0
40
80
120°C
Temperature
UMK1998E

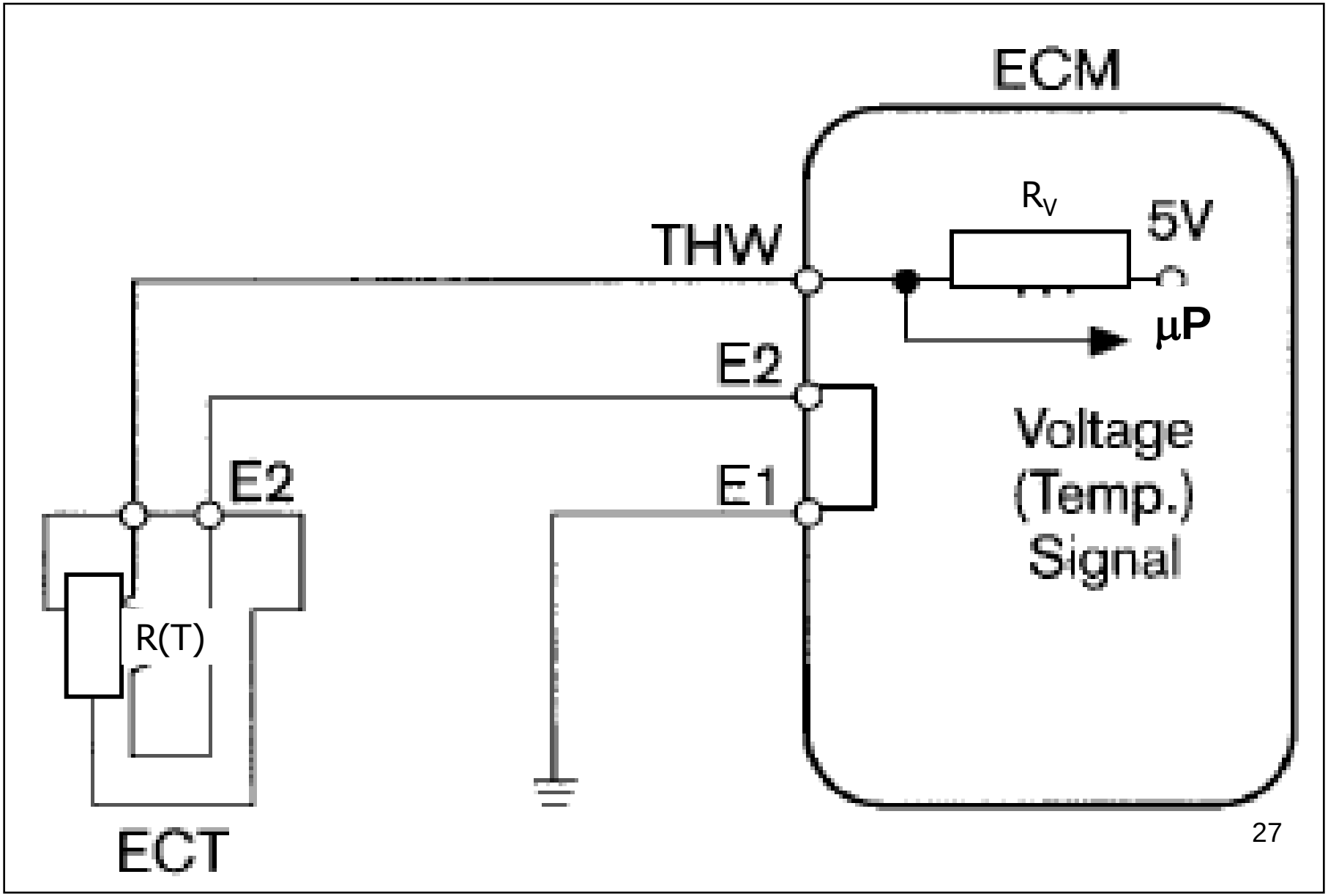

ECT
Thermistor
IAT
Thermistor
EGR Temperature
Sensor
Thermistor


ECM
THW
5V
E2
E2
E1
Voltage
(Temp.)
Signal
ECT


ECM
THA
5V
E2
E2
E1
Voltage
(Temp.)
Signal
IAT


EGR Gas Temperature Sensor
ECM
EGR Valve
Intake
Chamber
EGR Gas
EGR Valve
5 V
THG
EGR Gas
Temperature
Sensor
E2
E1

Šema senzora temperature rashladne tečnosti i ECU

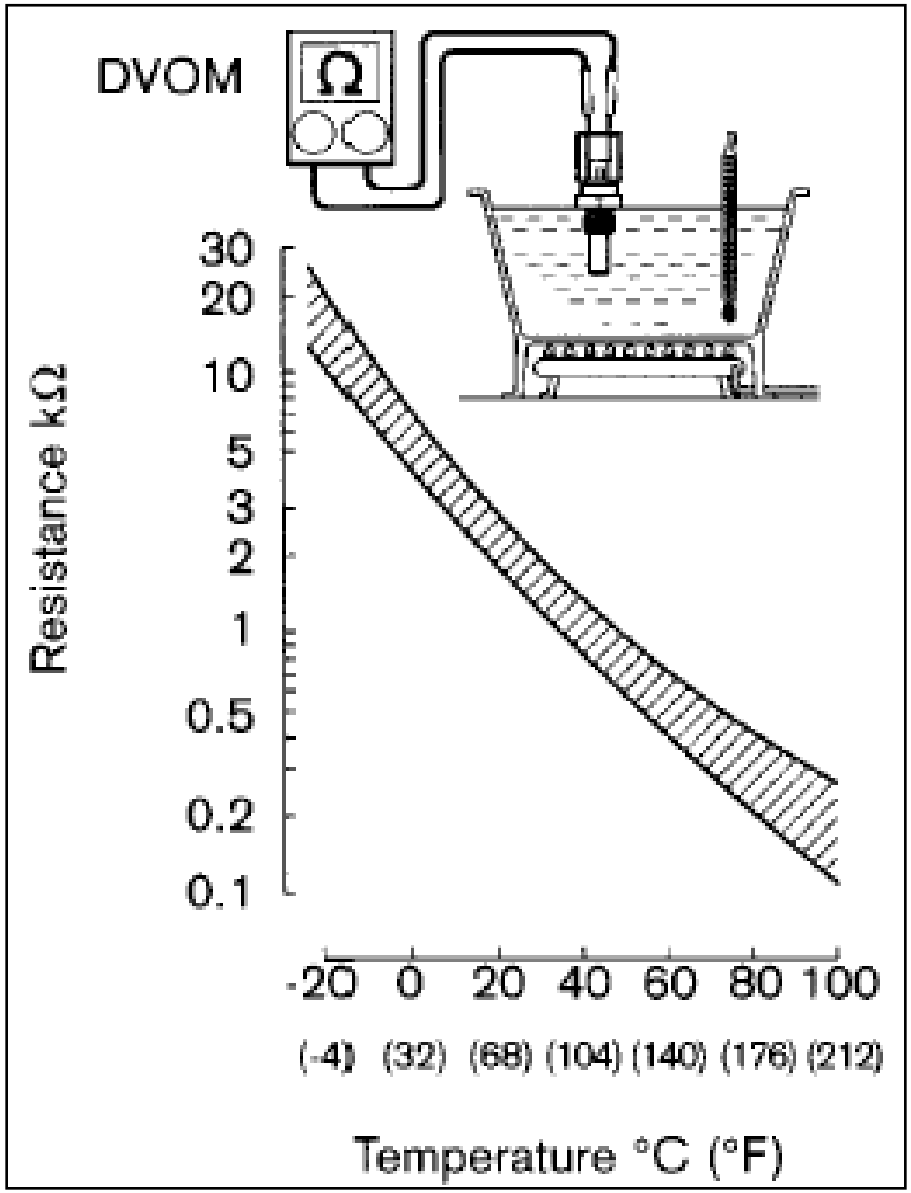


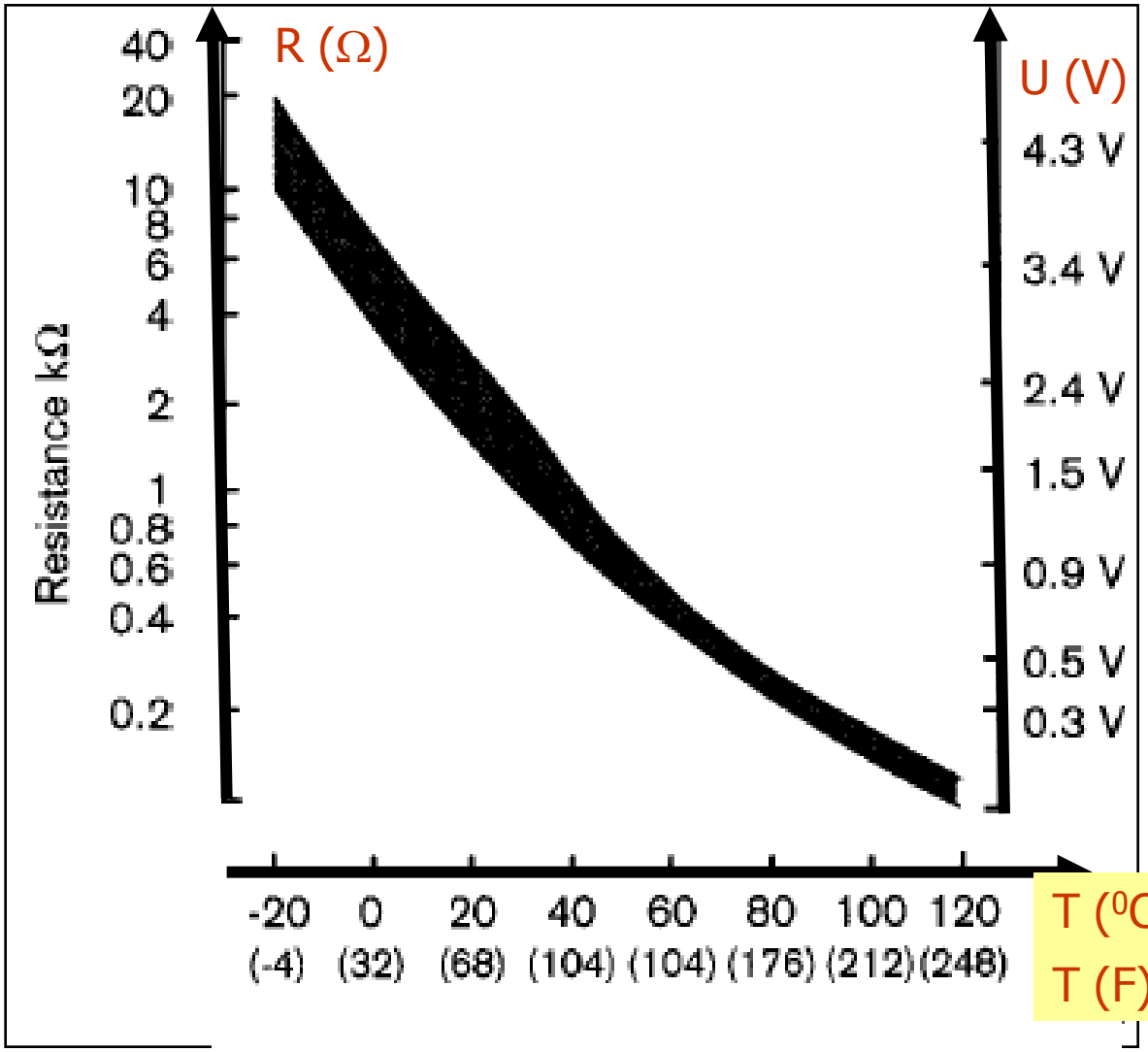
Ispitivanje ispravnosti senzora temperature

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

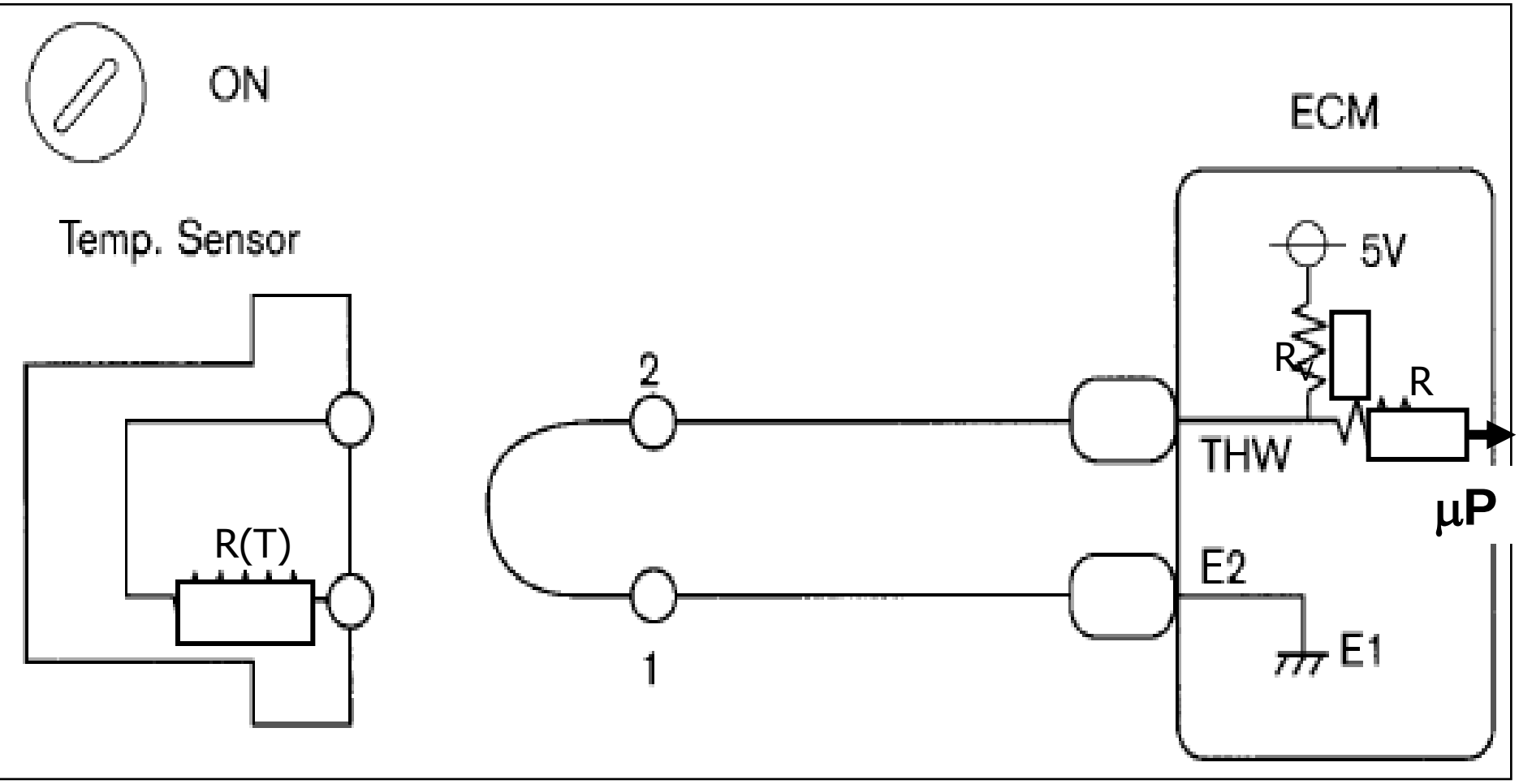




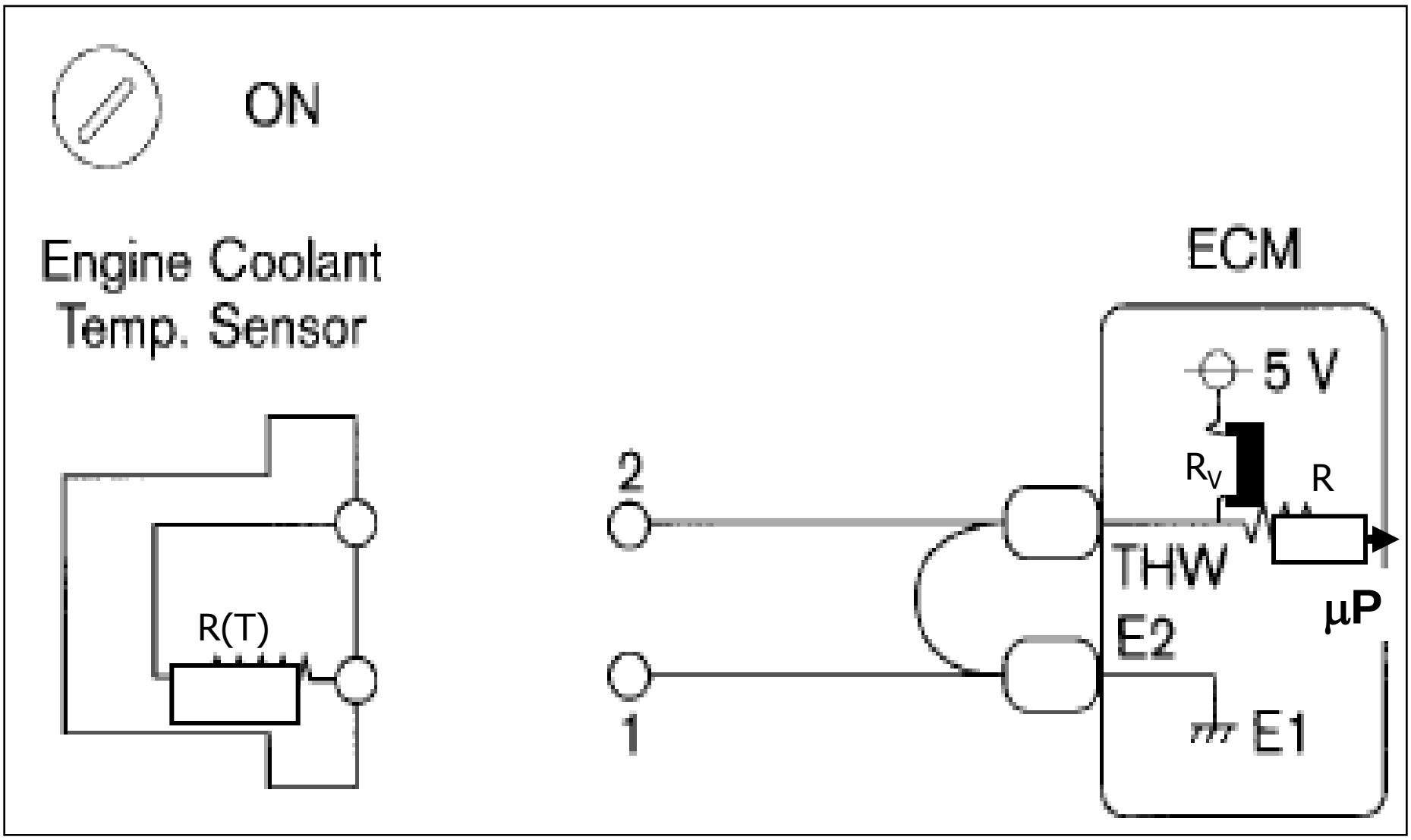
$$R_V \approx R\,(T_0)$$

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

Ispitivanje ispravnosti rada senzora kratkim spajanjem na konektoru



Ispitivanje ispravnosti rada senzora kratkim spajanjem na pinovima ECM



Ispitivanje ispravnosti rada senzora odspajanjem senzora