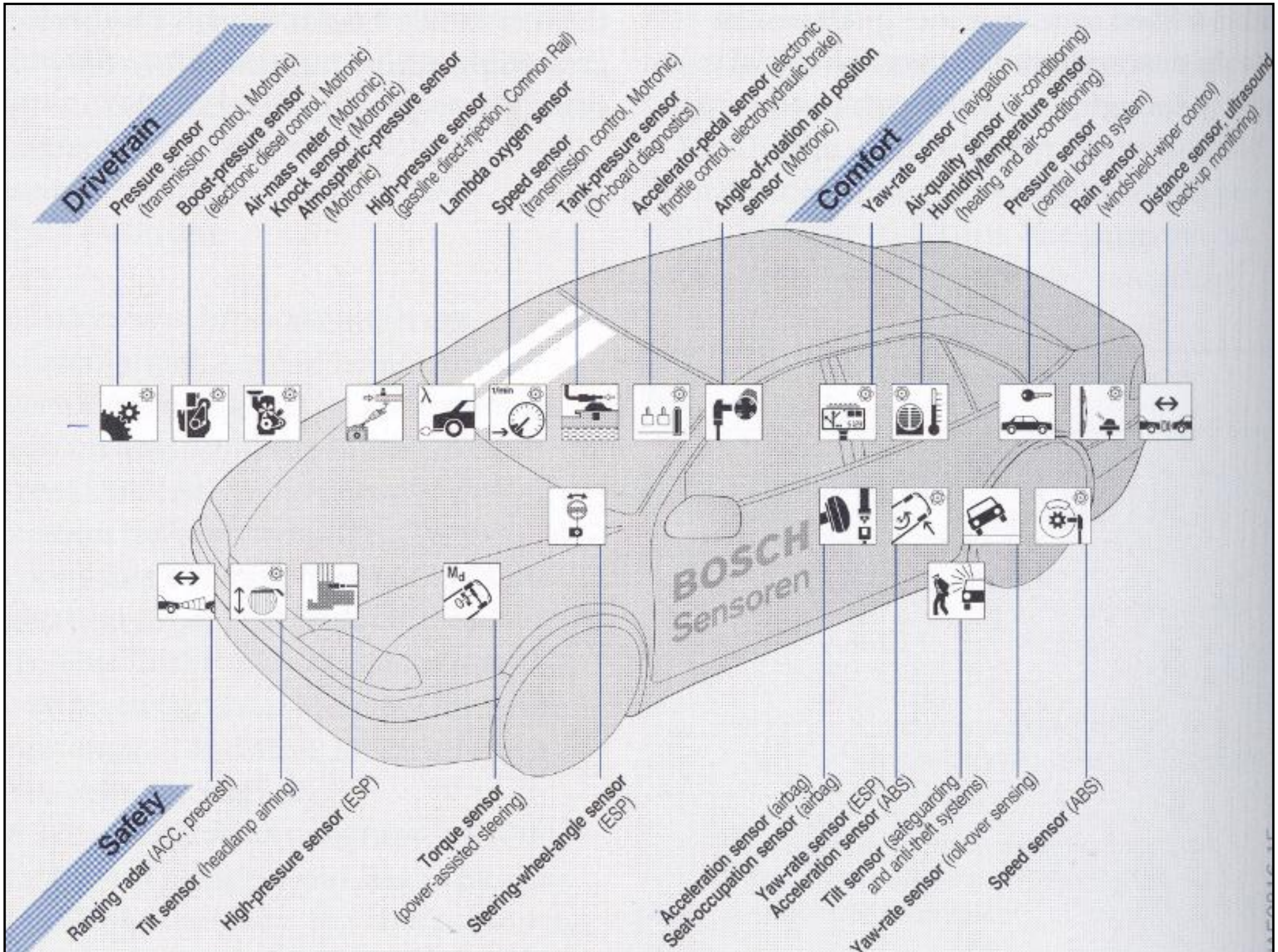
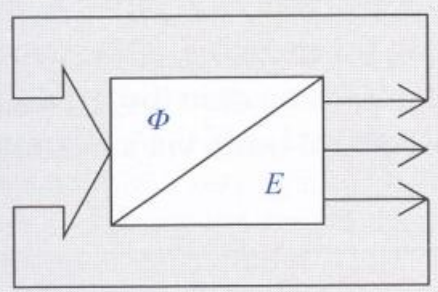
# Увод у сензоре на возилима



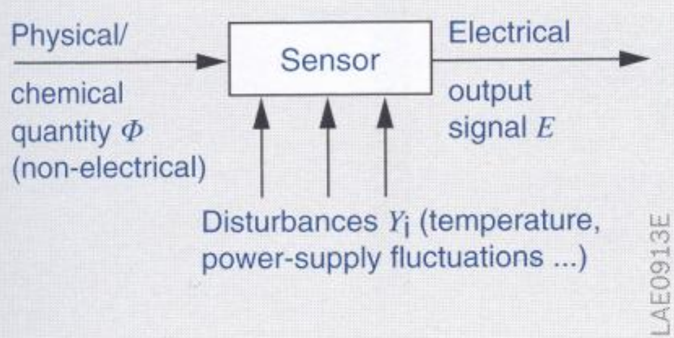
1 Areas in which sensors are used

| Typical features | Primary standards | Precision measurement | Industrial measurement | Consumer technology |
|---|---|---|---|---|
| Accuracy | $10^{-11}$ to $10^{-7}$ | 2 to $5 \cdot 10^{-4}$ | 2 to $5 \cdot 10^{-3}$ | 2 to $5 \cdot 10^{-2}$ |
| Costs | € 100 k to € 1 m | € thousands | € hundreds | € 1 to 10 |
| Units/year | single figures | approximately 10 | 100 to 1 k | 10 k to 10 m |
| Use | – Research<br>– Testing of secondary normals | – Calibration | – Process instrumentation<br>– In-process measurement | – Auto electronics<br>– Building services |

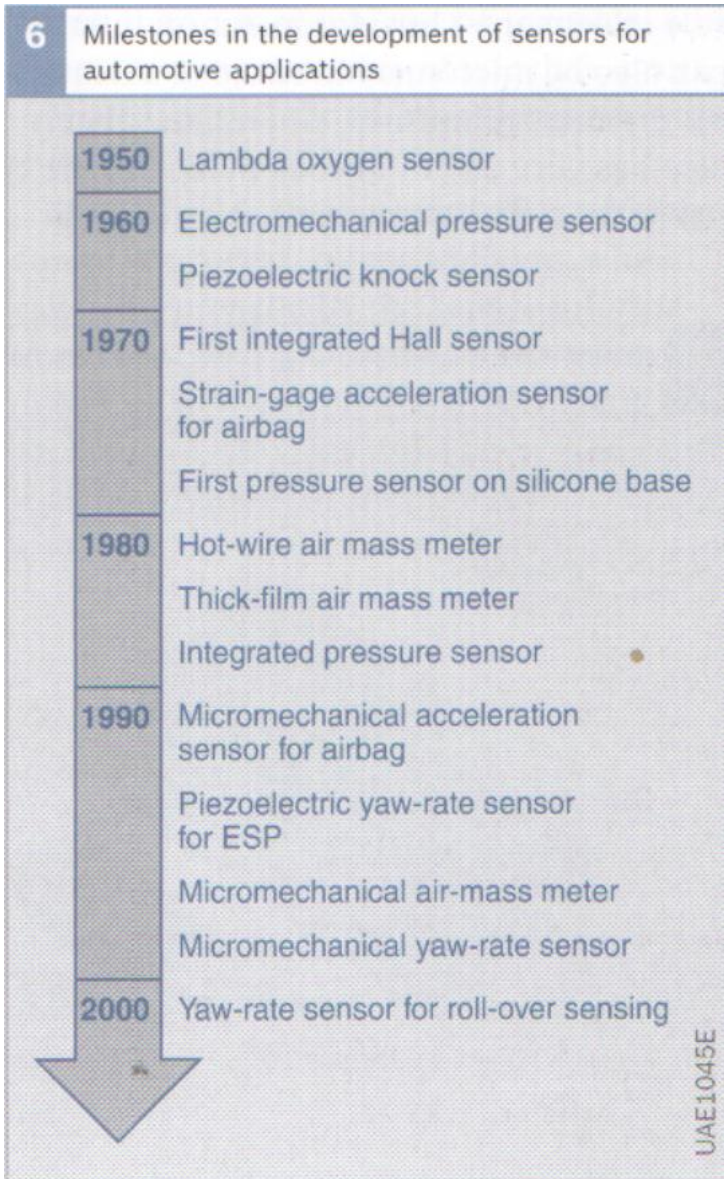
2 Sensor symbol

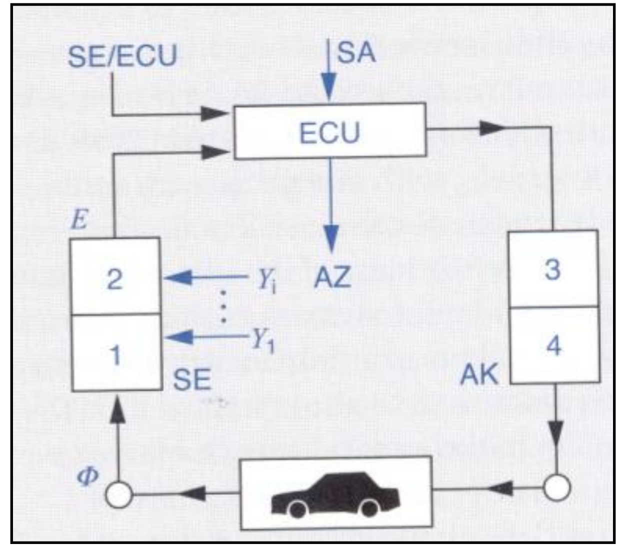



3 Basic sensor function



# Примена сензора на возилима




1 Measuring sensors
2 Adapter circuit
3 Driver circuit
4 Actuators
AK Actuator
AZ Display
SA Operating switch
SE Sensors
ECU Control unit
Φ Physical variable
*E* Electrical variable
$Y_i$ Disturbances

**Подела сензора на возилима**

- **према намени**
- **према карактеристикама**
- **према типу излазног сигнала**

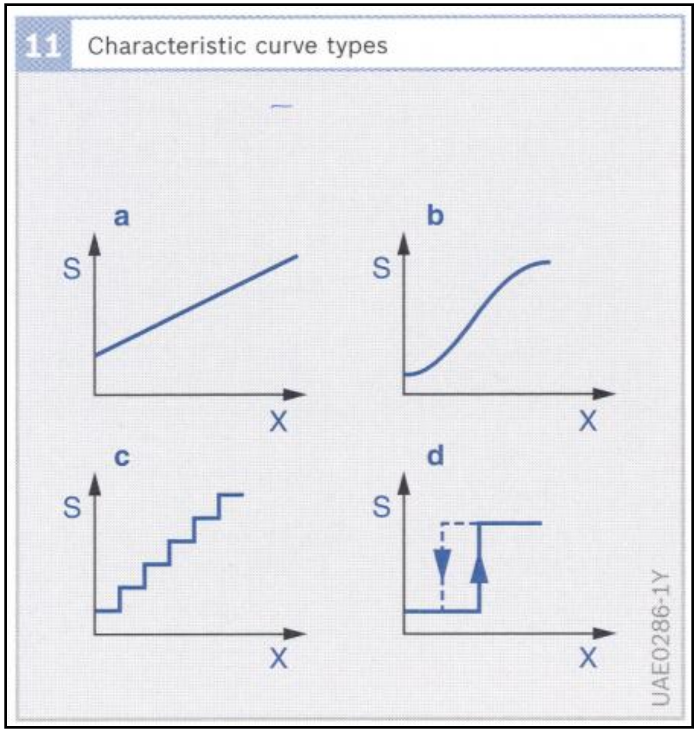



**Fig. 11**

S Output signal

X Measured variable

a Continuous, linear

b Continuous, nonlinear

c Discontinuous, multi-step

d Discontinuous, two-step (with hysteresis)

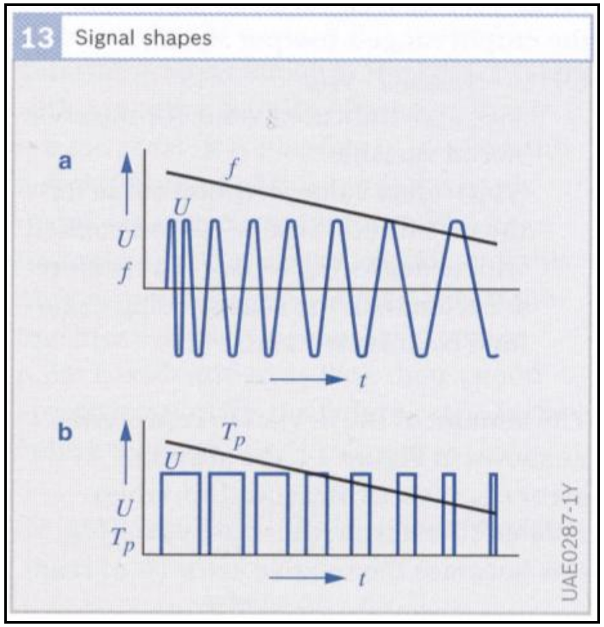
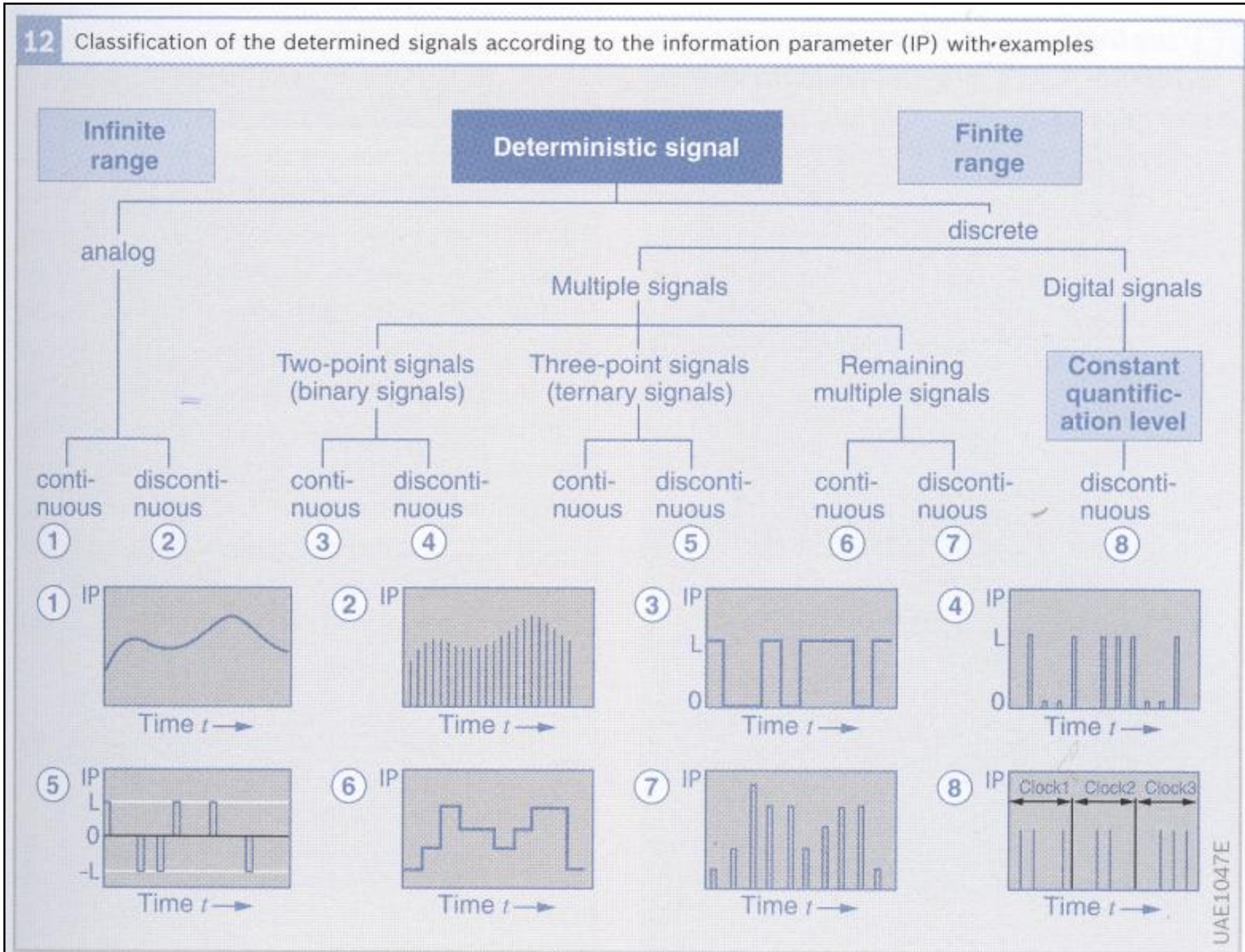
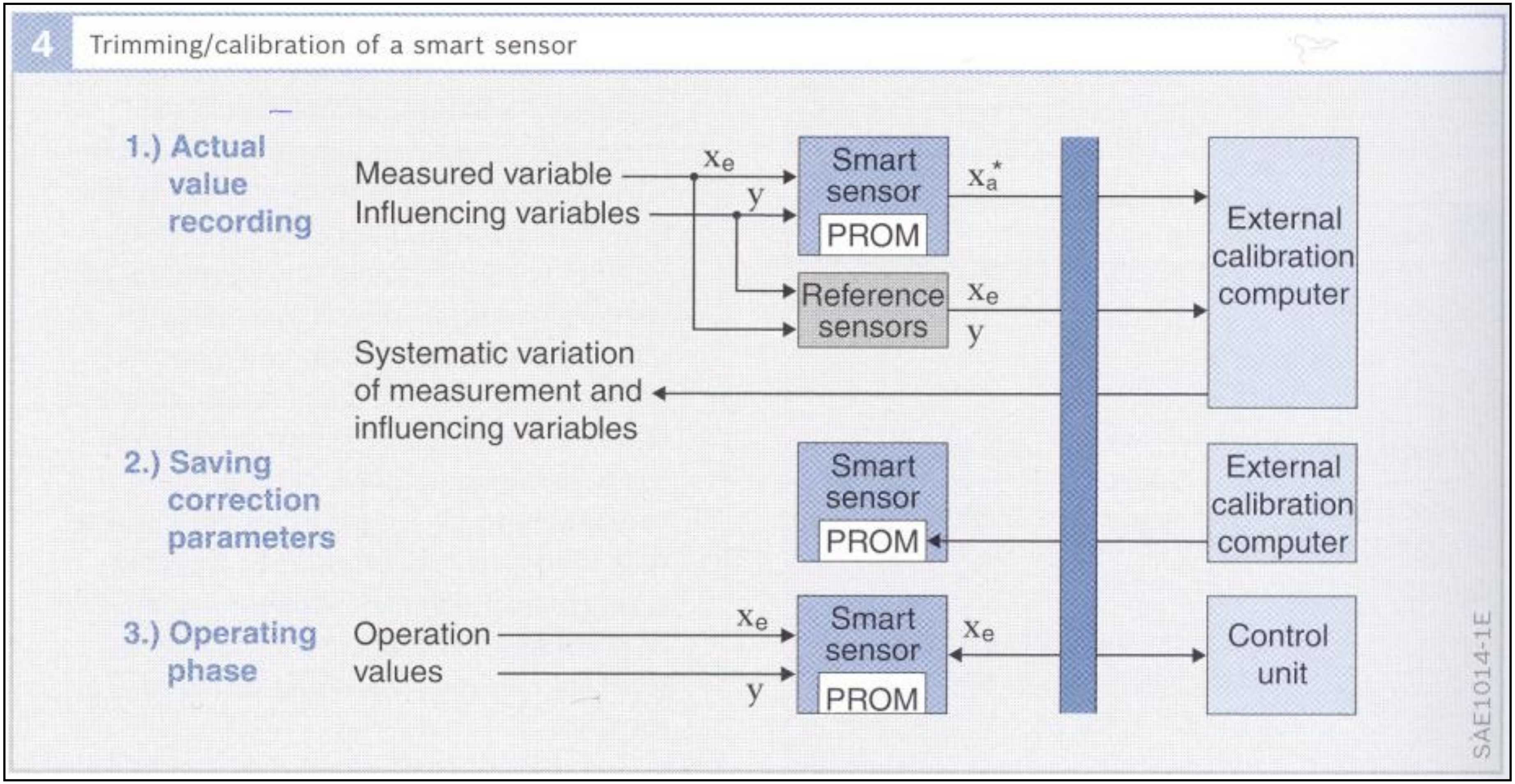



**Fig. 13**

a Output signal $U$, information parameter: frequency $f$

b Output signal $U$, information parameter: pulse duration $T_p$


12 Classification of the determined signals according to the information parameter (IP) with examples
Infinite range
Deterministic signal
Finite range
analog
discrete
Multiple signals
Digital signals
Two-point signals (binary signals)
Three-point signals (ternary signals)
Remaining multiple signals
Constant quantific-ation level
conti-nuous 1
disconti-nuous 2
conti-nuous 3
disconti-nuous 4
conti-nuous
disconti-nuous 5
conti-nuous 6
disconti-nuous 7
disconti-nuous 8
IP
L
0
-L
Time t
Clock1
Clock2
Clock3
UAE1047E


4
Trimming/calibration of a smart sensor
1.) Actual value recording
Measured variable
Influencing variables
xe
y
Smart sensor
PROM
Reference sensors
xa*
xe
y
External calibration computer
Systematic variation of measurement and influencing variables
2.) Saving correction parameters
Smart sensor
PROM
External calibration computer
3.) Operating phase
Operation values
xe
y
Smart sensor
PROM
xe
Control unit
SAE1014-1E

# Типови грешака

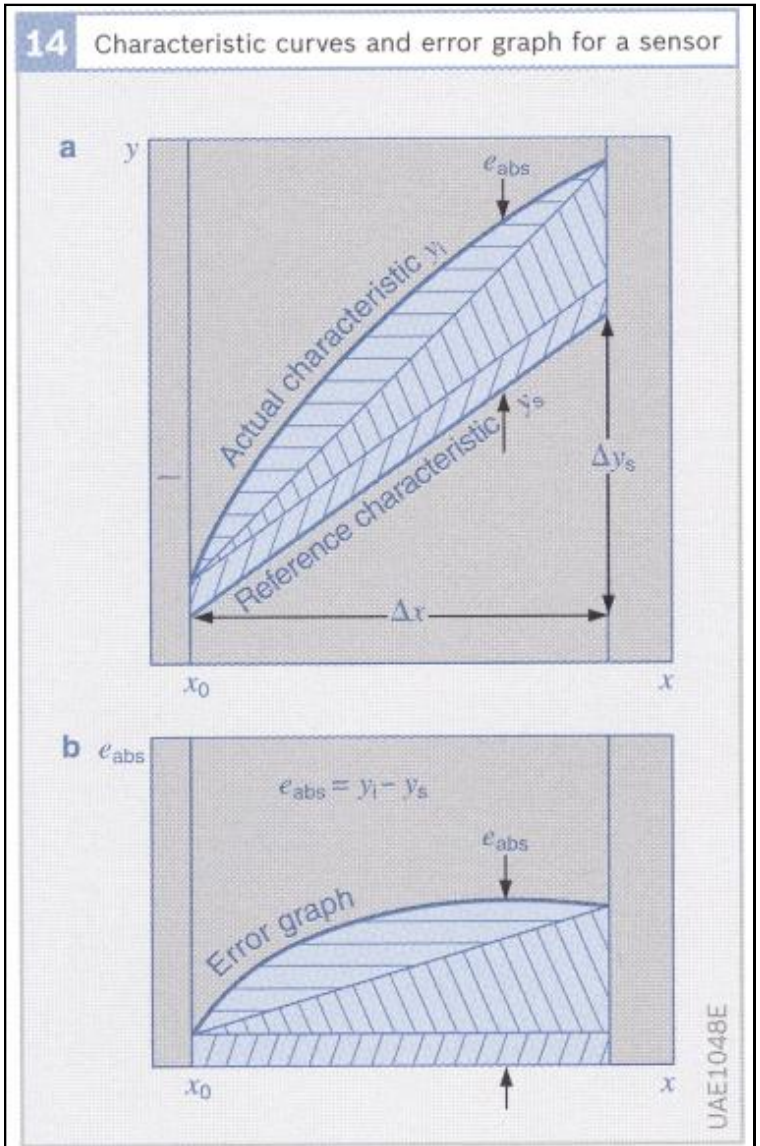



**Fig. 14**

a Actual and reference characteristic

b Error graph

$y$ Measured variable

$x$ Output signal

$\Delta x$ Measuring range

$e$ Error (deviation)

**Fig. 15**

a Zero error

b Gradient error

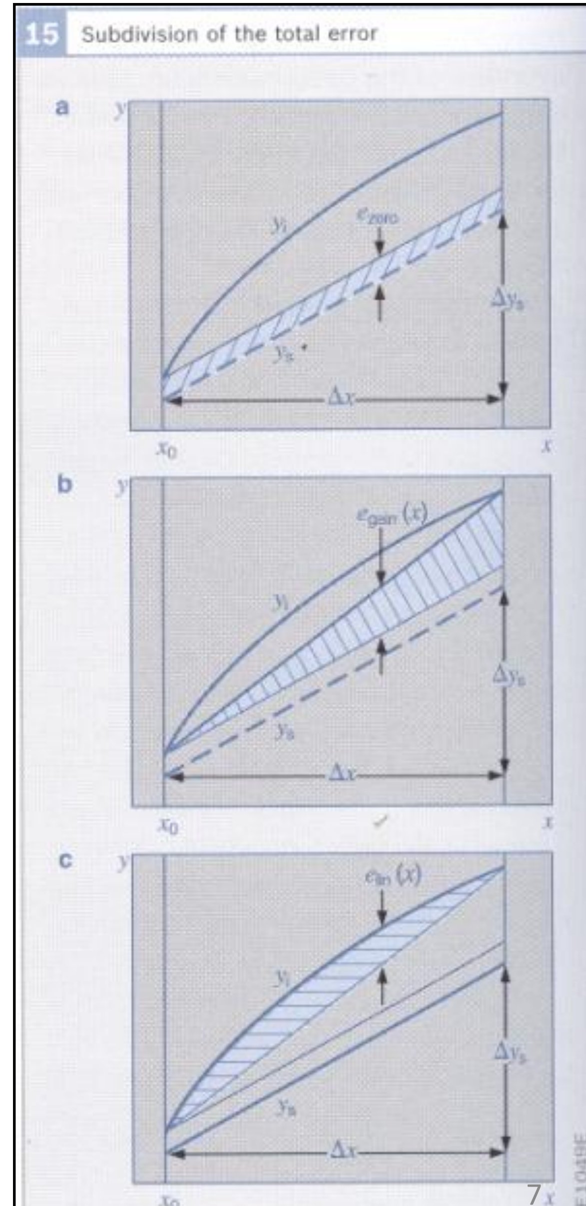
c Linearity error

$y$ Measured variable

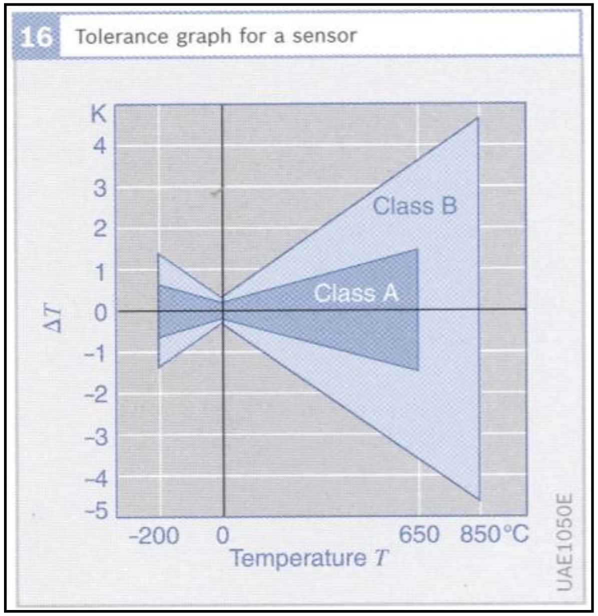
$x$ Output signal

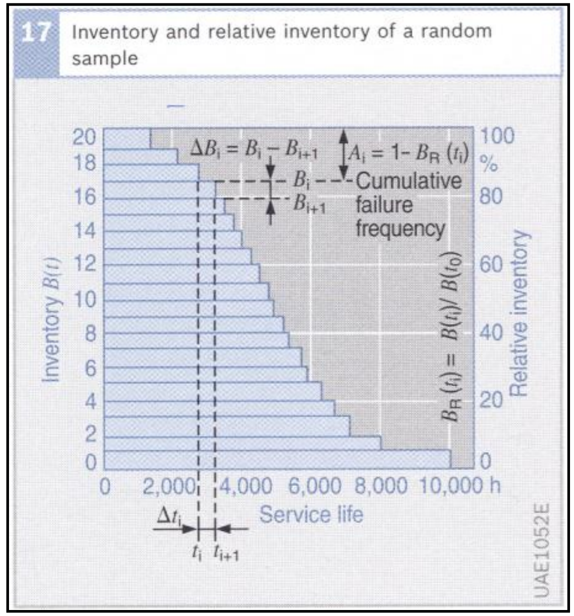
$\Delta x$ Measuring range

$e$ Error



# Поузданост сензора



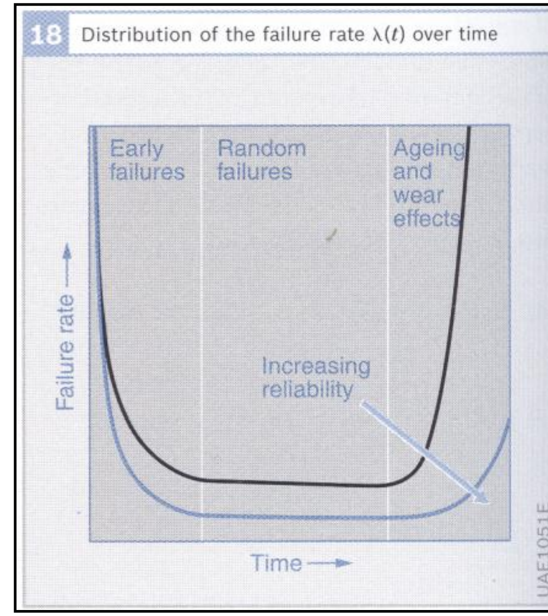




**Fig. 16**
Tolerance graph illustrated on the example of a resistance temperature sensor

**Fig. 17**
Observation for a random sample of N = 20 sensors; mean service life $T_M$ = 4,965 h.

# Захтеви и трендови код сензора на возилима

**3** Reliability requirements on vehicle systems

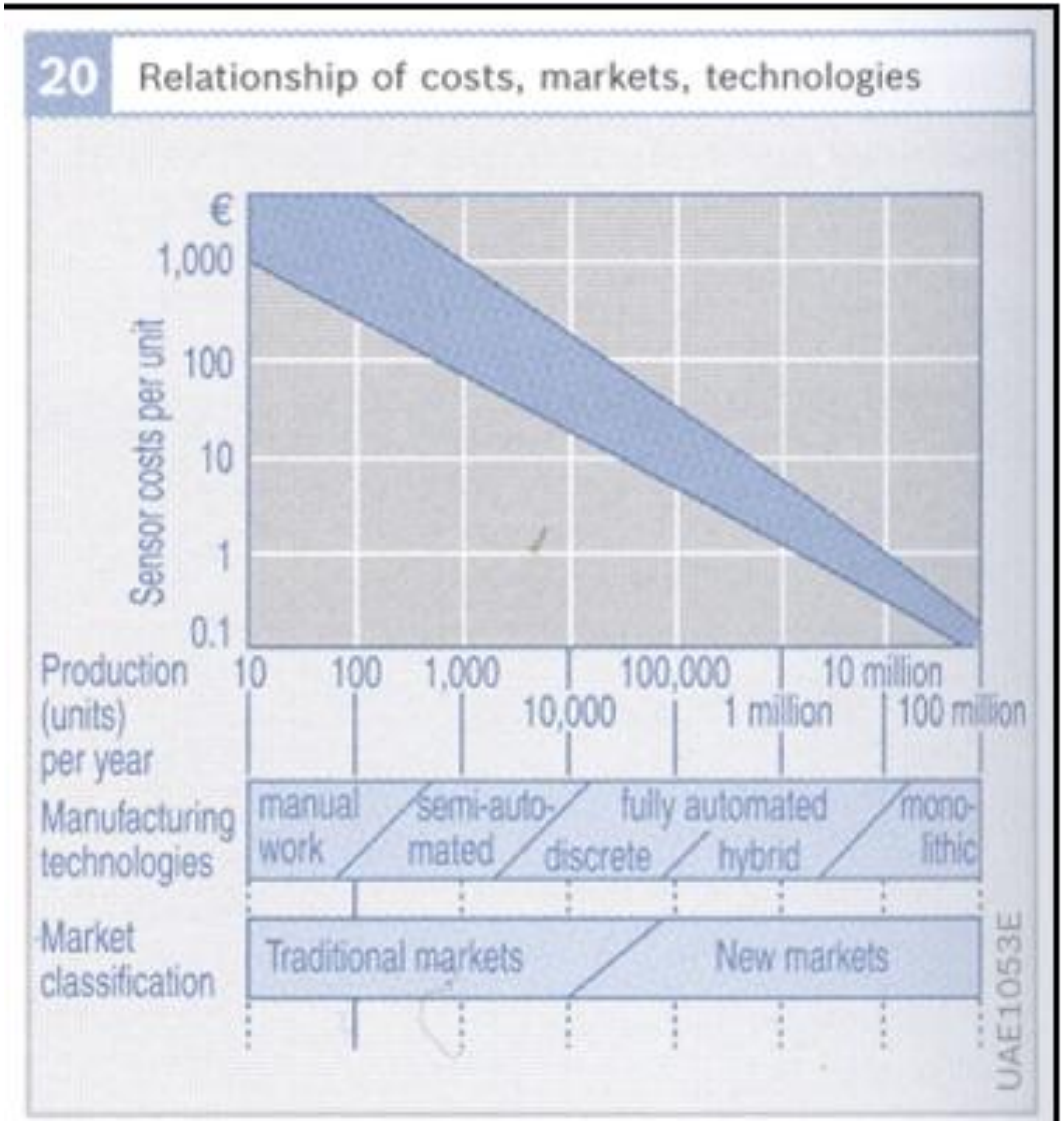
| Warranty target: 150,000 km/10 years | |
|---|---|
| → ECU failure rate (field) | < 50 ppm |
| → ECU failure rate (0 km) | < 15 ppm |
| → **Failure rate of modules and sensors** | **< 10 ppm** |
| → ASIC failure rate | < 3 ppm |
| → IC failure rate | << 1 ppm |
| → Failure rate of discrete components | < 0.5 ppm |
| → *For comparison* Mobile phone | ~ 5,000 ppm |

**19** Principal requirements on vehicle sensors

| Vehicle sensor | | Requirement |
|---|---|---|
| Rational mass production | ⇦ | Low costs |
| Robust, proven technology | ⇦ | High reliability |
| Appropriate pack-aging technology | ⇦ | Extremely severe operating conditions |
| Appropriate miniaturization technologies | ⇦ | Low space requirement |
| On-site error compensation | ⇦ | High-level accuracy |

SAE1013-1E

## Ниска цена производње



# Тешки радни услови

- механички (вибрације, удари)
- климатски (темп. влага)
- хемијски (гориво, мот. уље, електролит, со)
- електомагнетни (зрачење, линијска интерференција, напонски скокови)

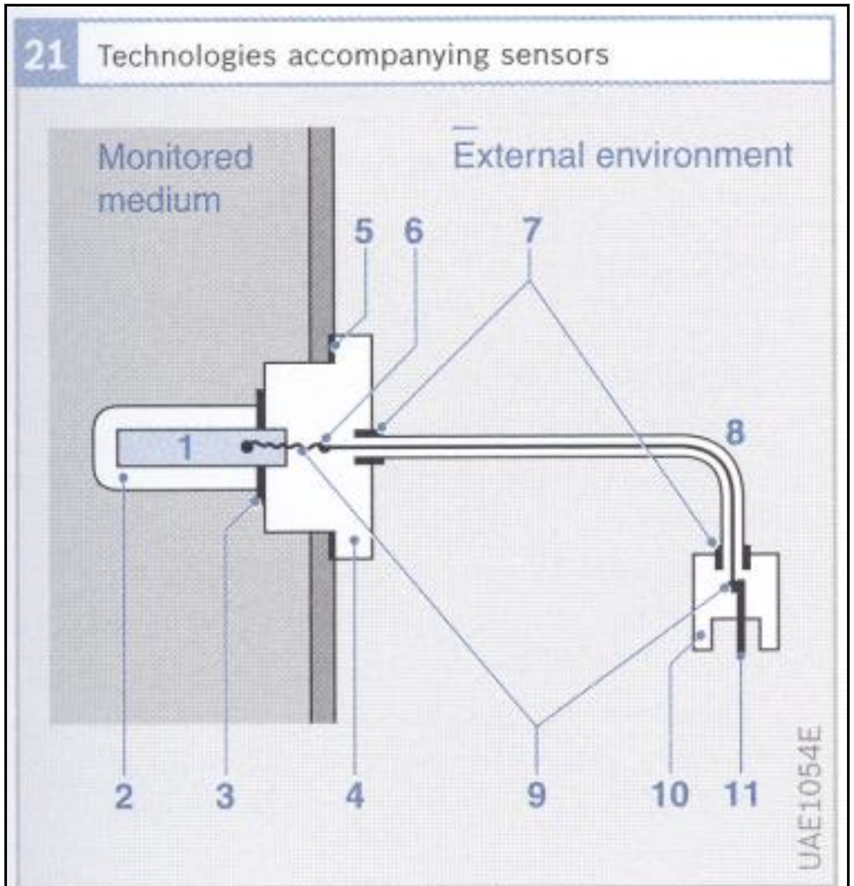
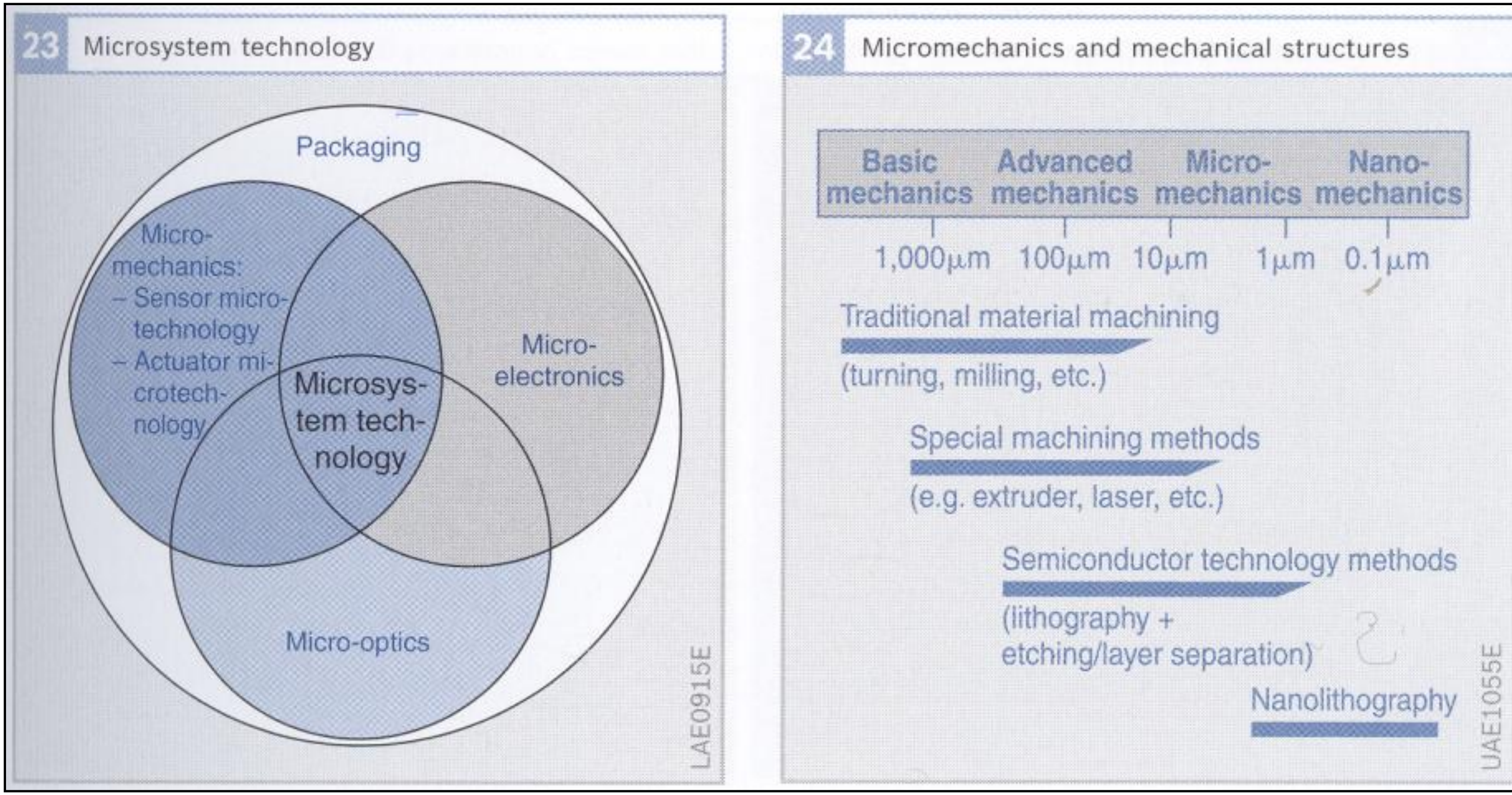


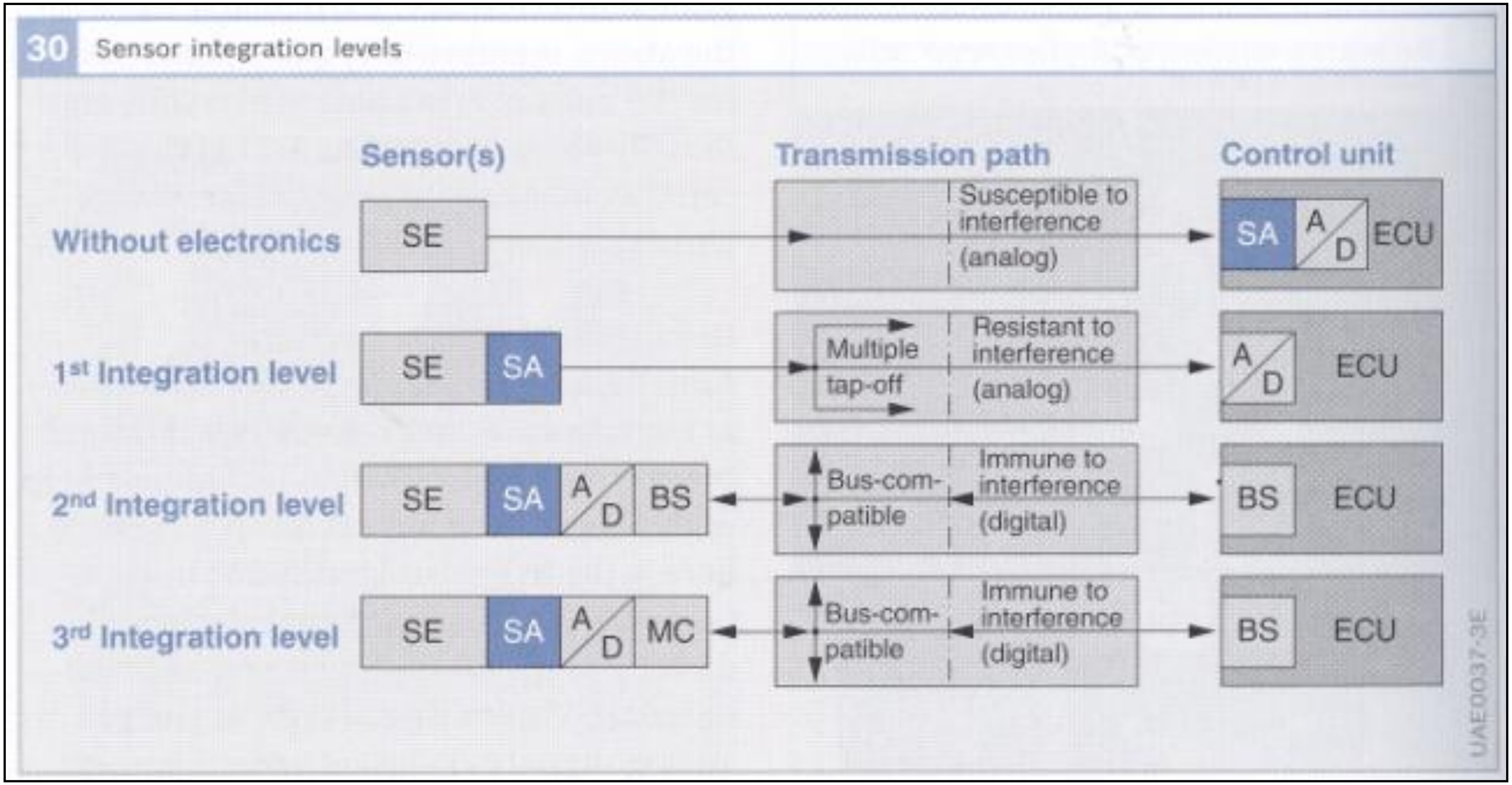

**Fig. 21**

1 Sensor
2 Protective sleeve (coating)
3 Seal
4 Mount
5 Seal, mounting
6 Data point
7 Seal, strain relief
8 Insulation (flexible)
9 Contacts
10 Plug housing
11 Plug contact

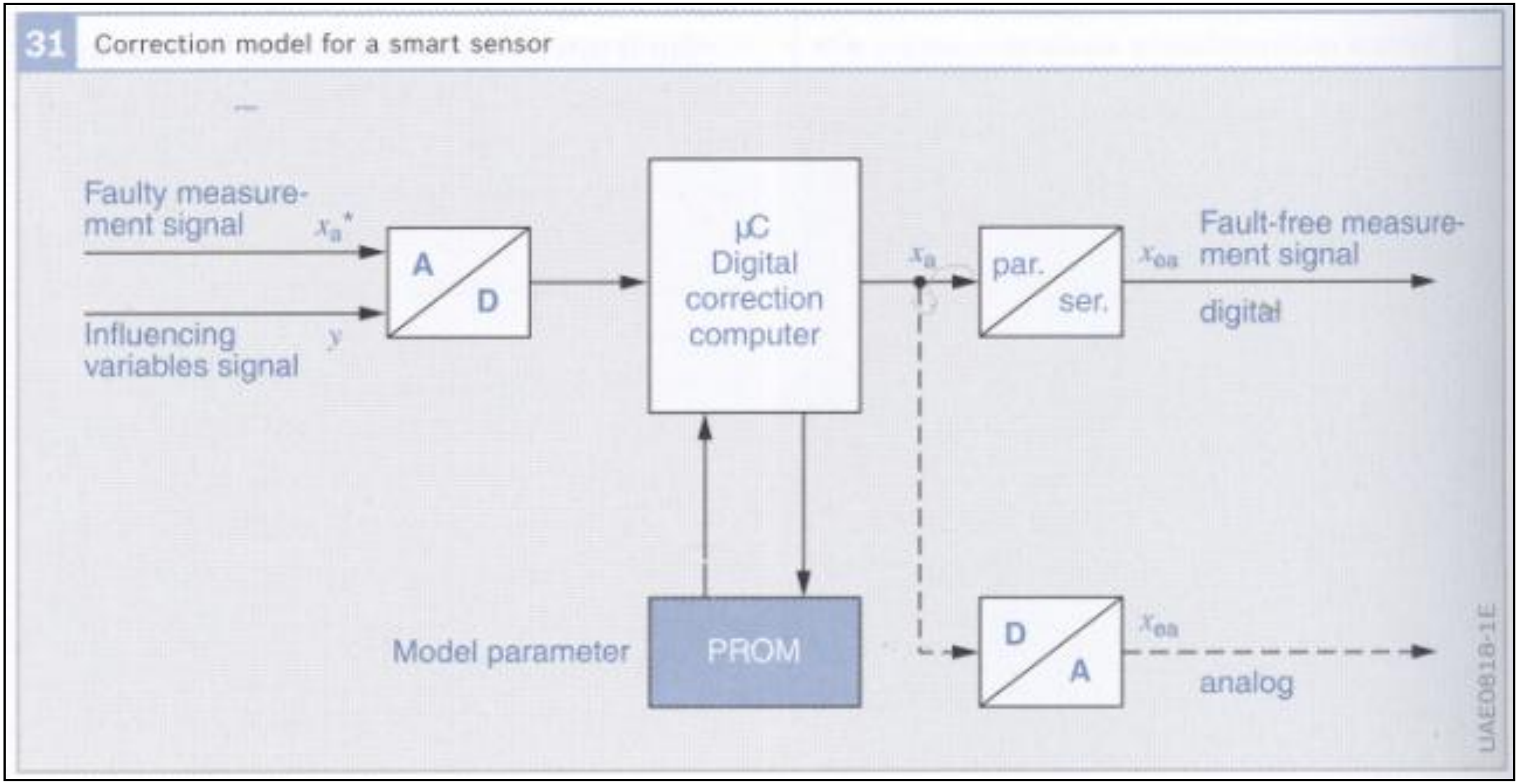
# Мали габарити (минијатуризација)



# Висока тачност



# Correction module of an intelligent sensor



# Преглед физикалних основа сензора

4 Physical effects for sensors

| Physical effect | Example | As at: Series production[1]/ Development[2] |
|---|---|---|
| **Resistive effects** (dependency of electrical resistance): | | |
| Influence of temperature on metallic and semiconductor materials | NTC and thin-film resistors for the measurement of air and engine temperature | S |
| Length or angular proportionality of resistors (potentiometer sensors) | Accelerator-pedal and throttle-valve sensor, fuel tank level | S |
| (In plane) tension or pressure dependency (piezoresistive): strain-gage resistors<br><br>Vertical pressure dependency (out of plane) | High-pressure sensors (e.g. common rail, ABS):<br>metal diaphragm,<br>low pressure sensors (silicon diaphragm),<br>force sensor | <br>S<br>S<br>D |
| Magnetic field dependency (magnetoresistive): semiconductor (magnetoresistors), AMR[3]) thin metal layers (e.g. NiFe, also in barber's pole form), GMR[4]) sensors (nanolayers) | Speed or delivery angle measurement in diesel distributor injection pumps | S/D |
| Light dependency: semiconductor photoresistors | Rain sensor, dirt sensor for headlight cleaning, automatic headlights, automatic low-beams | S |
| **Inductive effects** (effects of Faraday's law) | | |
| Induction voltage sensors (alternator): movement in the magnetic field | Wheel, camshaft, engine speed, needle lift (injection nozzle) | S |
| Wiegand effect | Speed of rotation | D |
| Variation in inductance as a result of the positional change of a ferromagnetic coil core | Solenoid armature sensor | D |
| Variation in inductance as a result of field limiting conductive elements (eddy current) | Semi-differential short-circuiting ring sensor (diesel pump load sensor) | S |

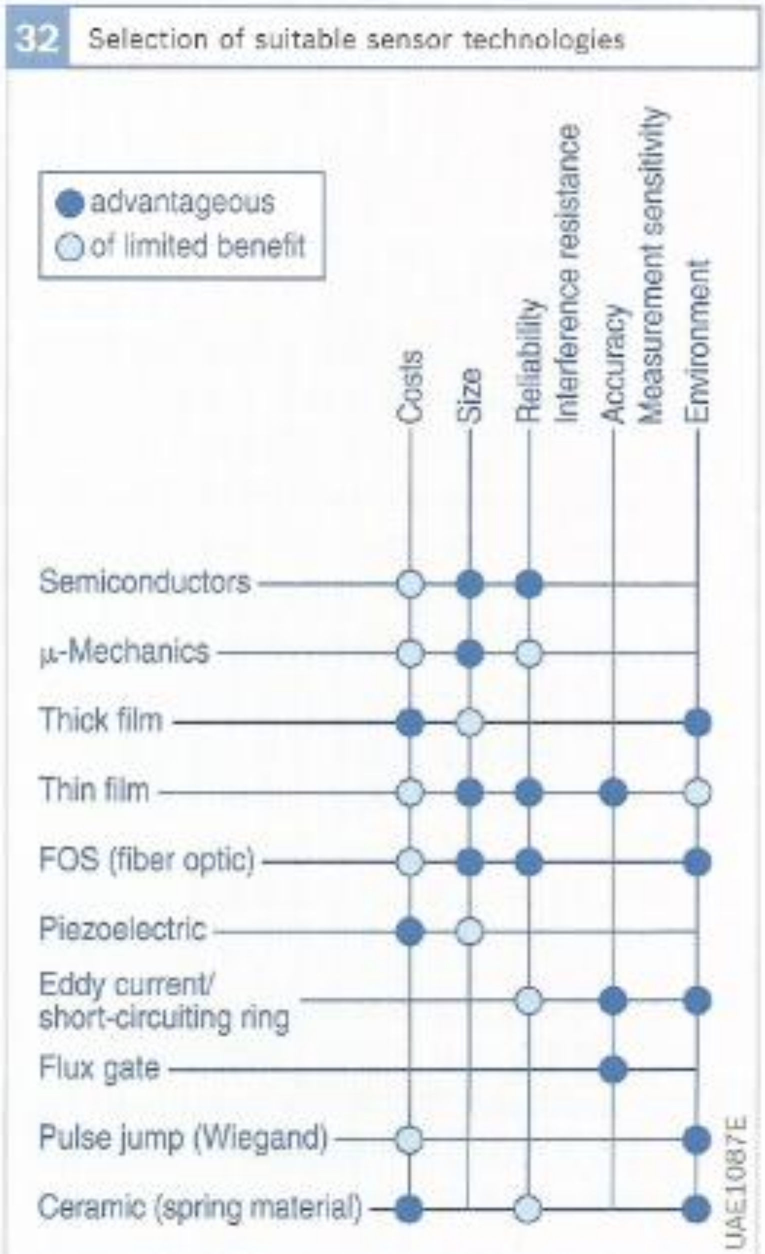
**Table 4**

1) Series production, at RB or competitors, possible also already phased out
2) Development possibly also concluded and in reserve
3) AMR = Anisotrop Magneto Resistive
4) GMR = Giant Magneto Resistive

| Physical effect | Example | As at: Series production[1]/ Development[2] |
|---|---|---|
| Variation of the degree of transformer coupling (by electrical or magnetic conductive elements) | Full-differential short-circuiting ring sensor | D |
| Variation in inductance or of the degree of transformer coupling (by magneto-elastic conductive elements) | Load bolt (Hitchtronik),<br>braking force | S<br>D |
| Saturation core sensors (e.g. Foerster probe) | Compass sensor | S |
| **Capacitive effects (influence)** | | |
| Capacitance change as a result in change in plate distance and degree of cover | Micromechanical acceleration sensors, e.g. for airbag, ESP,<br>MM2 yaw-rate sensor,<br>pressure sensor | S<br>S<br>D |
| Capacitance change as a result in a change of the relative dielectric constant | Oil grade,<br>humidity sensors | S<br>S |
| Capacitance change as a result of change in the electrolyte level with a dielectric medium | Fuel tank level | D |
| **Charge generating effects** | | |
| Piezoelectric effect (quartz, piezoceramics) | Knock sensor, airbag sensor,<br>DRS1 yaw-rate sensor | S<br>S |
| Pyroelectric effect | IR sensor (dynamic) | D |
| Photoelectric charge generation | CCD and CMOS imaging sensor (also IR range) | D |

# СЕНЗОРИ И АКТУАТОРИ

| | | |
|---|---|---|
| **Voltage generating, galvanic effects** | | |
| Hall effect (out-of-plane sensitivity, semiconductor material) | Hall switch (ignition), wheel and engine speed, acceleration sensor (ABS, 2g), front passenger weight detection (iBolt™), ARS1,2 (accelerator pedal etc.) | S |
| Pseudo-Hall effect (in-plane sensitivity, metal thin film) | LWS2 and LSW4 steering-angle sensors | S |
| Electrolytic diffusion probes (doped Zr oxide ceramic) | Lambda oxygen sensors | S |
| Thermocouple, thermopile | IR sensor (Bolometer) | D |
| **Photoelectric and fiber-optic effects** | | |
| Photoelectric cells, photodiodes, phototransistors (also in IR range) | Rain sensor, dirt sensor for headlight cleaning, automatic headlights, automatic low beams | S |
| Medium-dependent absorption | Soot particles, humidity | D |
| Extrinsic and intrinsic fiber-optic effects: influence on intensity, interference (influencing phases), influencing polarization; e.g. microbending effect | Finger protection (windows, sliding sunroof), pedal force, collision | D |
| **Thermal effects** | | |
| Resistor cooling as a function of the flow velocity, of the medium, of the density or fill level of a medium | HFM air-mass sensors,<br>analysis,<br>concentration,<br>fill level (fuel tank) | S<br>–<br>–<br>D |
| **Wave propagation effects** | | |
| Sound waves: propagation time effects (echo sounding), superposition with medium speed, Doppler effect (moving source/receiver) | Parking-aid assistant,<br>volume flow rate,<br>speed over the ground | S<br>D<br>S |
| Light waves: total reflection on boundary surfaces, optical resonators (color analysis)<br><br><br>Sagnac effect<br>Propagation time | Rain sensor,<br>fiber-optic finger protection,<br>fill level (analog, limit value),<br>yaw rate: fiber and laser gyroscopes,<br>lidar (light wave radar) | S<br>D<br>D<br>D<br>D |
| Electromagnetic radiation: Doppler, FMCW, propagation time radar | ACC distance sensor | S |



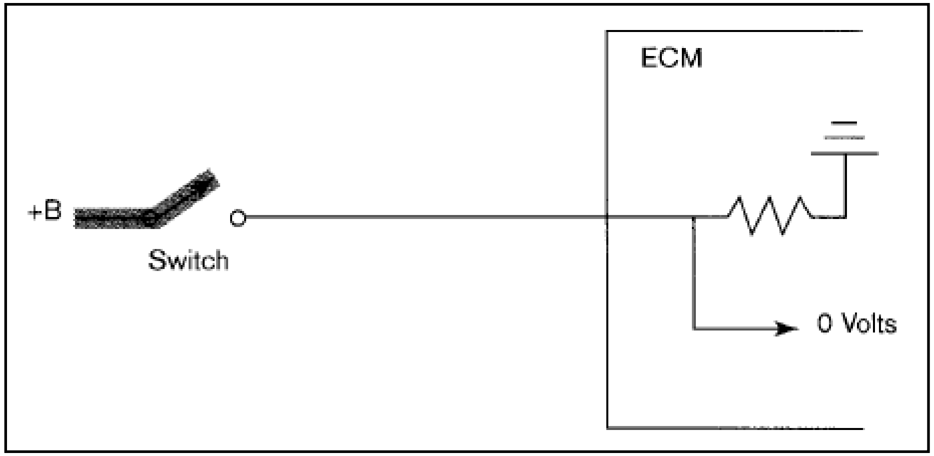

## Преглед сензорских технологија

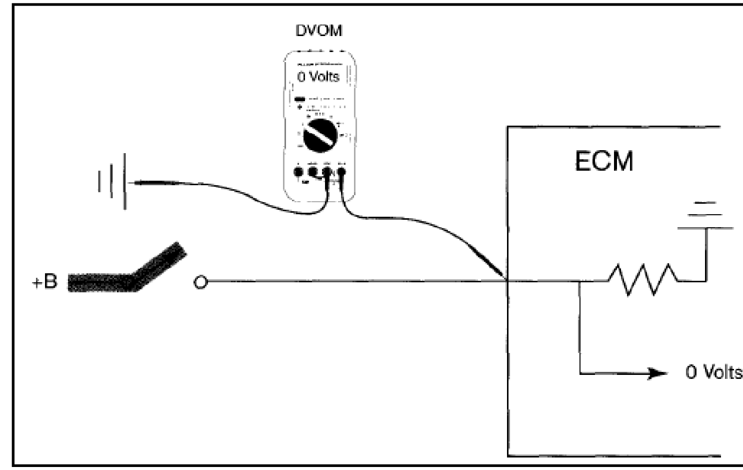
Различите сензорске технологије за коришћење мерних ефеката су блиско повезане са изабраним концептом мерења.

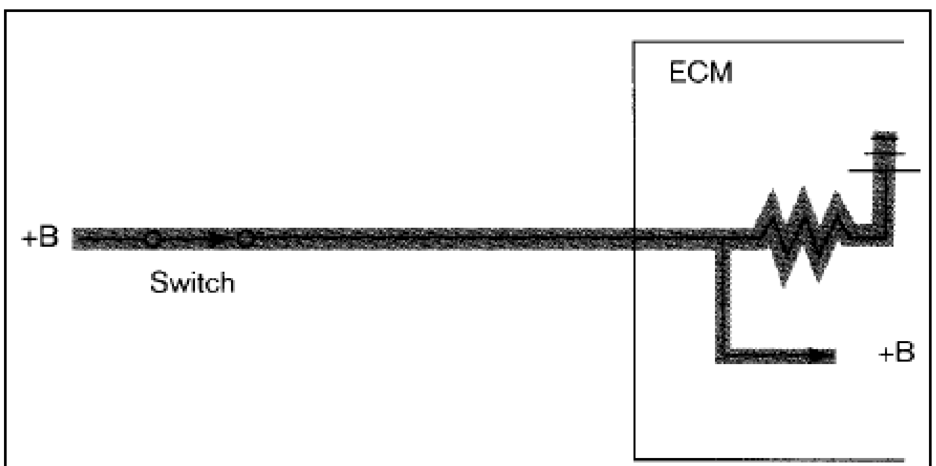
Тај избор првенствено зависи од захтева који се постављају при мерењу одређене величине:

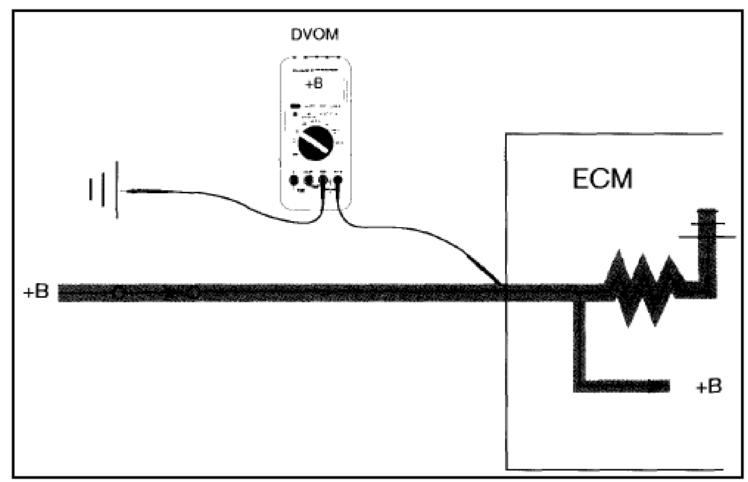
- цена
- величина
- поузданост,
- тачност
- околина

## Прекидач-давач мода

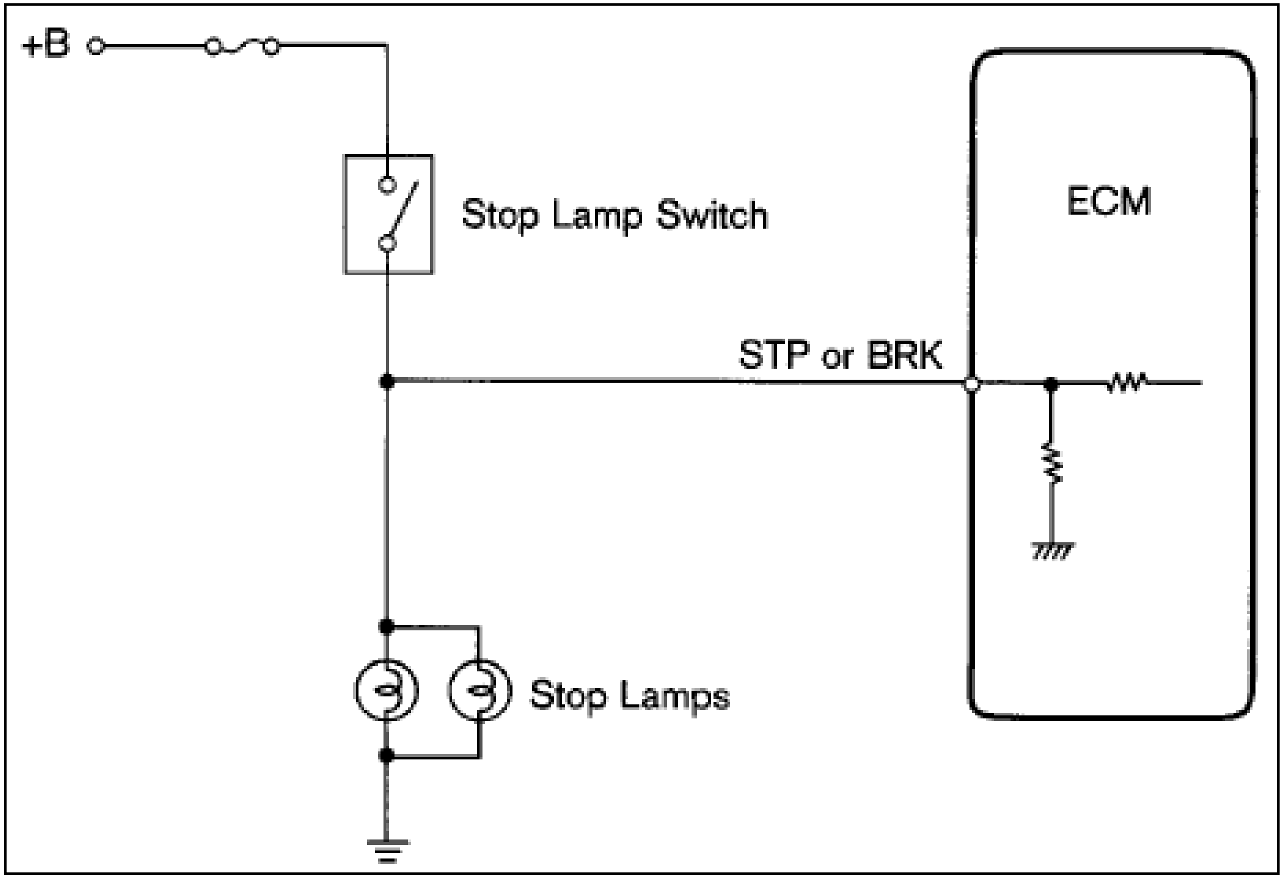


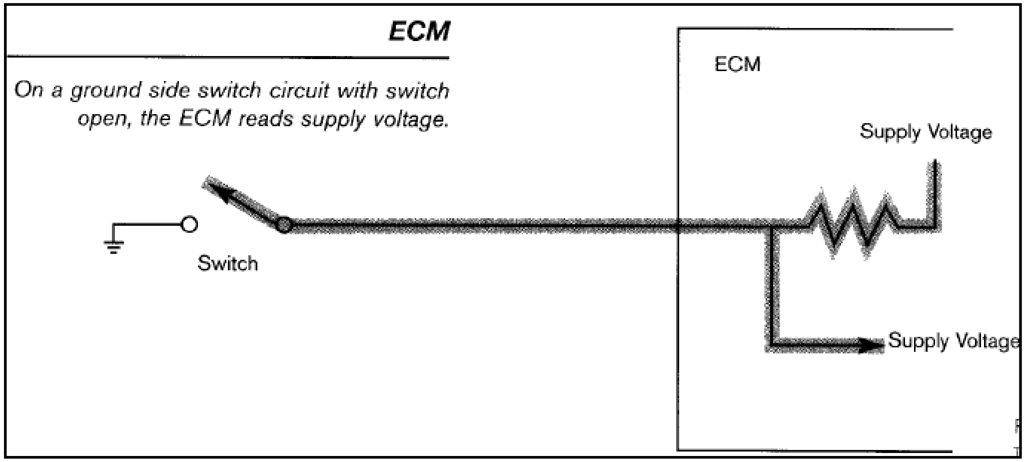



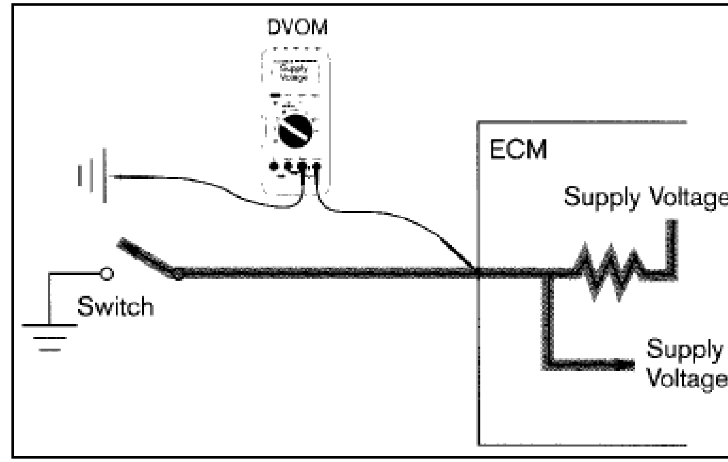



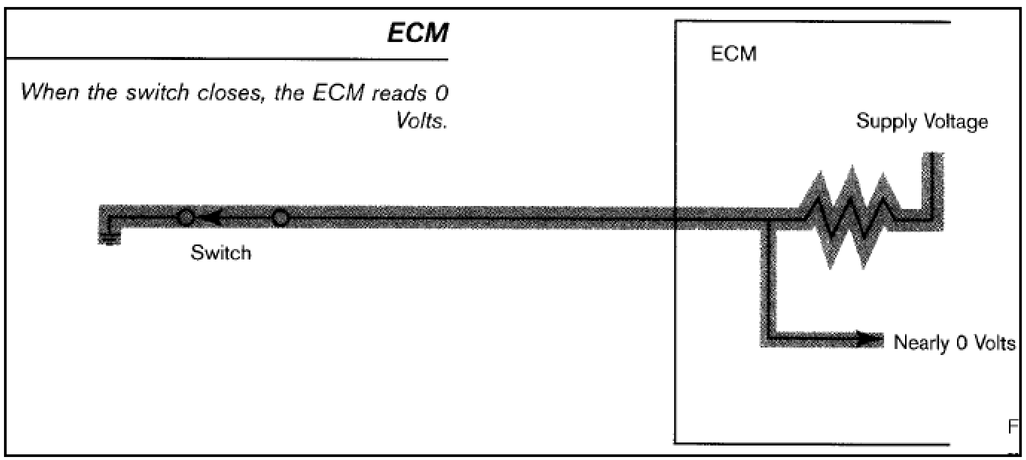
# СЕНЗОРИ И АКТУАТОРИ

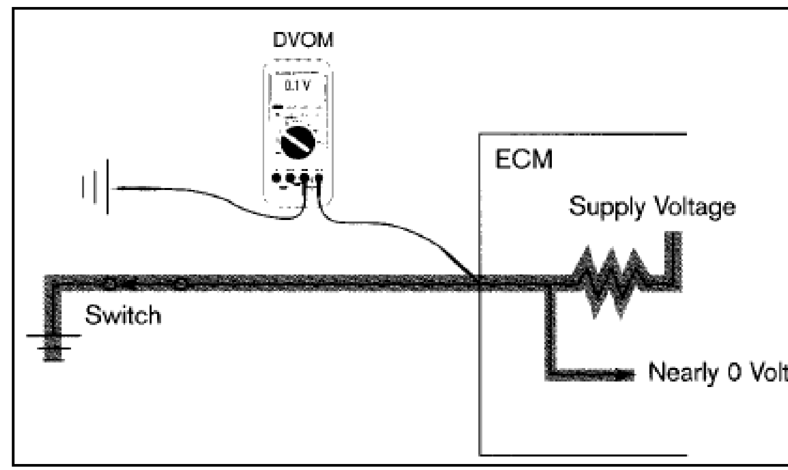


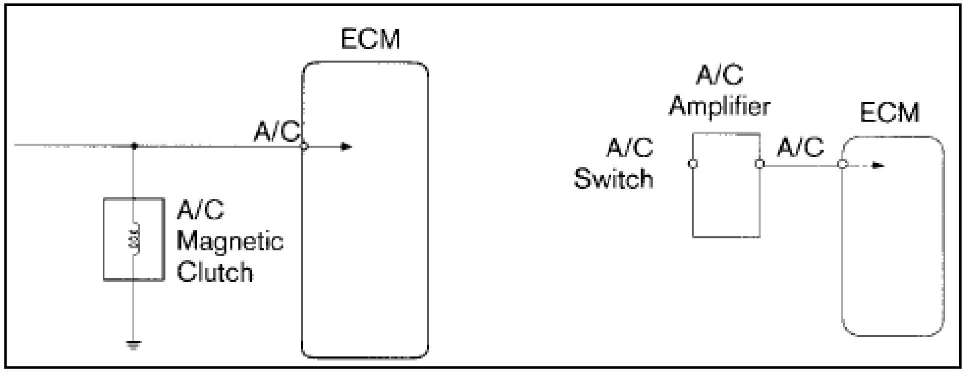
# СЕНЗОРИ И АКТУАТОРИ

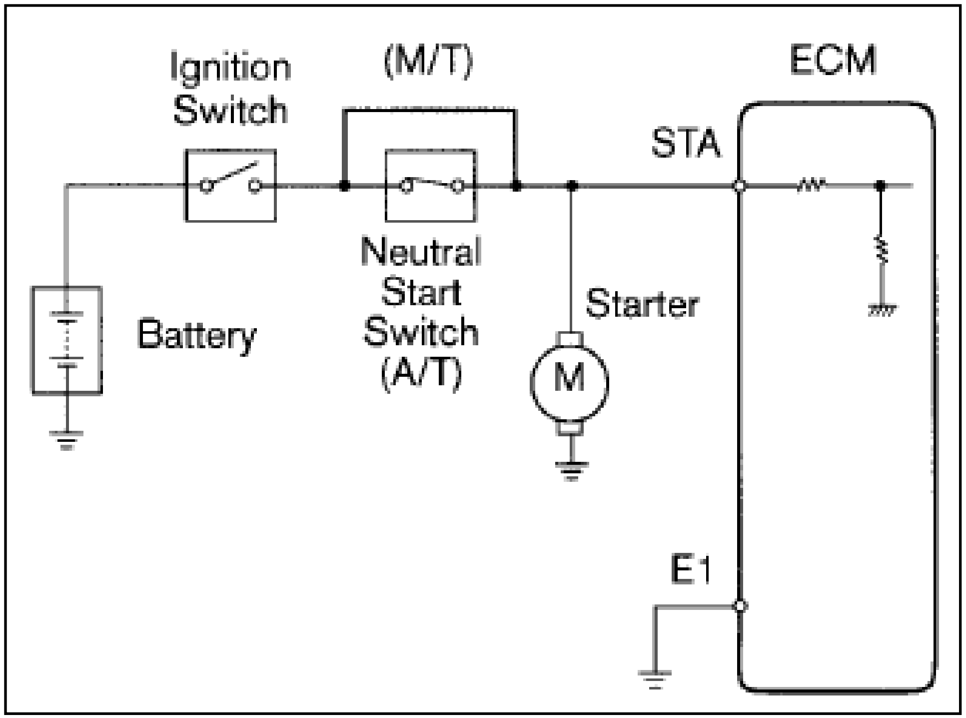


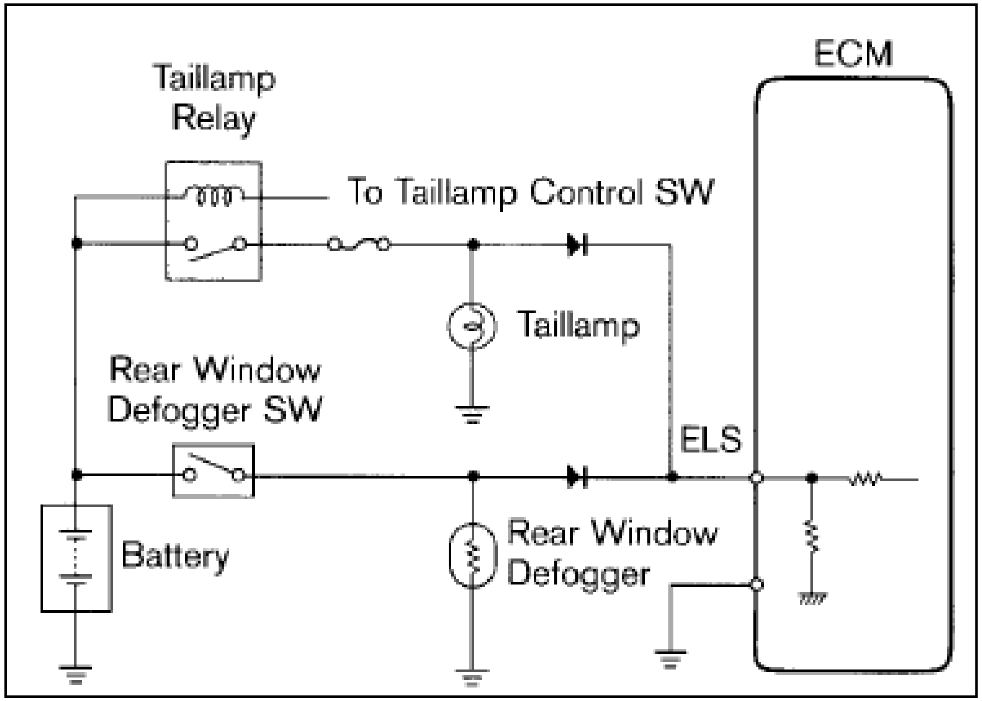



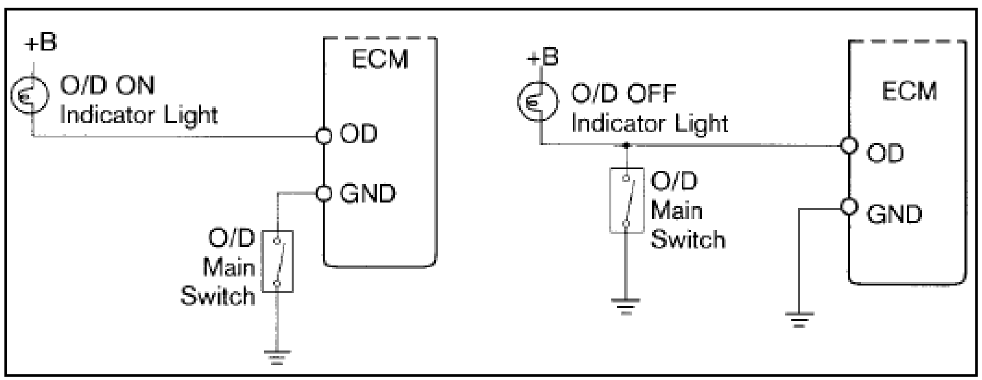




ECM
A/C
A/C
Magnetic
Clutch
A/C
Amplifier
ECM
A/C
Switch
A/C


Ignition
Switch
(M/T)
ECM
STA
Neutral
Start
Switch
(A/T)
Battery
Starter
M
E1


Taillamp Relay
To Taillamp Control SW
ECM
Taillamp
Rear Window Defogger SW
ELS
Battery
Rear Window Defogger


+B
O/D ON Indicator Light
ECM
OD
GND
O/D Main Switch
+B
O/D OFF Indicator Light
ECM
OD
GND
O/D Main Switch