3. SENZORI POZICIJE (POMAKA)

Dužina, Pozicija, Pomeraj, apsolutno i relativno merenje dužine.

- **Dužina** spada u red osnovnih fizikalnih veličina i njeno merenje ima fundamentalni značaj u tehnici i ljudskoj delatnosti uopšte.
- Merenje ukupne dužine nekog tela je **apsolutno merenje**, čiji se rezultat izražava u metrima. U tehnici često nije potrebno meriti ukupnu dužinu, već samo promenu dužine posmatranog tela **(relativno merenje)**.
- Pod pojmom **pozicija** podrazumevamo određivanje koordinata objekta (linearnih ili ugaonih) u odnosu na izabranu referencu.
- **Pomeraj (pomak)** podrazumeva pomeranje sa jedne pozicije na drugu za određenu udaljenost ili ugao.
- **Linearni pomak** je promena dužine (rastojanja) između dve tačke koje leže na pravoj liniji. Primarna funkcija senzora pomaka je merenje promene položaja tela pri njegovom translatornom kretanju.
- **Ugaoni pomak** je promena ugaonog položaja tela koje rotira oko neke ose.

- **Senzori pomaka** se mnogo primenjuju i kao sekundarni pretvarači u mernim uređajima u kojima se merena fizikalna veličina (mehaničko naprezanje, sila, pritisak, nivo, temperatura i dr.) pomoću primarnog senzora prvo pretvori u linearni ili ugaoni pomeraj.

SENZORI LINEARNOG POMAKA
- Otpornički potencimetarski senzori
- Kapacitivni senzori
- Elektromagnetni senzori
- Specijalni senzori *(koordinatometri, linearni induktosin, itd.)*

SENZORI UGAONOG POMAKA
- Obrtni transformatori
- Inkrementalni senzori

PODELA SENZORA POMAKA
- Kontaktni senzori
- Beskontaktni senzori

Pregled aplikacija na vozilu u kojima se meri pozicija (pomak)

1 Travel/angular positions as direct measured variables

Measured variable	Measuring range
Throttle-valve position in the gasoline engine	90°
Accelerator/brake-pedal position	30°
Seat, headlamp, rear-view mirror position	
Control-rack travel and position for diesel in-line fuel-injection pump	21 mm
Angular setting of the injected fuel-quantity actuator on the diesel distributor-type injection pump	60°
Fill level in the fuel tank	20 to 50 cm
Travel of clutch servo unit	50 mm
Distance: vehicle – vehicle or vehicle – obstacle	150 m
Steering (wheel) angle	±2·360° (±2 revolutions)
Tilt angle	15°
Angle of direction of travel	360°
GPS (Global Positioning System)	360° geographical latitude/longitude, geographical altitude
Near-range distance (US parking-aid assistant)	1.5 m
Near-range radar (precrash)	10 m
External video	40 m
Long-range and near-range infrared viewer	100 m

2 Travel/angular positions as indirect measured variables

Measured variable	Measuring range
Spring compression travel (headlamp range, vehicle tilt)	25 cm
Torsion angle (torque)	1 to 4°
Deflection of a sensor plate (volume flow)	30 to 90°
Deflection of a spring-mass system (acceleration)	1 to 500 µm
Deflection of pressure sensor diaphragm	1 to 20 µm
Deflection of force measuring spring (passenger weight)	10 to 500 µm

- Tabela 1 Pregled aplikacija u kojima se pomak (translatorni/ugaoni) meri direktno
- Tabela 2 Pregled aplikacija u kojima se pomak (translatorni/ugaoni) meri indirektno

1. Otpornički potenciometarski senzori pozicije (pomaka)

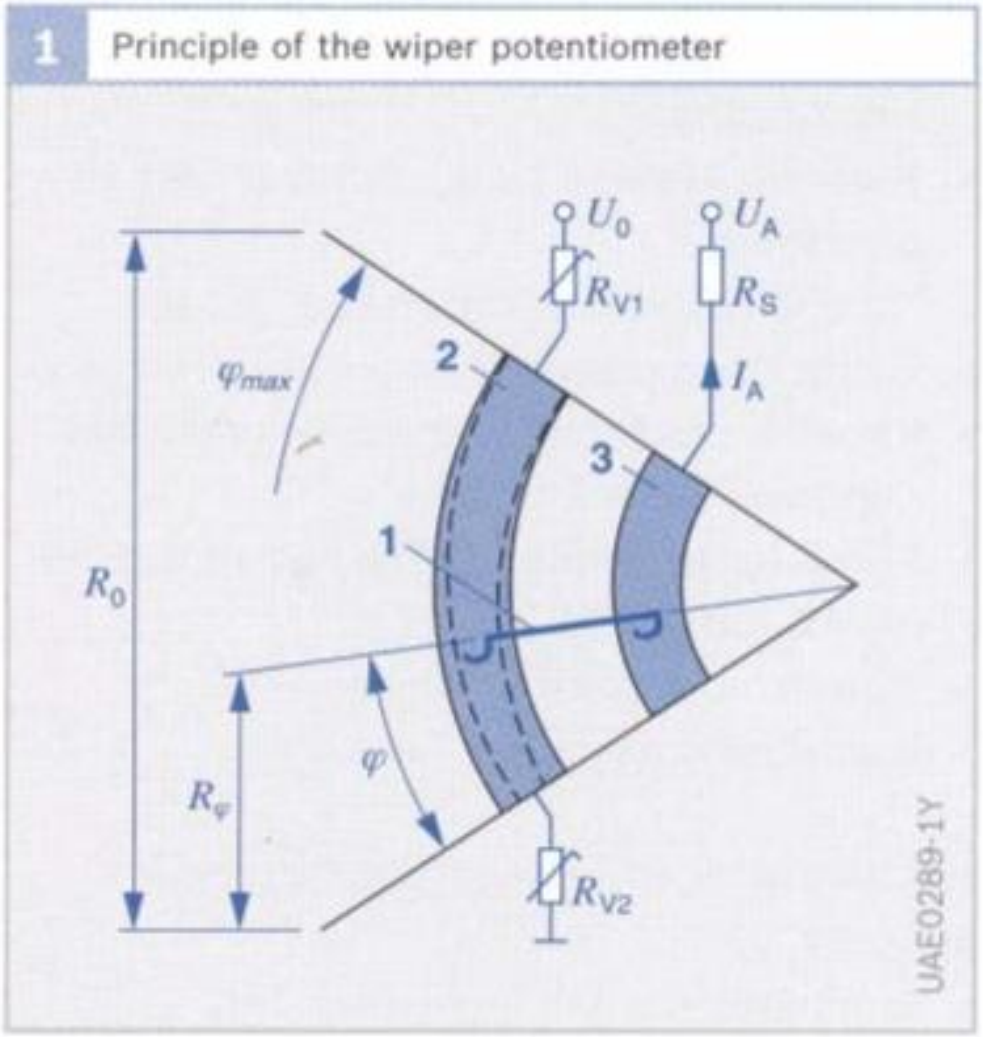
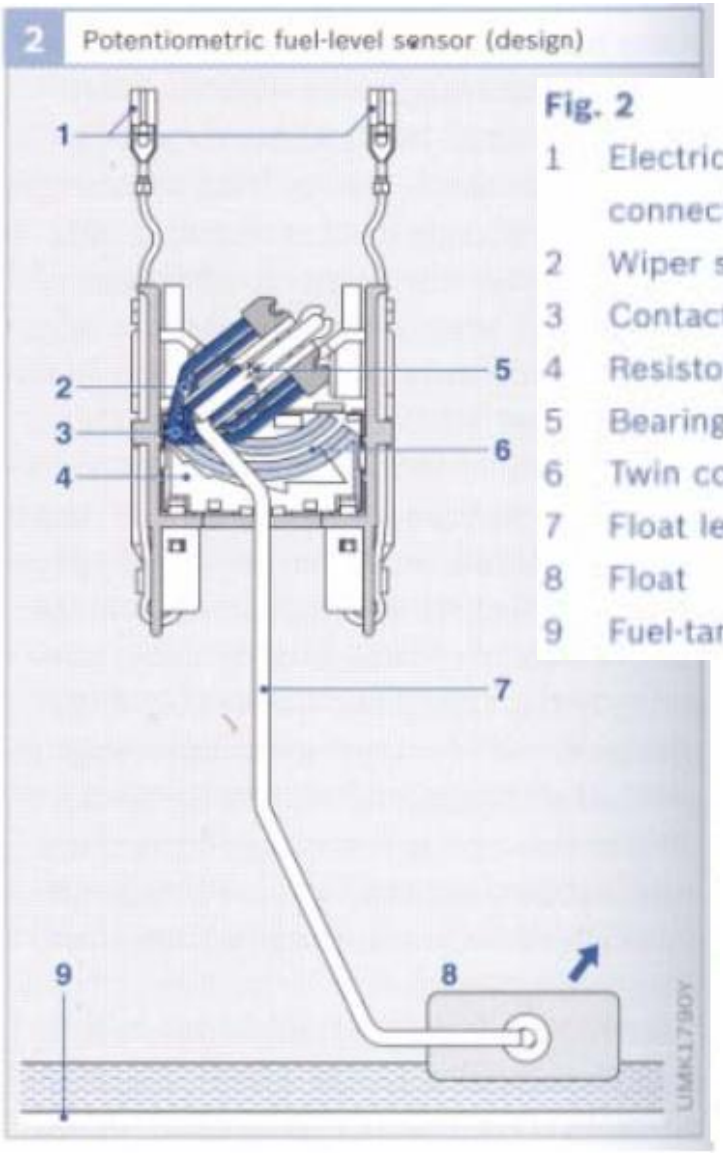


Fig. 1

1 Wiper
2 Resistance track
3 Contact conductor track
I_A Wiper current
U_0 Supply voltage
U_A Measurement voltage
R Resistance
φ_{max} Maximum angle of rotation
φ Measured angle

Primena:

- Senzor položaja pedale gasa za zadavanje potrebnog obrtnog momenta za sistem upravljanja motorom.
- Senzor nivoa goriva (Slika 2).
- Potenciometar senzorske ploče (KE-Jetronic i L-Jetronic) za detekciju količine usisanog vazduha motora.
- Senzor položaja prigušnog leptira za određivanje položaja prigušnog leptira kod benzinskih motora (slike 3 do 5).



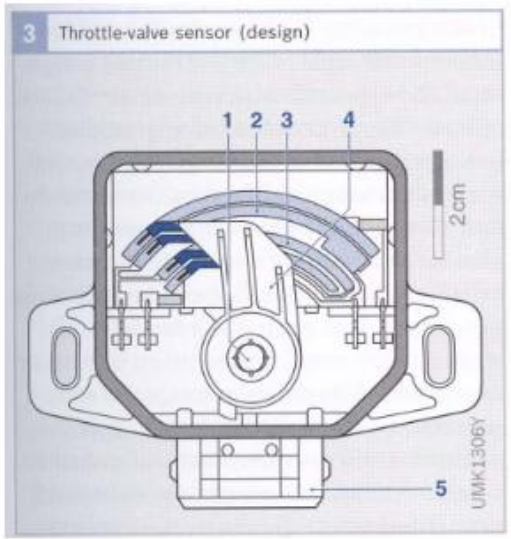


Fig. 3

1 Throttle-valve shaft
2 Resistance track 1
3 Resistance track 2
4 Wiper arm with wipers
5 Electrical connection

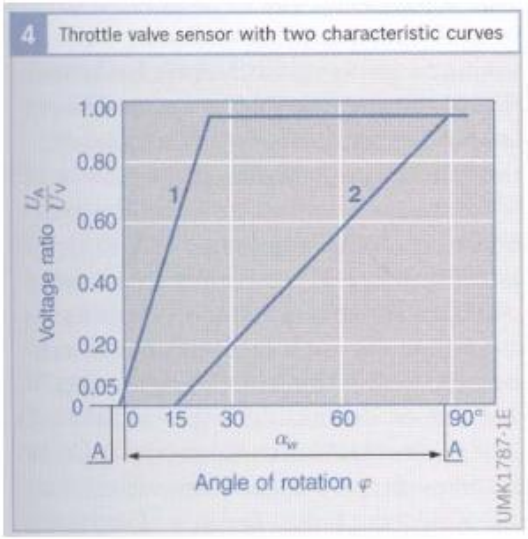


Fig. 4

A Internal stop
1 Characteristic curve for high resolution in the angular range 0° to 23°
2 Characteristic curve for angular range 15° to 88°
U_A Measurement voltage
U_V Operating voltage
α_W Effective measured angle

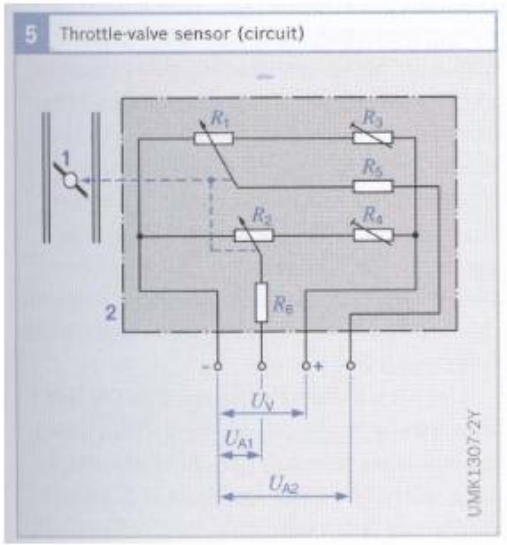


Fig. 5

1 Throttle valve
2 Throttle-valve sensor
U_A Measurement voltages
U_V Operating voltage
R_1, R_2 Resistance tracks 1 and 2
R_3, R_2 Calibration resistors
R_5, R_6 Protective resistors

Prednosti i nedostaci potenciometarskih senzora pozicije

Prednosti:

- Niska cena
- Jednostavana izrada
- Veoma širok merni efekat (izlazni merni opseg = napon napajanja)
- Visok nivo otpornosti na smetnje
- Široki temperaturni opseg (do 250 °C)
- Visoka tačnost (bolja od 1% mernog opsega)
- Širok merni opseg (moguće je skoro 360 °)
- Mogućnost kalibracije (laserska ablacija itd.)

- Fleksibilna statička karakteristika
- Fleksibilna montaža (na zakrivljene kao i ravne površine)
- Brojni proizvođači

Nedostaci:

- Mehaničko habanje
- Grešake merenja zbog abrazovanih čestica
- Problematična primena u tečnostima
- Promenljiva otpornost kontakta između klizača i merne trake
- Veliko ubrzanje ili vibracija mogu dovesti do podizanja klizača
- Ograničene mogućnosti za miniaturizaciju

Primer: potenciomet. senzora sa jednom mernom trakom

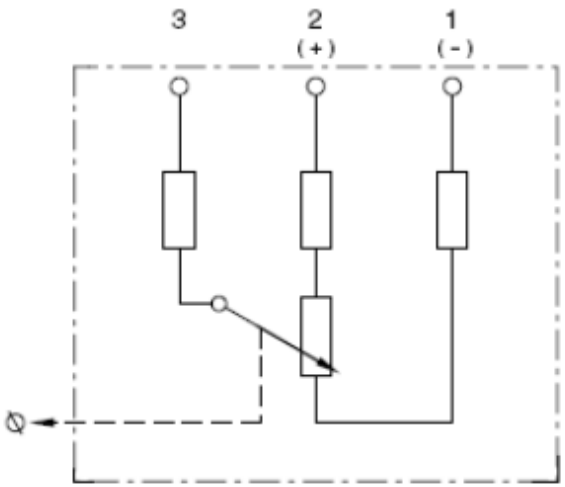
VIDI
BOSCH-Katalog
SENSORS
(u literaturi predmeta)

Part number **0 280 122 001**

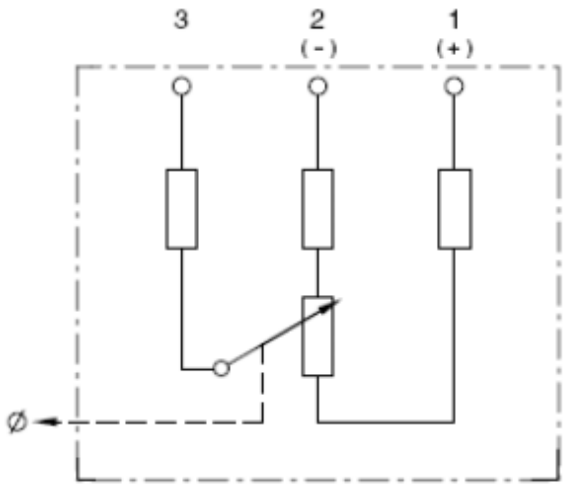
Technical data		
Useful electrical angle range	degrees	≤ 86
Useful mechanical angle range	degrees	≤ 86
Angle between internal stops (must not be reached when fitted)	degrees	≥ 95
Direction of rotation		Any
Total resistance (term. 1-2)	kΩ	2 ± 20 %
Wiper protective resistor (wiper in zero position, term. 2-3)	Ω	710 ... 1380
Permissible wiper current	µA	≤ 18
Voltage ratio from stop to stop - characteristic curve 1		$0{,}04 \le U_A/U_V \le 0{,}96$
Slope of nominal characteristic curve	deg^{-1}	0,00927
Operating temperature		- 40 ...+ 130
Approximate value for permissible vibration acceleration	m/s^2	≤ 700
Service life (rotary cycles)	Mill.	2

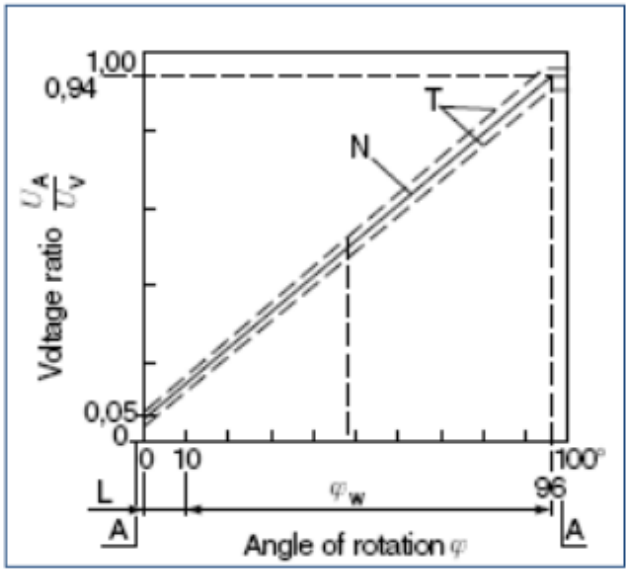
A Internal stop
L Positional tolerance of wiper when attached
N Nominal characteristic curve
T Tolerance limits
φ_w Useful electrical angle range

Circuit diagram 1



Circuit diagram 2





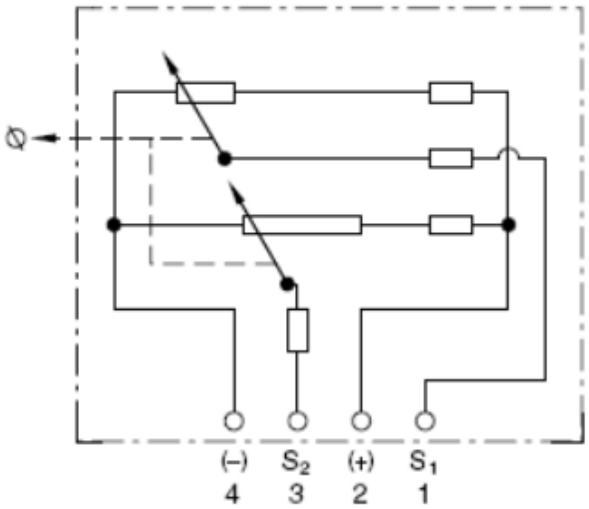
Primer: potenciometarskog senzora sa dve merne trake

Part number 0 280 122 201

Technical data

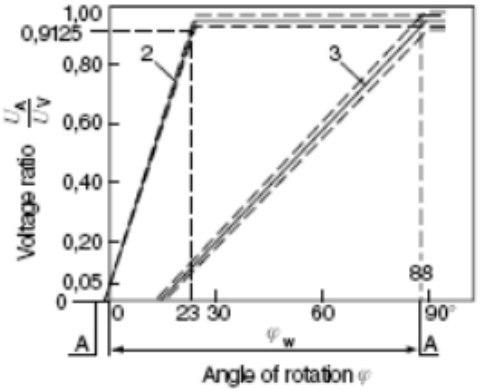
Useful electrical angle range	degrees	≤ 88
Useful mechanical angle range	degrees	≤ 92
Direction of rotation		Anti-clockwise
Permissible wiper current	µA	≤ 20
Voltage ratio in range 0...88 °C - characteristic curve 2		$0{,}05 \le U_{A1} / U_V \le 0{,}985$
Voltage ratio in range 0...88 °C - characteristic curve 3		$0{,}05 \le U_{A2} / U_V \le 0{,}970$
Operating temperature		- 40 ...+ 85
Approximate value for permissible vibration acceleration	m/s^2	≤ 300
Service life (rotary cycles)	Mill.	1,2

Circuit diagram



Throttle valve in idle position

Characteristic curve 1 and 2

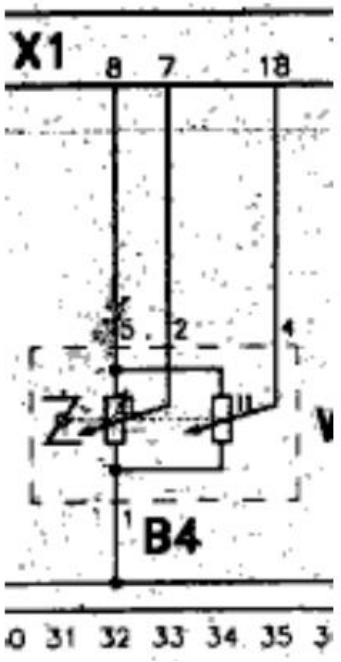


A Internal stop
Φ_w Useful electrical angle range

Angle sensor

Measurement of angles up to 88°

U_A Output voltage
U_V Supply voltage
φ Angle of rotation
U_{A1} Output-voltage characteristic curve 2
U_{A2} Output-voltage characteristic curve 3



2. Elektromagnetni senzori pomaka

2.1 Induktivni senzori pomaka sa kratko-spojnim prstenom

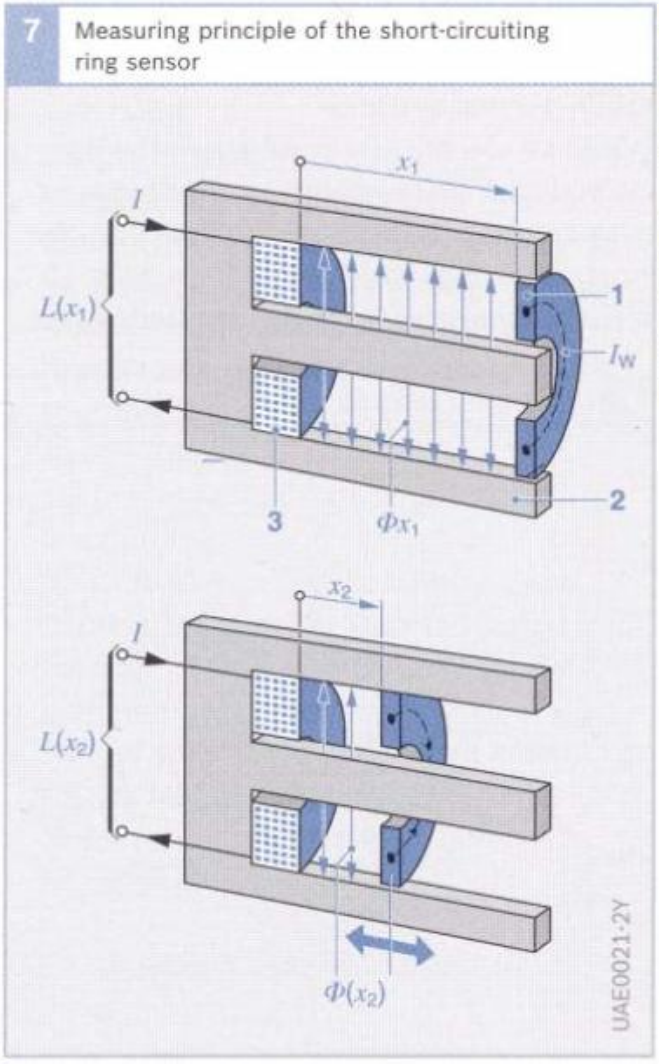
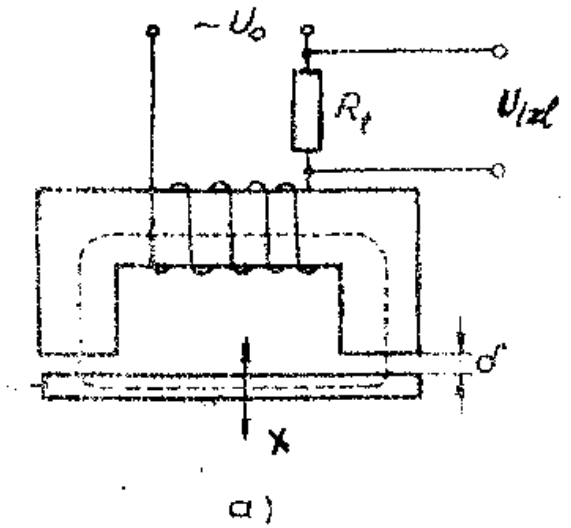


Fig. 7
Imaging for two different measured travels
1 Short-circuiting ring
2 Soft-magnetic core
3 Coil
I Current
I_W Eddy current
$L(s)$ Inductance and
$\Phi(s)$ Magnetic flux in measured travel s

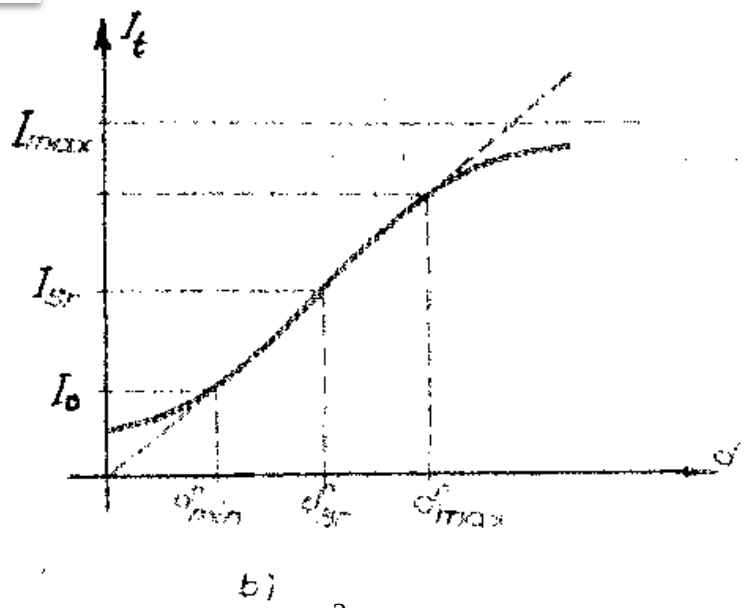
Princip rada **elektromagnetnih senzora** zasniva se na zavisnosti induktivnosti kalema od promene otpora elektromagnetnog kola

- Spadaju u beskontaktne senzore pozicije.
- Od svih senzora koji se koriste za beskontaktno merenje pozicije, induktivni senzori se odlikuju najrobusnijom konstrukcijom.
- Linerna statička karakteristika (zavisnost *L(s)* je linearna u mernom području senzora).
- Rade na relativno niskim frekvencijama (od 5 do 50 kHz) i bez potrebe za ugradnjom lokalne elektronike.
- Izuzetna otpornost na smetnje (feromagnetno jezgro veoma dobro vrši zaštitu od spoljnih elektromag. smetnji)
- U poređenju sa mikromehaničkim senzorima zahtevaju znatno veći prostor.

Induktivni senzori - princip rada



a)



b)

$$G_m = \frac{1}{R_{Fe} + R_\delta} \qquad R_\delta = \frac{2\delta}{\mu_0 S} \qquad R_{Fe} << R_\delta \qquad L = N^2 G_m = \frac{N^2 \mu_0 S}{2\delta}$$

$$I_t = \frac{U_0}{\sqrt{(R_t + R_d)^2 + X_L^2}} = \frac{U_0}{\sqrt{(R_t + R_d)^2 + \left(\frac{2\pi f \mu_0 S N^2}{2\delta}\right)^2}} \qquad X_L = 2\pi f L$$

$$X_L >> (R_t + R_d)$$

$$I_t = \frac{U_0}{X_L} = K_{ID} \cdot \delta \qquad K_{ID} = \frac{I}{\delta} = \frac{U_0}{\pi f \mu_0 S N^2} \qquad U_{iz} = I_t R_t = K_{ID} R_t \delta$$

Diferencijalni induktivni senzori pomaka sa kratko-spojenim prstenom

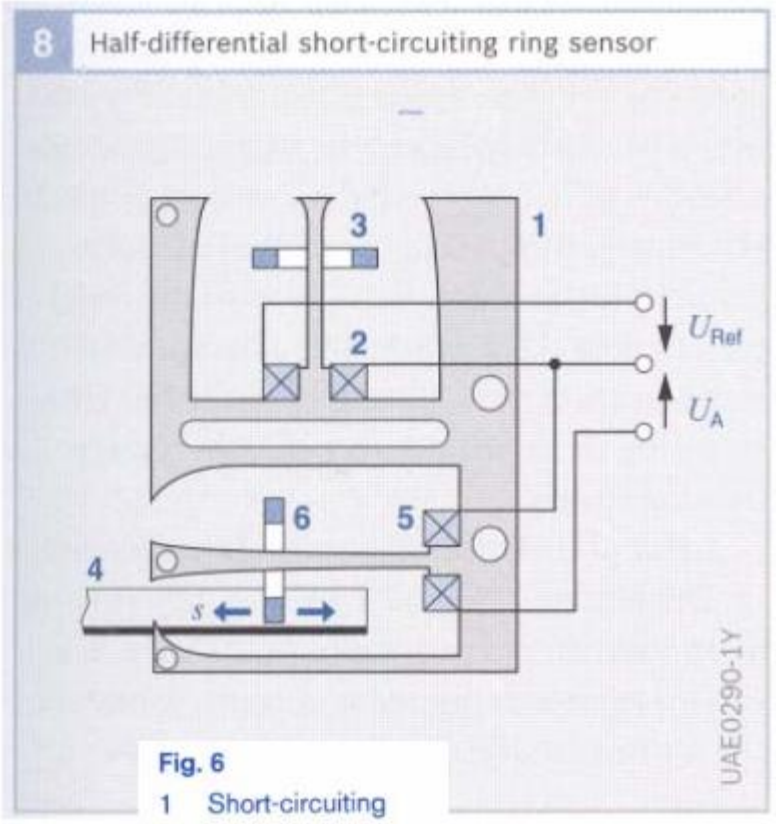


Fig. 6
1 Short-circuiting

Fig. 8
Design of the rack travel sensor (RW diesel in-line injec pumps
1 Soft-magnetic
2 Reference coil
3 Reference shor circuiting ring
4 Control rack
5 Measuring coil
6 Measuring shor circuiting ring
s Control-rack tra

Poludiferencijalni senzor sa kratko-spojnim prstenom (HD senzor) sa pomično-mernim i fiksnim referentnim kratko-spojnim prstenom (Slika 8) karakteriše se visokom tačnošću merenja.

.

Primena:

- Senzor položaja zupčaste letve kod linijskih pumpi visokog pritiska kod dizel motora (Slika 8) i
- Senzor položaja regulacionog prstena kod aksijalnih razdelnih pumpi visokog pritiska dizel motora (HDK senzor) – Slika 9.

6 Magnetic lines of force in a half-differential short-circuiting-ring travel sensor used in an electronically controlled diesel in-line pump

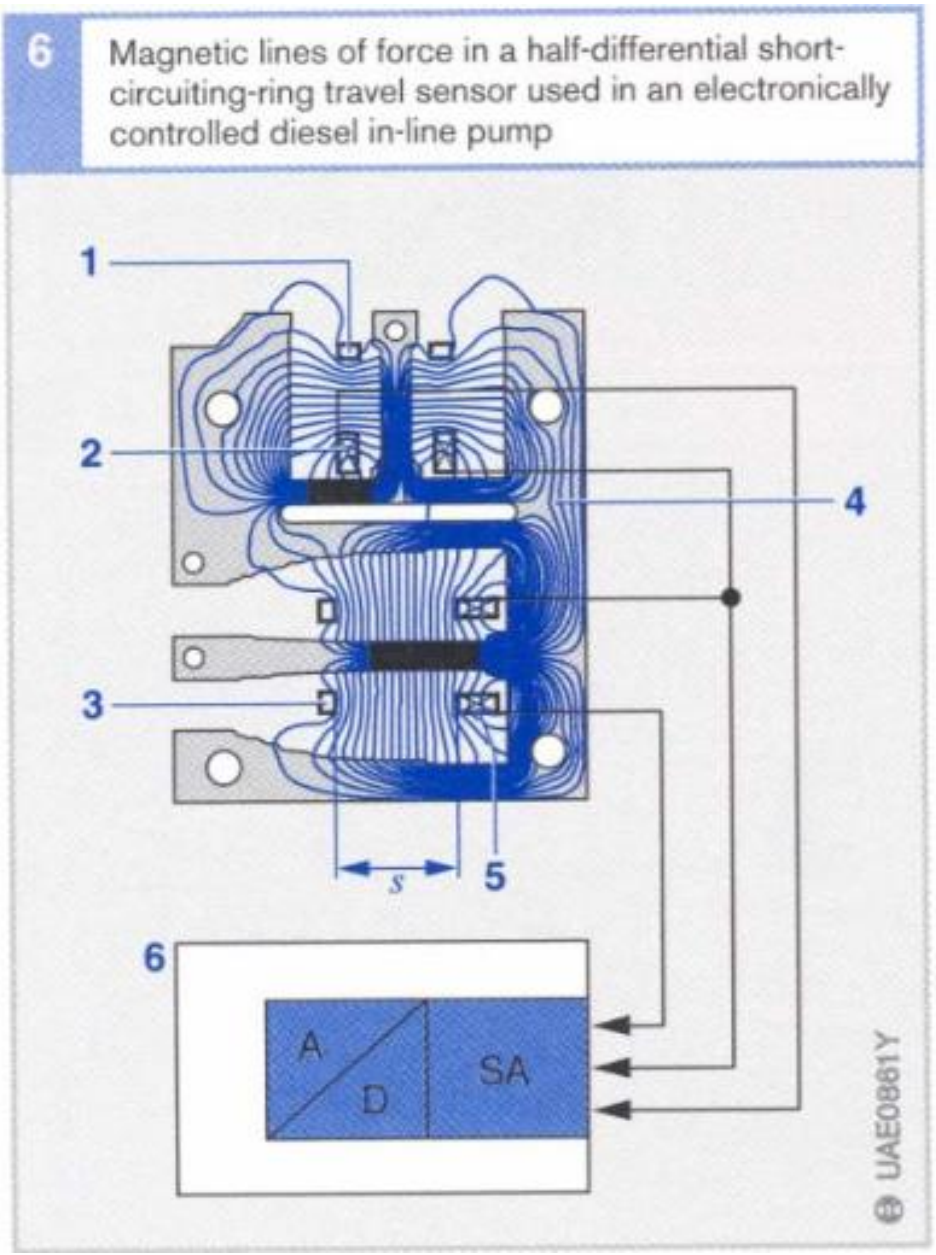


Fig. 6

1 Short-circuiting reference ring, fixed
2 Reference coil
3 Short-circuiting measuring ring, movable
4 Coupling flux
5 Measuring coil
6 ECU
s Control-rack travel
SA Signal conditioning A/DA/D converter

Poludiferencijalni induktivni senzori ugaonih pomaka sa kratko-spojenim prstenom

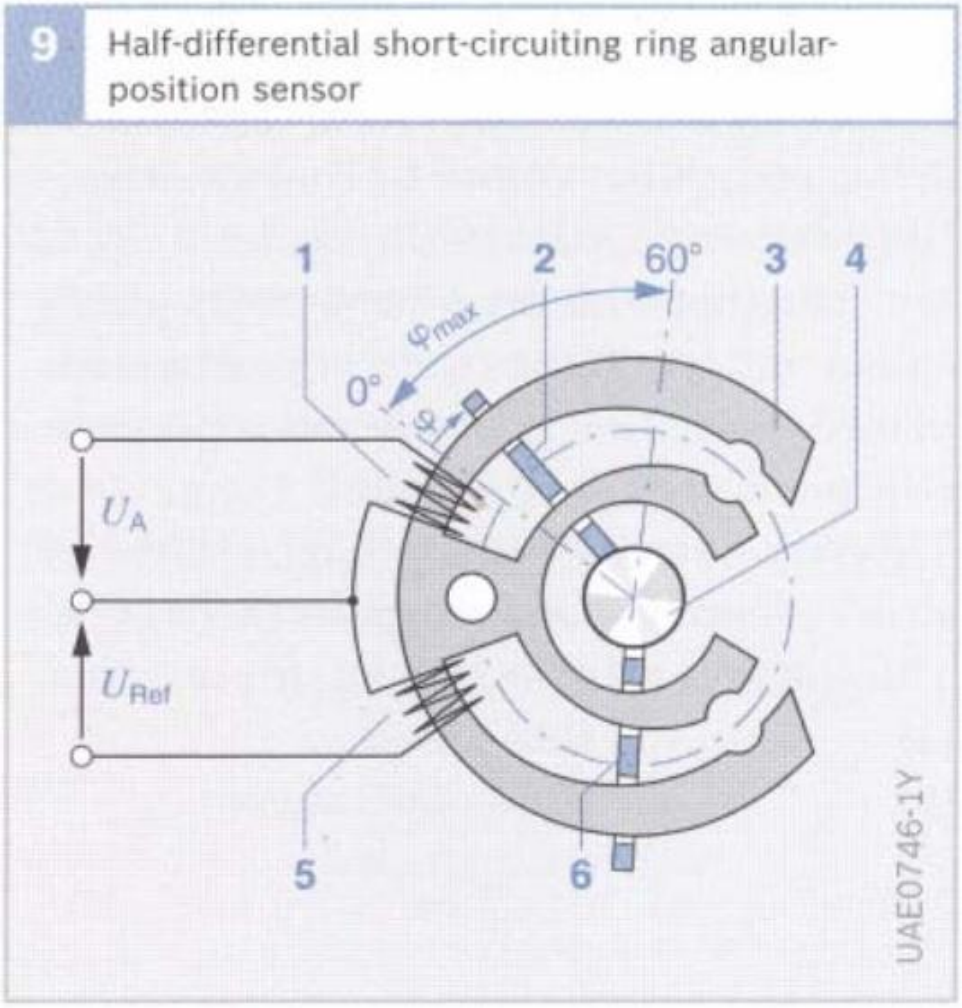


Fig. 9

1 Measuring coil
2 Measuring short-circuiting ring
3 Soft-magnetic core
4 Control-collar shaft
5 Reference coil
6 Reference short-circuiting ring
φ Measured angle
φ_{max} Adjustment-angle range for the control-collar shaft

Senzor položaja regulacionog prstena kod aksijalnih razdelnih pumpi visokog pritiska dizel motora (HD senzor).

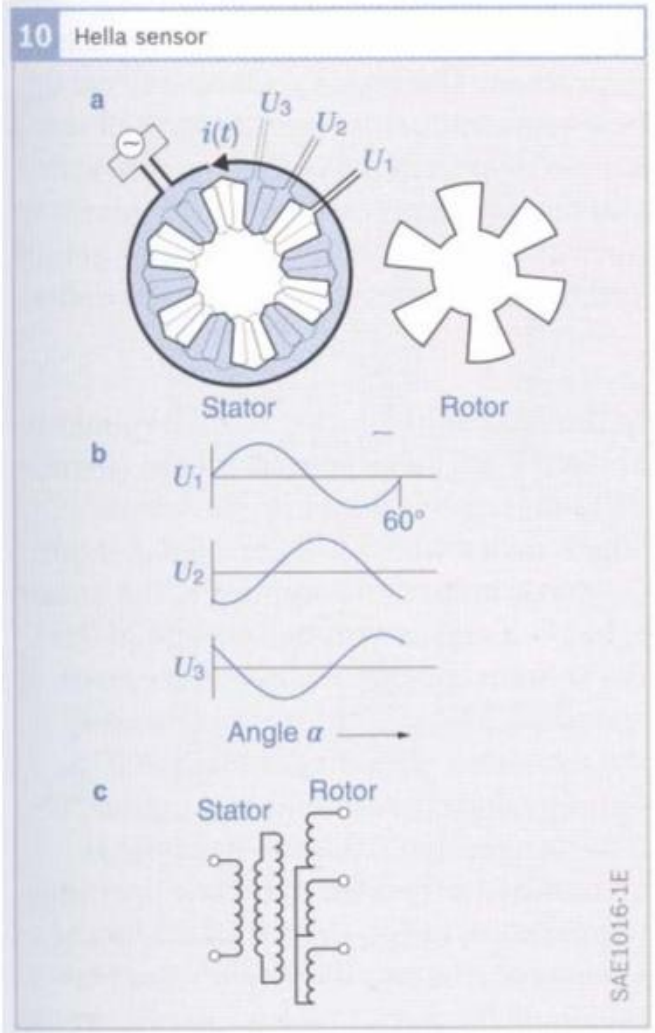


Fig. 10

a Schematic design

b Circuit

c Output signals

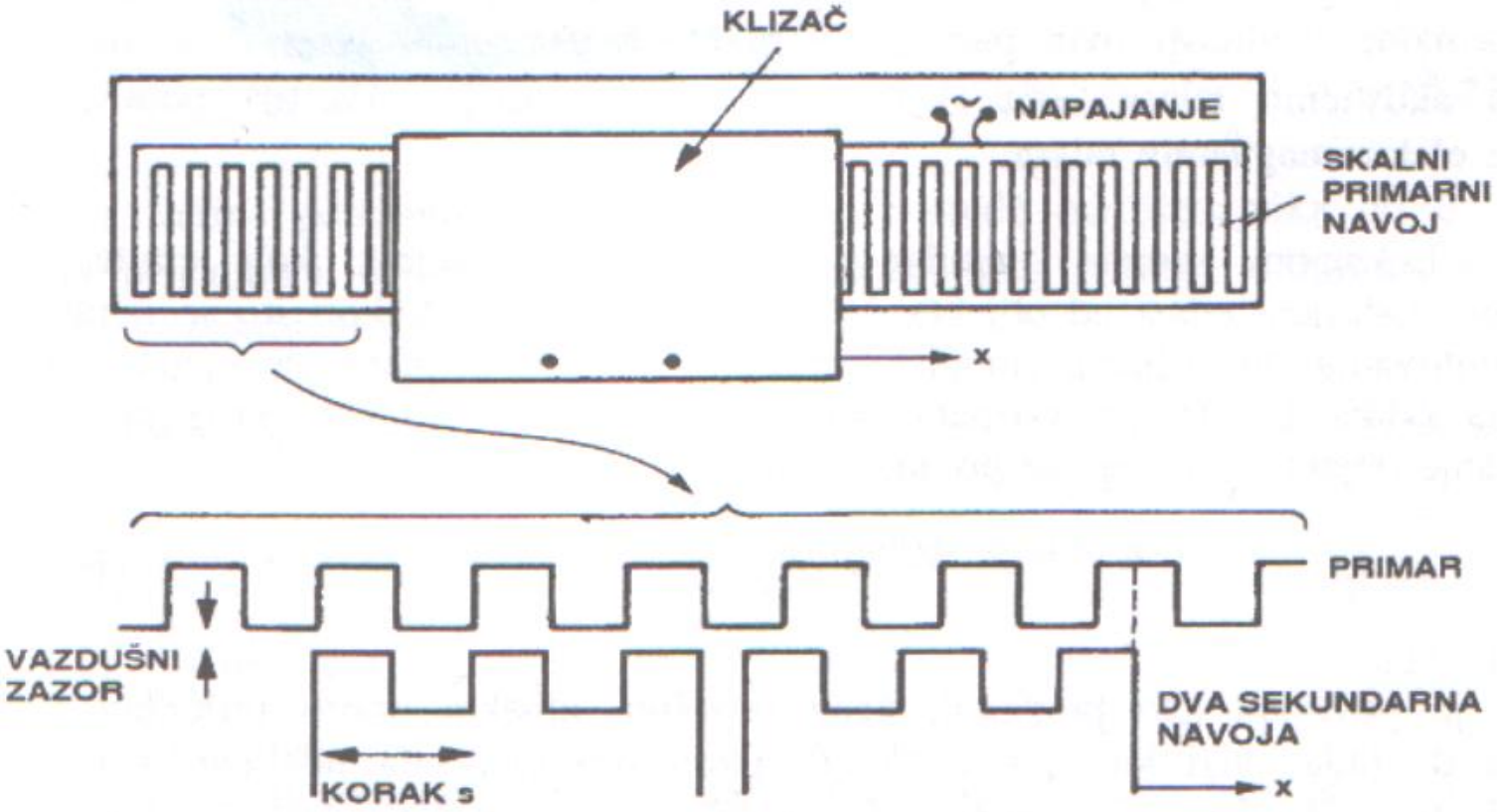
Kompanija *Hella* razvila je senzor ugaonih pomaka koji radi na principu induktosina.

Glavne prednosti ovog senzora su:

- Beskontakti merni koncept i bez habanje
- Temperaturna nezavisnost (do 150 °C)
- Visoka tačnost (oko ±0,09° za područje mjerenja od 360 °)
- Fleksibilnost primene (može se prilagoditi bilo kojem uglovnom rasponu do 360°)
- Mogućnost redundantnog dizajna
- Visoka otpornost na EM smetnje (EMC)
- Korišćenje isključivo standardnih materijala (bez feromagnetskih komponenti)
- Jednostavna izrada (princip folija)
- Niska cena

Zbog toga se koristi za mnoga merenja na motornim vozilima.

Linearni induktosin



s= 2 mm,
d= 0,125 mm
$V_s = V \sin(\omega t)$

$V_1 = V \sin(\omega t) \cos(2\pi x/s)$
$V_2 = V \sin(\omega t) \sin(2\pi x/s)$