Lectures on mechanics

(LESSON #3)

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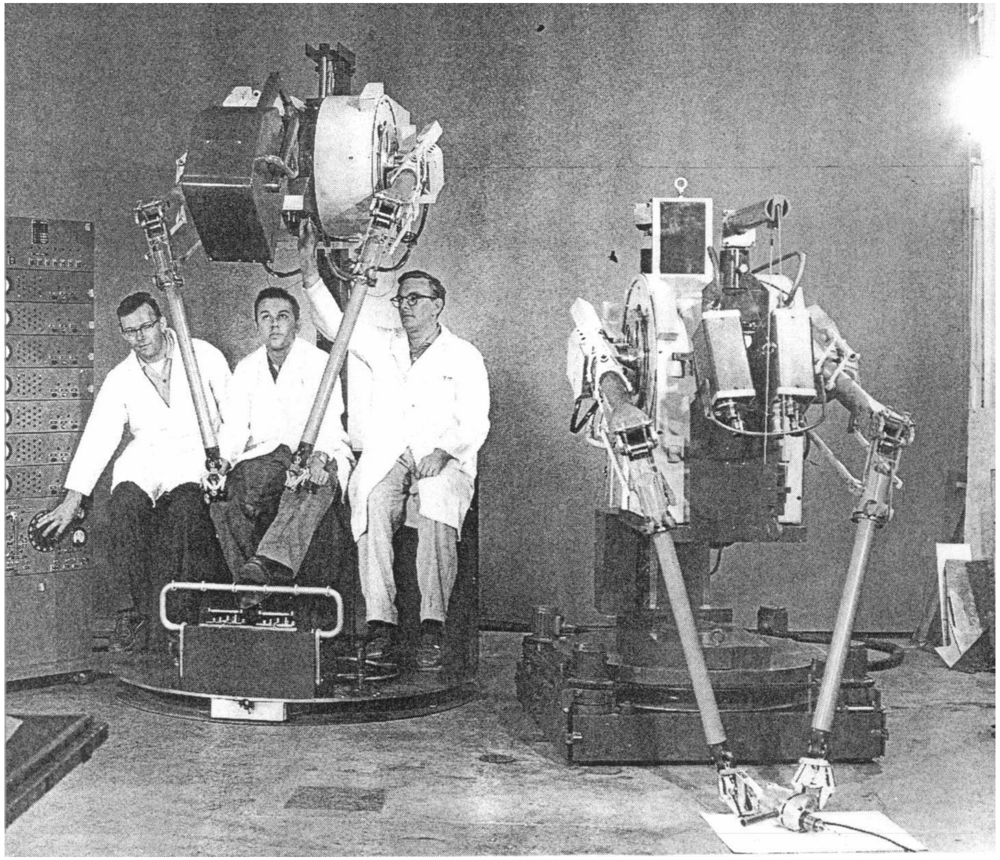

LESSONS TIME TABLE (pls. take note)

28/11 h9/12- mech components 1 (3h)
4/12 h9/12 mech components 2 (3h)
11/12 h9/12 mech technologies (3h)
16/12 h 9/12 (in TLR) - mech technologies tlr workshop
19/12 h9/12- robotic (3h) CHANGED!!

STUDENT LIST

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SYNCHRONOUS BELTS (TIMING BELTS)

the fastest overview..

Synchronous belts are toothed belts where timing is guaranteed by the presence of the teeth. Load is transferred both by the teeth and the belt core.

Synchronous belts – Shape of teeth

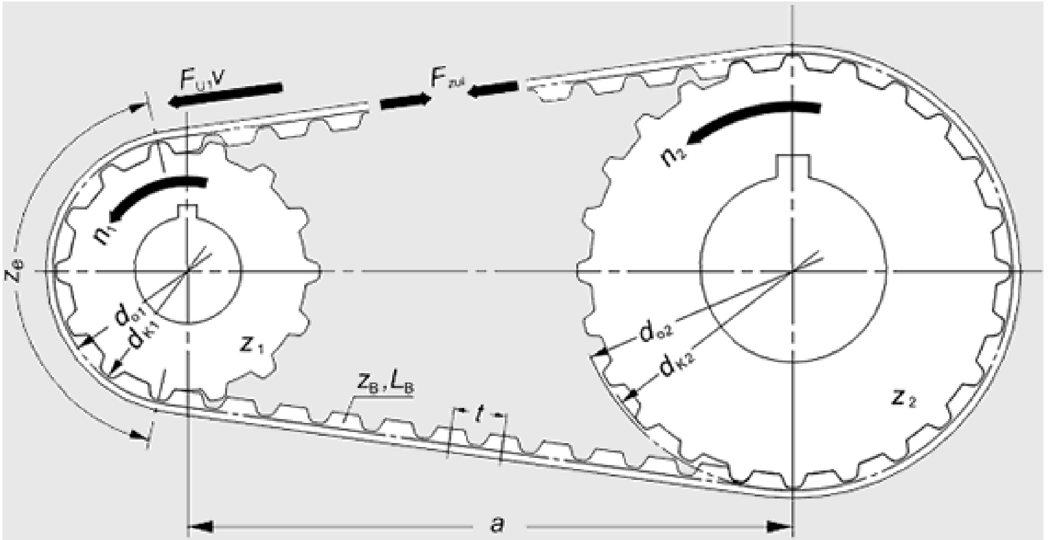
Purpose of tooth optimization is:

-Decrease of noise
-Increase of maximum load
-Increase of life (less wear)
-Increase of maximum speed

Each profile has its own characteristics

SYNCHRONOUS BELTS – TOOTHED PULLEYS

Synchronous belts – Some formulas



Peripheral force	F_U	[N]	Center to center distance	a	[mm]
specific tooth force	F_{Uspec}	[N/cm]	Belt length	L_B	[mm]
Pre-Tension force	F_V	[N]	Belt width	b	[mm]
Shaft force	F_W	[N]	Pulley width	B	[mm]
Torque	M	[Nm]	Bore, pulley	d	[mm]
Acceleration torque	M_B	[Nm]	Pitch circle diameter	d_0	[mm]
specific torque	M_{spec}	[Ncm/cm]	pulley outside diameter	d_K	[mm]
Power	P	[kW]	Span length	L_T	[mm]
specific power	P_{spec}	[W/cm]	Pitch	t	[mm]
Speed	v	[m/s]	Number of belt teeth	z_B	
Rotational speed	n	[min^{-1}]	Number of teeth in mesh	z_e	
Angular speed		[s^{-1}]	No. of teeth, small pulley	z_1	
Acceleration time	t_B	[s]	No. of teeth, large pulley	z_2	
			Number of teeth with i=1	z	
			pulley ratio	i	

Peripheral Force: $F_U = \frac{2 \cdot 10^3 \cdot M}{d_0} = \frac{19.1 \cdot 10^6 \cdot P}{n \cdot d_0} = \frac{10^3 \cdot P}{v}$

Torque: $M = \frac{d_0 \cdot F_U}{2 \cdot 10^3} = \frac{9.55 \cdot 10^3 \cdot P}{n} = \frac{d_0 \cdot P}{2 \cdot v}$

Power: $P = \frac{M \cdot n}{9.55 \cdot 10^3} = \frac{F_U \cdot d_0 \cdot n}{19.1 \cdot 10^6} = \frac{F_U \cdot v}{10^3}$

Angular speed: $w = \frac{\pi \cdot n}{30}$

Rotational speed: $n = \frac{19.1 \cdot 10^3 \cdot v}{d_0}$

Peripheral speed: $v = \frac{d_0 \cdot n}{19.1 \cdot 10^3}$

Pitch circle diameter: $d_0 = \frac{z \cdot t}{\pi}$

Belt Length for i = 1: $L_B = 2a + \pi \cdot d_0 = 2a + z \cdot t$

ROTARY TO LINEAR

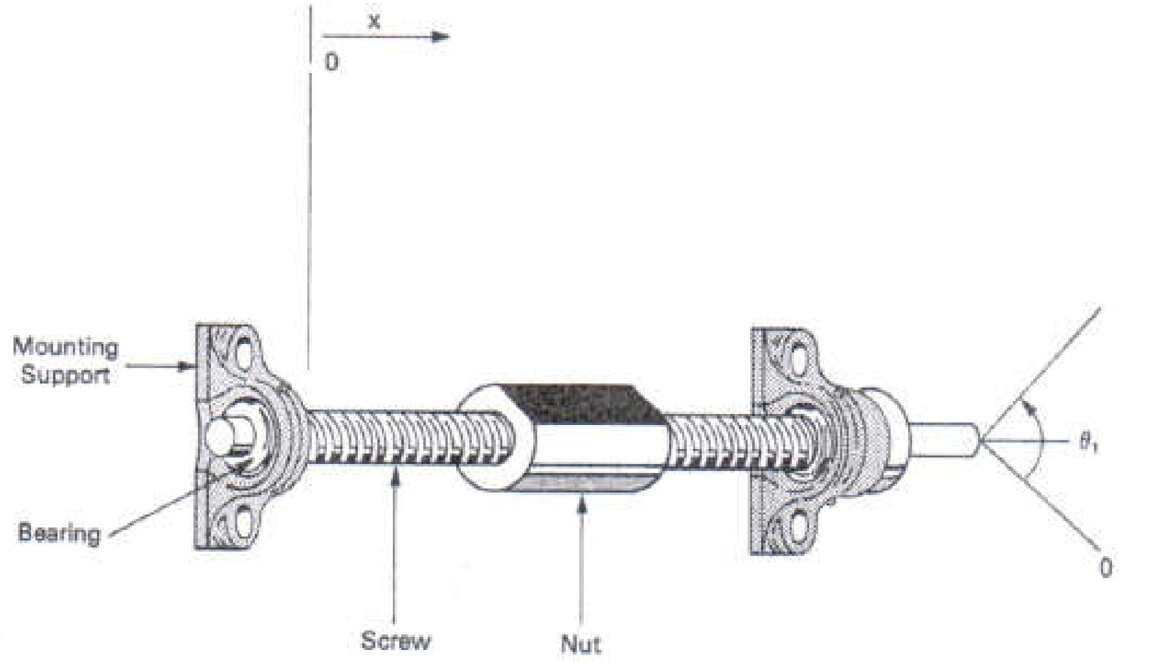
Lead screw

Rack and pinion

Slider cranks

Cams

Lead screws



Screw is fixed with its ends free to rotate: as the screw is turned, the nut moves along the shaft with the payload attached

A rotary displacement of the input shaft **$\theta 1$** causes a linear motion of the payload **x**

$$X = \theta \cdot P$$ (P pitch of the screw mm/rev)

This equation may be differentiated any number of times in order to obtain the relationship among linear velocity, acceleration and jerk and rotational relative quantities

How a load on th output is seen by the input? i.e. Equivalent **torque-inertia system**

For linear motion of the payload mass the kinetic energy is: $E_k = \frac{1}{2} M V_L^2$

The corresponding kinetic energy of a torque-inertia system $E_k = \frac{1}{2} J_{eq} \omega^2$

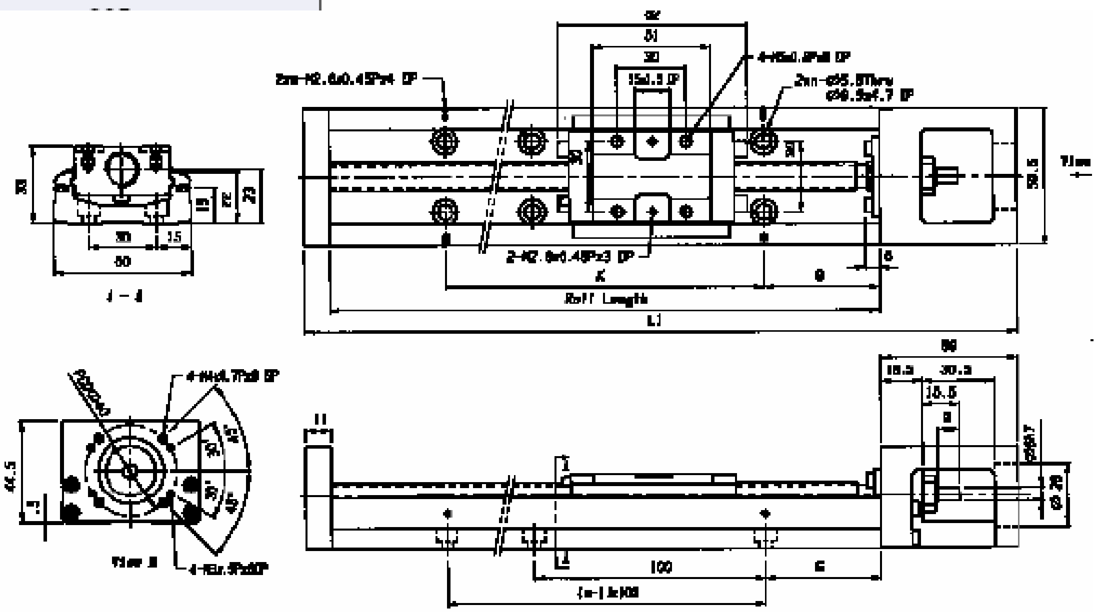
Solving for the inertia, after relating rotary and linear velocity with the pitch

$$J_{eq} = M \cdot (P/2\pi)^2$$

reflected inertia reduced by smaller pitch

linear stage

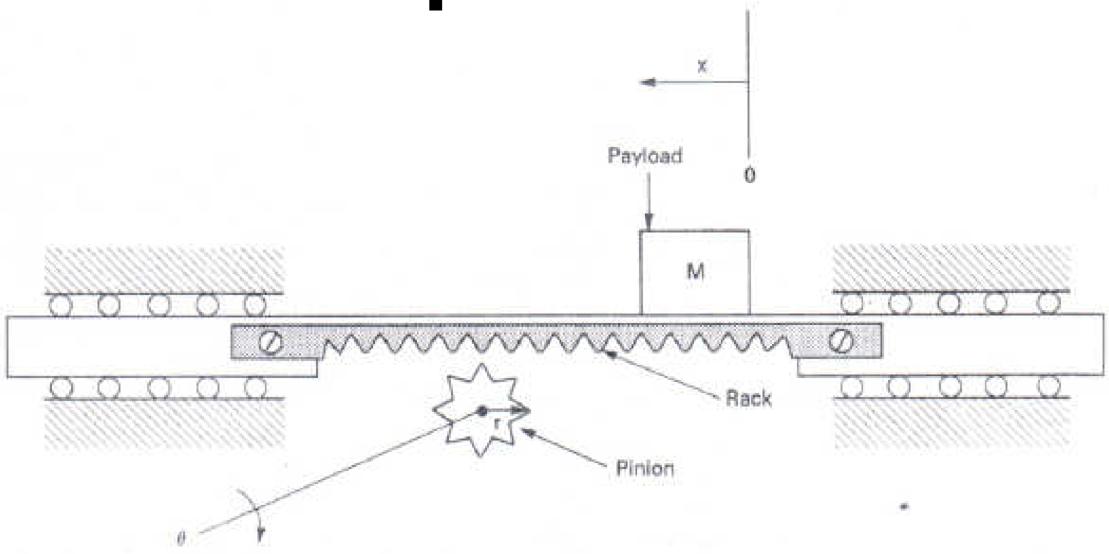
			KK5002		KK6005		KK6010	
			Precision	Normal	Precision	Normal	Precision	Normal
Ballscrew	Nominal Diameter (mm)		08		12			
	Lead (mm)		02		05		10	
	Basic Dynamic Load Rating (N)		2136		3744	3377	2410	2107
	Basic Static Load Rating (N)		3489		6243	5625	3743	3234
Guideway	Basic Dynamic Load Rating (N)	Block A	8007		13230			
		Block S	–		7173			
	Basic Static Load Rating (N)	Block A	12916		21462			
		Block S	–		11574			
	Allowable Static Moment M_x (pitching)(N-m)	Block A1	116		152			
		Block A2	278		348			
		Block S1	–		72			
		Block S2	–					
	Allowable Static Moment M_y (yawing)(N-m)	Block A1	116					
		Block A2	278					
		Block S1	–					
		Block S2	–					
	Allowable Static Moment M_o (rolling)(N-m)	Block A1	222					
		Block A2	444					
		Block S1	–					
		Block S2	–					



Unit: mm

Rail Length	Total Length L1	Maximun Stoke		G	K	n	m
		A1 Block	A2 Block				
150	220	60	-	25	100	2	2
200	270	110	-	50	100	2	2
300	370	210	135	50	200	3	2
400	470	310	235	50	100	4	3
500	570	410	335	50	200	5	3

Rack and pinion



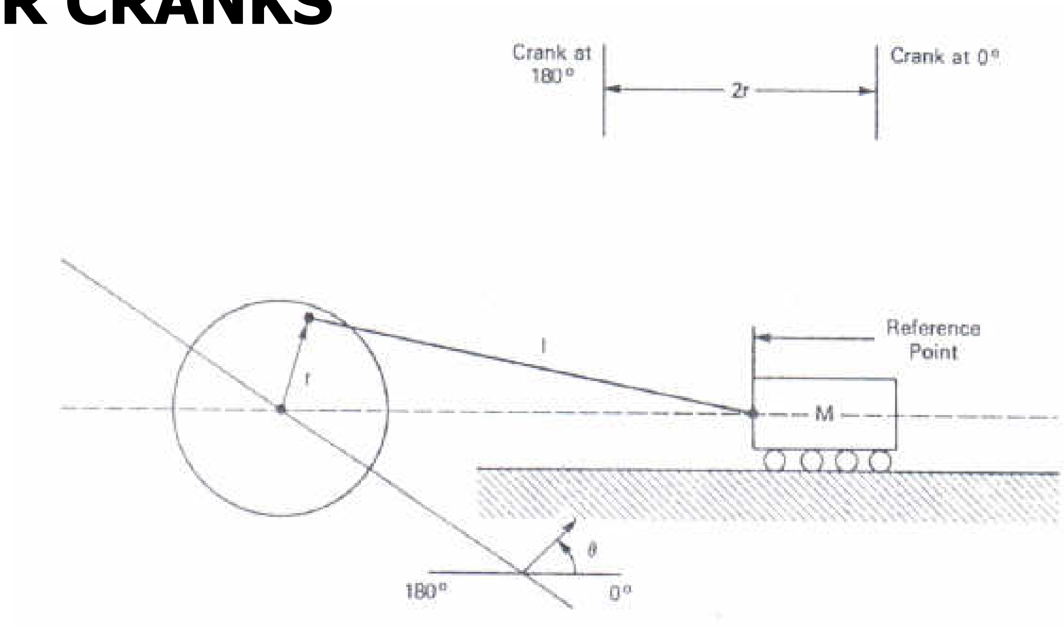
The pinion is the small gear attached to the actuator and the rack is a linear member with gear teeth on one side.

The relation between pinion angle and rack translation is

$$\mathbf{X = 2\,\pi\,r\,\theta}$$

The reflected inertia, as seen by the input shaft, is $\mathbf{J_{eq} = Mr^2}$

SLIDER CRANKS

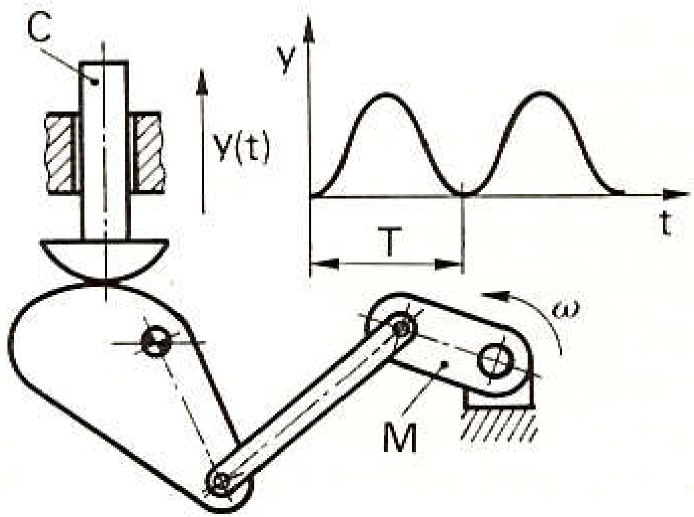


The crank portion is the wheel that rotates about its center and has a rod of fixed lenght mounted to a point on its circumference; the other end of the connecting rod is attached to a linear stage which is constrained to move in only one dimension.

As the disk travels from 0 to 180° in the counterclockwise direction, the linear stage moves a distance equal to 2r: if the disk continues to travle from 180° back to 0° - still in counterclockwise direction, the load will move in the opposite direction over exactly the same linear distance.

If the input shaft is rotated continuously the motion of the linear stage is reciprocating.

Cams



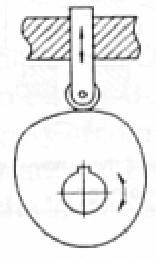
Cams are shape coupling.

Cams can be both uni or be directional

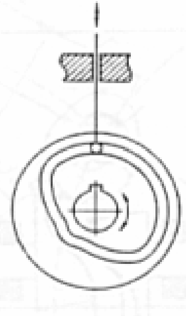
Relation between input rotating shaft and moved output is “in” the cam shape

“shape pre-programmed in hardware devices”

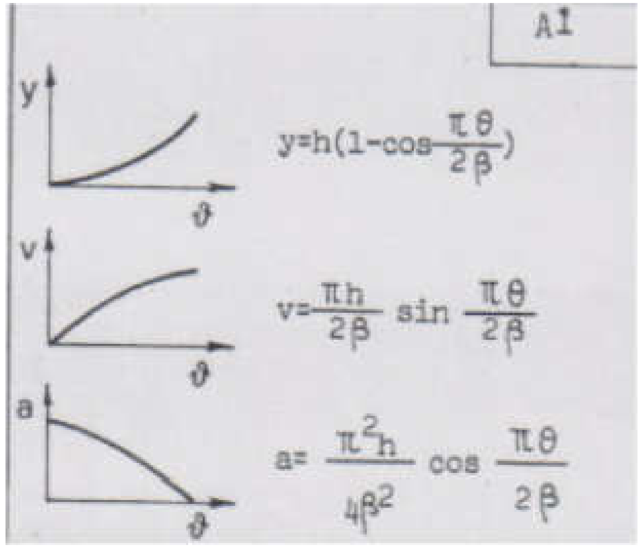
Some Cam devices examples

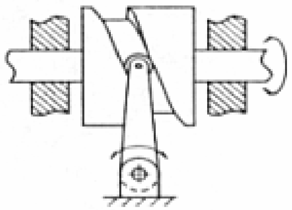


Linear movement-roller

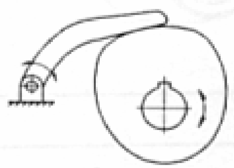


Linear movement-roller

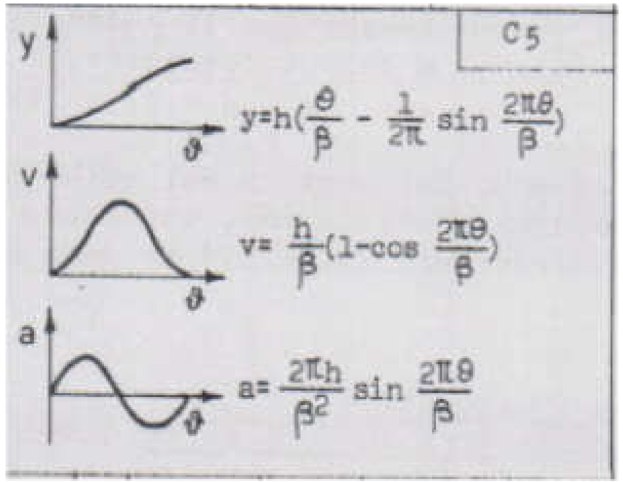


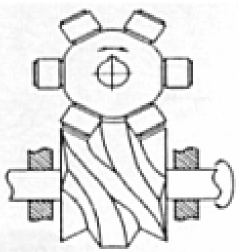


Oscillating movement- roller

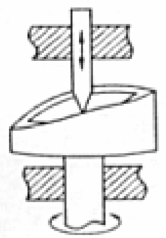


Oscillating movement-flat





Intermittent rotary movement -roller



Linear movement
knife edge

BEARINGS

Bearings are used to support rotating shafts and are classified according to the direction of the main load:

Axial bearings are designed to withstand axial thrust

Radial bearings are designed to withstand radial loads

..even more

Linear bearing

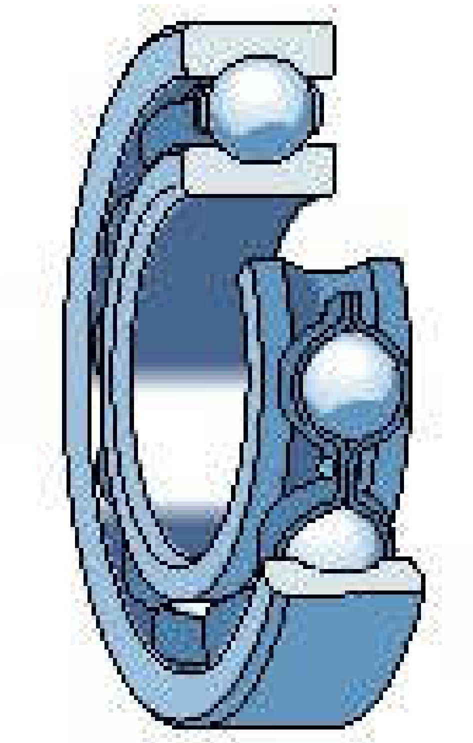
Bearings types

A bearing is constituted by an inner and an outer ring. Between them a serie of rolling element is found

Sometimes a fourth element (cage) is present to keep the rolling elements in their position

Rolling elements can be spheres (ball bearing) or cylinders (cylindrical roller bearings)

Deep groove ball bearing



- Good capacity to withstand radial and axial loads

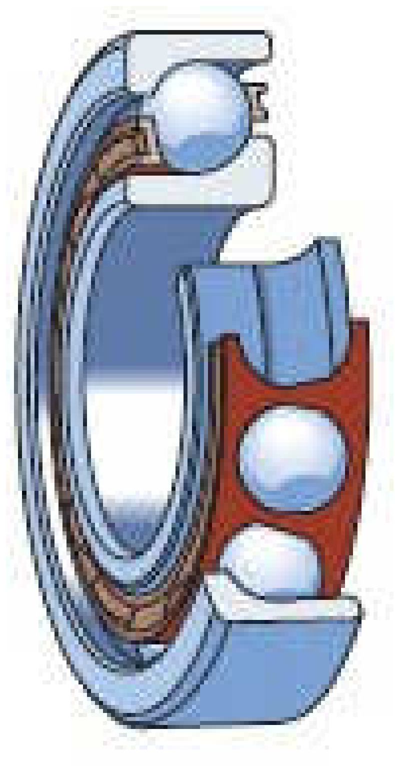
-May be of sealed type

-Available in a wide range of build precision

-Low cost

-Moderate tolerant towards misalignment

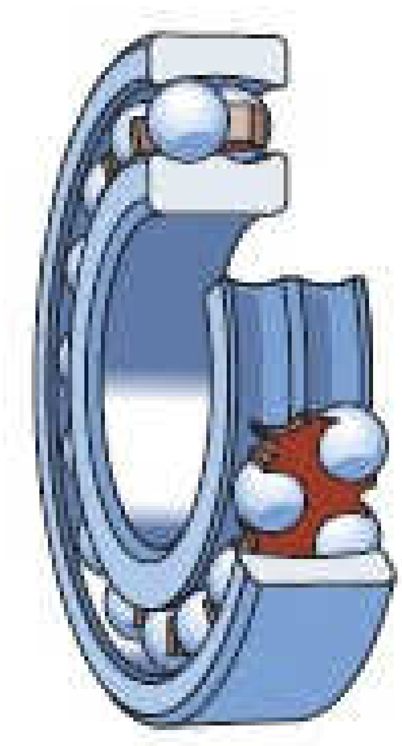
Angular contact ball bearing



- Increased capacity to withstand axial loads

-Coupled with another bearing of the same kind can withstand high bending torques

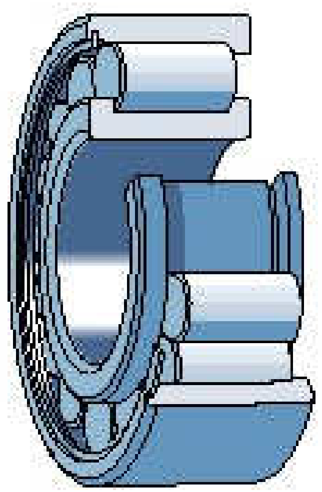
Self aligning ball bearing



- Very good capacity to tolerate misalignment

-Can’t withstand axial loads

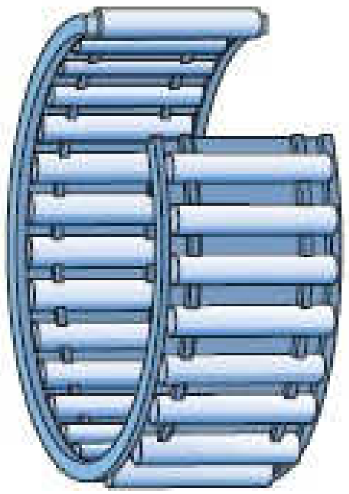
Cylindrical roller bearings

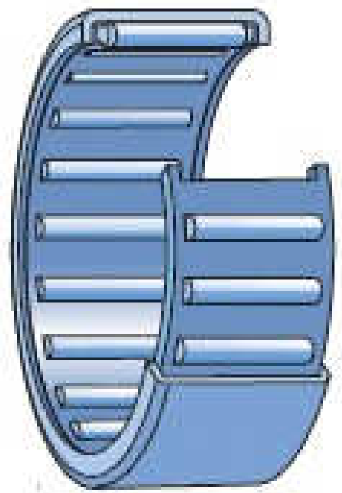


-High radial load

-low axial loads

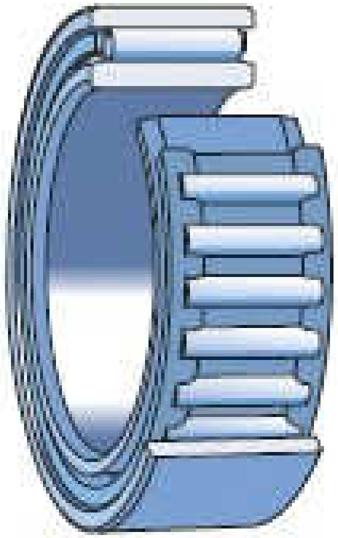
Needle roller bearings

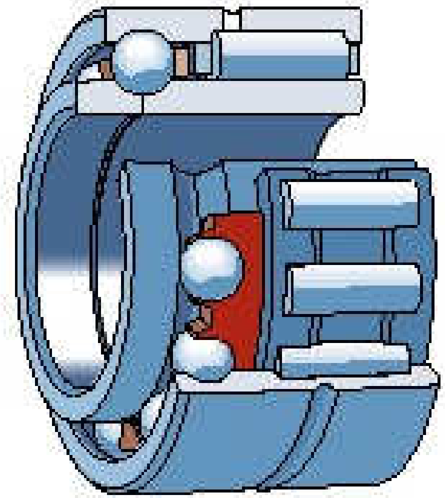




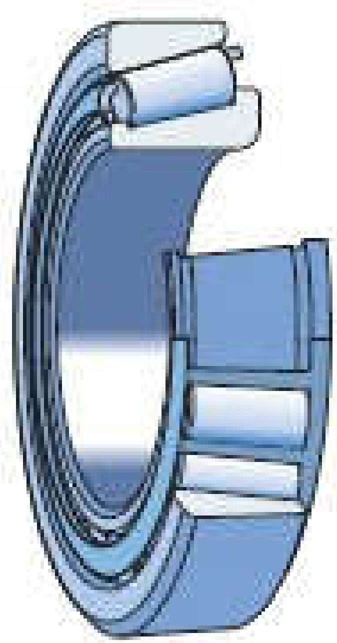
Look at this bearing..

Composed bearing





Taper roller bearings

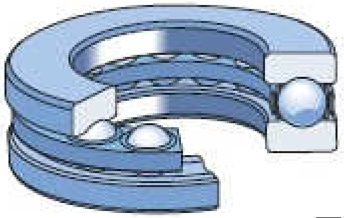


-High radial load

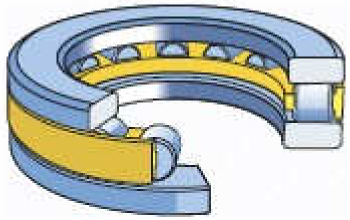
-High axial load in one direction

(generally are in paris)

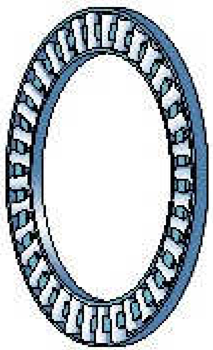
Thrust bearings
(axial)



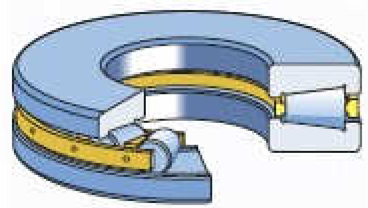
Thrust ball
bearing



Cylindrical roller
thrust bearing

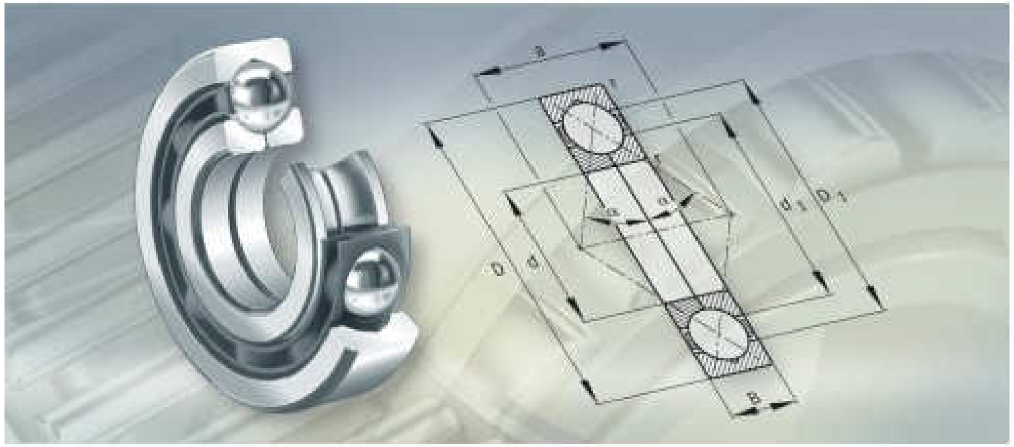


Needle roller
thrust bearing

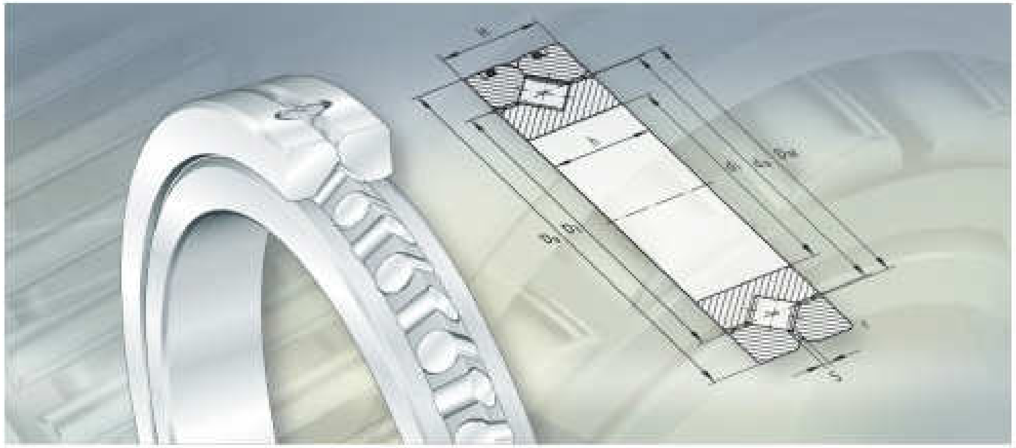


Taper roller
thrust bearing

More..



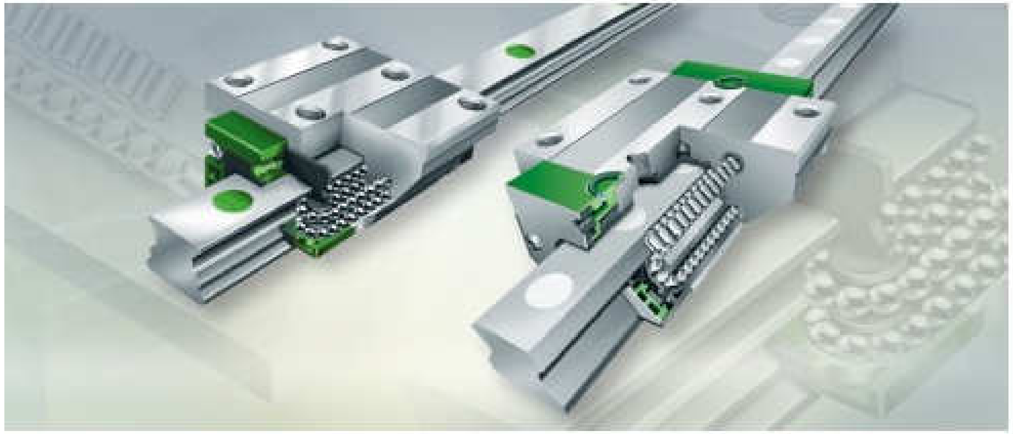
4 point contact



Crossed roller bearing

Due to the X arrangement of the rolling elements, these bearings can support axial forces from both directions as well as radial forces, tilting moment loads and any combination of loads with a single bearing position. This allows designs with two bearing positions to be reduced to a single bearing position. Crossed roller bearings are very rigid,

linear..



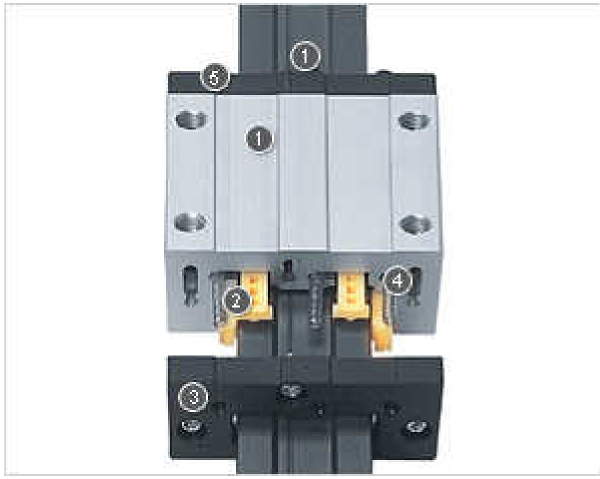
Linear guides
recirculating
balls or rollers

Track rollers

Linear ball
bushing

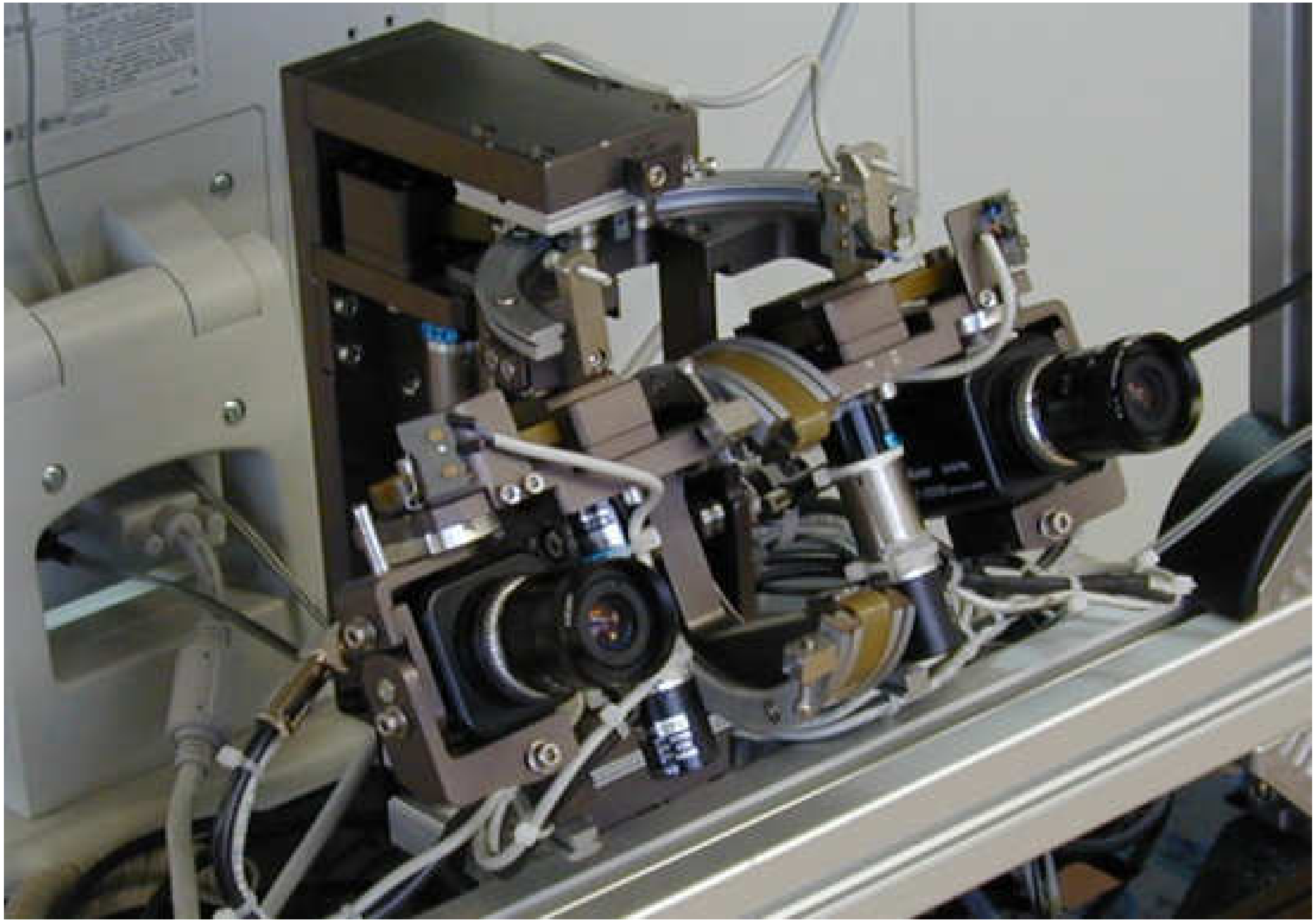
Last: friction bearing

Plastig bushing

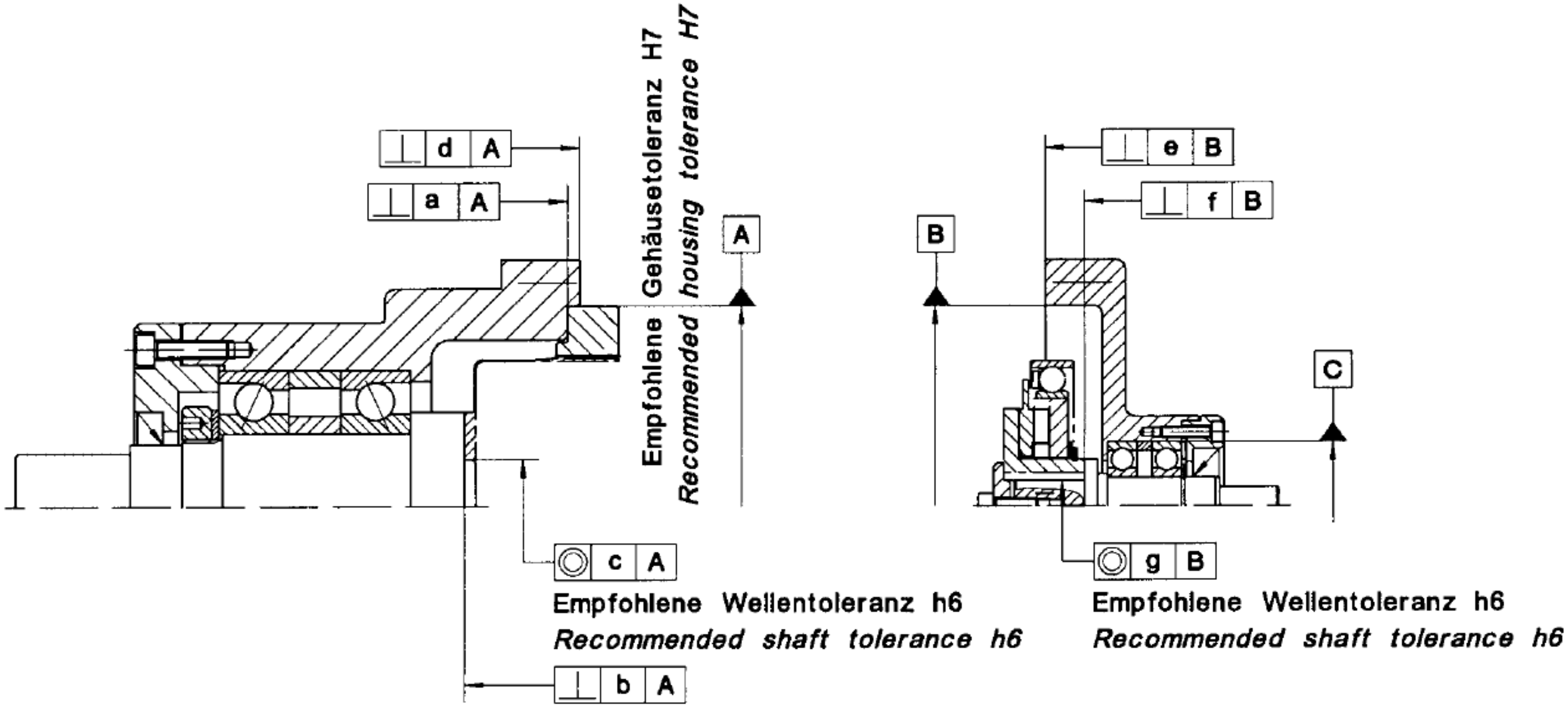


Linear friction guide

a tracker roller application example



Bearing assembly example



SENSORS

what does it mean?

How many different kind of sensor do you know?

Sensor to sense..

(free order list)

POSITION (LINEAR AND ANGLE)
POSITION (absolute and relative)
FORCE
SPEED
ACCELERATION
SHAPE
DISTANCE

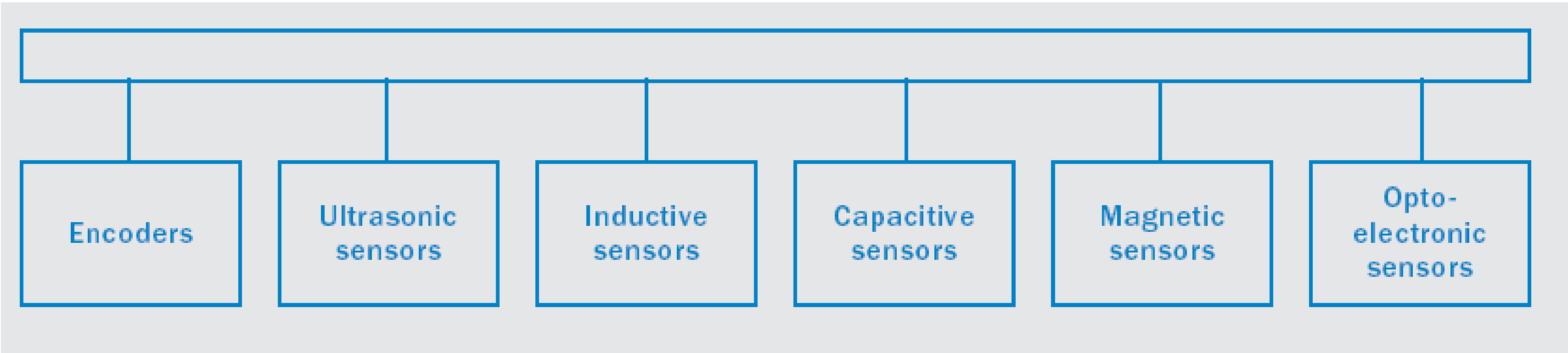
...

Sensor that sense..
(first approximation list)

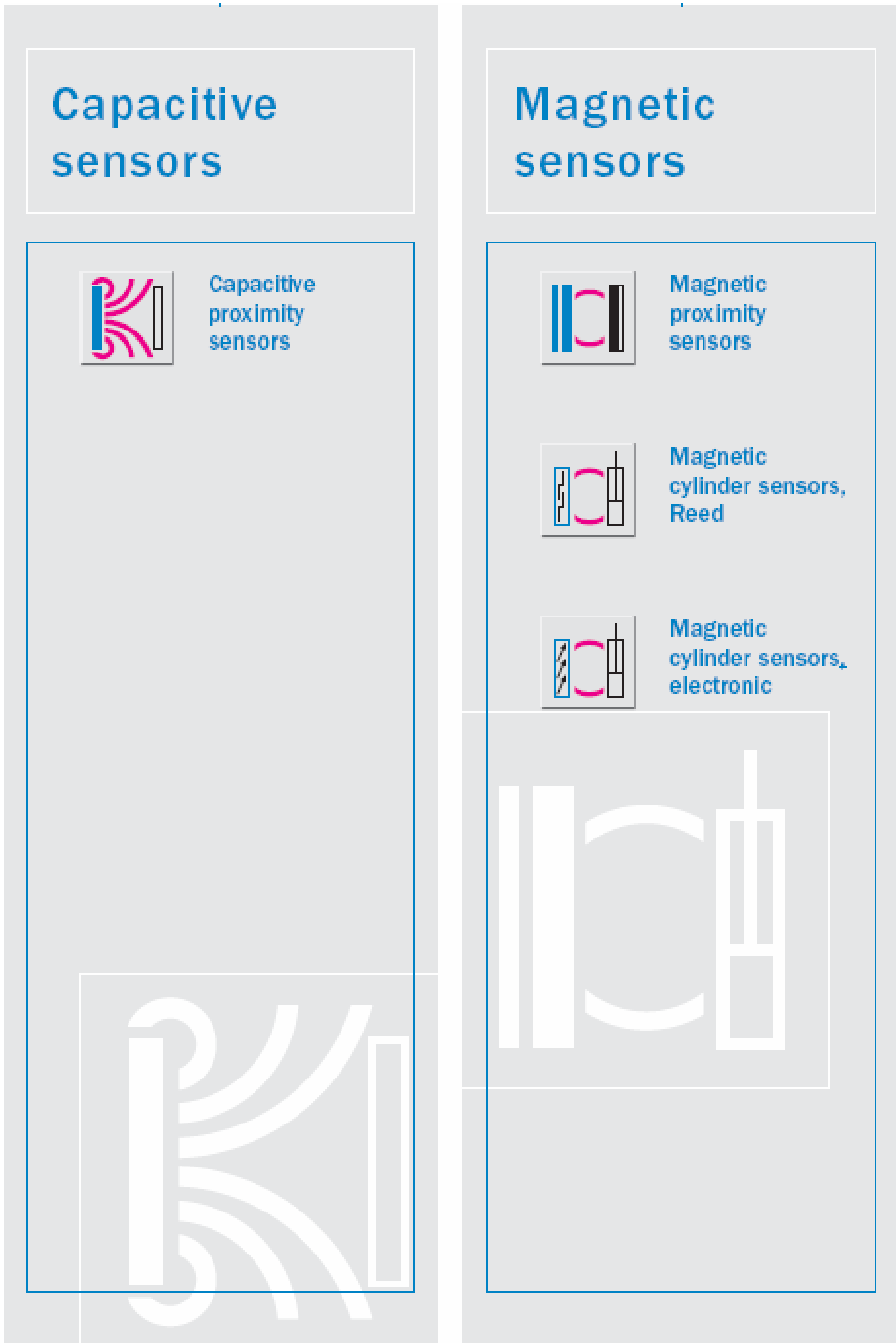
light intensity
magnetic field
electric field
electric current
strain
coupled electro magnetic flux
inertial forces
pressure

...

General industrial classification of sensors



A tentative classification of sensors (according to the sick products range)



Encoders

Incremental encoders

Absolute singleturn encoders

Absolute multiturn encoders

Incremental wire draw encoder

Absolute wire draw encoder

Absolute encoders, linear

Ultrasonic sensors

Ultrasonic proximity sensors

Ultrasonic double-sheet detectors

Inductive sensors

Inductive proximity sensors, single sensing range

Inductive proximity sensors, double sensing range

Inductive proximity sensors, triple sensing range

Inductive proximity sensors, flush installation

Inductive proximity sensors, non-flush installation

Inductive proximity sensors, cylinder housing

Inductive proximity sensors, threaded cylinder housing

Inductive proximity sensors, cuboid housing

Optoelectronic sensors

- Photoelectric proximity sensors, foreground suppression FGS
- Contrast scanners
- Light grids
- Photoelectric proximity sensors, background suppression BGS
- Color sensors
- Reflex light grids
- Photoelectric proximity sensors, energetic
- Luminescence scanners
- Intelligent Camera Sensors
- Photoelectric reflex sensors
- Fork sensors
- Color Vision Sensor
- Through-beam photoelectric sensors
- Distance sensors
- Light section sensors
- Photoelectric sensors with fibre-optic cable
- IR data transmission photoelectric sensors
- Position finders

Encoders:

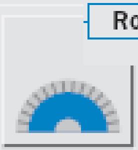
Incremental encoders, rotary

Incremental encoders generate information relating to position and angle in the form of electrical impulses. The number of pulses per revolution determines the resolving capability. The individual position is determined by counting these pulses from a point of reference. When the power is first switched on an initialising reference run is needed to determine absolute position.

Absolute encoders, rotary

Absolute encoders generate information relating to position, angle or number of revolutions in the form of unique codes. A unique code is assigned to each angular step. The number of unique code patterns per revolution determines the resolving capability. Since an absolute position is assigned to each unique code pattern, an initialising reference run is not required. Singleturn and multiturn versions are available.

Rotary encoders

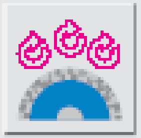


Incremental encoders

- Number of pulses from 1 to 10,000

Singleturn absolute encoders

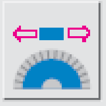
- Number of steps from 2 to 32,768



Multiturn absolute encoders

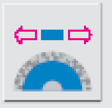
- Number of steps per revolution from 2 to 8,192. Maximum number of revolutions: 8,192.
- The multiturn function is achieved using a geared mechanism

Linear encoders



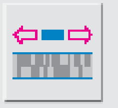
Incremental wire draw encoder

- Measuring lengths up to 50 m
- Resolution up to 0.025 mm



Absolute wire draw encoder

- Measuring lengths up to 50 m
- Resolution up to 0.025 mm



Absolute encoders

- Max. measuring length 1,700 m
- Resolution 0.1 mm

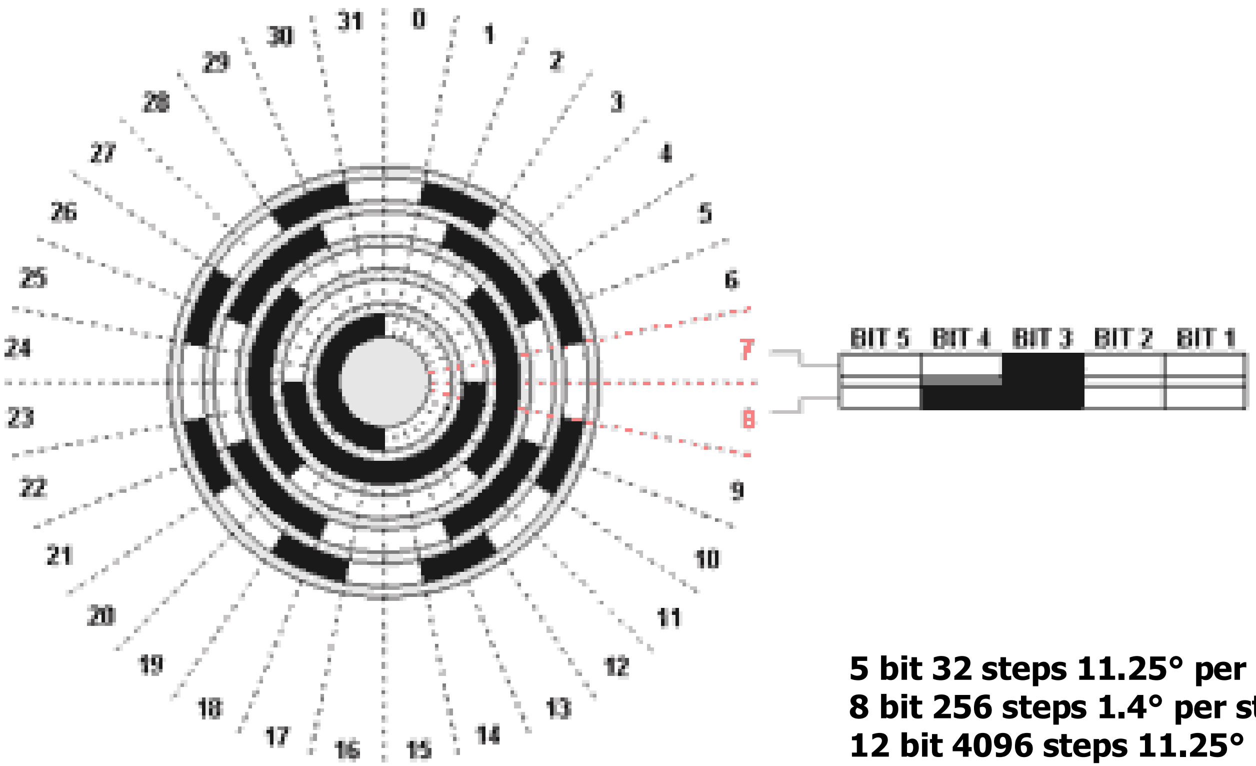
..let’s focus on sensor that will most be used in robotics..

MEASURING ANGLES:

- **ENCODER**
- **RESOLVER**

Absolute encoders..

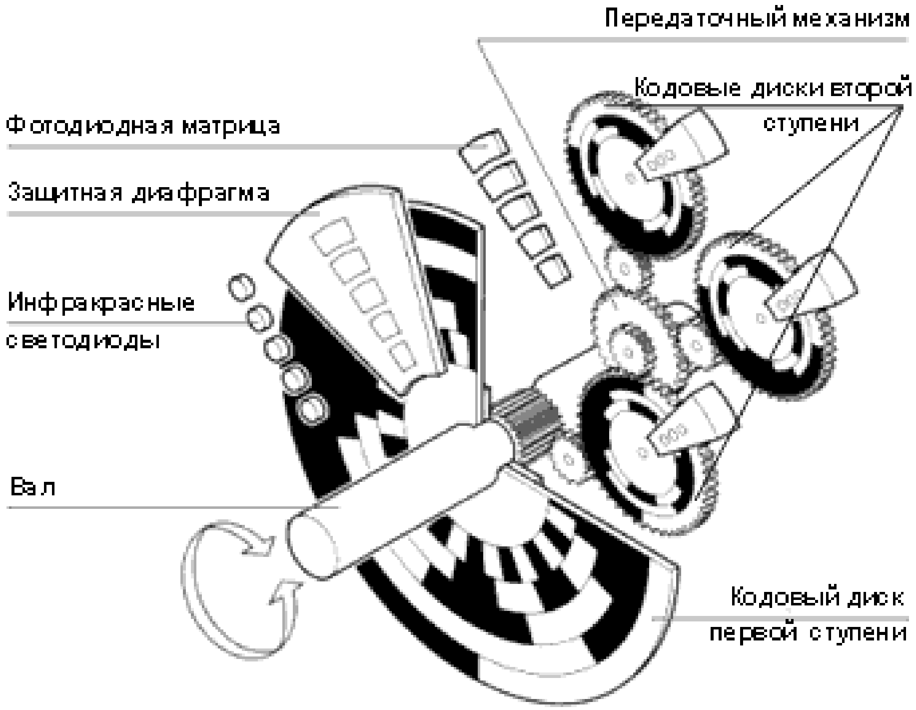
SINGLE TURN
OPTICAL



5 bit 32 steps 11.25° per step
8 bit 256 steps 1.4° per step
12 bit 4096 steps 11.25° per step

..an incremental encoder is a single row absolute encoder..

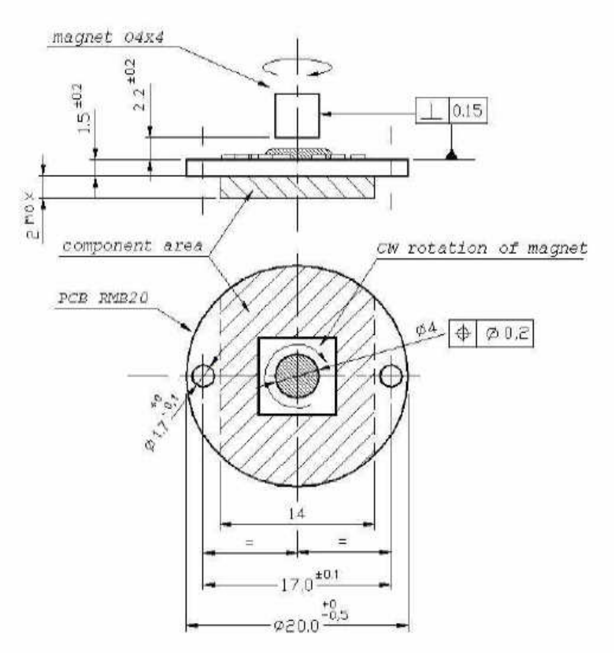
Absolute encoders..

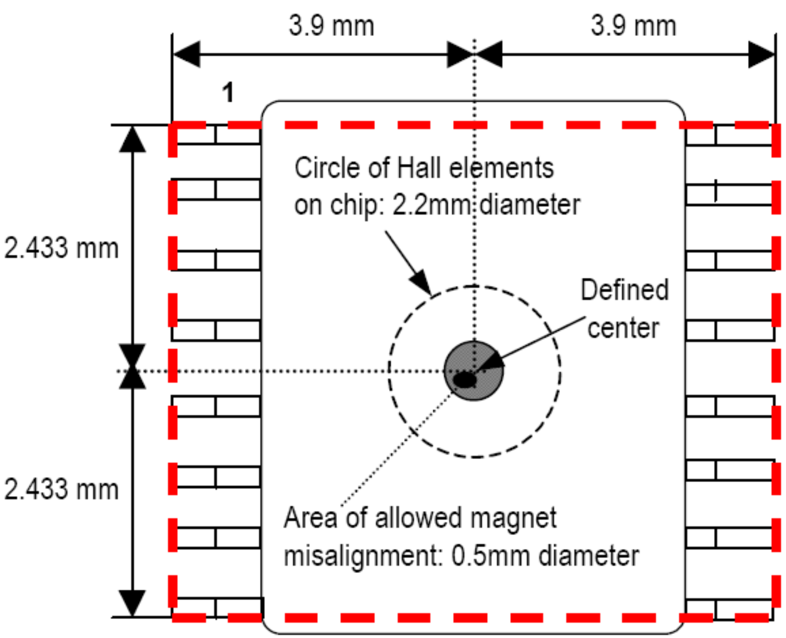


MULTI TURN
OPTICAL

Absolute encoders..

SINGLE TURN MAGNETIC





The AS5040 chip consists of a ring of hall elements, placed at the center of the IC at a circle diameter of 2.2mm (86.6mil).

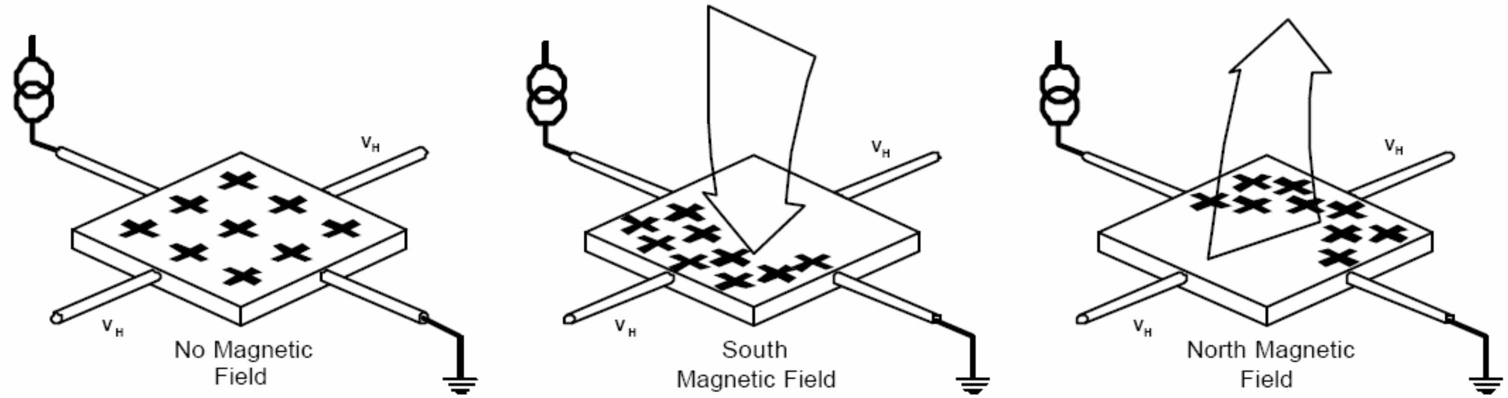
The hall elements pick up the field of a magnet, placed atop this hall array circle. This information is digitized and fed into a digital signal processor (DSP), which calculates the angle of the magnet with a resolution of 0.35 degrees or 1024 positions per revolution (10bit) at a sampling rate of 100µs (10kHz).

The digital angle information is available in several formats: as serial 10-bit data stream, as pulse-width modulated (PWM) signal or as quadrature incremental signal

in btw..

The Hall-Effect

The Hall-Effect principle is named for physicist **Edwin Hall**. In 1879 he discovered that when a conductor or semiconductor with current flowing in one direction was introduced perpendicular to a magnetic field a voltage could be measured at right angles to the current path.



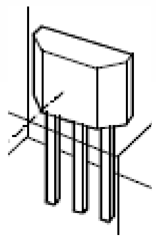
The Hall voltage can be calculated from $V_{Hall} = \sigma B$ where:

V_{Hall} = emf in volts

σ = sensitivity in Volts/Gauss

B = applied field in Gauss

I = bias current



Some examples

Rotary encoders

Incremental encoders

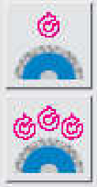
Technical data	DKS 40	DRS 60	DRS 61	DGS 60/DGS 65/DGS 66
Number of pulses per rotation	1 ... 2,048 all conventional numbers of pulses	Any number of pulses 1 ... 8,192	Any number of pulses between 1 ... 8,192 **programmable** by Programming Tool	100 to 10,000 all conventional numbers of pulses
Dimensions	Ø 50 mm	Ø 60 mm	Ø 60 mm	Ø 60 mm
Interfaces/drivers	Open Collector NPN, TTL/RS 422, HTL/push pull	TTL/RS 422, HTL/push pull	TTL/RS 422, HTL/push pull	TTL/RS 422, HTL/push pull
Supply voltage	4.5 ... 5.5 V DC or 10 ... 30 V DC	4.5 ... 5.5 V DC or 10 ... 32 V DC	4.5 ... 5.5 V DC or DC 10 ... 32 V	4 ... 6 V DC, 10 ... 30 V DC

Some examples

Rotary encoders

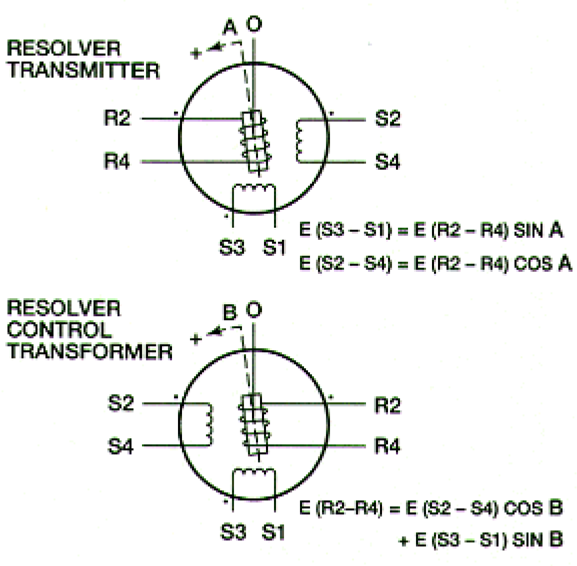
Absolute encoders | Incremental wire draw encoder | Absolute wire draw encoder

CoreTech by SICK|STEGMANN

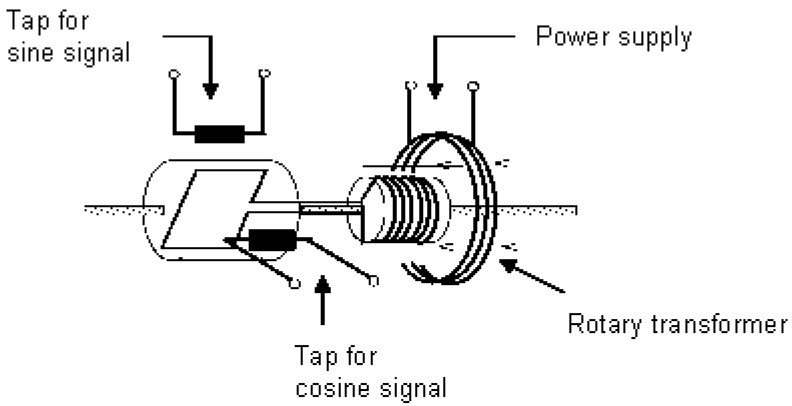


Technical data	ARS 60 Singleturn encoder	ATM 60/ATM 90 Multiturn encoder	PRF Incremental wire draw encoder	BTF Absolute wire draw encoder
Resolution	Any resolution from 2 ... 32,768 steps	8,192 steps per revolution 8,192 revolutions (max. 25 bit with SSI)	Up to 50 m Up to 0.025 mm ± 1 measuring step	Up to 50 m Up to 0.025 mm ± 1 measuring step
Dimensions	Ø 60 mm	Ø 60 mm (ATM 60) Ø 93 mm (ATM 90)		
Interfaces	SSI or parallel (push-pull)	SSI, RS 422 parameter interf., Profibus, DeviceNet, CANopen	TTL/RS 422, HTL/push pull	SSI, RS 422 configuration interface, Profibus, DeviceNet, CANopen
Supply voltage	10 ... 32 V DC	10 ... 30 V DC	4.5 ... 5.5 V DC or 10 ... 32 V DC	10 ... 30 V DC

RESOLVERS

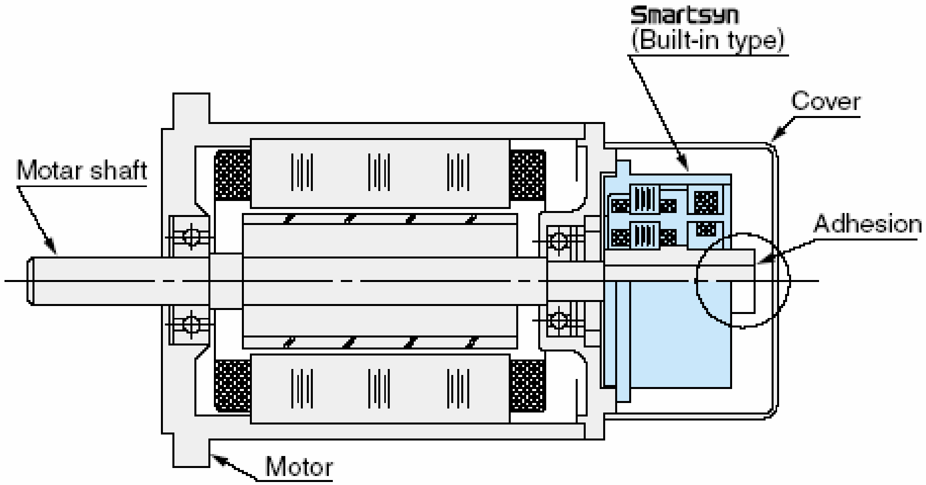


wired rotor

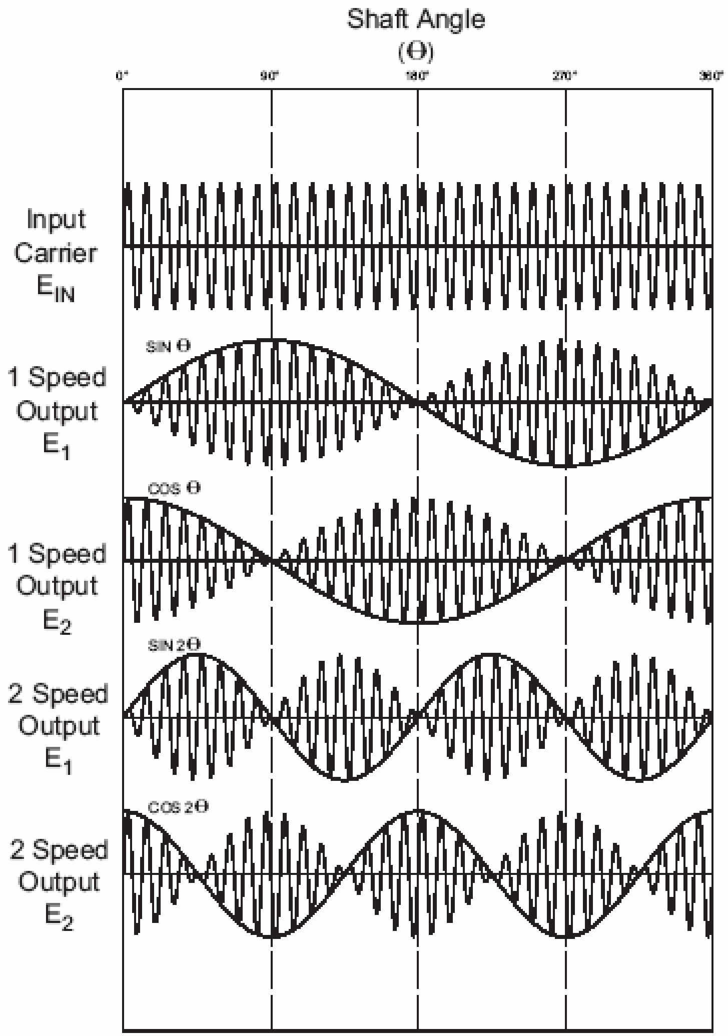


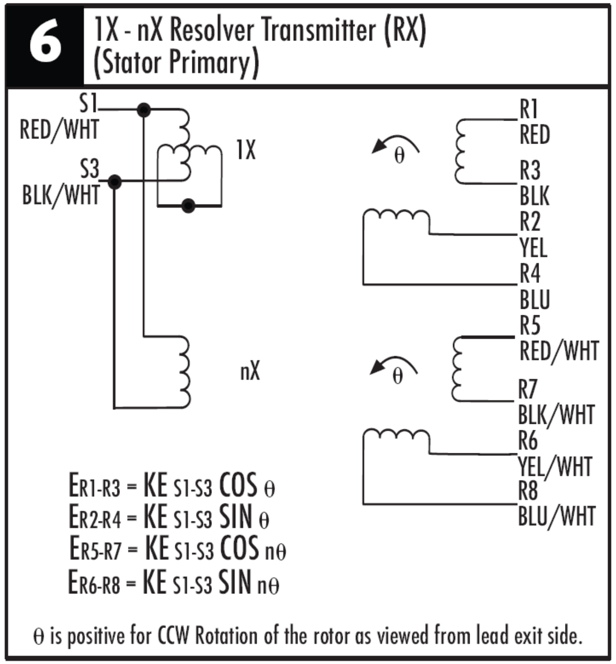
"brushless" rotor

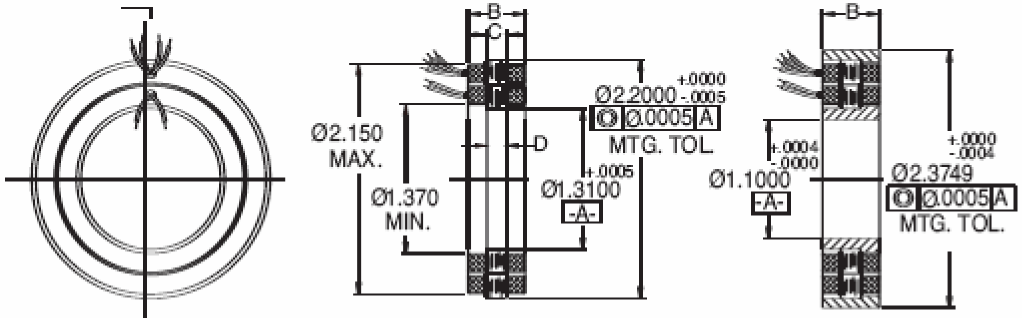
Resolver from real (typical application:brushless field commutation)



"MULTI SPEED" RESOLVER







BARE RESOLVER

RESOLVER WITH SLEEVE & HUB

"MULTI SPEED" RESOLVER

Selection Guide Part Number:	O.D. (in.)	I.D. (in.)	Height (in.)	Speed	Accuracy	Frequency (Hz)	Page No.
RP028-080SNFA-B4V	3.0000	1.5000	0.690	8	10″	2000	55
160SMFC-C7V	3.0000	1.5000	0.690	16	15″	5000	56
161BBFA-D7V	2.7500	1.7450	0.680	1/16	15′/20″	400	56
161BBFA-E0V	2.7500	1.7450	0.680	1/16	15′/30″	400	56
161BBFB-D7V	2.7500	1.7450	0.680	1/16	15′/20″	2000	56
161BBFB-E0V	2.7500	1.7450	0.680	1/16	15′/30″	2000	56
161SMFB-C7V	3.0000	1.5000	0.690	1/16	15′/15″	2000	56
161SMFB-D0V	3.0000	1.5000	0.690	1/16	15′/20″	2000	57
361SMFA-D0V	3.0000	1.5000	0.690	1/36	15″	2000	57
RP034-010BBFA-H0V1	3.3740	2.2503	0.520	1	2′	400	58
010BBFA-KOV	3.3740	2.2503	0.520	1	3′	400	58
010BBFA-L0V	3.3740	2.2503	0.520	1	3′	400	58
010BBFA-L0V1	3.3740	2.2503	0.520	1	6′	400	58
010BBFB-L0V	3.3740	2.2503	0.520	1	6′	800	58
010BBFB-L0V1	3.3740	2.2503	0.520	1	6′	2000	58
010BBFC-K0V1	3.3740	2.2503	0.520	1	3′	1000	59
010FMFA-H0V1	3.5700	2.0800	0.520	1	2′	400	59
080BBFA-C4V	3.3740	2.2503	0.600	8	15″	400	59
080BBFA-D0V	3.3740	2.2503	0.600	8	20″	400	59
080SMFA-B4V	3.5700	2.0800	0.600	8	10″	400	59
080SMFA-C0V	3.5700	2.0800	0.600	8	15″	400	59
160BBFD-C4V	3.3740	2.2503	0.600	16	15″	400	60
160BBFD-C4V1	3.3740	2.2503	0.600	16	15″	400	60
160BBFD-D4V1	3.3740	2.2503	0.600	16	15″	2000	60
160SMFC-C7V	3.5700	2.0800	0.600	16	15″	2000	60
161BBFA-D7V	3.3740	2.2503	0.600	1/16	15′/20″	400	60
161BBFA-E0V	3.3740	2.2503	0.600	1/16	15′/30″	400	60
161BBFB-D7V	3.3740	2.2503	0.600	1/16	15′/20″	2000	61
161BBFB-E0V	3.3740	2.2503	0.600	1/16	15″	2000	61
161BBFB-E0V1	3.3740	2.2503	0.600	1/16	15″	2000	61

Selection Guide Part Number:	O.D. (in.)	I.D. (in.)	Height (in.)	Speed	Accuracy	Frequency (Hz)	Page No.
RP065-321FMFB-B0V	6.750	4.712	0.650	1/32	15′/10″	2000	72
321SMFA-A2V	6.750	4.712	0.650	1/32	15′/5′	2000	72
321SMFA-B0V	6.750	4.712	0.650	1/32	15′/10″	2000	72
321FMFA-B0V	6.6875	4.7720	0.650	1/32	15′/10″	2000	72
321FMFA-A2V	6.6875	4.7720	0.650	1/32	15′/5′	2000	72
RP083-010BBFA-K0V1	8.2500	6.2300	0.850	1	3′	1500	73
010BBFA-L0V	8.2500	6.2300	0.850	1	6′	400	73
080BBFA-D5V1	8.2500	6.2300	0.600	8	20″	2000	73
081BBFA-B2V	8.2500	6.2300	0.850	1/8	15′/10″	400	73
081BBFA-C0V	8.2500	6.2300	0.850	1/8	15′/15″	400	73
161BBFA-C6V	8.2500	6.2300	0.850	1/16	15′/15″	400	73
161BBFA-D0V	8.2500	6.2300	0.850	1/16	15′/20″	400	74
161BBFB-B6V	8.2500	6.2300	0.850	1/16	15′/10″	400	74
161BBFB-C0V	8.2500	6.2300	0.850	1/16	15′/15″	400	74
321BBFA-A2V	8.2500	6.2300	0.850	1/32	15′/5′	400	74
321BBFA-B0V	8.2500	6.2300	0.850	1/32	15′/10″	400	74
321BBFB-D0V	8.2500	6.2300	0.850	1/32	15′/20″	400	74
RP094-010SMFA-M0V	9.6063	8.0709	1.024	1	10″	400	75
161SMFA-D5V	9.6063	8.0709	1.024	1/16	15′/20″	400	75
161SMFA-E0V	9.6063	8.0709	1.024	1/16	15′/30″	400	75
RP115-010BBFA-L0V	11.360	9.192	1.000	1	6′	400	76
010SMFA-L0V	11.675	8.880	1.000	1	6′	400	76
161BBFA-B6V	11.360	9.192	1.000	1/16	15′/10″	400	76
161BBFA-D0V	11.360	9.192	1.000	1/16	15′/20″	400	76
161SMFA-A6V	11.675	8.880	1.000	1/16	15′/5′	400	76
161SMFA-C0V	11.675	8.880	1.000	1/16	15′/15″	400	76
320SMFA-B0V	11.675	8.880	1.000	32	10″	400	77
321SMFA-C0V	11.675	8.880	1.000	1/32	15′/15″	400	77
321SMFD-B0V	11.675	8.880	1.000	1/32	15′/10″	1200	77

MEASURING LINEAR:

- **“LINEAR” ENCODER**
- **LVDT**

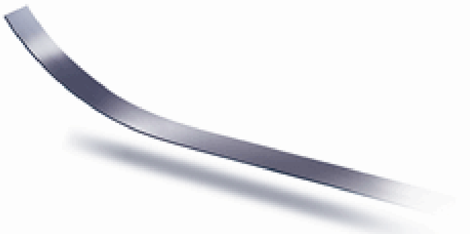
Linear encoders

Absolute encoder

Technical data	POMUX® KH 53
Measurement range	Up to 1,700 m
Resolution	0.1 mm
Reproducibility	300 µm
Interfaces	SSI, RS 422, Profibus
Operating voltage	10 ... 32 V DC

Magnetic strip MBA511

The base material is absolutely coded at defined distances and firmly joined to the steel carrier strip. For fixing, a special adhesive tape is premounted. An additional stainless steel cover strip is also included as standard.



Magnetic Display MA505

With this display the information of the absolute magnetic sensors MSA or LSA200 is processed for distance or position measurement. The display is comprehensively and indivually programmable and optionally available with serial interface and integrated power supply unit.

Features

- high-contrast LCD, 12-digit, dot matrix
- integrated translation module for absolute length measurement
- incremental/reset function
- calibration input
- direct reference/offset value input
- serial RS232/RS485 interface as an option

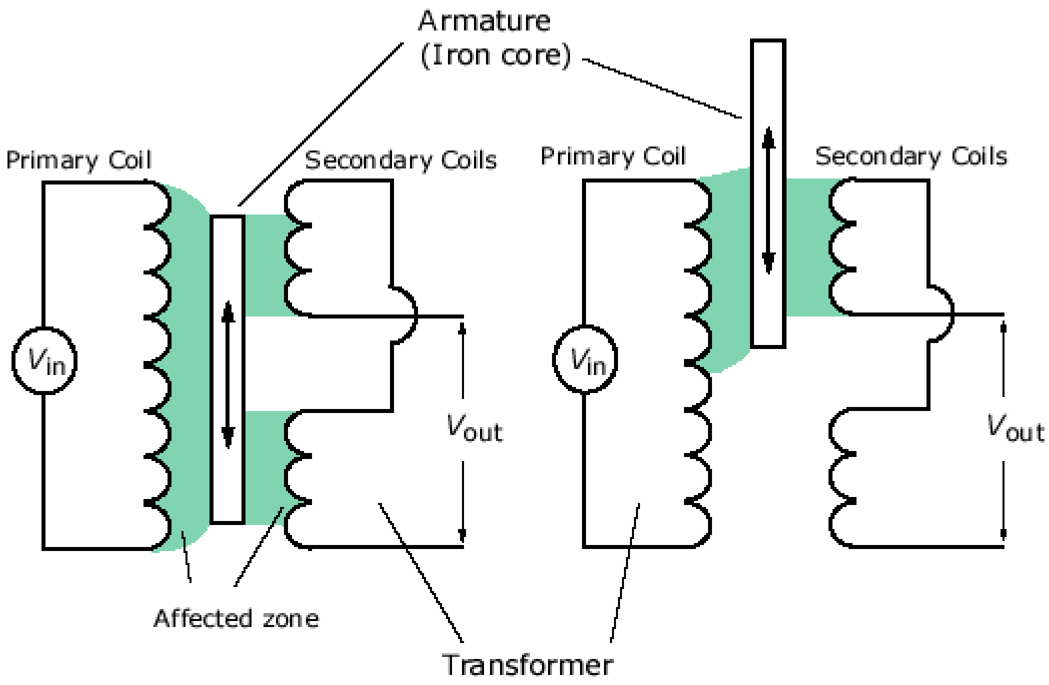
Magnetic sensor MSA510

This sensor gathers the absolute length information of the coded MBA magnetic strip and forms an absolute, linear distance or position measuring system for measuring lengths up to 5120 mm.

Features

- compact design with integrated translation module
- SSI interface
- measuring length up to 5120 mm
- accuracy class 0.05 mm, resolution 0.01 mm
- strip/sensor gap max. 1.0 mm
- use with MBA magnetic strip

LINEAR DIFFERENTIAL VARIABLE TRANSFORMER (LVDT)



..even more:

LINEAR OPTICAL ENCODER;

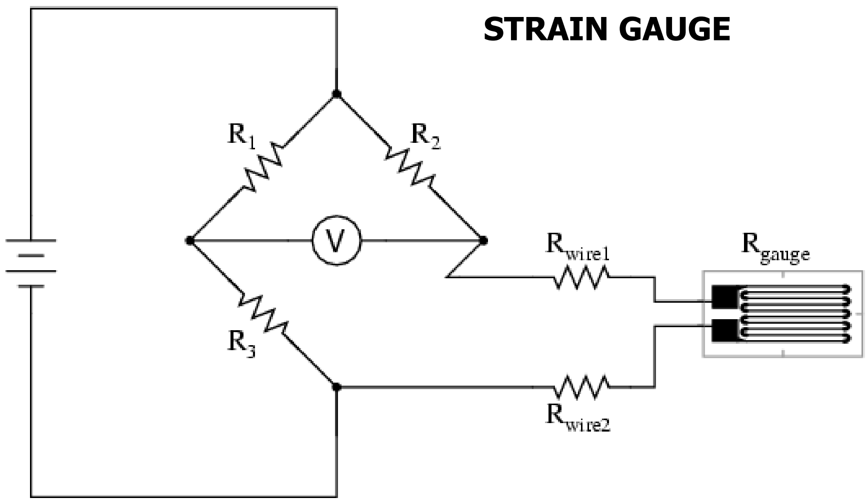
INDUCTOSYN;

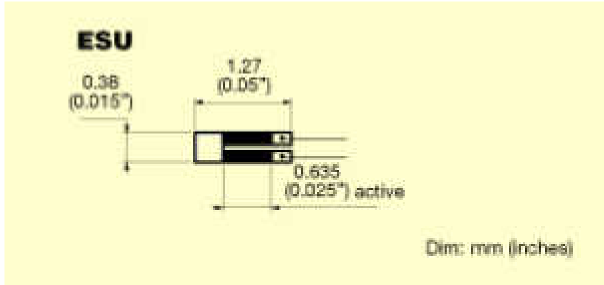
OPTICAL TRIANGULATION MEASUREMENT SENSOR;

...

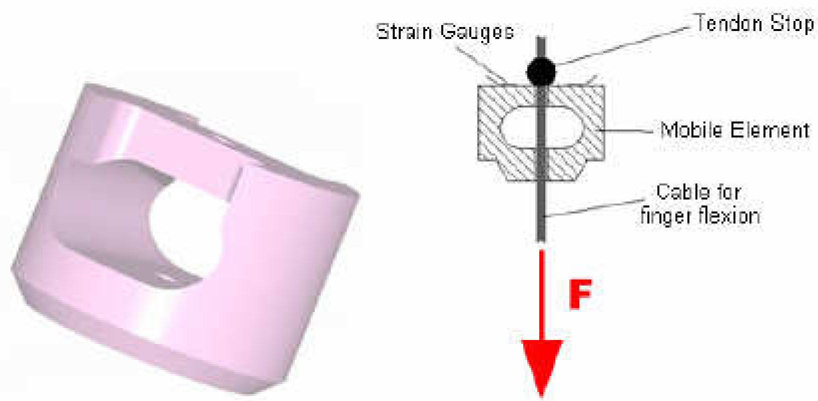
MEASURING FORCES

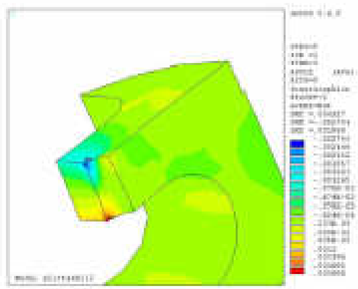
STRAIN GAUGE

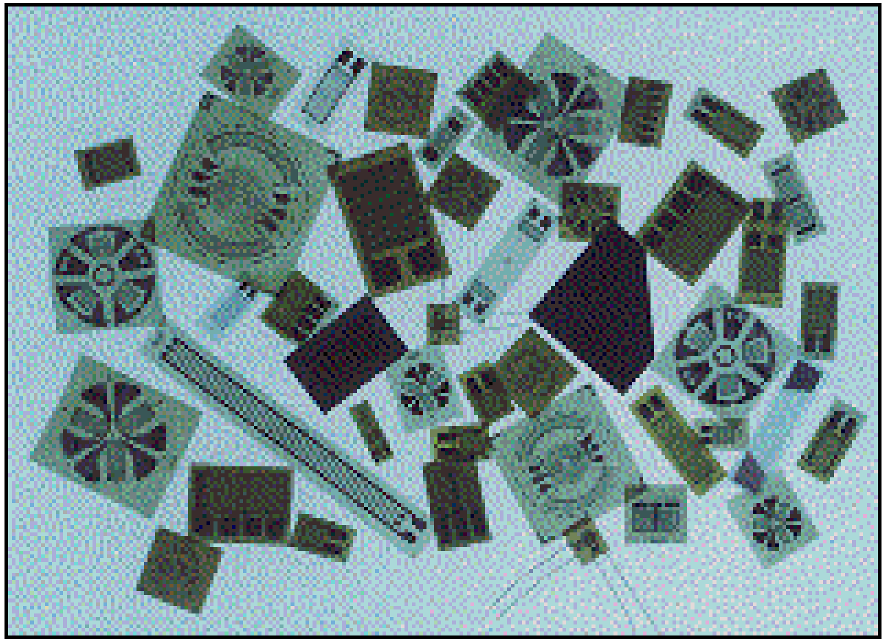




semi-conductor strain gauge







typical single and multi axis strain gauges

several "packaged" strain gauges: LOAD CELLS

COMPRESSION

TENSION

PUSH-PULL

FLEXION

TORSION

..more strain gauges coupled..MULTI AXIS LOAD CELL

Standard Calibrations

Transducer Body	English lb / in-lb	Metric (N / N-m)
Nano17	US-3-1 US-6-2 US-12-4	SI-12-0.12 SI-25-0.25 SI-50-0.50
Nano25	US-25-25 US-50-50	SI-125-3 SI-250-6
Nano43	US-4-2 US-8-4	SI-18-0.25 SI-36-0.5
Mini40	US-5-10 US-10-20 US-20-40	SI-20-1 SI-40-2 SI-80-4
Mini45	US-30-40 US-60-80 US-120-160	SI-145-5 SI-290-10 SI-580-20
Gamma	US-7.5-25 US-15-50 US-30-100	SI-32-2.5 SI-65-5 SI-130-10
Delta	US-75-300 US-150-600	SI-330-30 SI-660-60
Theta	US-200-1000 US-350-2100 US-600-3600	SI-1000-120 SI-1500-240 SI-2500-400
Omega160	US-200-1000 US-350-2100 US-600-3600	SI-1000-120 SI-1500-240 SI-2500-400
Omega190	US-400-3000 US-800-6000 US-1600-12,000	SI-1800-350 SI-3600-700 SI-7200-1400
Omega250	US-3600-18000 others available	SI-16000-2030 others available

Maximum Single-Axis Load

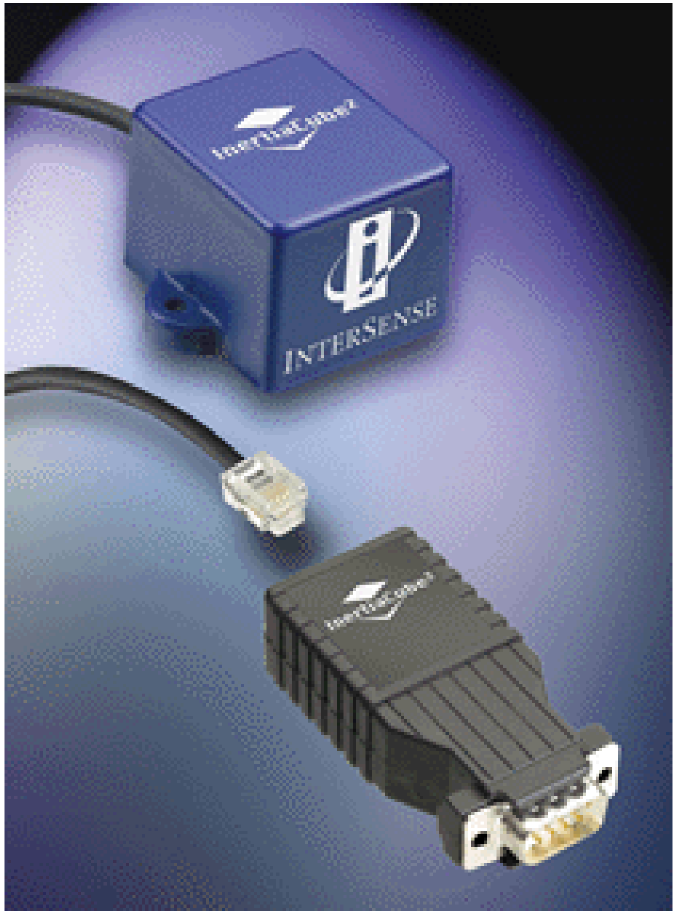
(without damage...these loads beyond sensing range)

Transducer Body	Axes	English	Metric
Nano17	Fxy Fz Txy Tz	± 79 lbs ± 180 lbs ± 23 in-lbs ± 28 in-lbs	± 350 N ± 800 N ± 2.6 N-m ± 3.1 N-m
Nano25	Fxy Fz Txy Tz	± 520 lbs ± 1400 lbs ± 310 in-lbs ± 560 in-lbs	± 2325 N ± 6250 N ± 34 N-m ± 62 N-m
Nano43	Fxy Fz Txy Tz	± 68 lbs ± 89 lbs ± 30 in-lbs ± 48 in-lbs	± 300 N ± 400 N ± 3.4 N-m ± 5.4 N-m
Mini40	Fxy Fz Txy Tz	± 200 lbs ± 610 lbs ± 190 in-lbs ± 190 in-lbs	± 870 N ± 2700 N ± 21 N-m ± 21 N-m
Mini 45	Fxy Fz Txy Tz	± 1200 lbs ± 2300 lbs ± 950 in-lbs ±1200 in-lbs	± 5100 N ± 10000 N ± 110 N-m ± 140 N-m
Gamma	Fxy Fz Txy Tz	± 270 lbs ± 910 lbs ± 690 in-lbs ± 730 in-lbs	± 1200 N ± 4100 N ± 79 N-m ± 82 N-m
Delta	Fxy Fz Txy Tz	± 770 lbs ± 2600 lbs ± 2000 in-lbs ± 3700 in-lbs	± 3400 N ± 12000 N ± 220 N-m ± 420 N-m
Theta	Fxy Fz Txy Tz	± 5700 lbs ± 14000 lbs ± 22000 in-lbs ± 24700 in-lbs	± 25000 N ± 61000 N ± 2500 N-m ± 2700 N-m
Omega160	Fxy Fz Txy Tz	± 4000 lbs ±11000 lbs ±15000 in-lbs ±17000 in-lbs	±18000 N ± 48000 N ±1700 N-m ±1900 N-m
Omega190	Fxy Fz Txy	± 8000 lbs ± 25000 lbs ± 49000 in-lbs	± 36000 N ±11000 N ± 5500 N-m

inertia sensors

..from the “classic” GYROSCOPE

..to MEMS GYRO



SMD Accelerometer

Miniature DC Response

Piezoresistive MEMS

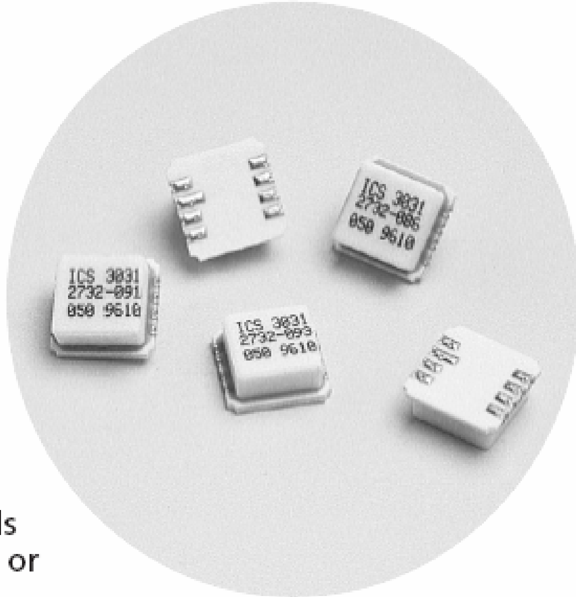
10,000g Over-Range Protection

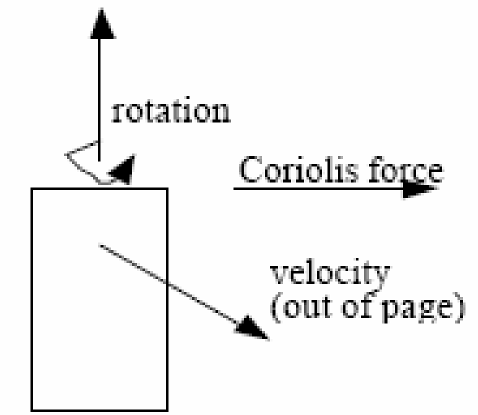
DESCRIPTION

The Model 3031 is a piezoresistive SMD accelerometer designed for demanding high volume applications. The accelerometer is ideal for applications requiring a miniature light weight accelerometer with outstanding performance.

The model 3031 incorporates a 2nd generation MEMS sensing element providing superior long-term stability. The accelerometer provides a millivolt output signal and features mechanical overload stops that provide shock protection to 10,000g.

For non-surface mount accelerometers please see Models 3022, 3028, 3052 or 3058.

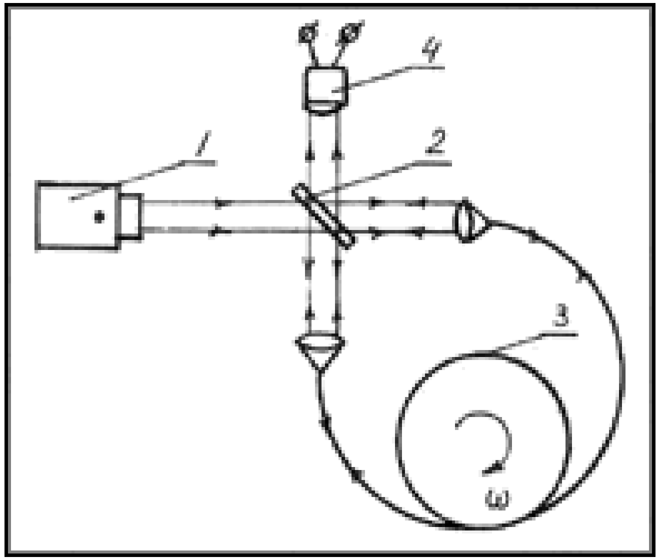


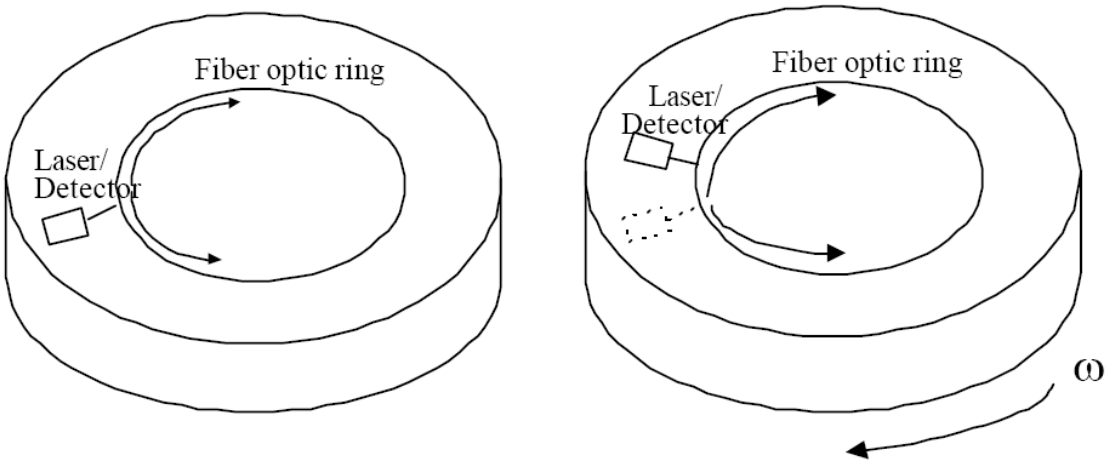


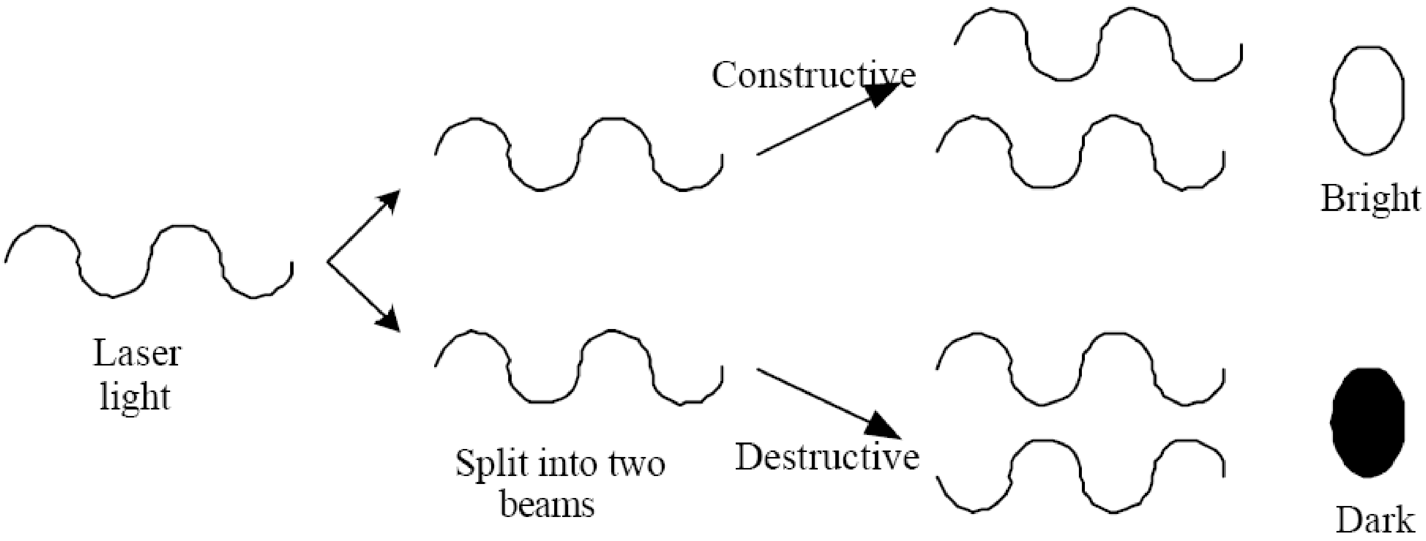
. MEMS Vibrating Structure Rate Sensor

$$F = 2m\omega V$$

FIBER OPTIC GYRO (fog)







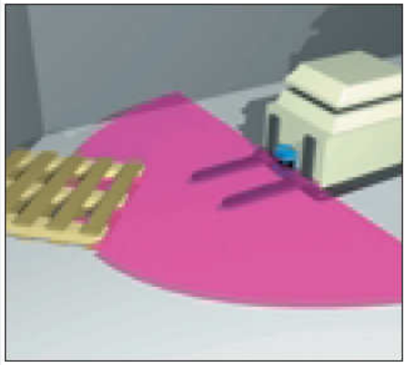
$$\Delta S = 8\pi n A\omega / c\lambda$$

Sagnac effect

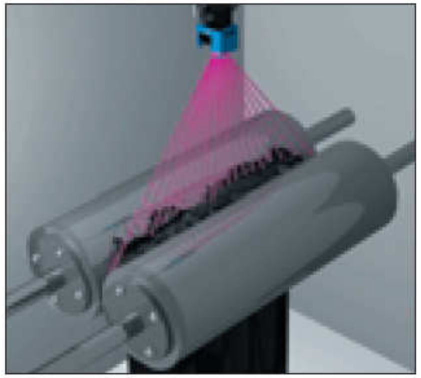
LASER SCANNER

Technical data	LMS 200 ID	LMS 220 ID	LMS 211 OD
Range (max. / 10% reflectivity)	80 m/10 m	80 m/10 m	80 m/30 m
Scanning angle	max. 180°	max. 180°	max. 100°
Angular resolution	0.25°/0.5°/1° adjustable	0.25°/0.5°/1° adjustable	0.25°/0.5°/1° adjustable
Response time	53 ms / 26 ms / 13 ms	53 ms / 26 ms / 13 ms	53 ms / 26 ms / 13 ms
Resolution / systematic error	10 mm/typ. ± 15 mm	10 mm/typ. ± 15 mm	10 mm/typ. ± 35 mm
Data interface	RS 232 / RS 422	RS 232 / RS 422	RS 232 / RS 422
Switching outputs	3 x PNP; typ. 24 V DC	3 x PNP; typ. 24 V DC	3 x PNP; typ. 24 V DC
Laser protection class	1 (eye-safe)	1 (eye-safe)	1 (eye-safe)
Operating ambient temperature	0...+50 °C	-30...+50 °C	-30...+50 °C
Enclosure rating	IP 65	IP 67	IP 67/heated front window
Dimensions (W x H x D)	155 x 210 x 156 mm^3	352 x 266 x 229 mm^3	352 x 266 x 236 mm^3 *

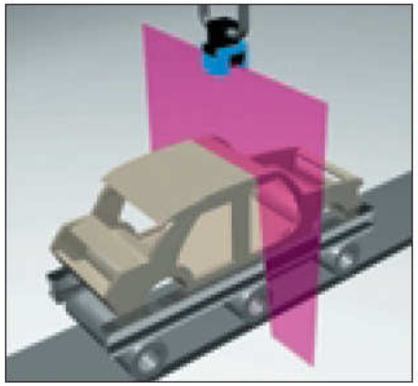
* (w/o dust prevention shield)



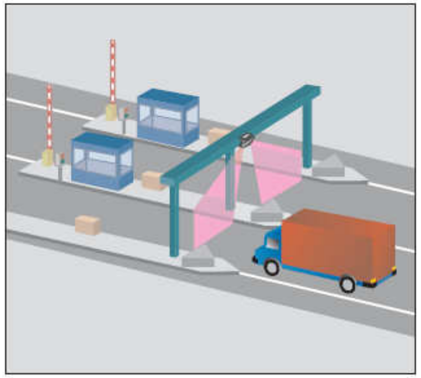
e.g. detecting positions/ collision prevention



e.g. determining filling levels

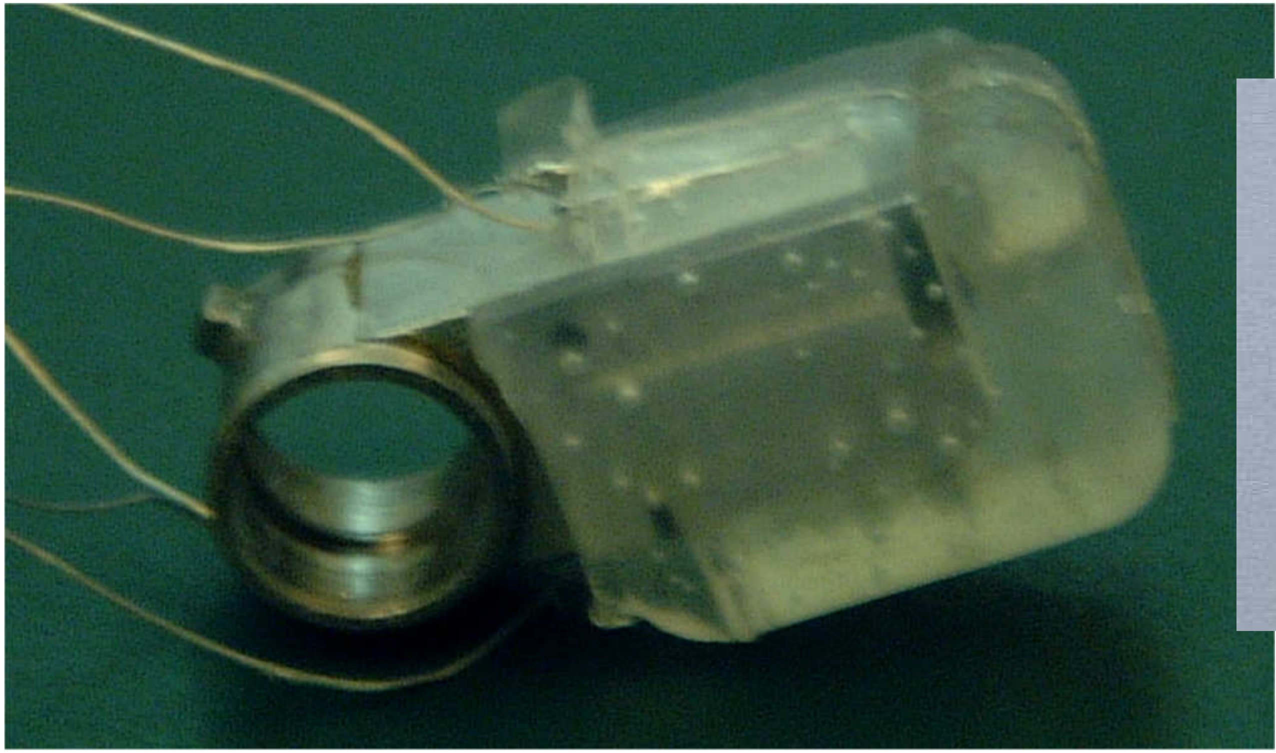


e.g. classifying bodywork



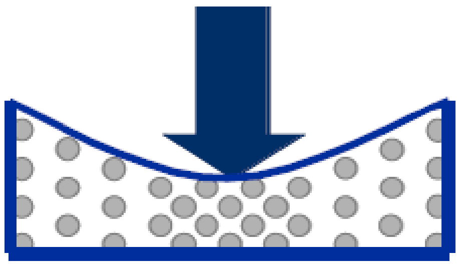
e.g. vehicle detection

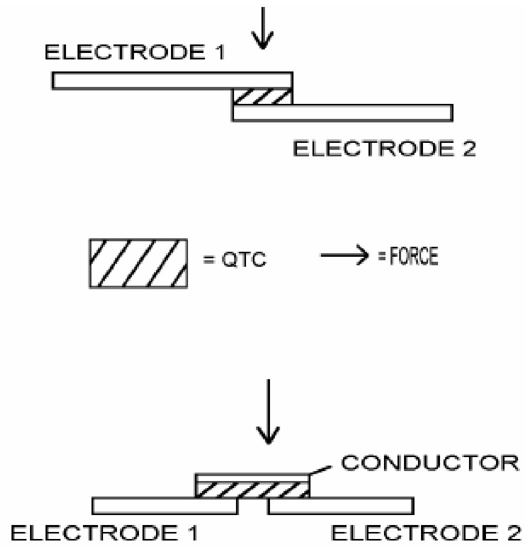
A SIMPLE tactile sensor made using hall effect sensor



another tactile sensor: quantum tunneling composite (QTC)

- Carbon composites always show some conduction typically with a resistance of a few thousand ohms, whereas in the unstressed state QTCs can be considered an insulator at 10^{12} ohms
- Under pressure, carbon composites can decrease to a few hundred ohms, whereas QTCs reduce to less that 1 ohm
- The deformation required to produce a significant (factor of 10) change in resistance is significantly less for QTC than for carbon composites





(fine !)