ROBOTIKA

Pengantar

Oleh:

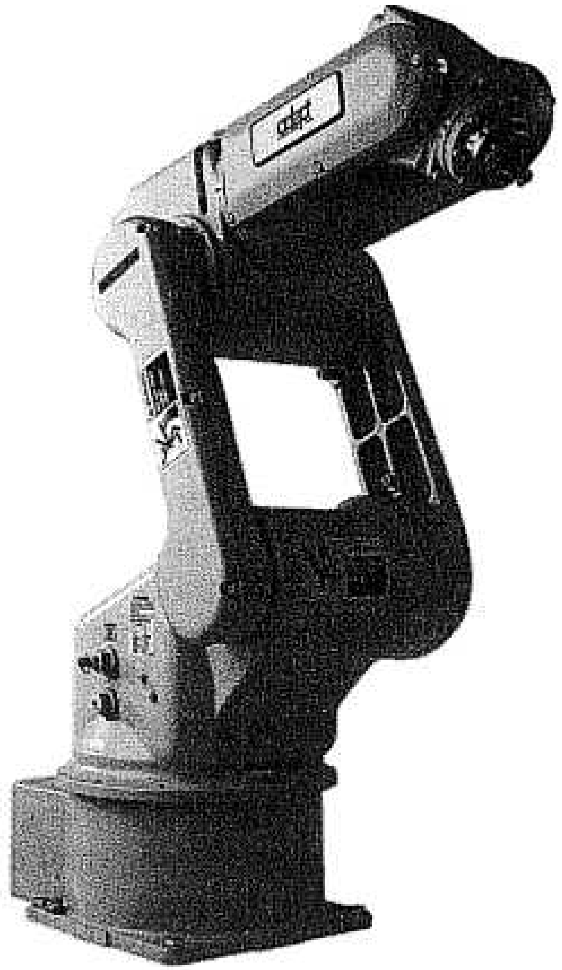
Andik Asmara

ROBOT?

"A robot is a mechanical arm, a manipulator designed to perform many different tasks and capable of repeated, variable programming. To perform its assigned tasks, the robot moves parts, objects, tools, and special devices by means of pre programmed motions and points.“

Moshe Shoham (auth.) A Textbook of Robotics 1 Basic Concepts-Springer US (1984)

SEPERTI APA ROBOT?



KENAPA ROBOT?

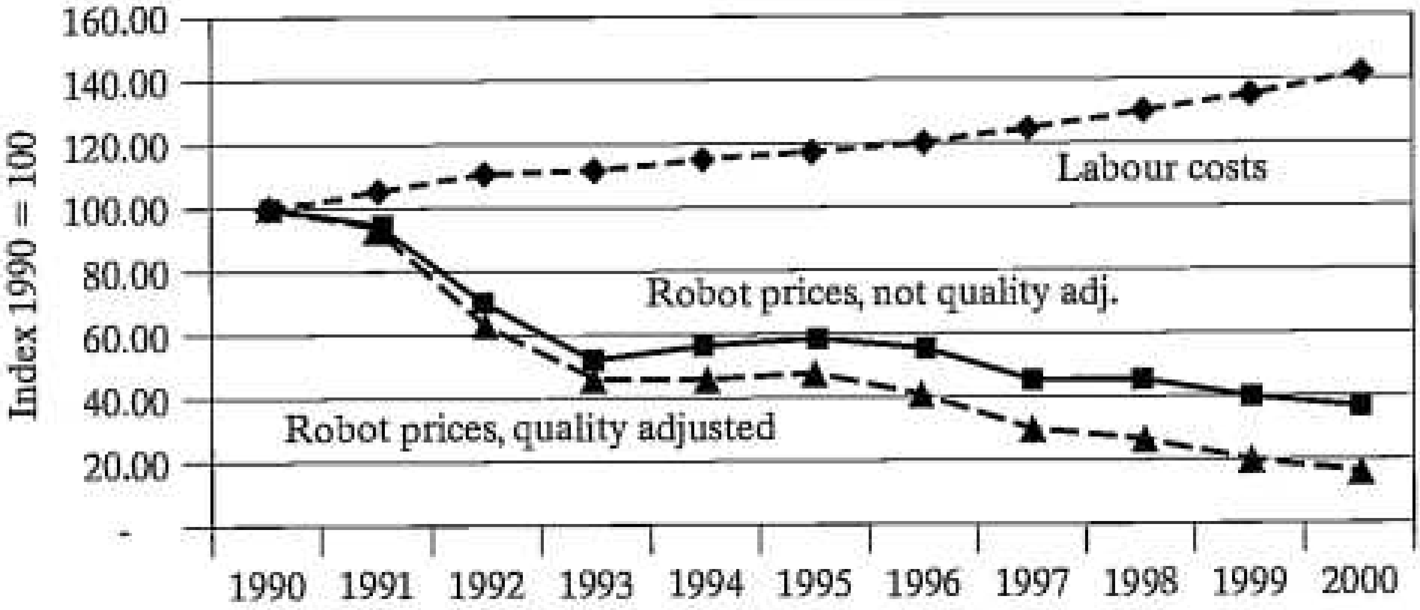


FIGURE 1.3: Robot prices compared with human labor costs in the 1990s [3].

PERKEMBANGANNYA?

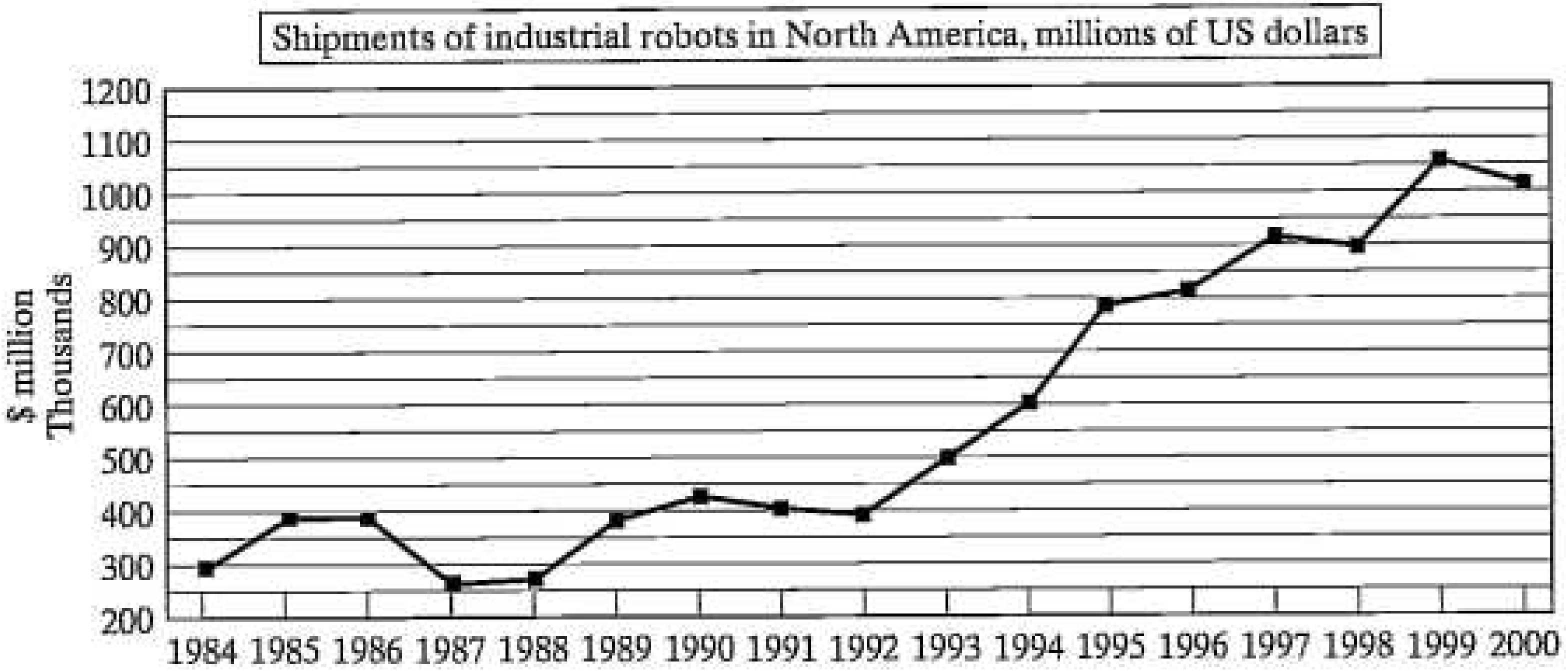


FIGURE 1.1: Shipments of industrial robots in North America in millions of US dollars [3].

PERKEMBANGANNYA?

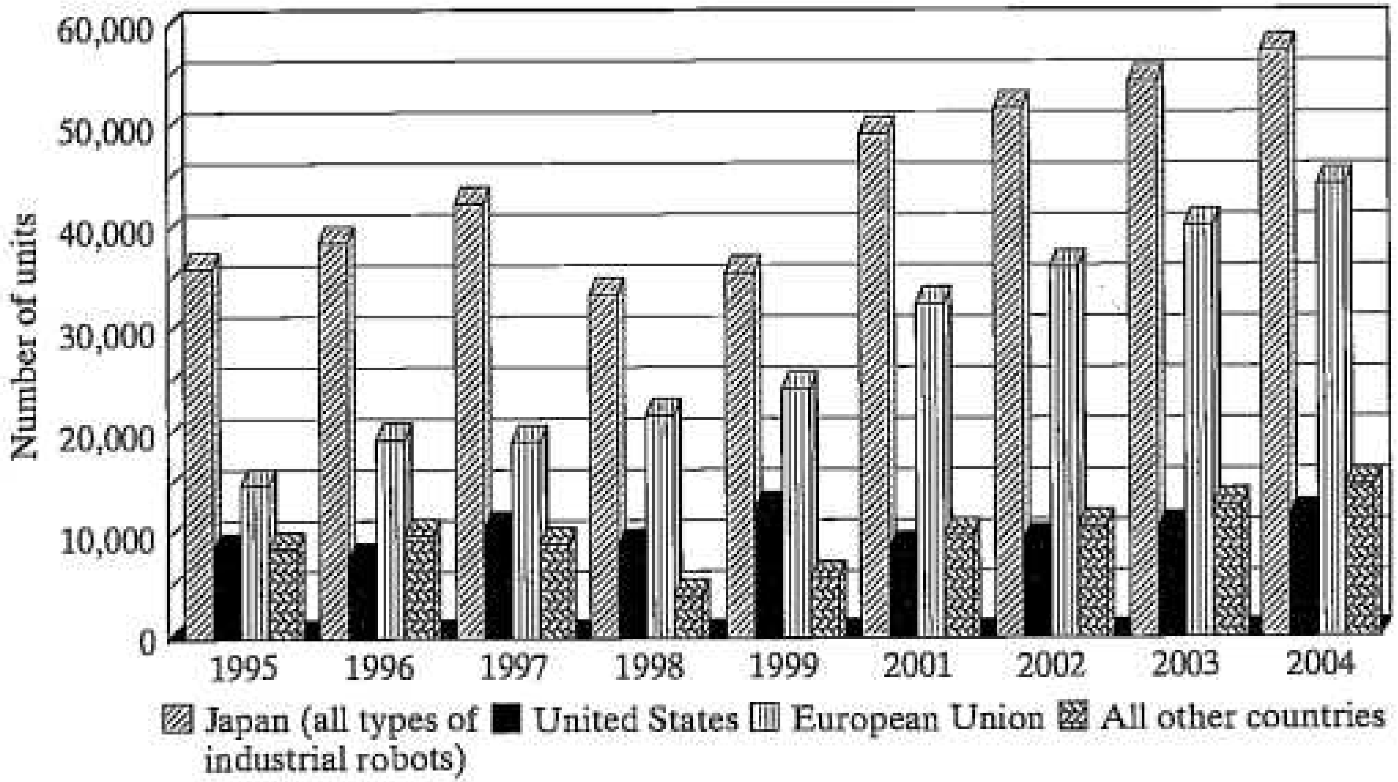


FIGURE 1.2: Yearly installations of multipurpose industrial robots for 1995–2000 and forecasts for 2001–2004 [3].

ROBOT VS MANUSIA

	Robot	Human
Mobility	Generally fixed in one spot, except for a small number of mobile models.	Capable of free motion from place to place.

LINK

KEILMUAN APA YANG MENDUKUNG?

"By and large, the study of the mechanics and control of manipulators is not a new science, but merely a collection of topics taken from "classical" fields. Mechanical engineering contributes methodologies for the study of machines in static and dynamic situations. Mathematics supplies tools for describing spatial motions and other attributes of manipulators. Control theory provides tools for designing and evaluating algorithms to realize desired motions or force applications. Electrical-engineering techniques are brought to bear in the design of sensors and interfaces for industrial robots, and computer science contributes a basis for programming these devices to perform a desired task."

John J.Craig *Introduction to Robotics Mechanics and Control* (2005:3)

AKTUATOR

Robotika

Andik Asmara

PENGERTIAN

Aktuator adalah sebuah peralatan mekanis untuk menggerakkan atau mengontrol sebuah mekanisme atau sistem.

FUNGSI

Fungsi aktuator adalah sebagai berikut.

- Penghasil gerakan
- Gerakan rotasi dan translasi
- Mayoritas aktuator > motor based
- Aktuator dalam simulasi cenderung dibuat linier
- Aktuator riil cenderung non-linier

JENIS AKTUATOR

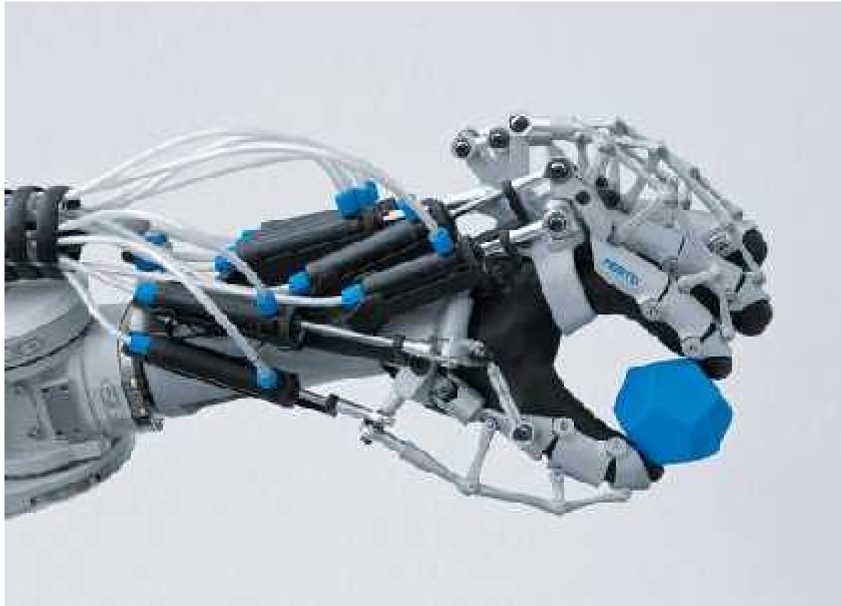
Jenis tenaga penggerak pada actuator secara umum:

- Aktuator tenaga elektris, biasanya digunakan solenoid, motor arus searah (Mesin DC
- Aktuator tenaga hidrolik
- Aktuator tenaga pneumatic
- Aktuator lainnya: piezoelectric, magnetic, ultra sound.

AKTUATOR ROBOTIK

Aktuator didalam robot
digunakan untuk menghasilkan
gerakan mekanik.

CONTOH:



JENIS-JENIS AKTUTOR ROBOT

Hollerbach, Hunter, Ballantyne: 1992

1. Electromagnetic Motor
2. Hydraulic Actuator
3. Pneumatic Actuator
4. Shape Memory Alloy Actuator
5. Polymeric Actuator (Contractile Polymers)
6. Piezoelectric Actuator
7. Magnetostriction
8. Muscle, Nature’s Actuator

ELECTROMAGNETIC MOTOR (EM)

Seperti motor sinkron, induksi dan motor DC.

Sumber kekuatan terdapat pada kemampuan putaran motor.

KONSTANTA PADA MOTOR

$$\begin{aligned} \tau &= K_T i \\ V &= K_T \omega + Ri \end{aligned}$$

where τ is the motor torque, K_T is the torque constant, i is the current, V is the supplied voltage, ω is the rotor speed, $E = K_T\omega$ is the back-emf, and R is the winding resistance. For a fixed voltage V, the torque-speed

$$\tau = K_T(V - K_T\omega)/R = K_TV/R - K_m^2\omega$$

where the motor constant is $K_m = K_T/\sqrt{R}$ and the slope of the torque-speed curves is $-K_m^2$.

By the conservation of energy, we can write

$$P_{in} = P_{loss} + P_{mech} \tag{4}$$

where $P_{in} = Vi$ is the electrical power delivered by the power supply, $P_{mech} = Ei$ is the mechanical power produced by the motor, and $P_{loss} = i^2R$ is the power lost to ohmic heating. The mechanical power P_{mech} versus speed ω has a parabolic form, and can be derived from (3):

$$P_{mech} = \tau\omega = K_T\omega(V - K_T\omega)/R \tag{5}$$

The maximum velocity is given by $\omega_{max} = V/K_T$, and the maximum mechanical power occurs at $\omega_0 = \omega_{max}/2$, or $(P_{mech})_{max} = (VK_m/2K_T)^2$.

KARAKTERISTIK

- Kekuatan motor dapat dilihat pada konsumsi arus
- Konsumsi arus hanya dibatasi dengan suhu pada motor itu sendiri
- Suhu harus dibawah 180°C, typical 130°C

The achievable torque depends on the specified "duty cycle": much higher torques can be achieved for short durations than for long or continuous periods. From Equation (3), the peak torque at stall is $\tau_{peak} = K_T V/R$, and hence depends not only on the intrinsic motor design (the term K_T/R) but also on the voltage V delivered by the power supply. A better indication of intrinsic motor performance would be the continuous stall torque τ_{cont}, which can be derived from R_{therm}. The maximum continuously sustainable power lost to ohmic heating is:

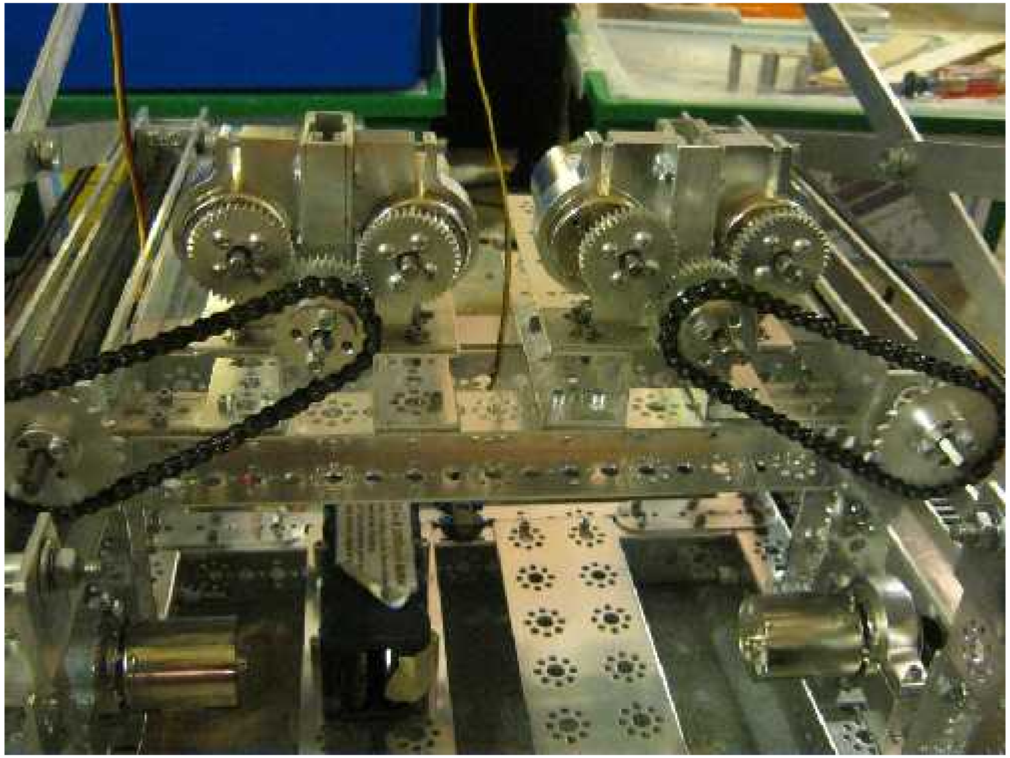
$$(P_{loss})_{cont} = (T_w - T_a)/R_{therm} = i^2_{cont} R \tag{6}$$

Parameter	Units	1410-01	1410-02	1410-03	1410-05
K_T	N·m/A	0.2	0.50	0.31	0.26
R	Ω	0.28	1.97	0.71	0.45
K_m	N·m/$\sqrt{W}$	0.27			
R_{therm}	°C/W	1.16			
T_w	°C	155			
τ_{cont}	N·m	2.89			

Table 1: Specifications for Aerotech Model 1410 dc servo motors. Four different winding configurations are shown.

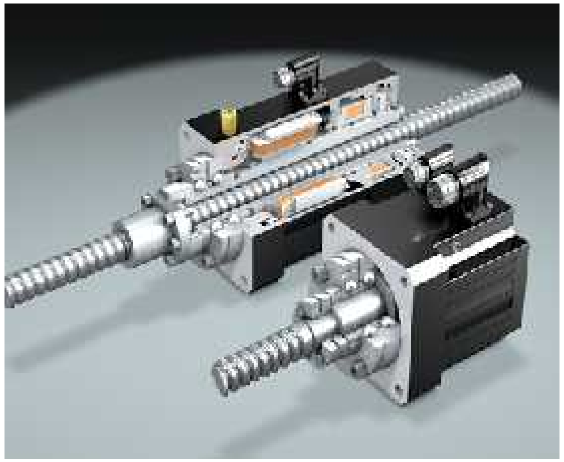
APLIKASI PADA ROBOT

- Motor Kendali dengan Gear



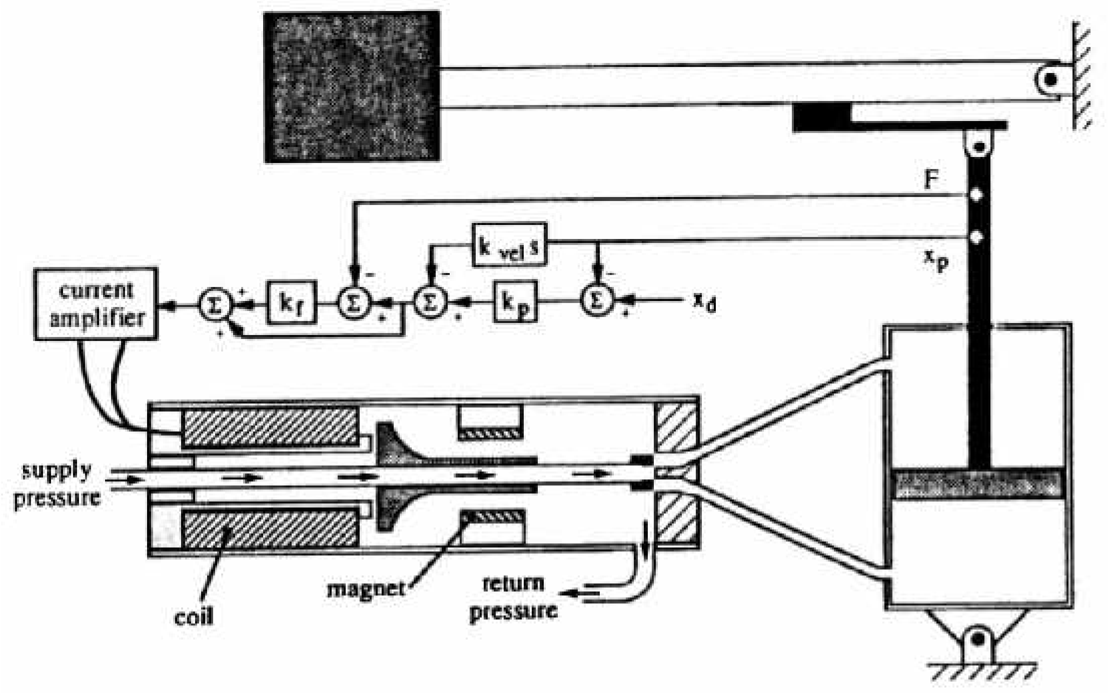
- Motor Kendali Langsung

Lebih mudah untuk dikendalikan dibanding menggunakan gear.



HYDRAULIC ACTUATOR

- Mengubah dari tekanan pada zat cair menjadi putaran atau gerakan linier.
- Memiliki gaya yang besar



Output	Linear Actuator	Rotary Actuator
Speed	$v = Q_c/A_c$	$\omega = Q_c/D_m$
Force or torque	$F = A_c p_l$	$\tau = D_m p_l$
Mechanical power	$P_{mech} = Q_c p_l$	$P_{mech} = Q_c p_l$

Table 2: Output characteristics of hydraulic actuators (Nakanishi, 1991).

Q_c is the control flow—the flow through the valve control ports to the load actuator.

p_l is the load pressure drop—the differential pressure between the control ports on the load actuator.

A_c is the pressure receiving area.

D_m is the volumetric displacement per radian of rotation.

KARAKTERISTIK

$p_v = (p_s - p_r) - p_l$: Valve pressure drop—the differential pressure drop across the control orifices of the servovalve. Assuming that the return pressure p_r is at atmospheric and the supply pressure is high yields $p_s - p_r \approx p_s$.

Q_{nl} : No-load flow—the control flow when $p_l = 0$. The load is moving freely and no torque is generated. This would correspond to the maximum rotational speed ω_{max} on the torque-speed curves for a dc motor.

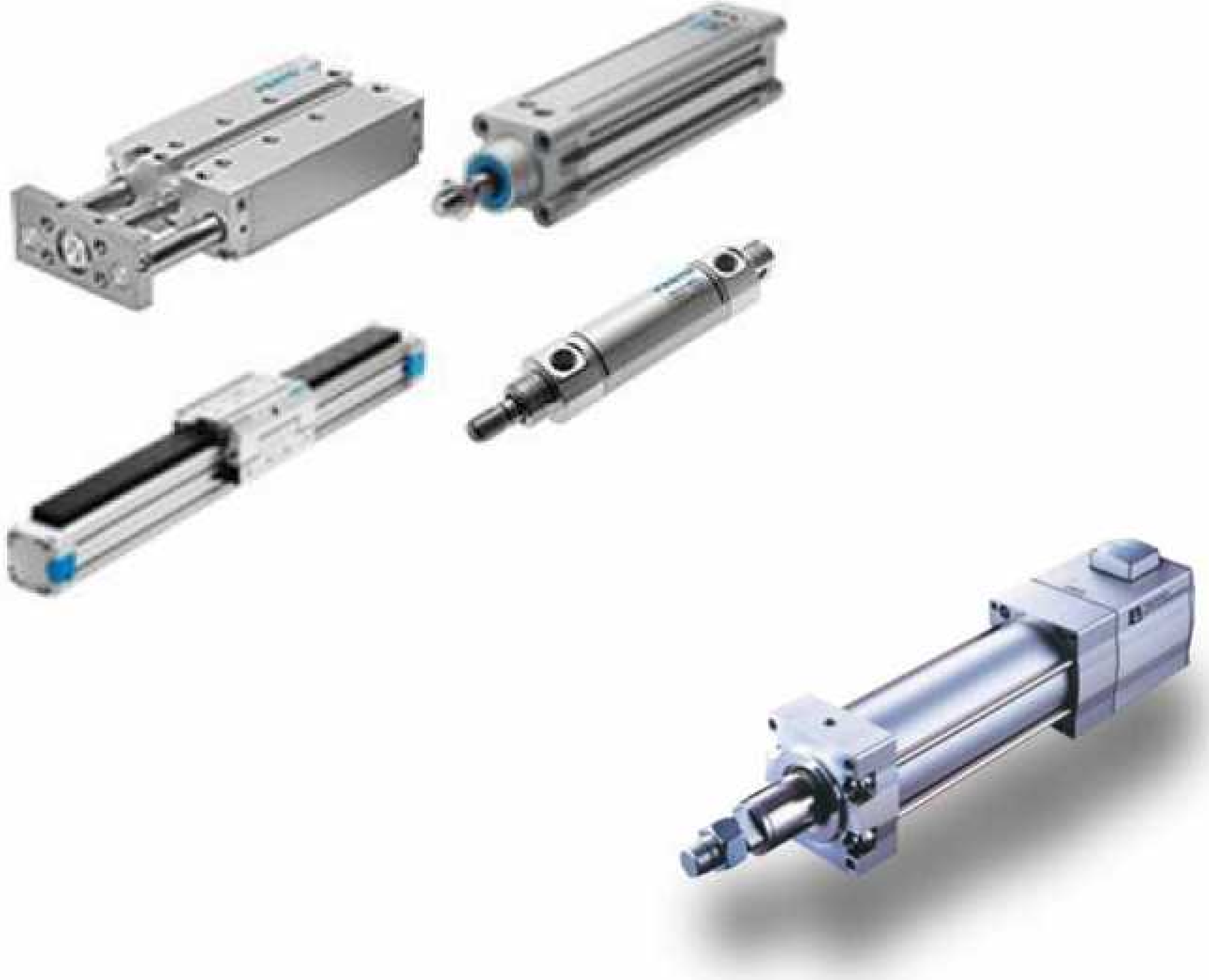
Q_r : Rated flow—the no-load flow at full valve flow when $p_v = 6.7$ MPa (1000 psi). Call this pressure p_{vr}.

APLIKASI

PNEUMATIC ACTUATOR

Keuntungan penggunaan pneumatic

- Viscosity yang rendah
- Penggerak menggunakan udara bertekanan
- Tidak memerlukan pelumasan
- Bentuk yang kecil
- Aksi yang cepat dibanding hidrolik



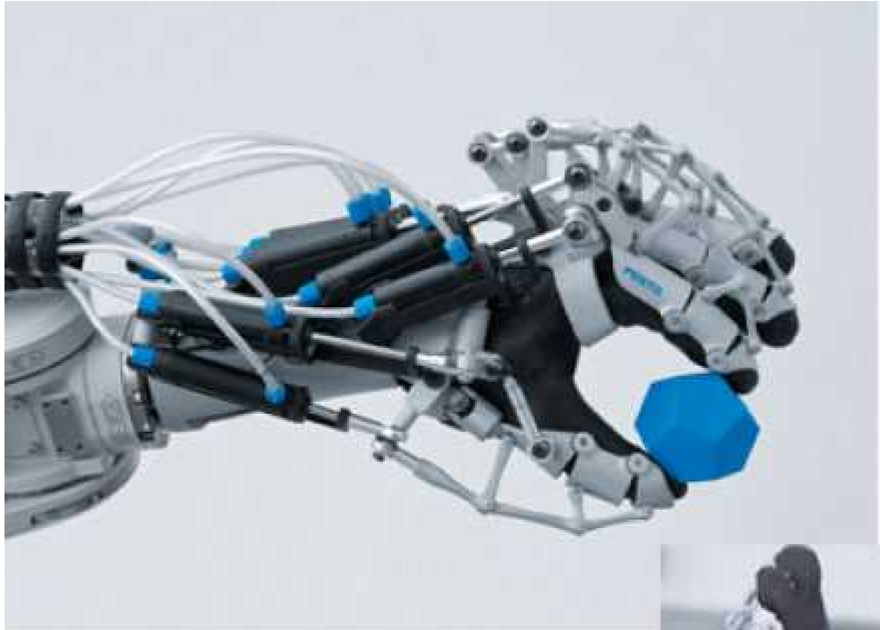
KARAKTERISTIK

The typical maximum supply pressure for pneumatic actuators is about $p_s = 670$ kPa (100 psi). For piston-type pneumatic actuators the thrust force f is given by (Saito, 1991):

$$f = \mu p_s A, \tag{14}$$

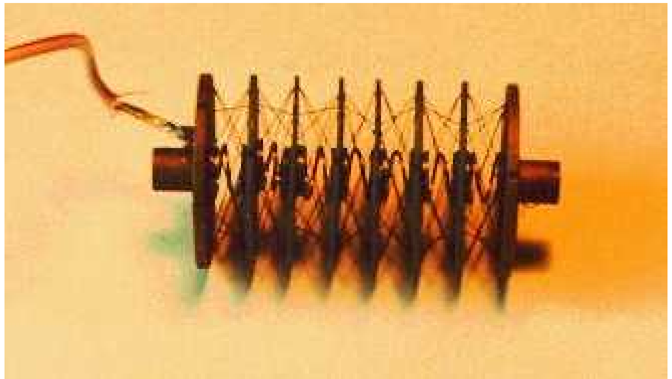
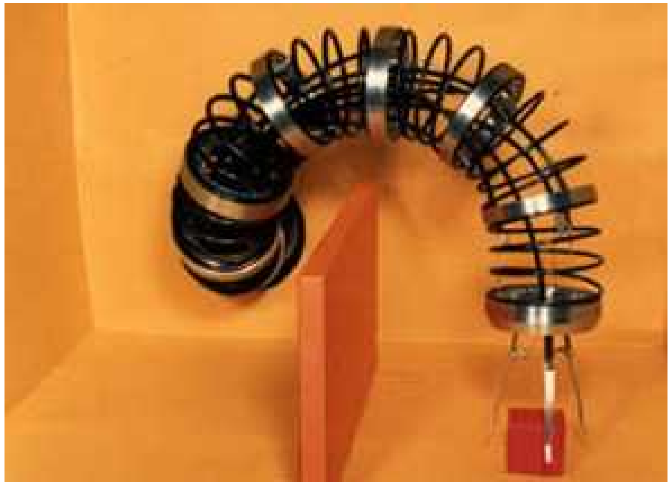
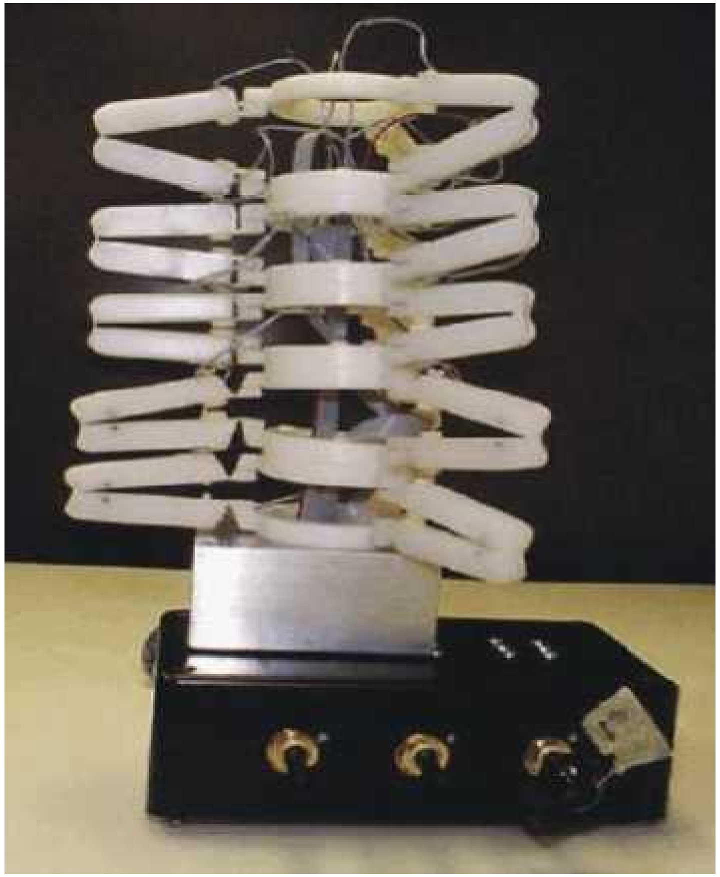
where A is the cross-sectional area of the cylinder, and μ is the thrust coefficient. The thrust coefficient depends on friction and air pressure; it approaches 1 at higher pressures, and so the force per area is the same as the supply pressure.

APLIKASI



SHAPE MEMORY ALLOY ACTUATOR

- Akan berubah jika diberikan suhu tertentu.

KARAKTERISTIK

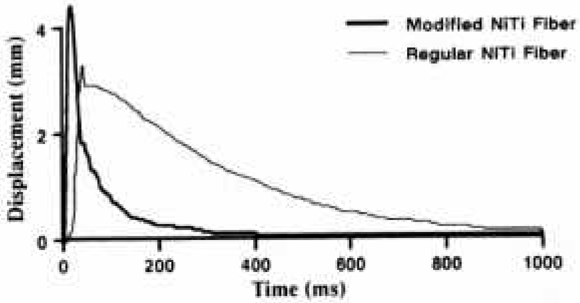


Figure 4: Displacement time function for NiTi for regular and modified fibers in response to a current pulse.

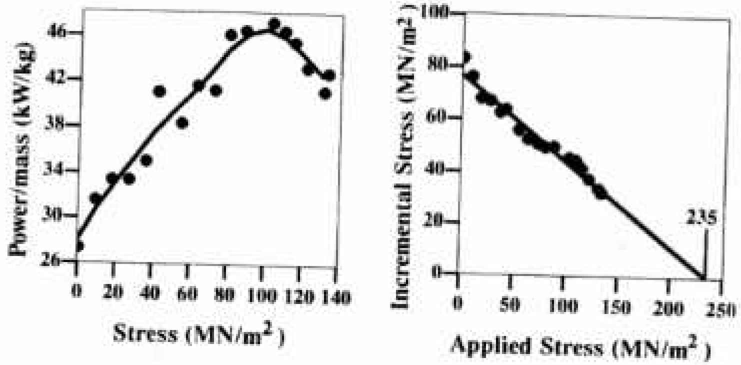
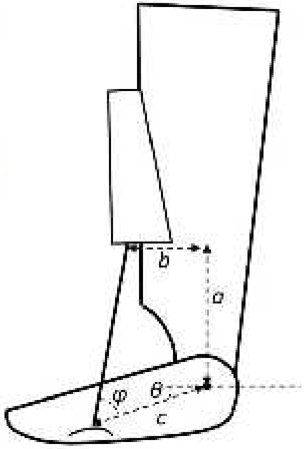
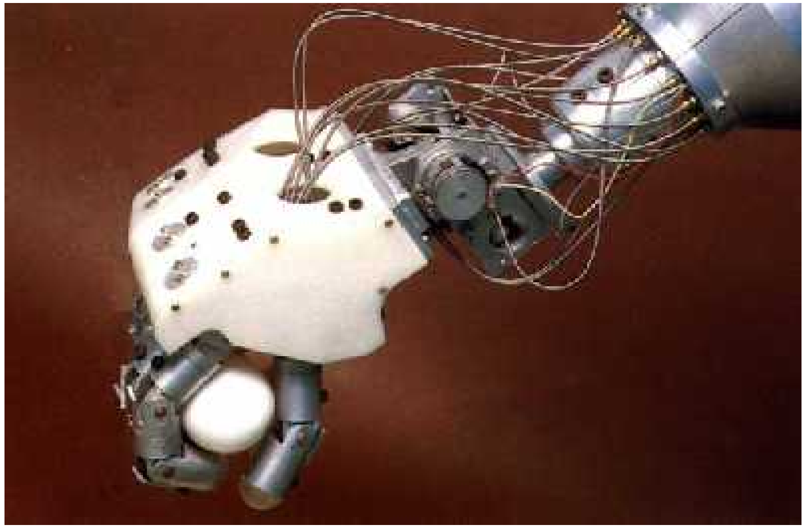


Figure 5: (a) Power/mass versus stress for NiTi. (b) Incremental stress versus applied stress.

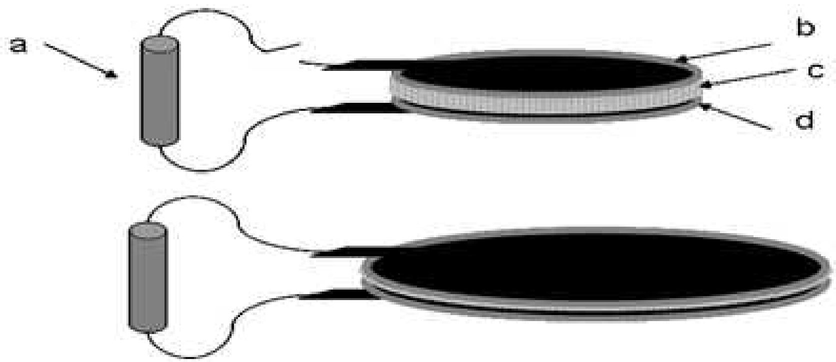
APLIKASI

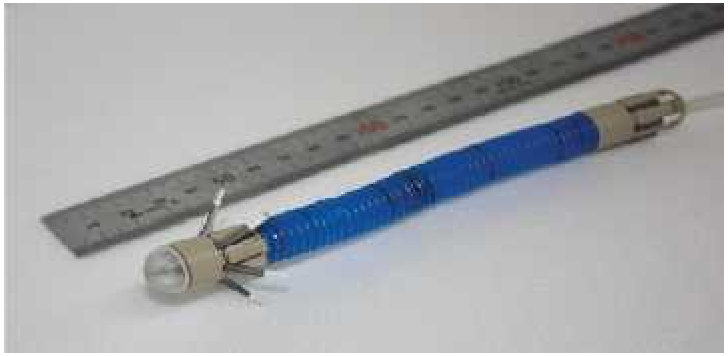


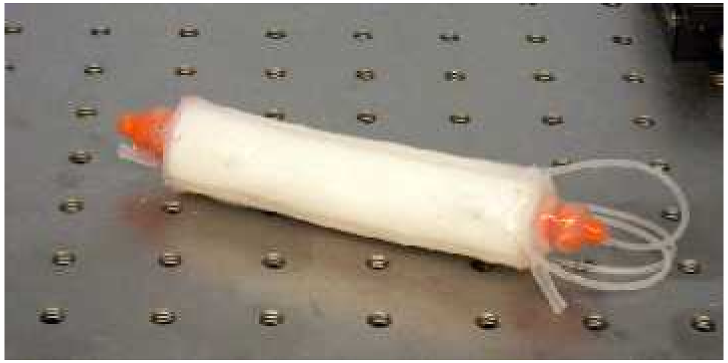


POLYMERIC ACTUATOR

- Mengubah dari larutan kimia atau larutan elektrolisasi menjadi energy gerak





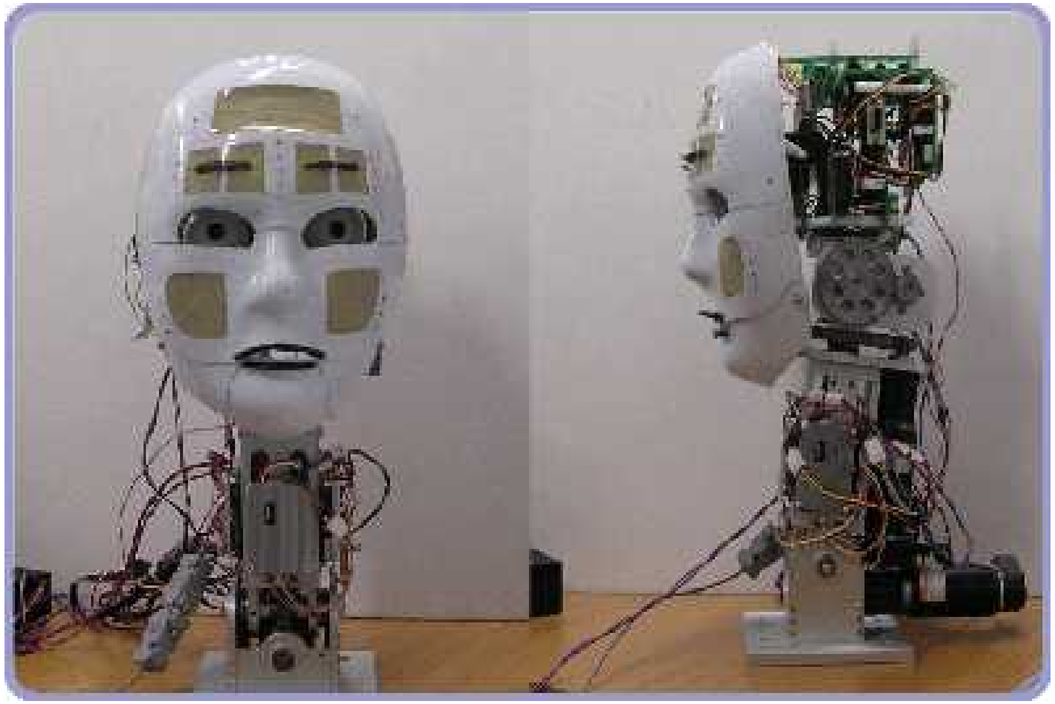


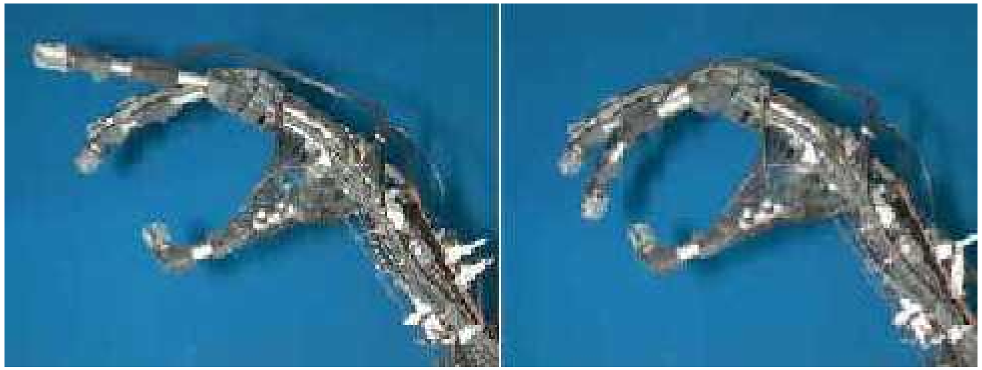
KARAKTERISTIK

Range of Motion	±85 °
Angular velocity	0.28 rad/s
Maximum torque	1.1 N·m
Torque/mass	1.2 N·m/kg
Output power	6.32 W
Efficiency	5.7 %
Power/mass (NiTi)	216.4 W/kg
Power/mass (motor)	5.75 W/kg

Table 4: NiTi actuator developed by Hirose *et al.* (1989).

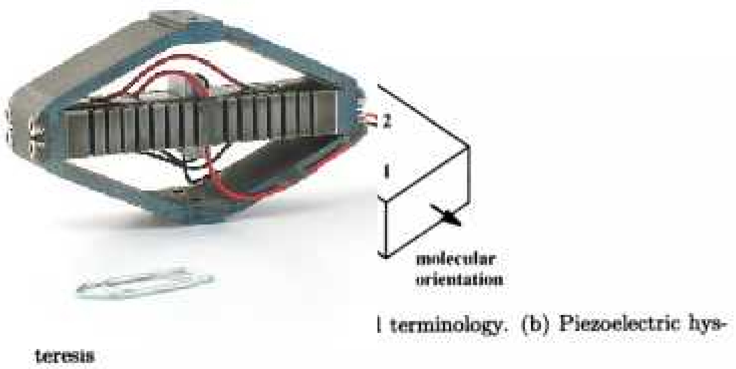
APLIKASI

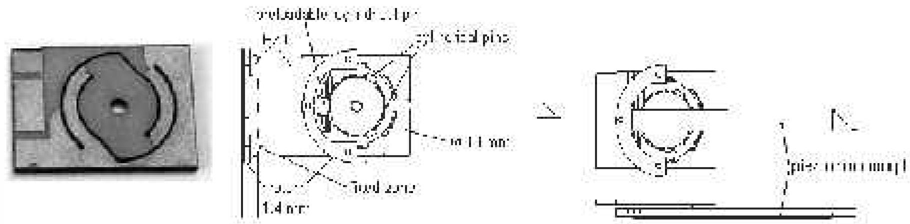




PIEZOELECTRIC ACTUATOR

- Menggunakan picuan tegangan untuk merubah gaya atau tekanan pada kristal





KARAKTERISTIK

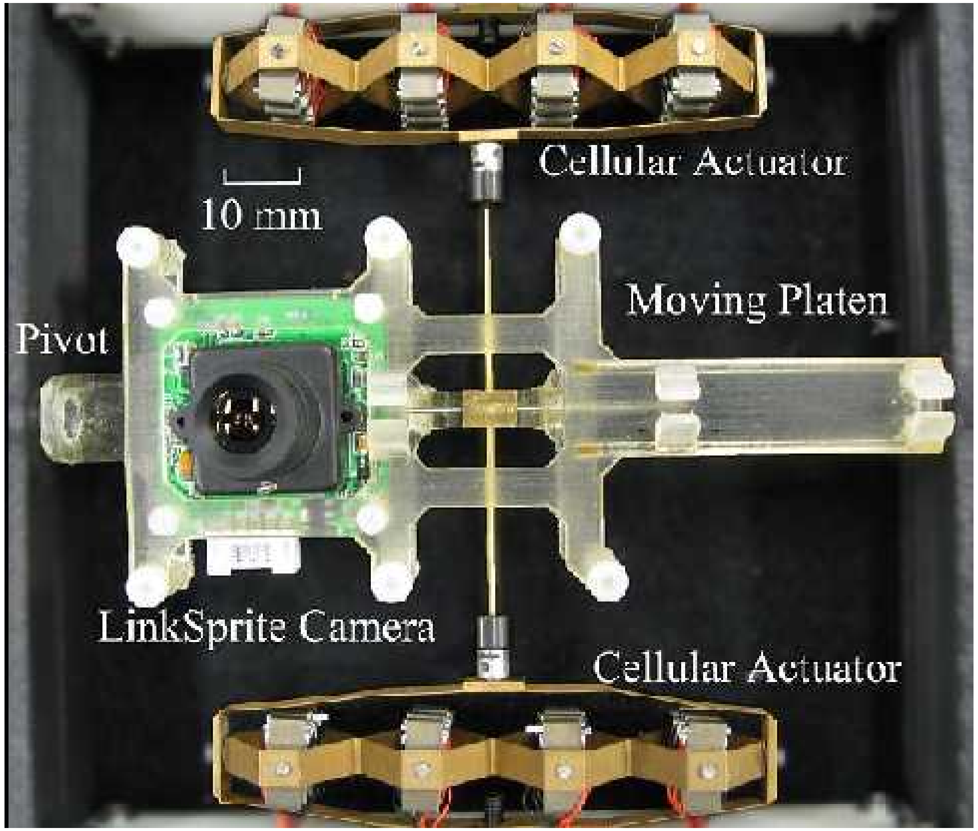
Constant name	Symbol	Value	Unit
Piezoelectric constant	d_{31}	-287	10^{-12} m/N
	d_{33}	635	
Elastic modulus	c_1	67.6	10^9 N/m^2
	c_3	55.2	
Density	ρ	8.0	10^3 kg/m^3

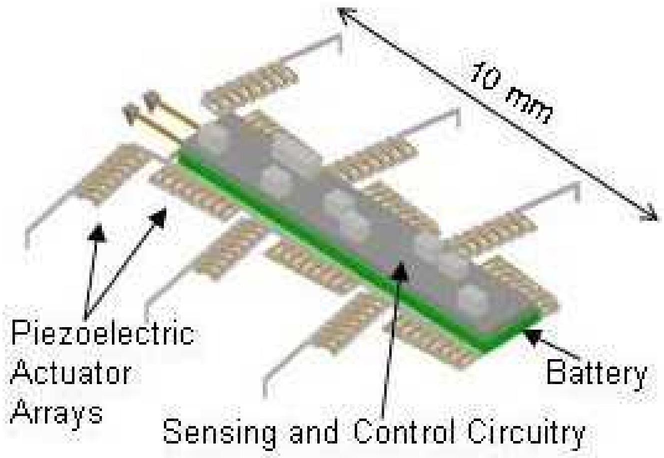
Table 5: Material constants for piezoelectric ceramic NEPEC-10.

Constant name	Symbol	Value
Maximum strain	s_1	-0.3×10^{-3}
	s_3	0.6×10^{-3}
Electromechanical conversion efficiency	k_1	0.16
	k_3	0.46

Table 6: Comparison of transverse and longitudinal piezoelectric effects in NEPEC-10.

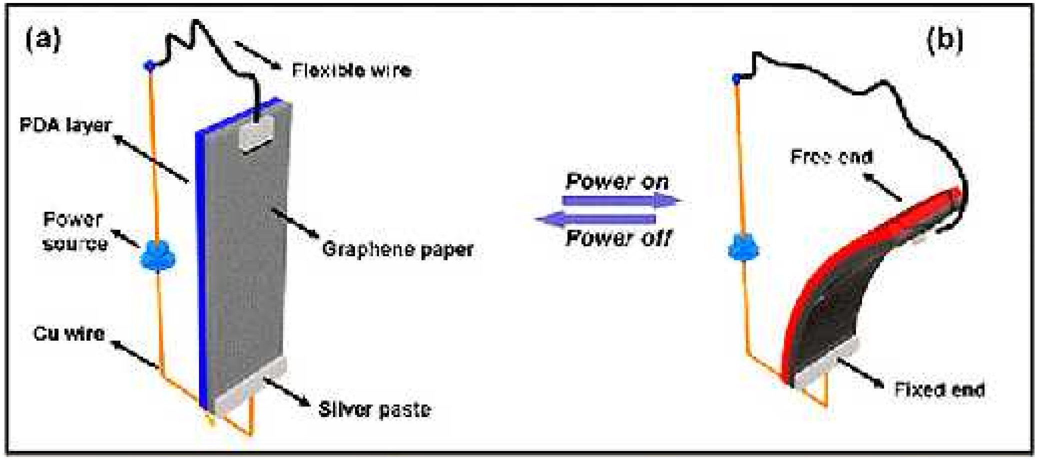
APLIKASI


Cellular Actuator
10 mm
Moving Platen
Pivot
LinkSprite Camera
Cellular Actuator


10 mm
Piezoelectric Actuator Arrays
Battery
Sensing and Control Circuitry

MAGNETOSTRICTION

- Energi magnet yang digunakan untuk pergerakan mekanik.



KARAKTERISTIK

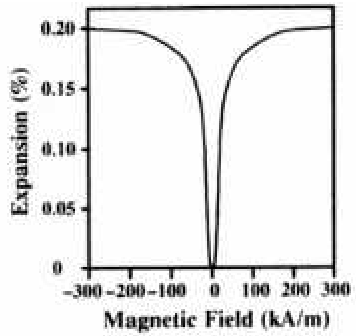
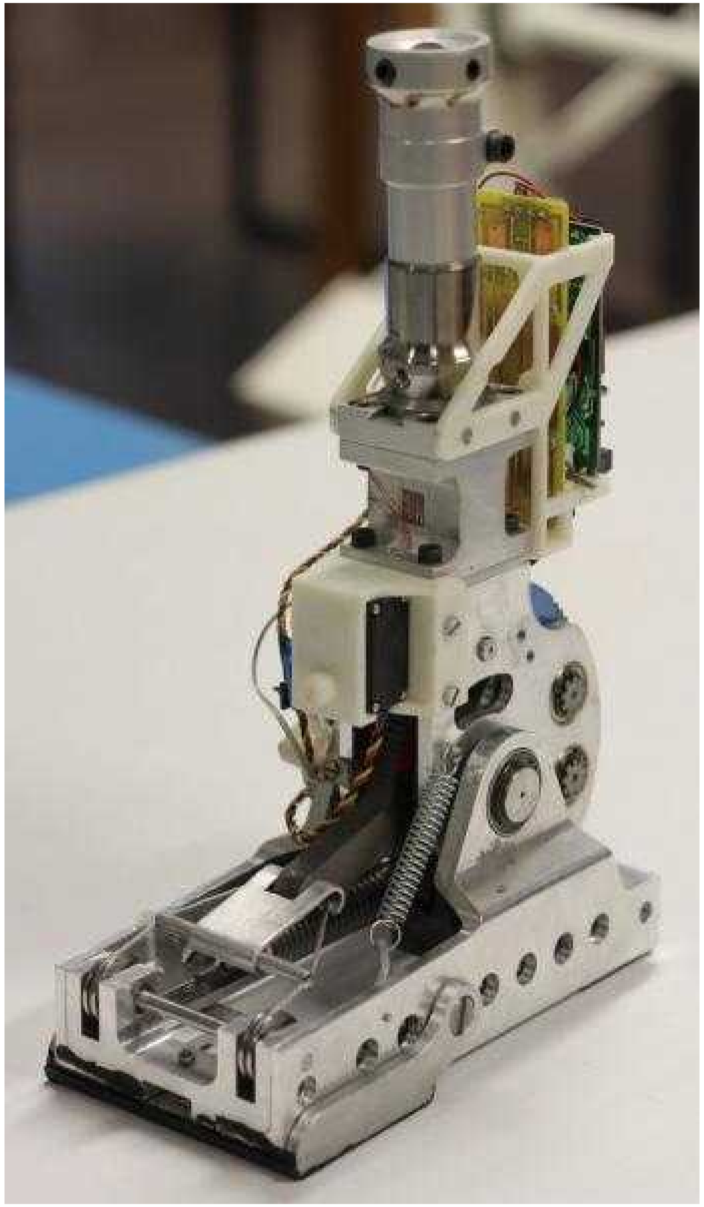
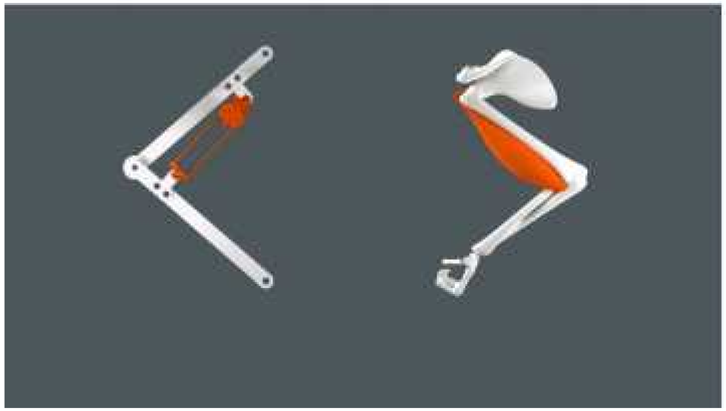


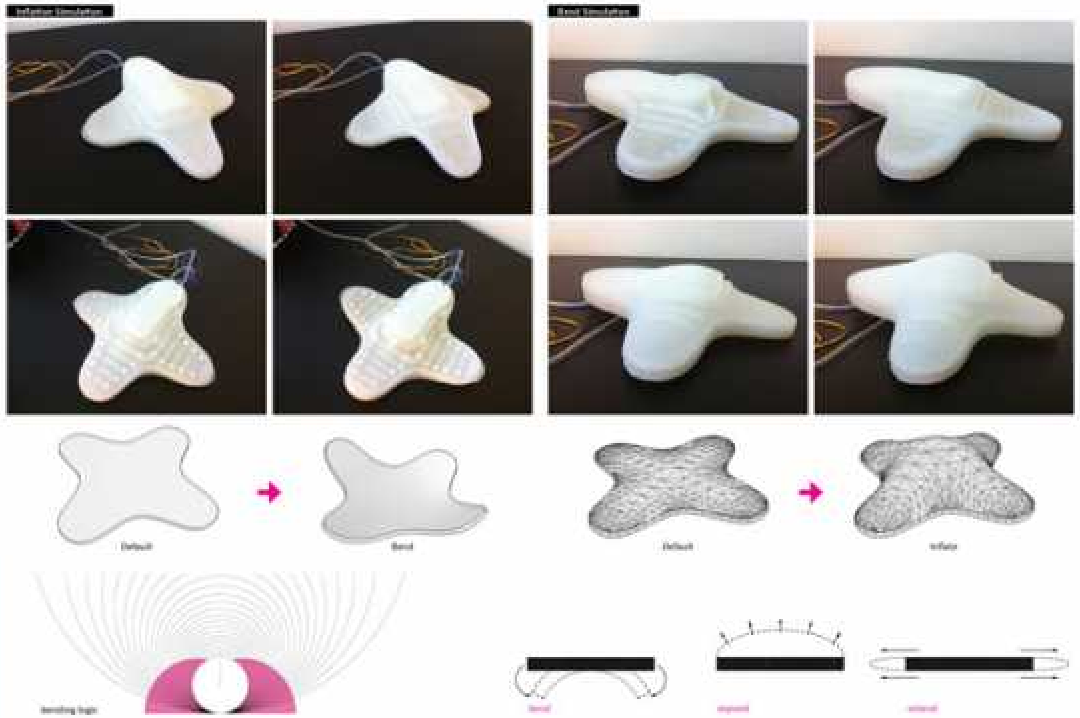
Figure 7: Expansion of Terfenol-D as a function of magnetic field strength.

APLIKASI



MUSCLE, NATURE'S ACTUATOR





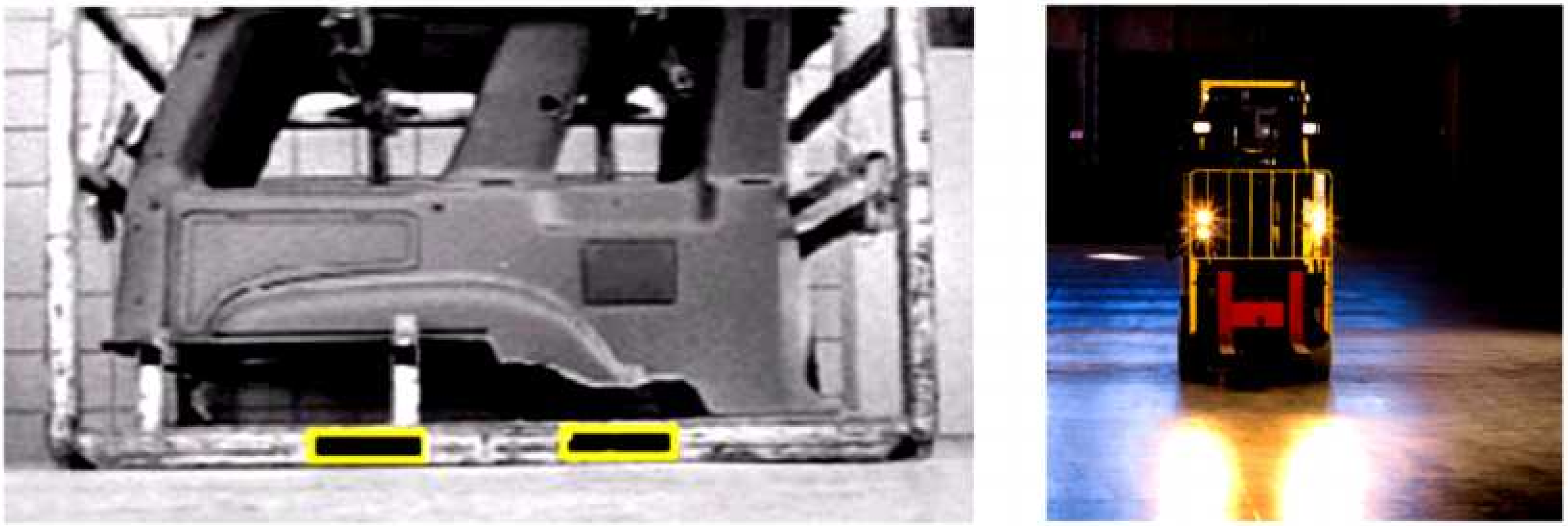
SENSOR

ROBOTIKA

Andik Asmara

Ref: Václav Hlaváč, Czech Republic

Dimana Lubangnya?



Autonomous forklift for material handling

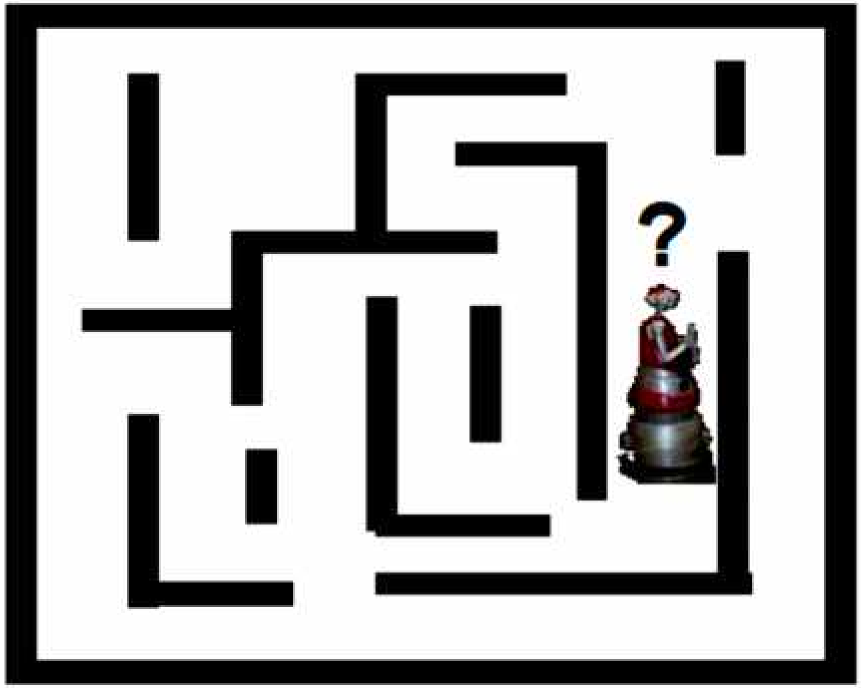
Apakah Robot Akan Mengenai Sesuatu?

Obstacle detection

Dimana Garisnya?

Autonomous harvesting

Dimana Posisi Saya?



Localization in the environment

Fungsi Sensor Robot

- Sebagai penghubung anatara robot dengan sekitarnya
- Robot perlu untuk mendeteksi segala sesuatu yang ada disekitarnya
- Setiap sensor memiliki prinsip tranduser, yaitu merubah suatu energy kebesaran tertentu
- Sensor mengukur besaran fisik, tidak menghasilkan besaran sendiri

Kasifikasi dari sensor

- **Proprioceptive** (Pengukuran pada diri sendiri)

Pengukuran pada sistem internal (dalam diri robot), meliputi battery level, posisi roda, derajat putaran atau poros

- **Exteroceptive** (pengukuran diluar diri robot)

Mengukur sesuatu yang ada disekitar, benda disekitar.

Klasifikasi dari Sensor

- Aktif (menghasilkan energy)

Contoh:

- Pasif (hanya menerima energy)

Contoh:

Klasisfikasi Sensor Lebih spesifik

General classification (typical use)	Sensor Sensor System	PC or EC	A or P
Tactile sensors (detection of physical contact or closeness; security switches)	Contact switches, bumpers	EC	P
	Optical barriers	EC	A
	Noncontact proximity sensors	EC	A
Wheel/motor sensors (wheel/motor speed and position)	Brush encoders	PC	P
	Potentiometers	PC	P
	Synchros, resolvers	PC	A
	Optical encoders	PC	A
	Magnetic encoders	PC	A
	Inductive encoders	PC	A
	Capacitive encoders	PC	A
Heading sensors (orientation of the robot in relation to a fixed reference frame)	Compass	EC	P
	Gyroscopes	PC	P
	Inclinometers	EC	A/P

A, active; P, passive; P/A, passive/active; PC, proprioceptive; EC, exteroceptive.

Klasisfikasi Sensor Lebih spesifik

General classification (typical use)	Sensor Sensor System	PC or EC	A or P
Ground-based beacons (localization in a fixed reference frame)	GPS Active optical or RF beacons Active ultrasonic beacons Reflective beacons	EC EC EC EC	A A A A
Active ranging (reflectivity, time-of-flight, and geometric triangulation)	Reflectivity sensors Ultrasonic sensor Laser rangefinder Optical triangulation (1D) Structured light (2D)	EC EC EC EC EC	A A A A A
Motion/speed sensors (speed relative to fixed or moving objects)	Doppler radar Doppler sound	EC EC	A A
Vision-based sensors (visual ranging, whole-image analysis, segmentation, object recognition)	CCD/CMOS camera(s) Visual ranging packages Object tracking packages	EC	P

Karakteristik Kemampuan Sensor

- Pengukuran pada alam sebenarnya, rawan terjadi kesalahan.
- Dasar penilaian kemampuan sensor:

Dynamic range: Rasio antara batas atas dan bawah, biasanya dalam desibel.
Rentang: Perbedaan antara min dan max.
Resolusi: Perbedaan Minimum antara dua nilai.
Linearitas: Variasi sinyal output karena fungsi dari sinyal input.
Bandwidth atau frekuensi: Kecepatan yang sensor dapat memberikan aliran pembacaan.

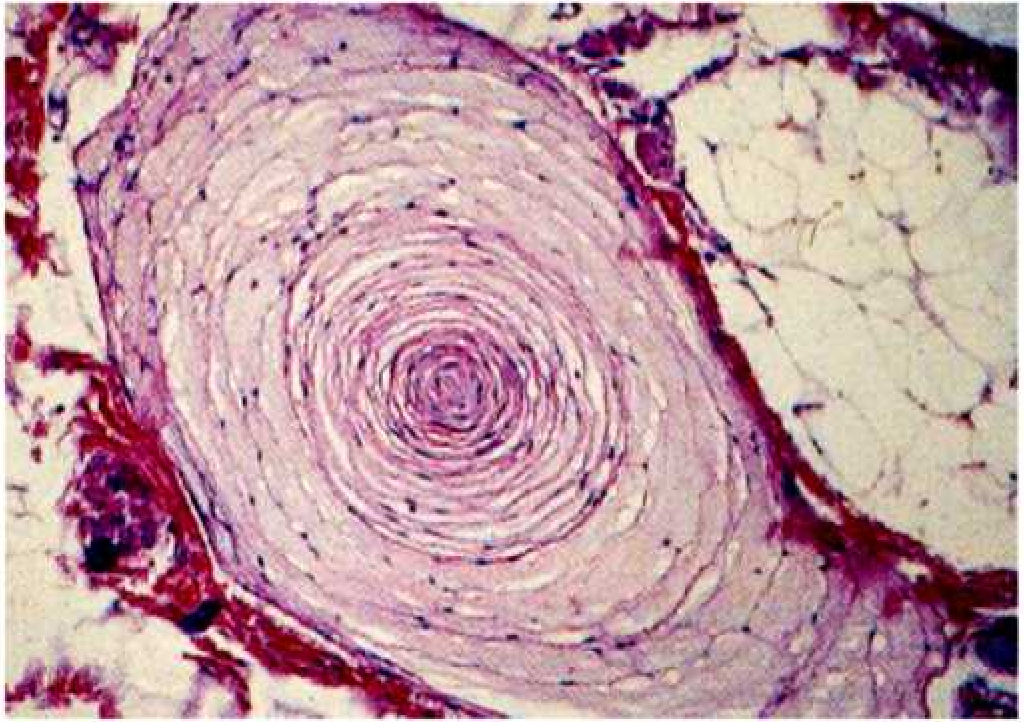
Kinerja Sensor

Karakteristik yang sangat relevan pada lingkungan dunia nyata,

- Sensitivitas: Rasio perubahan output dengan perubahan masukan.
- Cross-Sensitivitas: Sensitivitas terhadap parameter lingkungan yang ortogonal dengan parameter sasaran.
- Kesalahan / Accuracy: Perbedaan antara output sensor dan nilai sebenarnya.
- Systematic / deterministik Kesalahan: Disebabkan oleh faktor-faktor yang dapat dimodelkan (dalam teori), misalnya, kalibrasi sensor laser.
- Kesalahan Acak: misalnya, ketidakstabilan rona kamera, hitam tingkat kebisingan kamera.
- Reproducibility: Reproducibility hasil sensor.

Perbandingan: Dengan Sensor Manuasia

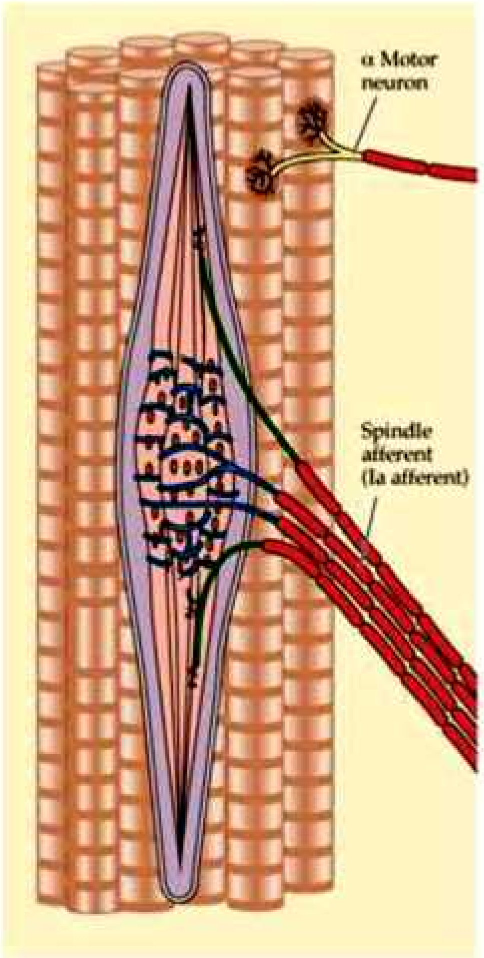
- To control our limbs, we need feedback on where they are.
- Muscle spindles *(svalové vřeténko)*.
- Pressure sensors in skin.

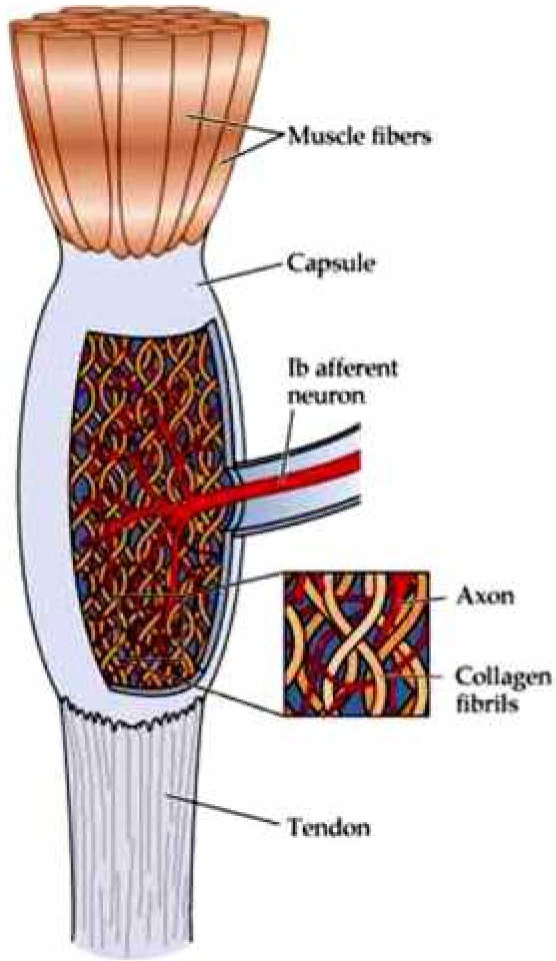


Pacinian corpuscle – transient pressure response

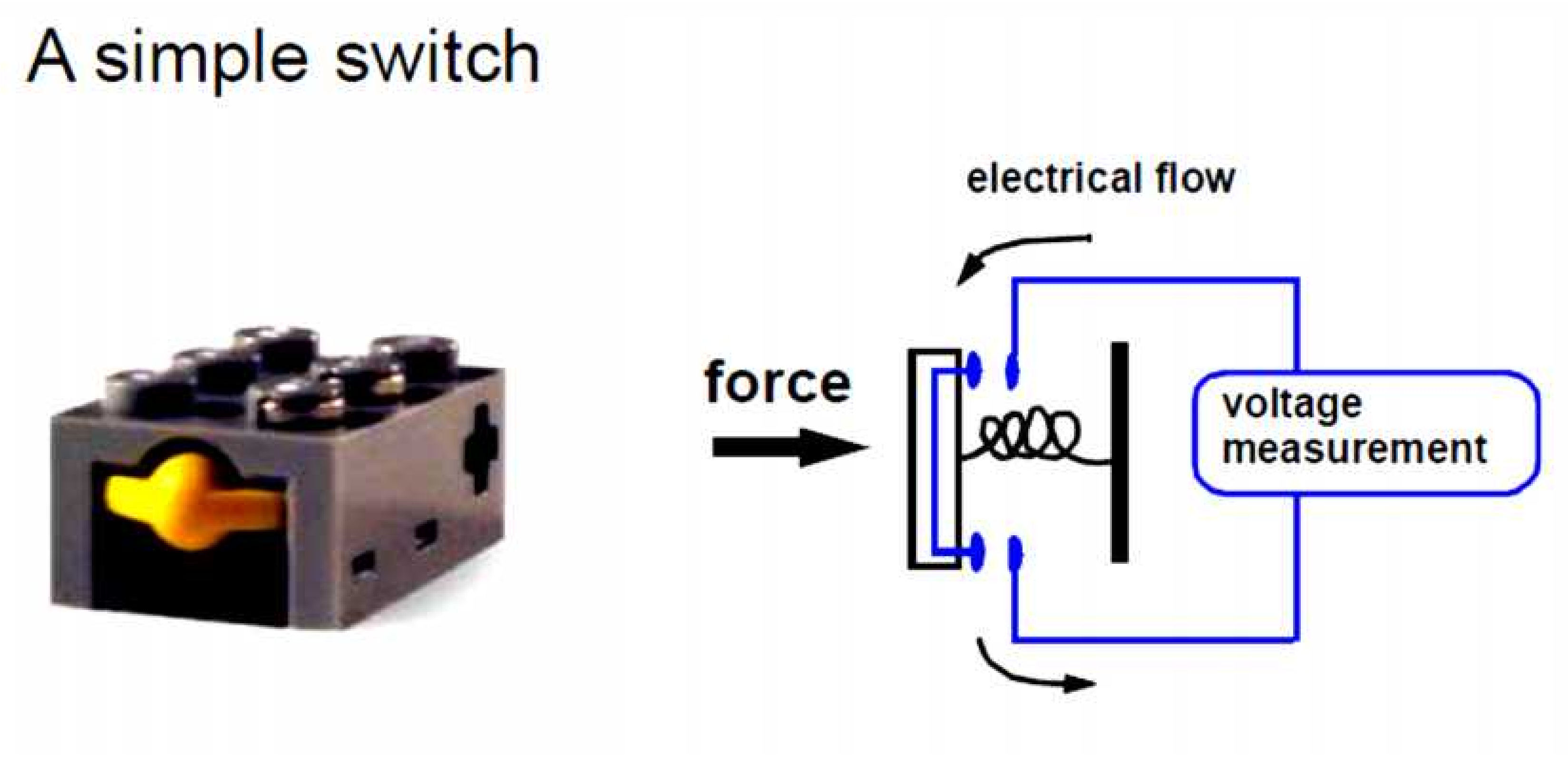
Sensor Manusia, Nilai Balik pada Otot

- To control our limbs we need feedback.
- Muscle spindles
  - where: length
  - how fast: rate of stretch
- Golgi tendon organ
  - how hard: force



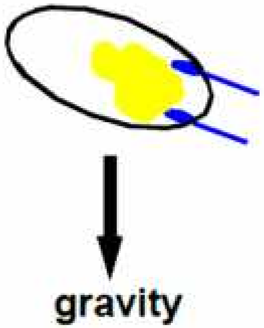


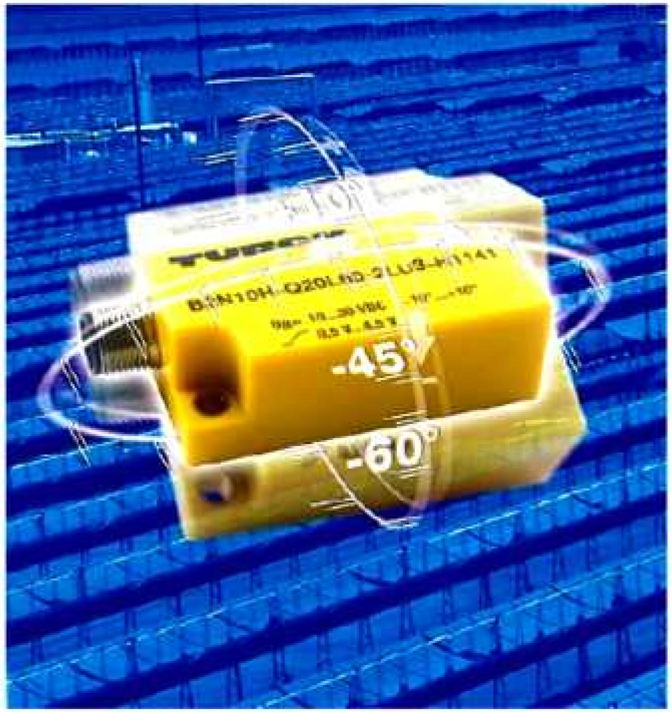
Sensor Sentuh Sederhana



Sensor Kemiringan

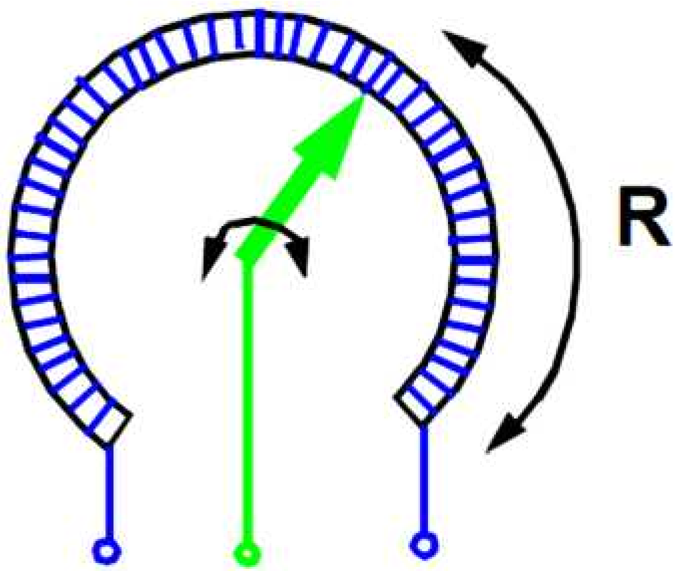
Mercury tilt switch, obsolete





Dual axis inclinometer

Sensor Posisi

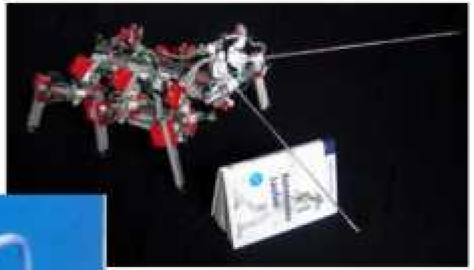


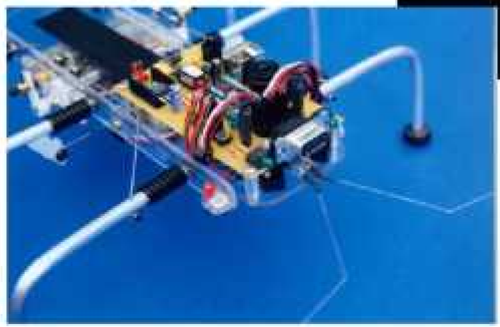
Resistance changes with the position of the dial

Kumis

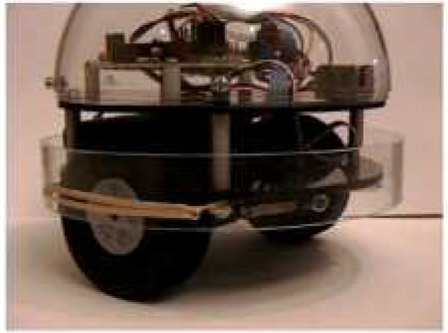
- Springy wire suspended through conductive "hoop".
- Deflection causes contact with "hoop".
- Reaches beyond robot a few centimeters.
- Simple, cheap, provides the binary output.

Contoh aplikasi



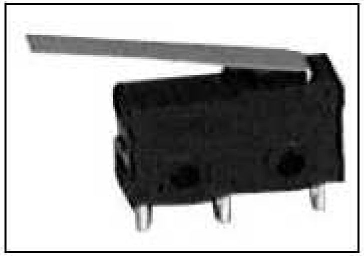


Bumpers

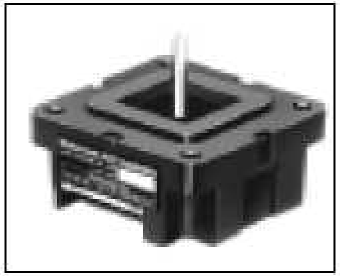


Contoh Microswitch

- One-directional reed switch.



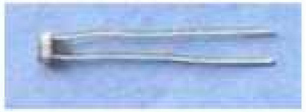
- Omni-directional reed switch.



- Roller contact switch.

Sensor Cahaya

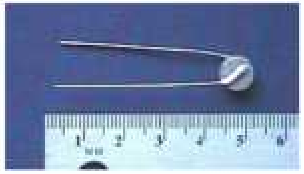
- Photoresistor.
- Photodiode.
- Differential photodiode.
- Phototransistor.



Photoresistor example

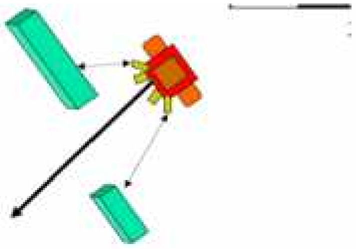
Sensor Suhu

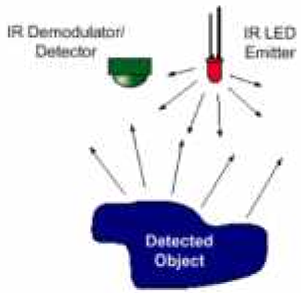
Thermal resistor
(thermistor)
example



Sensor Proximity

- Non-contact.
- Devices that can be used in areas that are near to an object to be sensed.
- Types:
  - Photocells.
  - Capacitance sensors.
  - Inductive sensors.

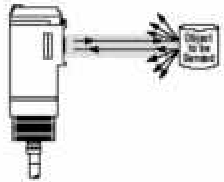




Photocells

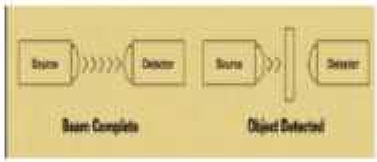
- Emitters LEDs, receivers phototransistors.

- Diffuse mode photosensor.



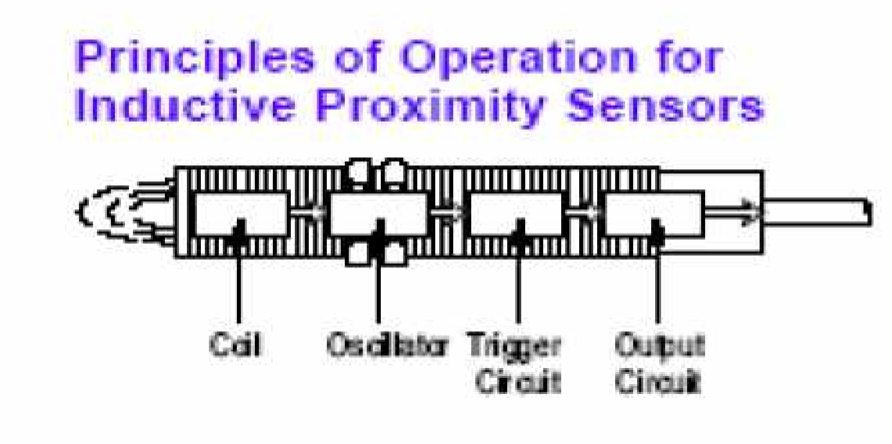
- Retro-Reflective Photosensors.

- Thru-beam detectors.



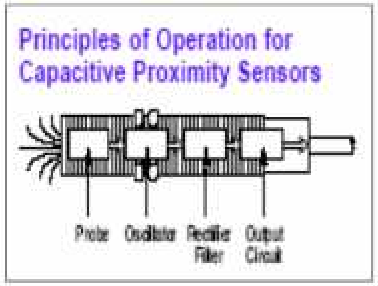
Sensor Proximity Induktif

- Detect Eddy current losses *(vířivý proud)*.
- Usually on/off mode only.
- They typically oscillate in ranges: 3 KHz – 1MHz.



Sensor Proximity Kapasitif

- Generate an electrostatic field.
- Consists of probe, oscillator, feliciter filter, output circuit.
- In absence of a target, the oscillator is inactive.
- An approaching target raises capacitance, which triggers the oscillator.



Contoh Penggunaan Kapasitif Sensor

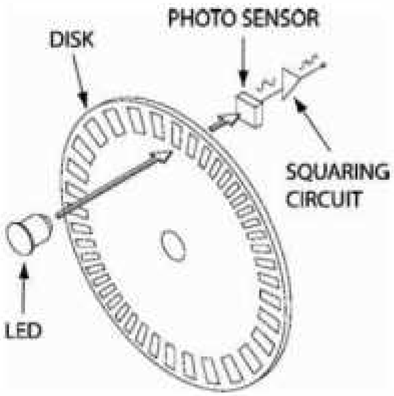
- When properly calibrated, the sensor can detect any higher dielectric material thru any lower dielectric material.
- Typical Application of Capacitive Sensor: Detecting Liquid (H_2O) levels in bottles.

Sensor Posisi

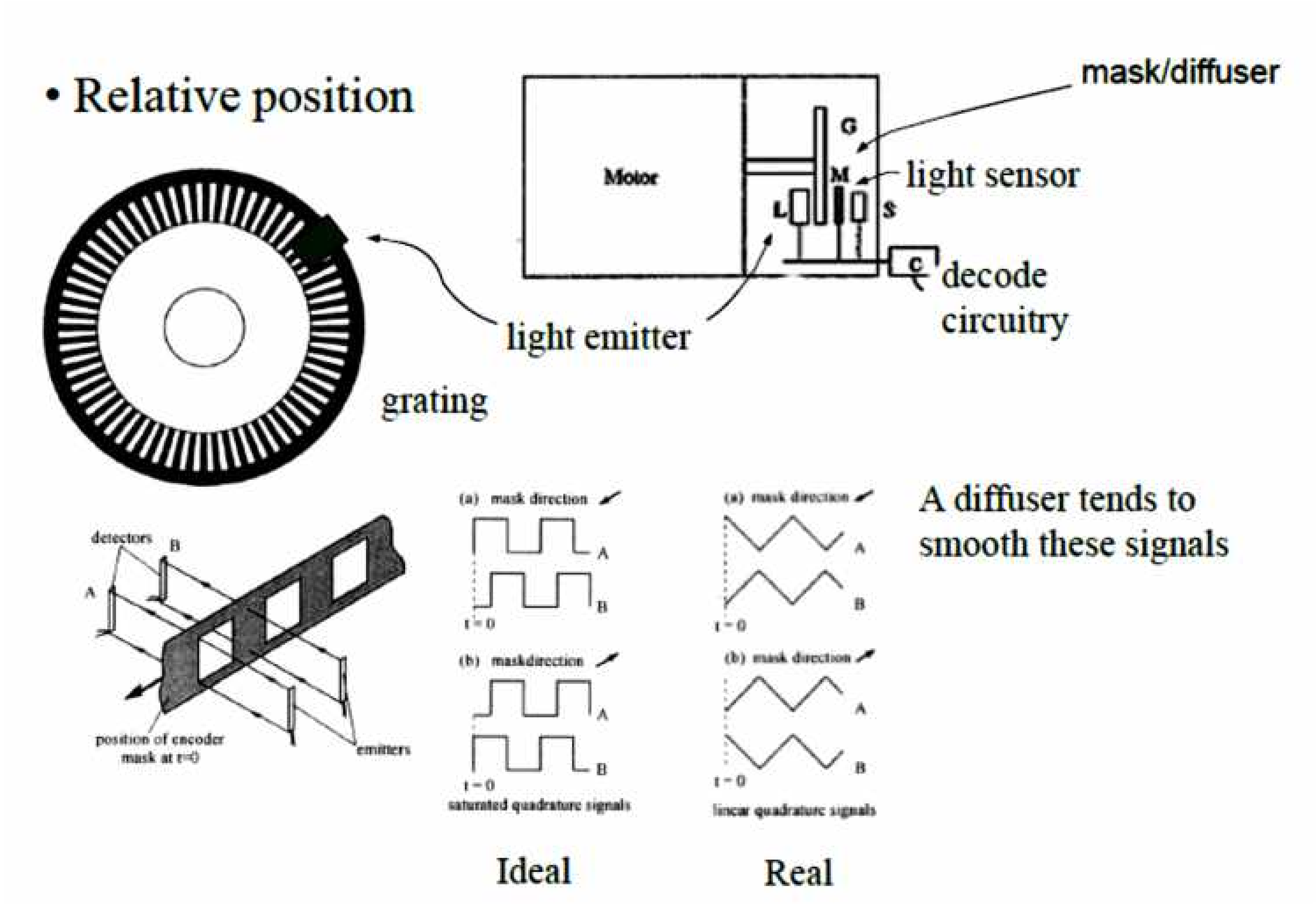
- Potenciometer
- Resolver
- Optical Encoders
  - Relative position
  - Absolute position

Encoder Motor/Roda

- Measure position, speed, direction of revolution of the wheel.
- **Odometry** - wheel movements can be integrated to get an estimate of the robots position.
- Typical resolutions of 2000 increments per revolution.
- Either relative or abslute.

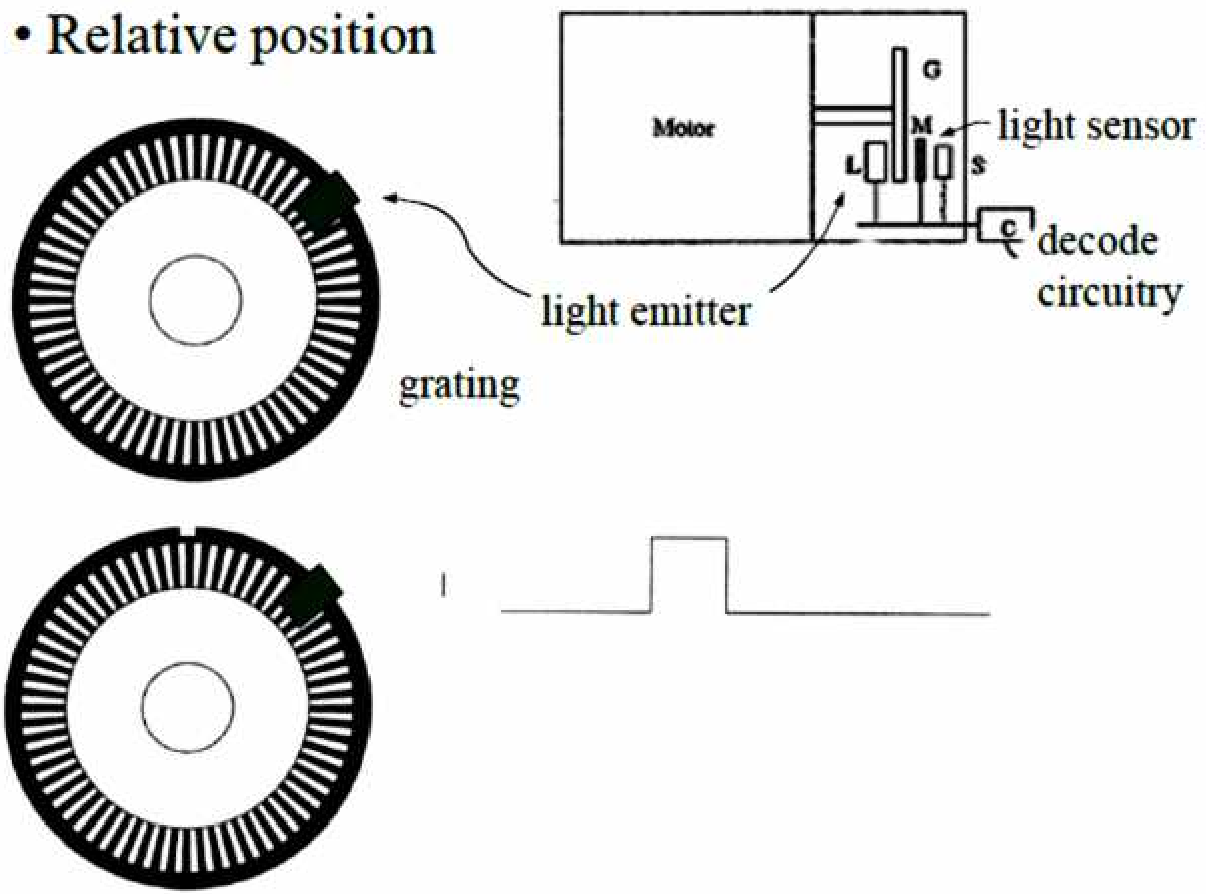


Optical Encoder



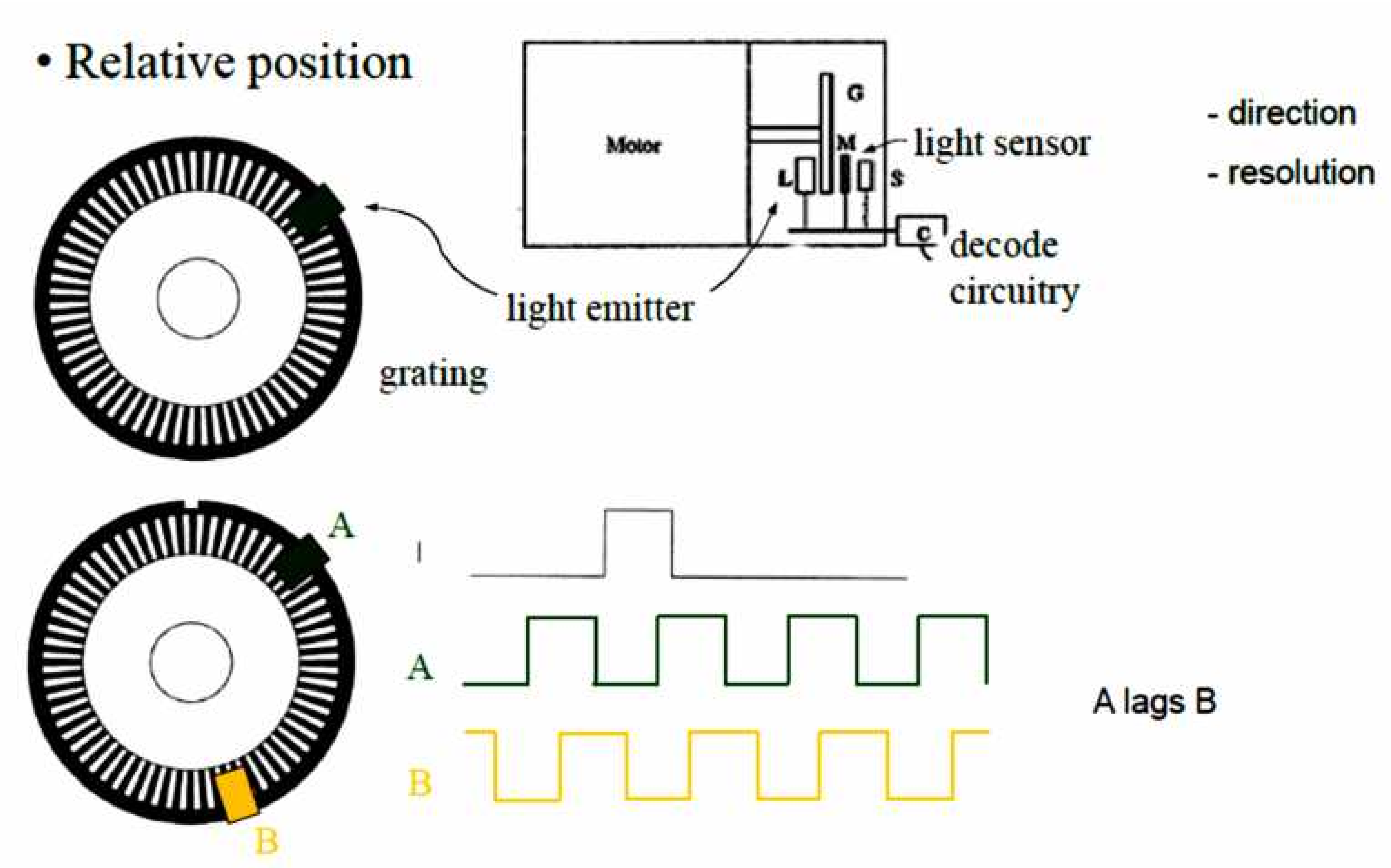
Optical Encoder

- Relative position



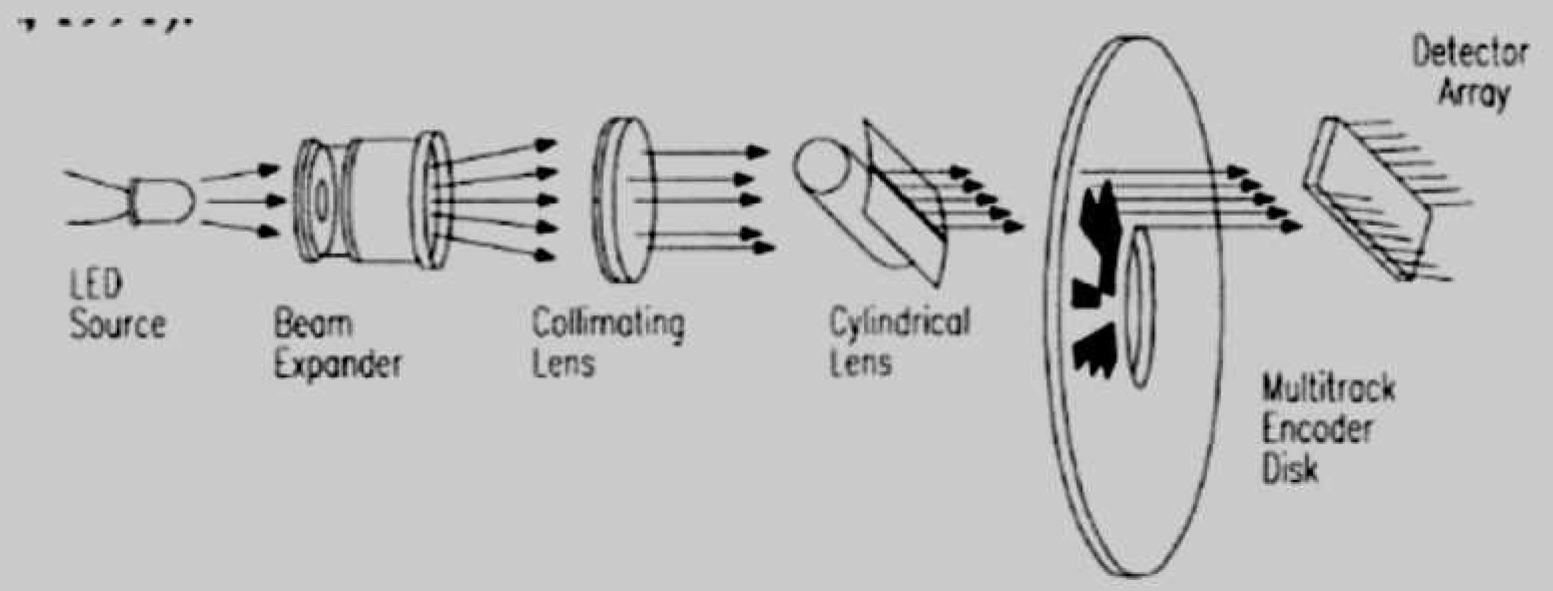
- direction
- resolution

Optical Encoder



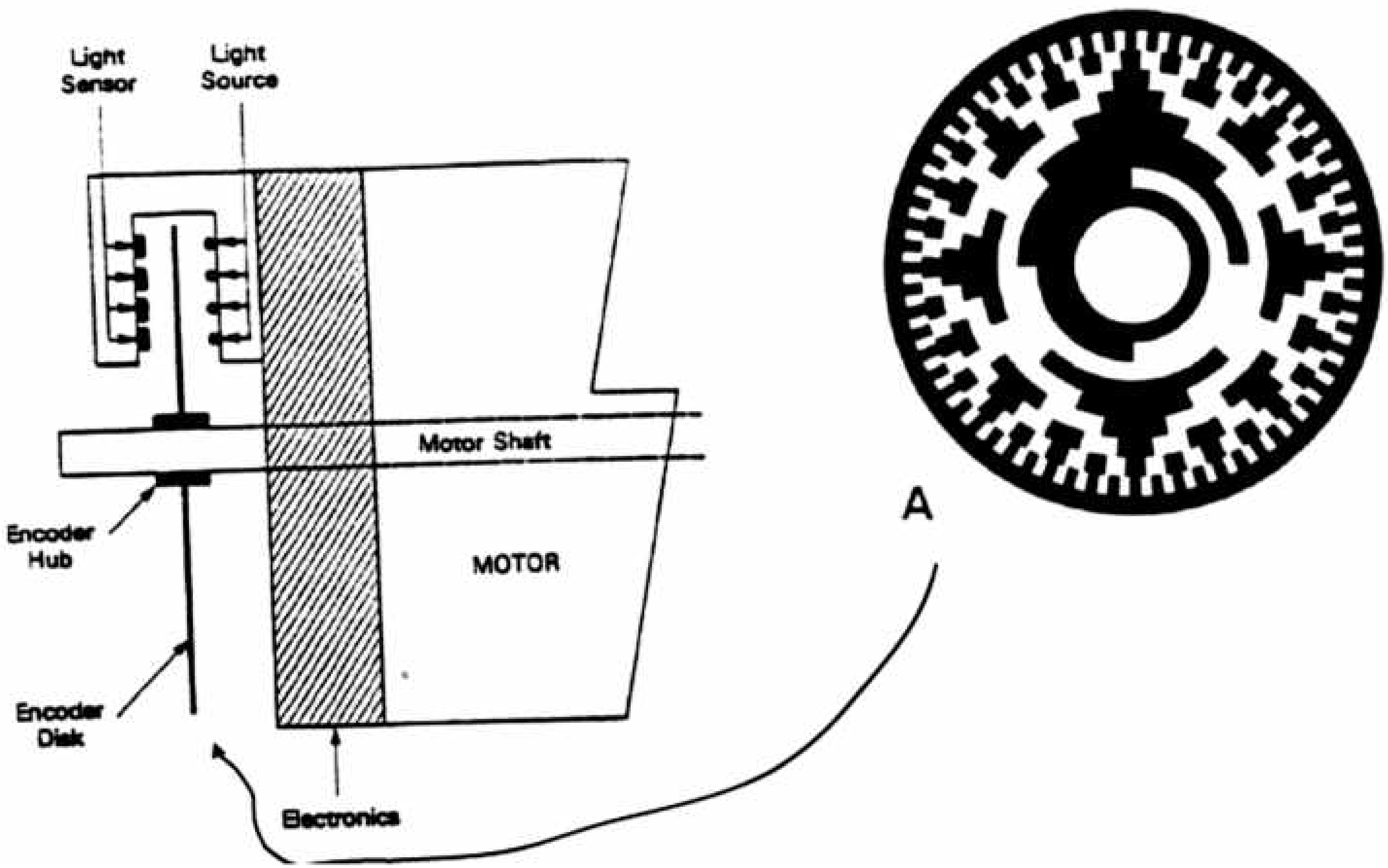
Optical Encoder

• **Detecting absolute position**



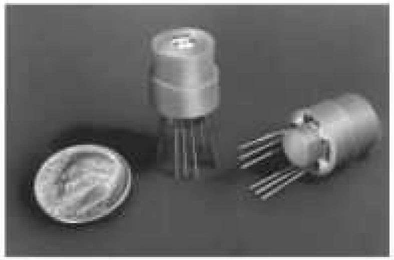
Optical Encoder

- Detecting absolute position



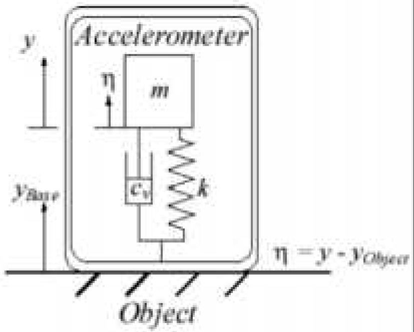
Kompas

- Several ways how to measure Earth magnetic field:
  - Mechanical magnetic compass.
  - Direct measure of the magnetic field (Hall-effect, magneto-resistive sensors).
- Major drawback
  - Weakness of the earth's magnetic field.
  - Easily disturbed by magnetic objects or other sources.
  - Not feasible for indoor environments.



Accelerometer

- By virtue of Newton's second law (F = ma) a sensor may be made to sense acceleration by simply measuring the force on a mass.
- Sensing force:
  - Magnetic.
  - Capacitive.
  - Piezoelectric.

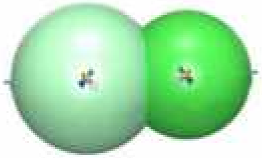


Gyroscope

- Heading sensors, that keep the orientation to a fixed frame.
- Gyroscopes are used in aeroplanes, Segways.
- Two gyroscope principles:
  - Mechanical (flywheel).
  - Electrical.

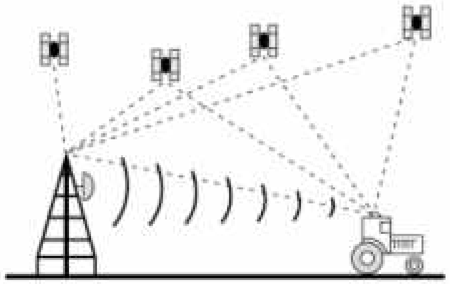
GPS (global Positioning System)

- 1 satellite = distance.
- 2 satellites = intersection of two spheres.
- 3 satellites = circle.
- ≥ 4 satellites = unique solution.
- Precision up to a few meters.



Pengukuran GPS

- Correction with respect to a base station with known position.
- Improved location accuracy, from the 15 m nominal GPS accuracy to about 10 cm for the best implementations.



Differential GPS System

Proximity Sensor

Robotika

Andik Asmara

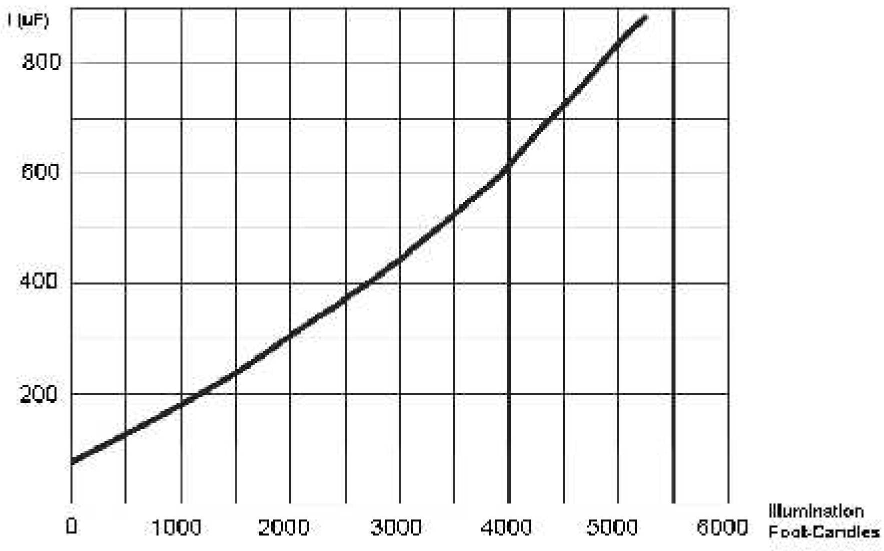
Dalam robot,

- Proximity light sensor
- Proximity inductive sensor
- Proximity capacitive sensor

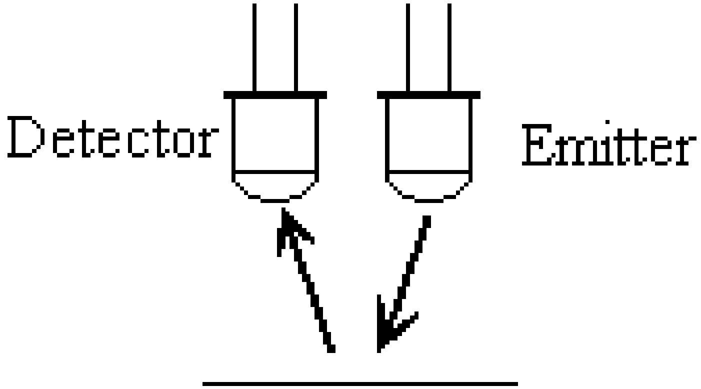
Proximity sensor cahaya

- Menggunakan photo diode/photo transistor

Fotodioda dapat mendeteksi ada tidaknya cahaya, dipasang secara reverse. Pemasangan secara reverse bertujuan untuk mendapatkan resistansi akan turun seiring dengan intensitas cahaya yang masuk.



Aplikasi



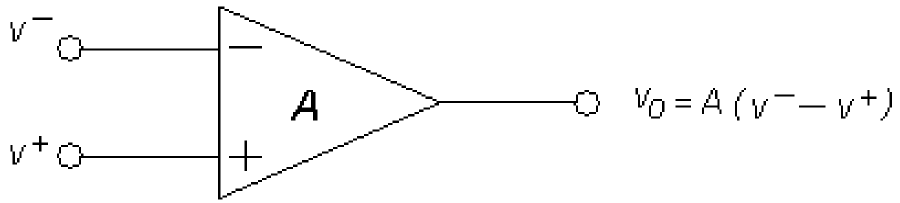
Sensor garis bekerja dengan memanfaatkan pantulan cahaya yang dipancarkan oleh LED yang ditangkap oleh fotodioda untuk membentuk pulsa logika digital pada keluaran sensor garis. Adanya perbedaan warna yang disensor maka terjadi adanya perbedaan intensitas yang mengakibatkan terjadinya perbedaan logika pada keluaran rangkaian.

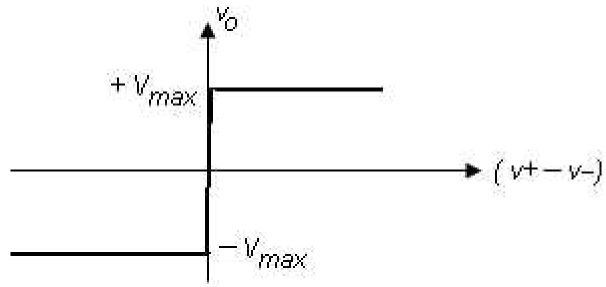
Pengkondisian signal

- OP-Amp
- Digunakan sebagai pembanding (comparator)

Pembanding tegangan merupakan cara sederhana untuk melakukan antarmuka antara dunia analog dan dunia digital. Pembanding mempunyai penguatan yang tinggi keadaan diferensial masukannya, cara yang sama ditemukan pada penguat operasi (*op-amp*). Keadaan *level* keluaran pembanding tegangan didesain hanya mengeluarakan dua *level* tegangan keluaran.

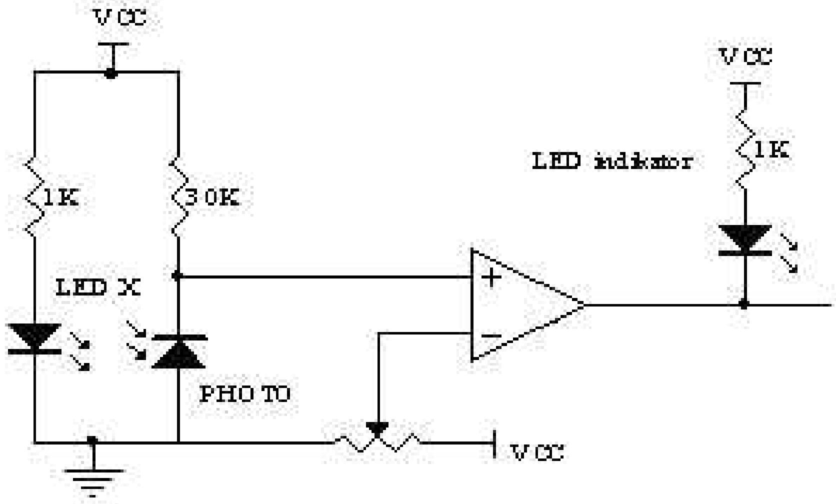
Rangkaian





Misalnya, apabila pada tegangan masukan + sedikit lebih tinggi dari pada tegangan masukan – maka dengan cepat penguat akan mengeluarkan tegangan maksimum positif keluaran, tapi apabila pada tegangan masukan – sedikit lebih tinggi dari pada tegangan masukan + maka penguat akan mengeluarkan tegangan maksimum negatif keluaran seperti yang terlihat pada Gambar

Aplikasi di Robot

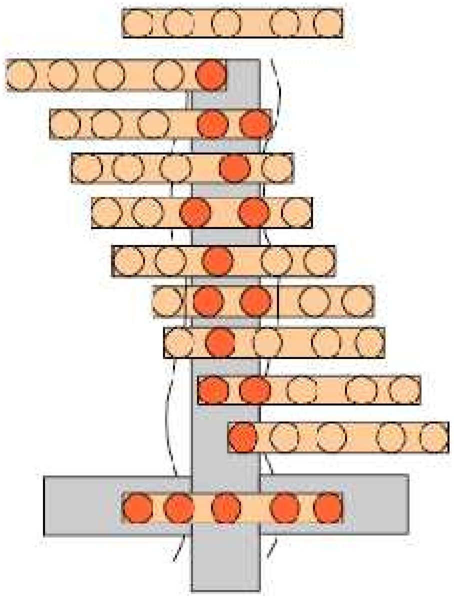


Sensor garis dirancang dengan menggunakan *bright* LED yang disejajarkan dengan fotodioda dengan arah yang sama dengan sistem pemantulan cahaya. LED diseri dengan *resistor* 1k ohm agar menyala, fotodioda diseri *resistor* 100k ohm dan dibandingkan oleh komparator dengan tegangan *variable resistor* yang digunakan untuk kalibrasi sensor. LED indikator digunakan untuk mengetahui keadaan sensor membaca objek.

Kerja sensor

Pengaruh Jumlah Sensor

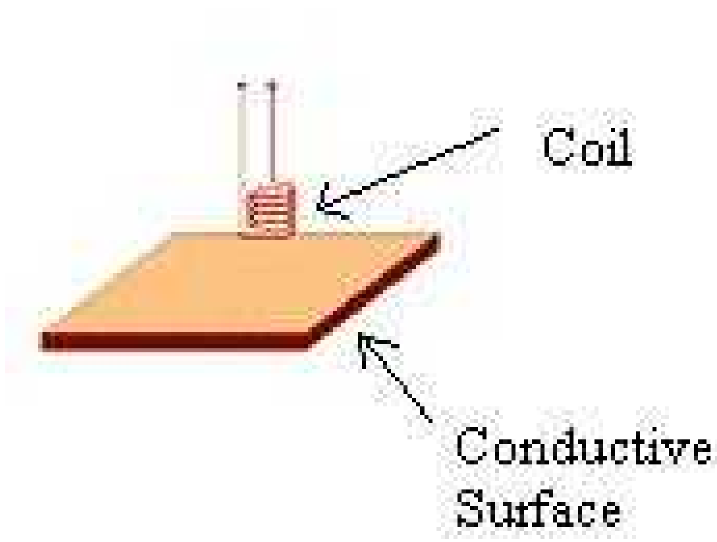
- 00000 – Kehilangan garis / garis patah
- 00001 - Hampir diluar jalur, kemudikan ke kanan dan kurangin kecepatan
- 00011 – sensor terlalu ke kiri i, kemudikan ke kanan
- 00010 – sensor ke kiri, kemudikan ke kekanan
- 00110 – sensor agak kekiri, Kemudikan kekanan
- 00100 – di dalam jalur, tingkatkan kecepatan
- 01100 – sensor agak ke kanan, kemudikan ke kiri
- 01000 – sensor ke kanan, kemudikan ke kiri
- 11000 – sensor terlalu kekanan, kemudikan ke kiri
- 10000 – sensor hampir diluar jalur, kemudikan ke kiri dan kurangi kecepatan
- 11111 – ada simpangan



Inductive Proximity Sensor

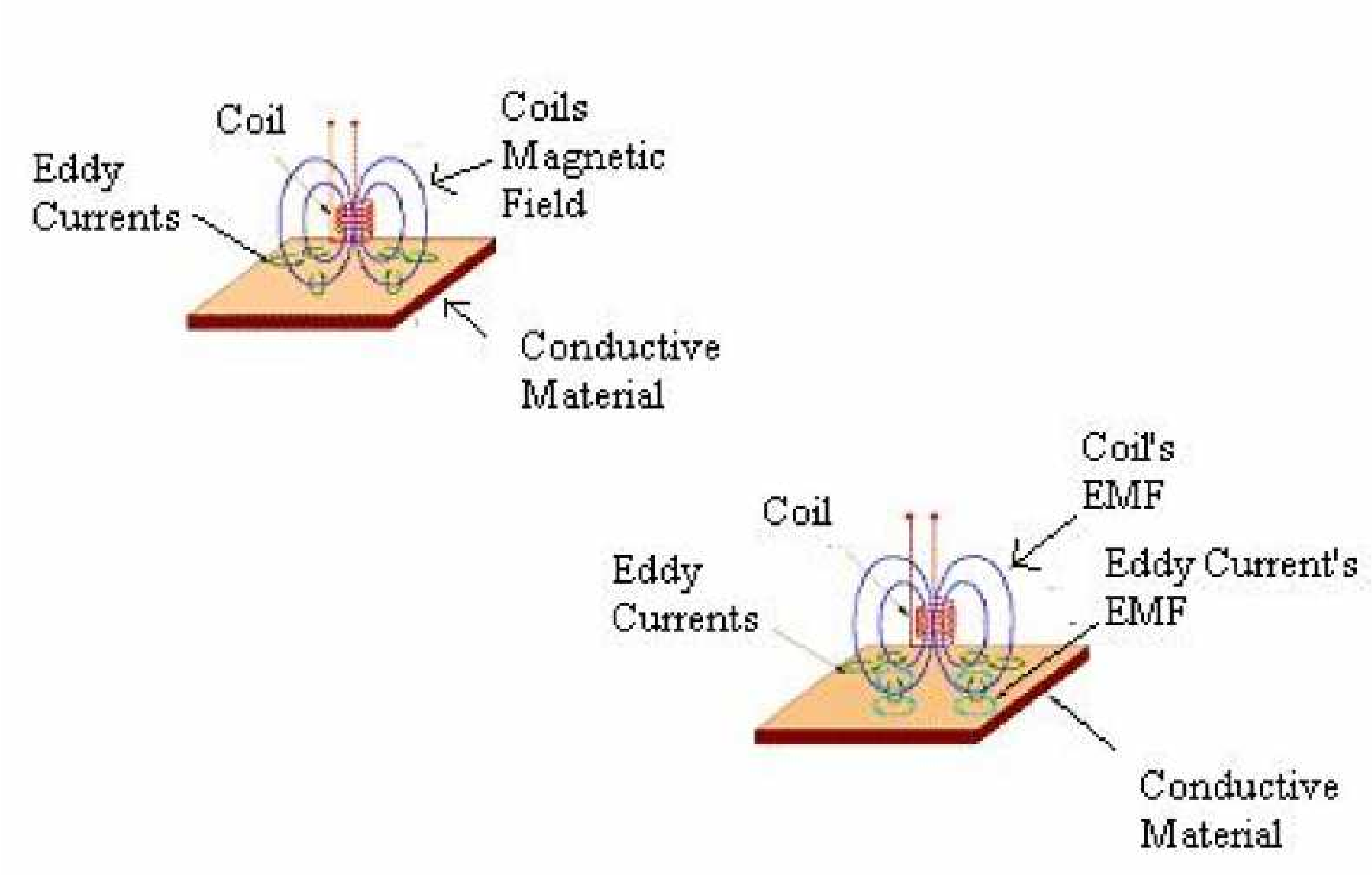
- Menggunakan prinsip eddy current yang banyak dimanfaatkan diindustri.
- Sensor dapat bekerja dengan baik walaupun dalam keadaan sekitar yang extreme
- Menggunakan prinsip induktansi, yaitu jarak antara inductor dan materi

Bagaimana eddy current bekerja

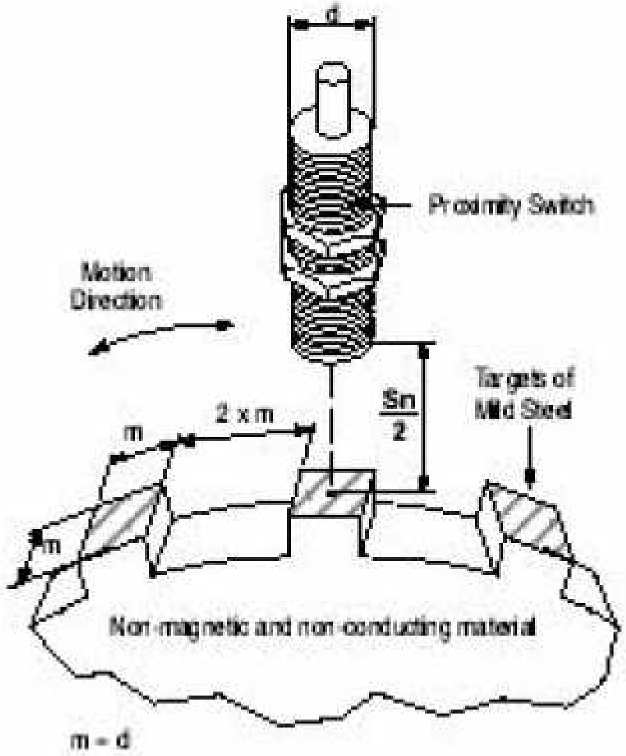


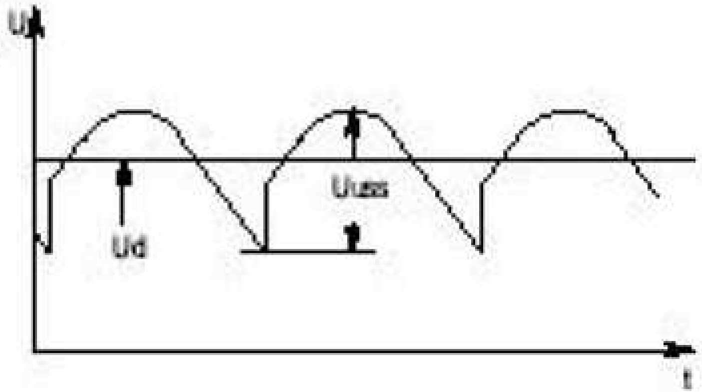
- Kumparan inductor didekatkan pada permukaan inductor
- Diberikan tegangan ac dengan frekuensi 2Mhz
- Maka induktansi mulai terjadi

Bagaimana bekerja



Aplikasi


d
Proximity Switch
Motion Direction
Targets of Mild Steel
2 x m
m
Sn
2
m
Non-magnetic and non-conducting material
m = d


U
Uss
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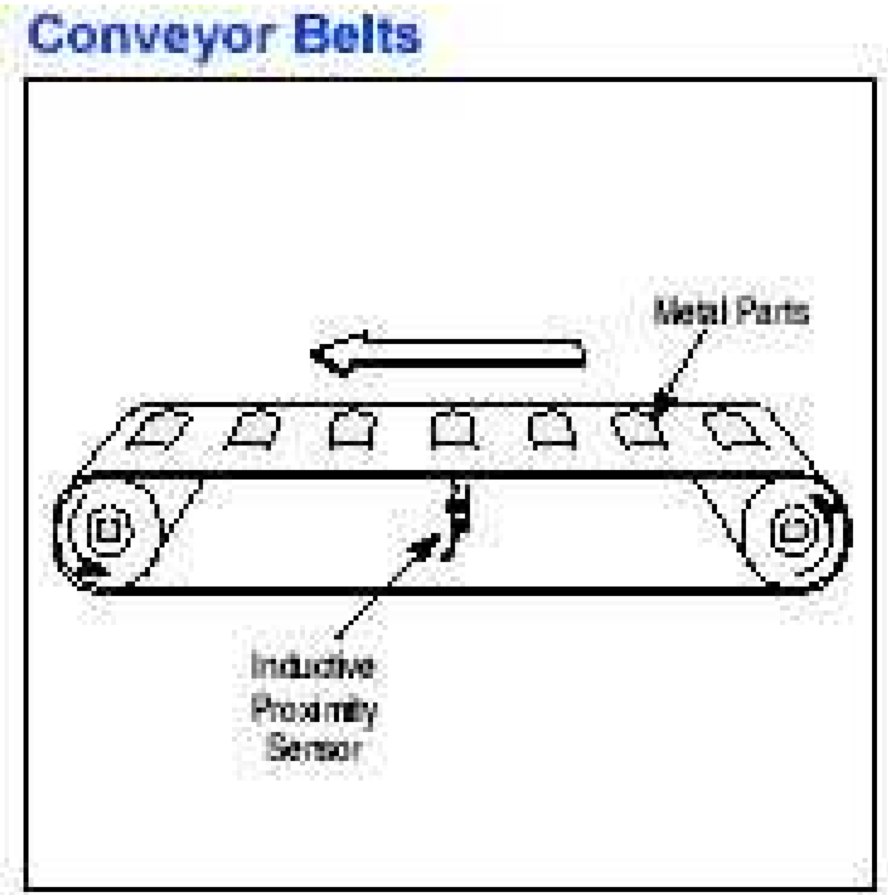
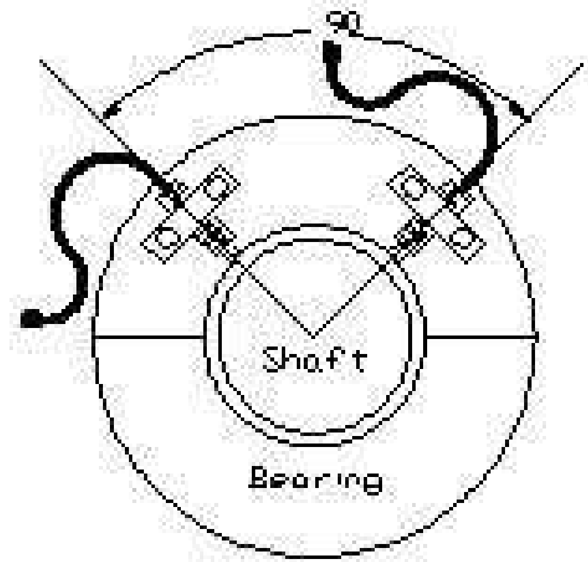
Aplikasi dalam penghitung

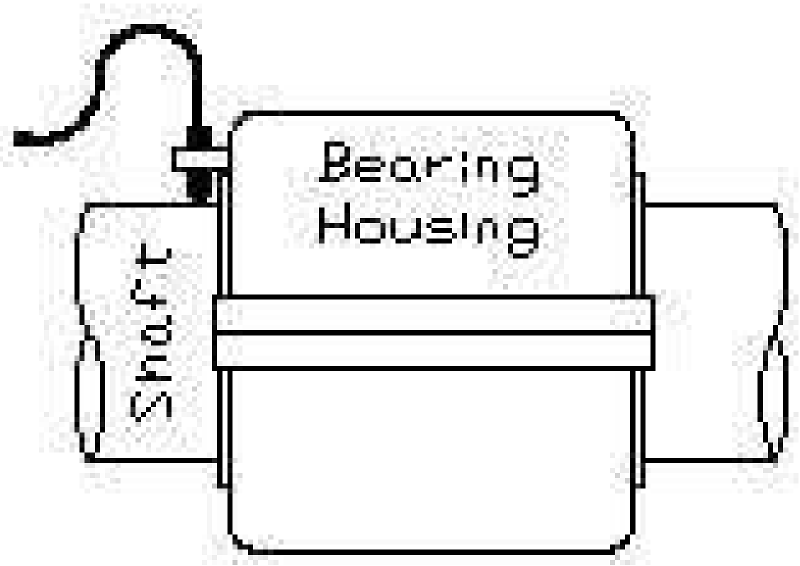


Aplikasi pada Power system

Dua sensor induktif dapat digunakan untuk memantau kesehatan turbin. Ketika ditempatkan 90 derajat , dapat memantau posisi X dan Y poros seperti berputar Ketika bantalan mulai keluar , gerakan di X dan arah Y mulai meningkat. Hal ini terdeteksi oleh sensor , dan bantalan bisa diganti sebelum kerusakan serius terjad

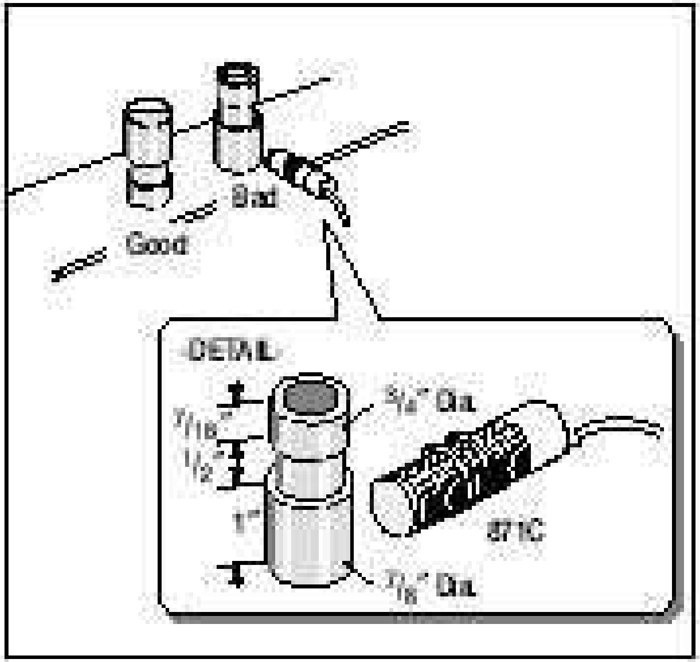


Vibration Monitoring

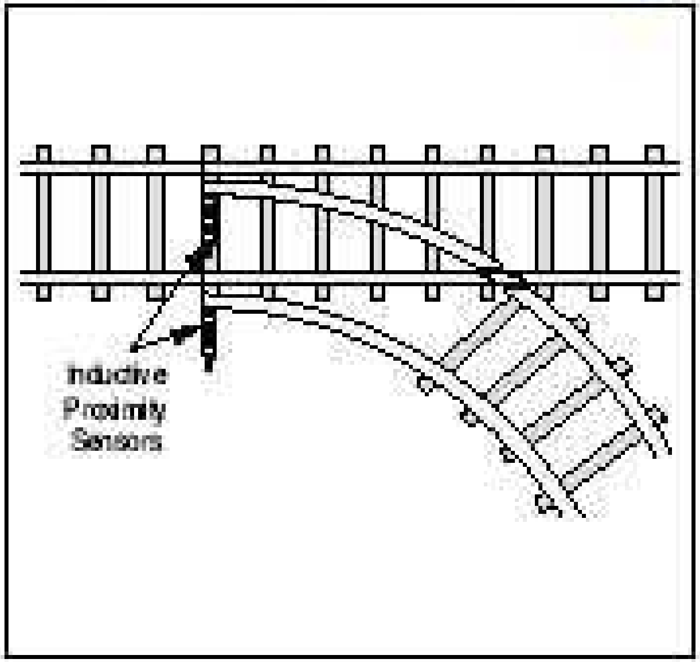


Aplikasi lain

On Line Parts Sorting

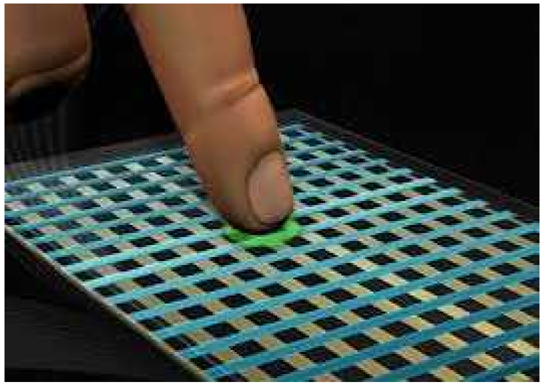


Railroad Yard Position Sensing



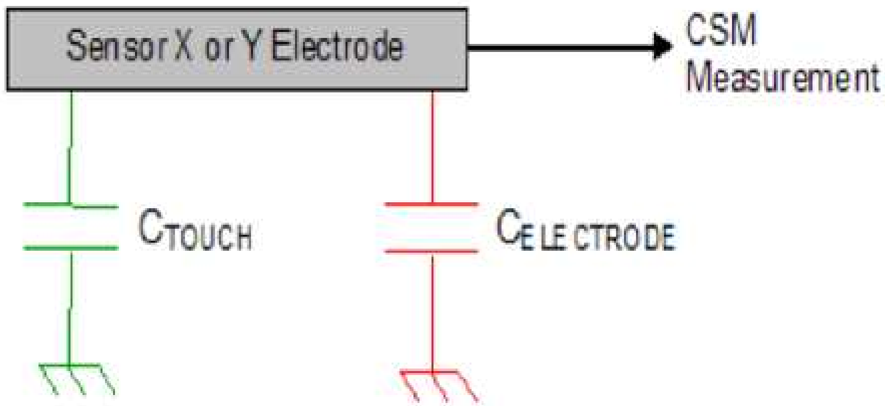
Capacitive Sensor

- Menggunakan kapasitansi tubuh manusia sebagai masukan
- Teknologi yang dimulai pada tahun 1971, dengan aplikasi NE555 sebagai timer solid state
- Perpaduan R dan C yang kemudian digunakan mikrokontroler untuk melihat waktu sentuhan
- Setelah 30 th cukup menggunakan sebuah ic kapasitansi yang sederhana



Jenis Kapasitif sensor

- ***Self – Capacitance:***



- ***Mutual- Capacitance:***