



HARDWARE: LOCOMOTIONS & MECHANICAL DESIGN (2- ACTUATORS)

Task for 11 Apr 22 (Online Lecture)

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TABLE OF CONTENT

Introduction to Hardware Components that move the Robots

I) Basic Motion Principle

II) Hardware Components (Specification, Brands and Price)

1) Stationary Robots

a) Omron FORPHEUS robot

2) Wheeled Robots & Tracked Robots

a) Single wheel BB-8

b) 4WD Omni-Directional Mobile Robot

c) Wall Climbing Robot (Metal vs Wall vs Glass)

3) Legged

a) Humanoid Robot (BIOLOID)

4) Swimming

a) Fish robot

b) Underwater glider robot

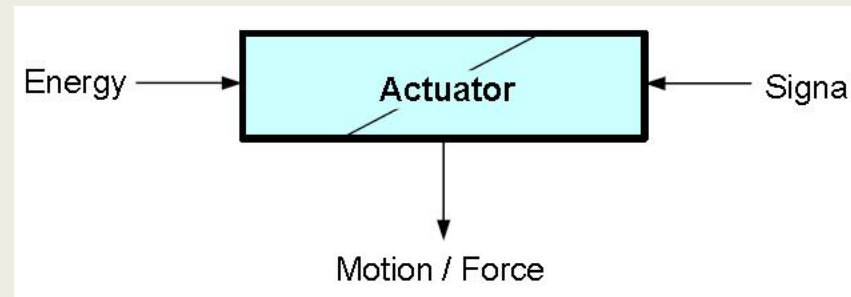
5) Others

a) Kilobot

BASIC MOTION PRINCIPLE

The first issue affecting mobile robots is locomotion. The robot's locomotion system is an important aspect of the mobile robot design, and it depends not only on the medium in which the robot moves (on the Earth's surface, under water, in the air, etc.) but also on technical criteria such as maneuverability, controllability, terrain conditions, efficiency, stability, and so on.

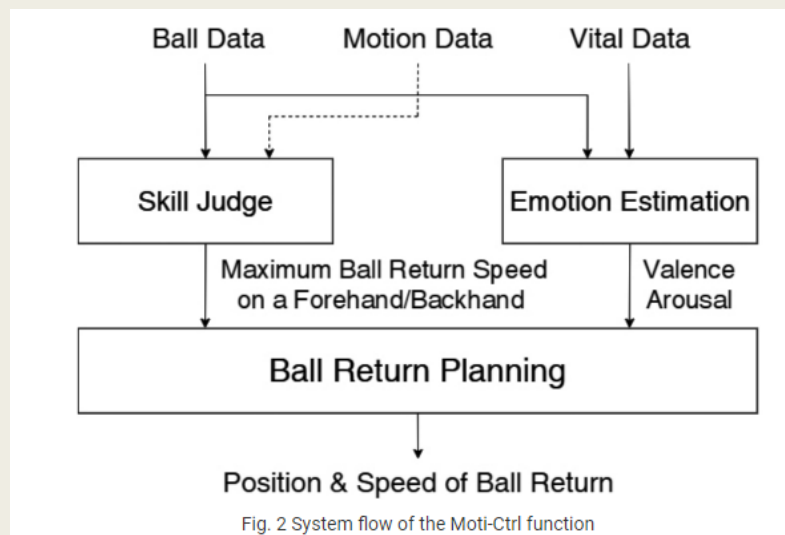
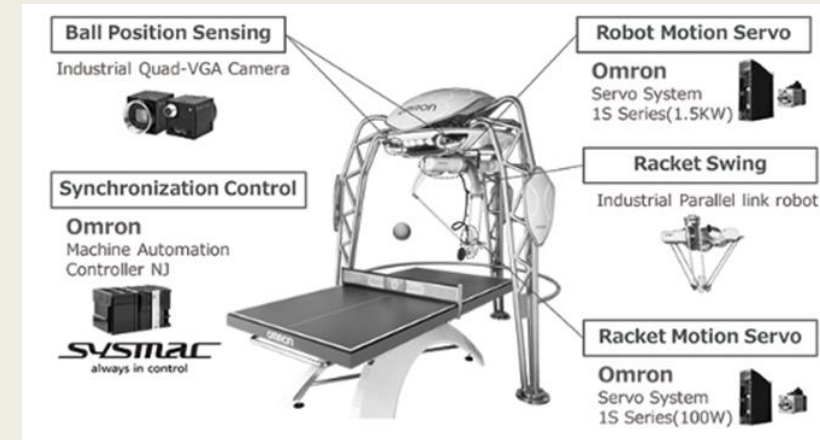
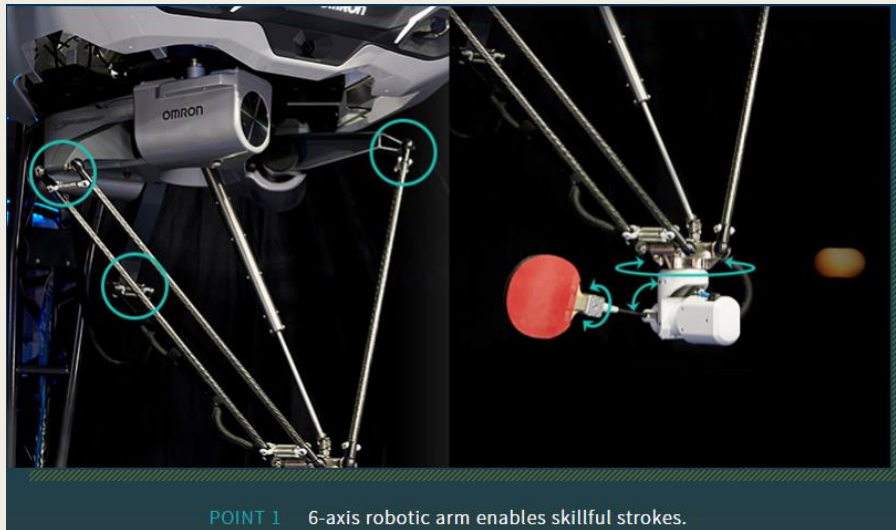
An actuator is a device that converts energy into physical motion, and most actuators produce rotary or linear motion.



STATIONARY ROBOTS

a) Omron FORPHEUS robot

■ Robot Motion Principle



- In racket motion planning for return shots, the racket velocity V [m/s] and the racket posture α, β [rad] at the moment of the return shot are determined to allow the robot to hit a return shot at the ball velocity determined based on the outgoing ball trajectory prediction.
- The errors between the actual landing points of the balls hit back by the ping-pong robot and the target position for outgoing balls were compared with those encountered with the conventional system to verify the effectiveness of the proposed system. For both the proposed and conventional systems, missed return shots (air shots, faulty shots hit by the edge of the racket, etc.) due to the influence of trajectory prediction errors were deemed as outliers.

■ Robot Actuator



Servo features

- Power range from 50 W to 15 kW
- 23 bit high resolution encoder
- Battery-free absolute multi-turn encoder
- Improved loop control for low overshoot and quick settling time
- Safety function built-in:
 - Hardwired Safe Torque Off:
EN ISO 13849-1(Cat.3 PLe), EN61508(SIL3), EN62061(SIL3), EN61800-5-2(STO)
 - Safety over EtherCAT(FSoE):
EN ISO 13849-1(Cat.3 PLd), EN61508(SIL2), EN62061(SIL2), EN61800-5-2(STO)

Specifications

Attribute	Value
Power Rating	1 kW
Supply Voltage	230 V
Phase	1
Series	1S

- OMRON R88M-1L1K030T-S2
- PRICE: \$1095.00/EA

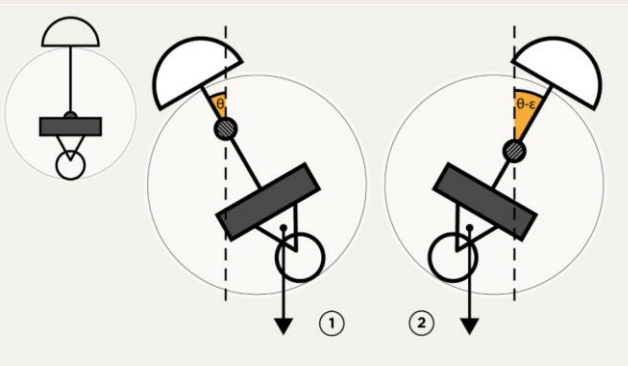
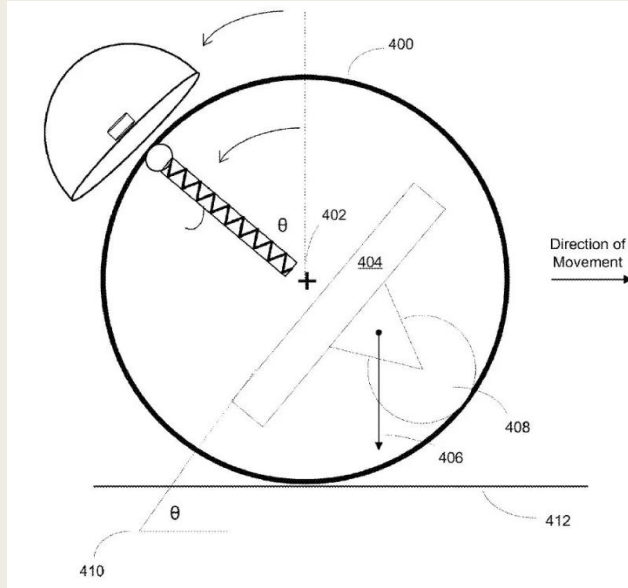
The Omron professional range of 1S AC servo motor offers simplified machine design and maintenance. This compact and small size servo motor come with a 23-bit resolution encoder and are designed with a straight shaft with key and tap. It is another element to make up the 1S Servo system designed to optimize the full cycle. It is reliable and has excellent quality. This 1S series low-inertia type AC servo motor has 23-bit absolute battery-less encoder and tap without brake. It has 3.18 Nm rated torque, 3000 rpm speed and 1 kW power capacity. It operates on 230 VAC.

- Multi-turn encoder design without mechanics: 16-bit,
- 65536 turns
- Battery-free absolute multi-turn encoder or
- incremental encoder
- Pre-assembled motor cables
- Designed for easy EMC compliance

Wheeled Robots & Tracked Robots

a) Single wheel BB-8

■ Robot Motion Principle



- In a nutshell, what we've got is a sphere with wheeled mechanism inside it. The wheels are forced down against the wall of BB-8 in some way (either spring or gravity, it doesn't matter a huge deal).
- Rotating the wheels shifts the center of the system's mass, the bulk of which is in the wheel assembly, off the vertical line that includes the center of the ball and the contact point with the ground.
- Leaning generates a moment. Do this right, and the ball moves in the direction that the wheels were shifted to. If we were to picture a mast mounted perpendicularly on top of the wheelbase, the ball would move in a direction opposite to the mast.

■ Robot Actuator



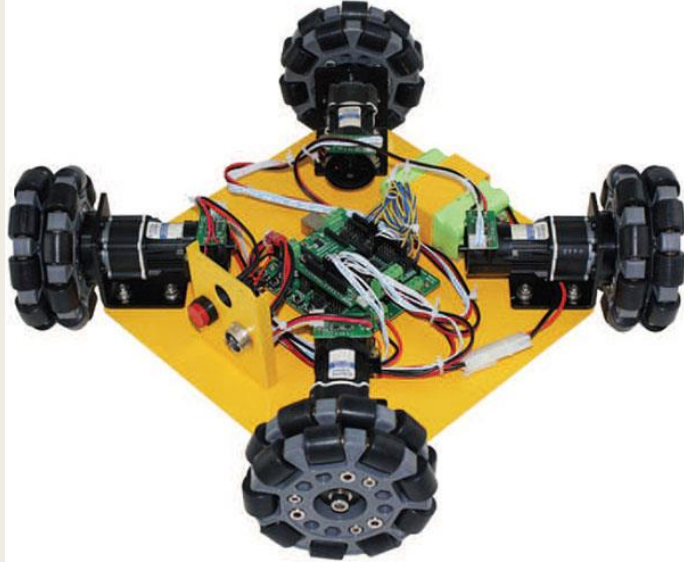
Specifications

Attribute	Value
Stepper Motor Type	Hybrid, Single Shaft
Step Angle	1.8°
Holding Torque	6.4Nm
Number Of Wires	4
Supply Voltage	100 V
Shaft Diameter	14mm
Shaft Length	30mm
Resistance Per Phase	0.36Ω
Series	SM2862
Standards Met	CE, UL, TUV, RoHS Compliant

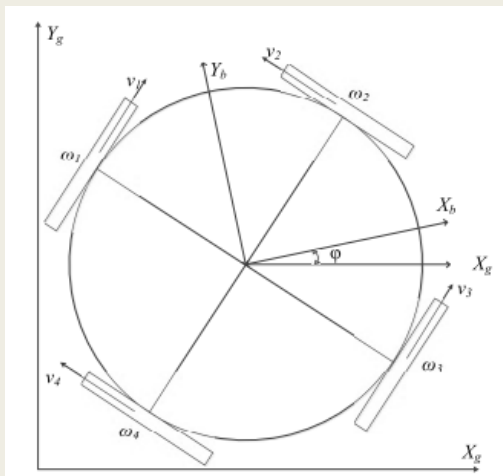
- The Sanyo Denki SANMOTION F2 series
- Price : 376.59USD/EA
- It offers stepper motor a wide variety of models that can be selected to meet the needs of the application. In addition, motors can be customized according to customer needs, such as with hollow shafts, connectors, or adapted for use in vacuum environments. With high torque, low vibration, low noise, and high resolution. Their rich line-up is used in a wide range of fields.
- 1.8° step angle type
- Thin type
- 86 mm compact type
- Mounting surface damper

b) 4WD Omni-Directional Mobile Robot

■ Robot Motion Principle



- An omnidirectional mobile robot is a type of holonomic robots. It can move simultaneously and independently in translation and rotation.
- special wheels called omni-wheels are assembled with a motors that offer friction-less movement to any direction independently. Secondary small wheels are also placed perpendicular to the main wheel.
- An omnidirectional drive robot requires more than two wheels. Nearly every team has robots with four wheels. The primary reason of using more than three wheels is to have more torque and acceleration which enables the robot to move quickly across the field.



■ Robot Actuator



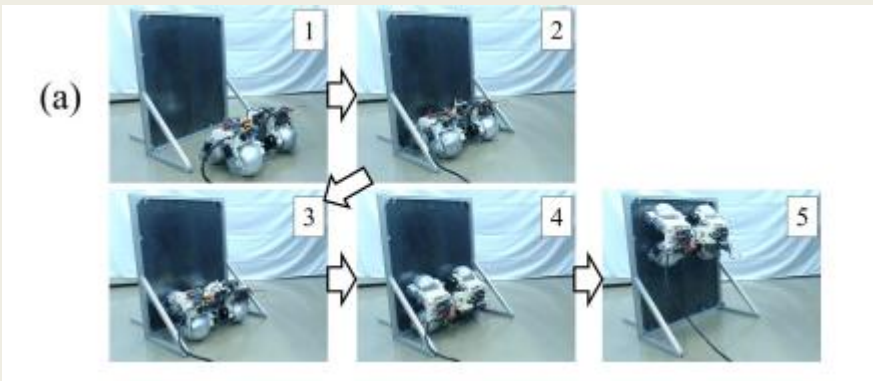
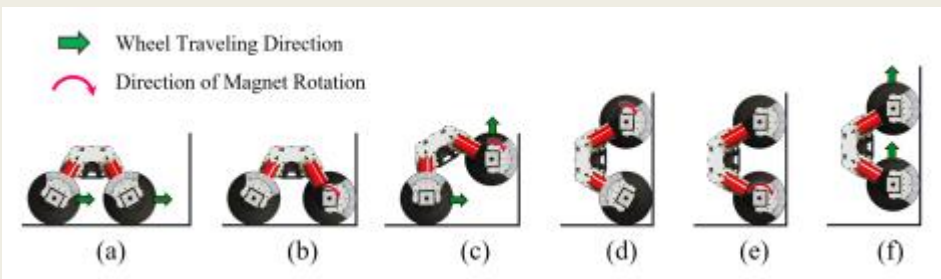
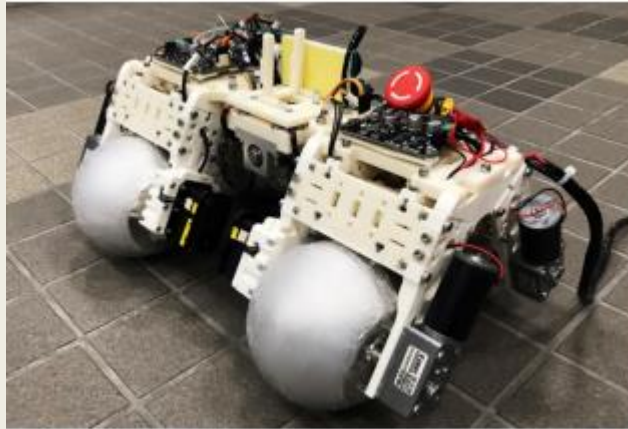
Specifications

Attribute	Value
Supply Voltage	24 V
DC Motor Type	Brushless
Output Speed	4600 rpm
Shaft Diameter	6.2mm
Maximum Output Torque	0.021 Nm
Dimensions	22 (Dia.) x 55.7 mm
Current Rating	1.1 A
Length	55.7mm
Width	22mm
Standards Met	CE, RoHS Compliant

- RS PRO Brushless DC Motor, 24 V, 0.021 Nm, 4600 rpm, 6.2mm Shaft Diameter
- Price: MYR655.22/EA
- From RS PRO, this brushless DC motor is ideal for a variety of applications. With a sturdy construction from high quality materials, the DC motor delivers efficient power and consistent torque output. As the electric motor is brushless, it uses hall effect sensors to monitor the rotor position and control speed, ensuring greater reliability and efficiency.
- Features and Benefits:
 1. Hall effect sensors with 120° electrical angle
 2. 5mm Shaft Diameter
 3. Speed control feedback via hall sensors.
 4. Class B insulation
 5. Metal Core

c) Wall Climbing Robot (Metal)

■ Robot Motion Principle



- The structure of the robot consists of a pair of rocker arms with magnetic spherical wheels and a center body. The robot dimensions are 307 mm × 480 mm × 185 mm, and the weight is 7.4 kg.
- The combination of the rocker arm suspension and the magnetic spherical wheel can achieve surface adaptability as shown.
- The rocker mechanism and the spherical wheels can find contact points for each wheel, and the magnets will be normal to contact surfaces.

■ Robot Actuator



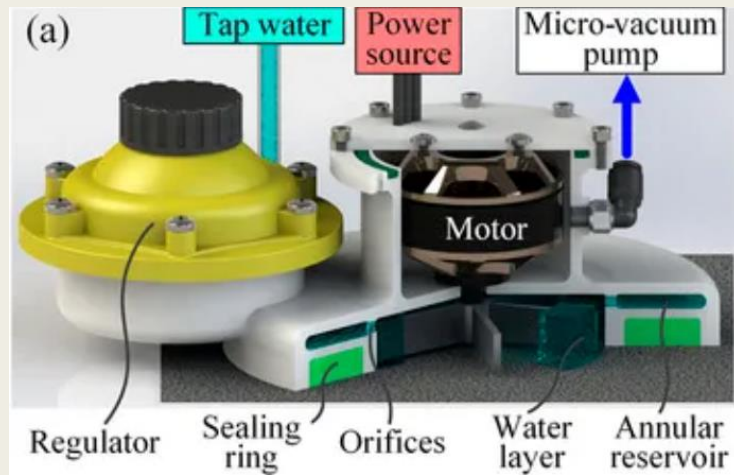
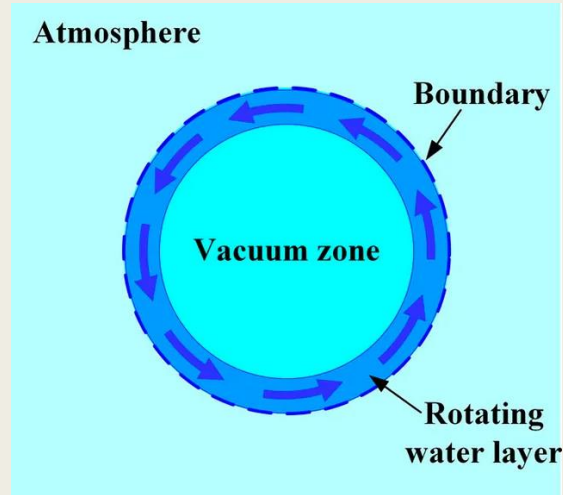
Specifications

Attribute	Value
Maximum Output Torque	0.64 Nm
Supply Voltage	200 V
Output Speed	3000 rpm
Power Rating	200 W
Shaft Diameter	50mm
Length	60mm
Width	60mm
Depth	109mm
Current Rating	1.6 A
Series	SMARTSTEP2
Standards Met	CE, cUL 22.2, IEC 60034-5, UL 1004 File No:E 179189

- Omron 200 V 200 W Servo Motor, 3000 rpm, 0.64 Nm Max Output Torque, 50mm Shaft Diameter
- Price: MYR3,931.89/EA
- Professional range of G series servo motors from Omron. This wide range of compact servo motors are designed to meet all application needs. When used with a SmartStep 2 drive, the G-series servo motors offer the simplicity and cost-effectiveness of a stepper. These servo motors have the added advantages of a servo system
- Peak torque 300% for 3 secs
- Servo motors supported by SmartStep 2, G-Series and Accurax G5 servo drives
- IP65 Rating
- No motor settings required

c) Wall Climbing Robot (Wall)

■ Robot Motion Principle



- Researchers from Zhejiang University in China have created a new kind of vacuum suction unit to help wall-climbing robots traverse over any kind of surface.
- Shi and Li created a suction cup that relies on a rotating stream of water to maintain a seal over any surface. This new method for preventing vacuum leakage eliminates any pressure difference at the boundary of the vacuum zone. The researchers call it the "zero pressure difference (ZPD) method."
- As shown in the image, their ZPD method uses a rotating layer of water on the outside of the vacuum zone to create a pressure gradient. Inside the water layer, there's a high vacuum. Pressure increases radially and reaches the same level as the atmospheric pressure outside the water layer. Since there's no pressure difference at the boundary anymore, the second condition for vacuum leakage is then broken.
- Shi and Li designed a new suction cup with their zero-pressure difference method in mind. Both the regulator and the suction unit were 3D-printed. Similarly, to other suction units, a nitrile foam rubber ring is embedded on the outside periphery of the chamber. A motor drives a fan that is fixed in the chamber. A micro-vacuum pump is used to evacuate the initial air, creating a vacuum zone in the chamber. The water in the reservoir is supplied by an outside water source.

■ Robot Actuator

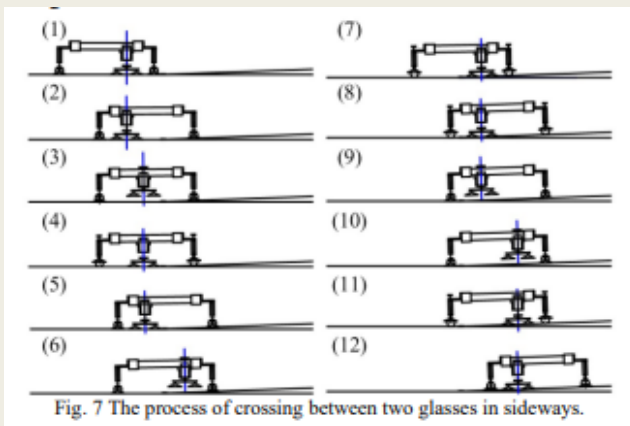
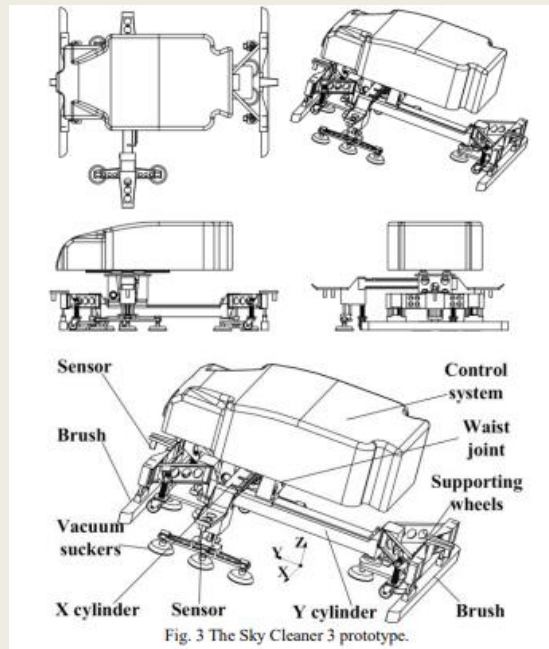
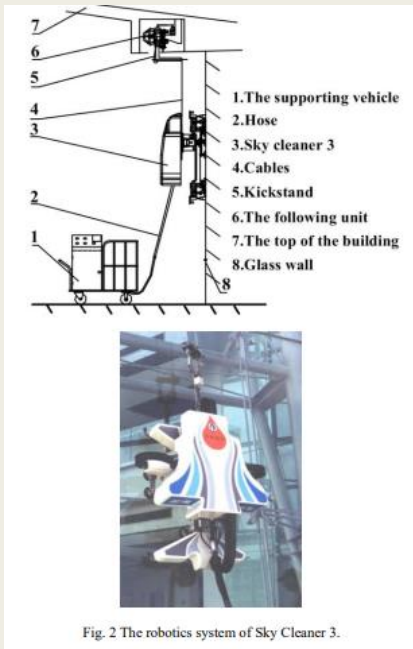


- FANUC DC GEAR MOTOR 300W ENCODER A06B-0116-B175
- Price : US\$227.34/EA
- Armored for severe conditions and have the facility for extensive input/output (I/O) arrangements.
- Read limit switches, analog process variables and the positions of complex positioning systems.
- Operate electric motors, pneumatic or hydraulic cylinders, magnetic relays, solenoids, or analog outputs.

Feature	<ol style="list-style-type: none">1. CNC series, Servo Motor, Laser, Robot, ROBODRILL2. ROBOSHOT (Electric Injection Molding Machine)3. ROBOCUT (Wire-cut Electric Discharge Machine)4. Ge Fanuc PLC5. ROBONANO (Super Nano Machine)
Application	<ol style="list-style-type: none">1. Power industry, the elevator industry, parking, automobile, auto ancillary2. feed industry, aluminum smelting machines, refrigeration industry3. steel industry, combustion control systems, non-ferrous metal smelting4. glass industry, construction machinery, textile machinery, water treatment

c) Wall Climbing Robot (Glass)

■ Robot Motion Principle



■ The robotic system consists of three parts:

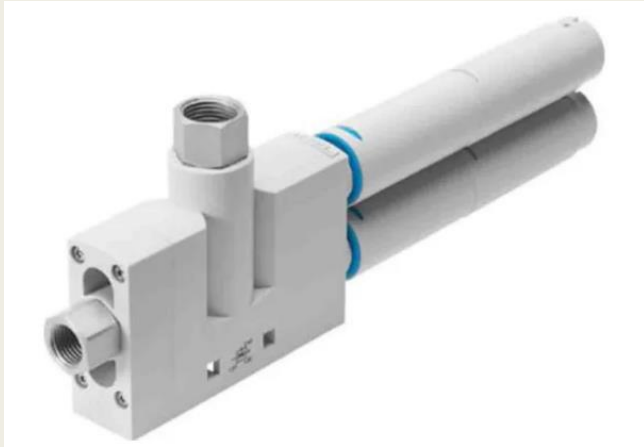
- 1) a following unit;
- 2) a supporting vehicle;
- 3) the cleaning robot.

■ The cleaning robot is supported from above by cables from the following unit mounted on the top of the building. All following movements of the unit which protects against falling due to any type of malfunction are synchronized by the robot itself. A hose for water, a trachea for pressured air, and cables for power and control signals are provided from the supporting vehicle on the ground. The GUI is also installed on this vehicle.

■ On the other hand, the following cables will carry some of the weight of the hose and trachea when the robot is in mid-air.

■ The vacuum suckers connected to the X cylinder straddles the seal, the Y cylinder is moving from left to right and position control begins while approaching the seal. After exchanging attachment, the vacuum suckers in the Y cylinders are sucked to the glass.

■ Robot Actuator



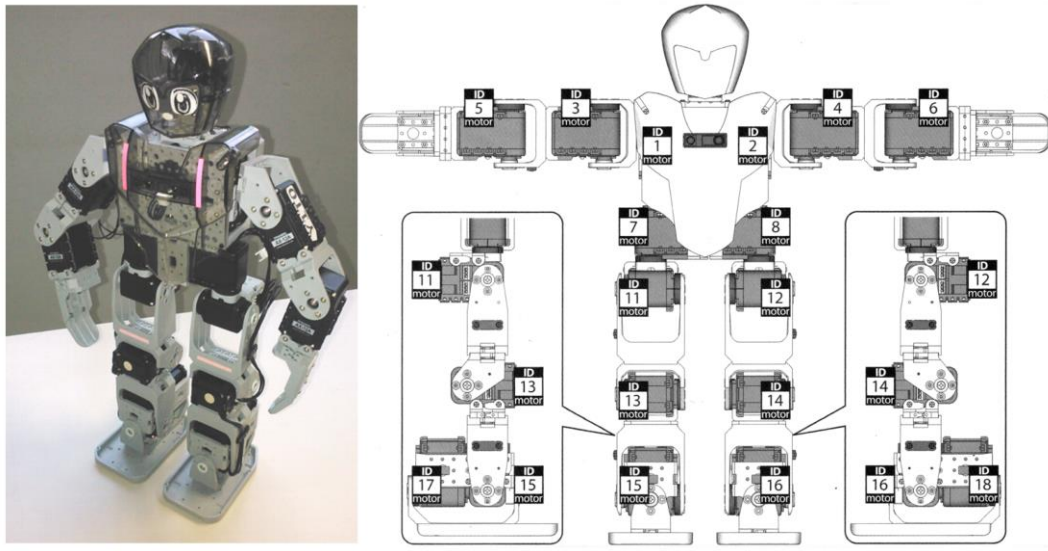
Attribute	Value
Manufacturer Series	VN
Nozzle Diameter	2mm
Maximum Vacuum Pressure	-0.92bar
Maximum Input Pressure	6bar
Maximum Suction Flow	188L/min
Operating Pressure	1-8bar

- The Festo T-shaped vacuum generator has a nozzle size of 2mm with internal thread. It has operating pressure ranges between 1 bar to 8 bar.
- Grid dimension - 24 mm
- Width - 24 mm
- High suction flow rate
- Price : RM686.90/EA

LEGGED

a) Humanoid Robot (BIOLOID)

■ Robot Motion Principle



- The robot was named Y1T0 (“yito”) and was integrated by 16 Dynamixel servomechanisms. Because each Dynamixel is an independent mechanism with independent motions, each servomechanism represents a degree-of-freedom (DOF). Hence, the Type-B Bioloid was a 16 DOF humanoid robot.
- In Figure 1, the array of Dynamixel servomechanisms (dyn1–dyn8 and dyn11–dyn18) used for the Type-B Bioloid is presented.

■ Robot Actuator



Features and Specifications

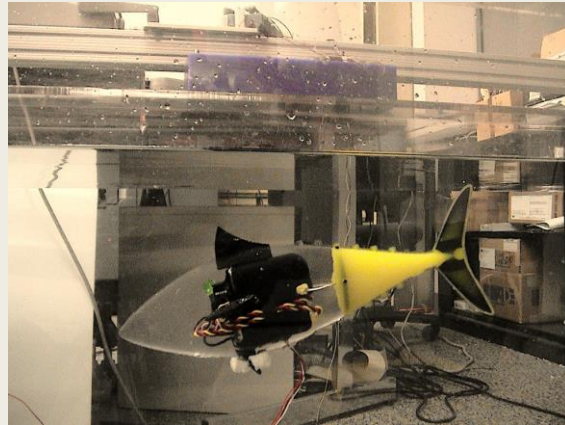
- **Operating Voltage:** 9V-12V
- **No-Load Speed:** 59 RPM
- **Stall Torque:** 15.3 kg-cm
- **Resolution:** 0.29 degrees
- **Compatible with:** AX-12+ at 1:1 scale
- **Communication Protocol:** TTL Half Duplex Async Serial
- **Gear Ratio** 254:1
- **Maximum Current:** 900mA
- **Standby Current:** 50mA
- **Dimensions:** 32 x 50 x 40 mm
- **Weight:** 55g

- Dynamixel AX-12A Smart Serial Servo
- Price: USD33.75/EA
- The Dynamixel AX-12A Smart Serial Servo from Robotis is the most advanced actuator on the market in this price range and has become the defector standard for the next generation of hobby robotics.
- The Robotis AX servo product line features a simple, and robust, TTL level communication protocol. Over a single TTL signal line you can daisy chain several servos and position of several servos independently and read back their positions.

SWIMMING

a) Fish robot

■ Robot Motion Principle

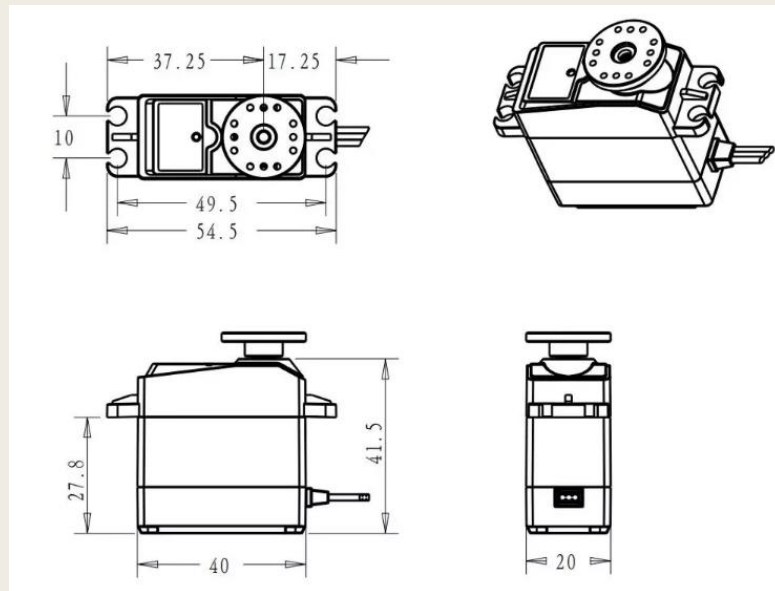


- A motor situated in the fish's head pulls the tail's jointed active segment from side to side.
- The resulting forward motion is amplified by the adjoining passive segment of the tail, which continues the flapping motion and bends with the resistance of the surrounding water.
- Slender-body theory is often used when studying robot fish locomotion. The mean rate of work of the lateral movements is equal to the sum of the mean rate of work available for producing the mean thrust and the rate of shedding of kinetic energy of lateral fluid motions.
- The mean thrust can be calculated entirely from the displacement and swimming speed at the trailing edge of the caudal fin.[8] This simple formula is used when calculating the locomotion of both robot and living fish.
- Realistic Propulsion Systems can help improve autonomous maneuvering and exhibit a higher level of locomotion performance. A diverse option of fins can be used in the creation of robot fish to achieve this goal. By including pectoral fins, robot fish can perform force vectoring and perform complex swimming behaviors instead of forward swimming only.

■ Robot Actuator



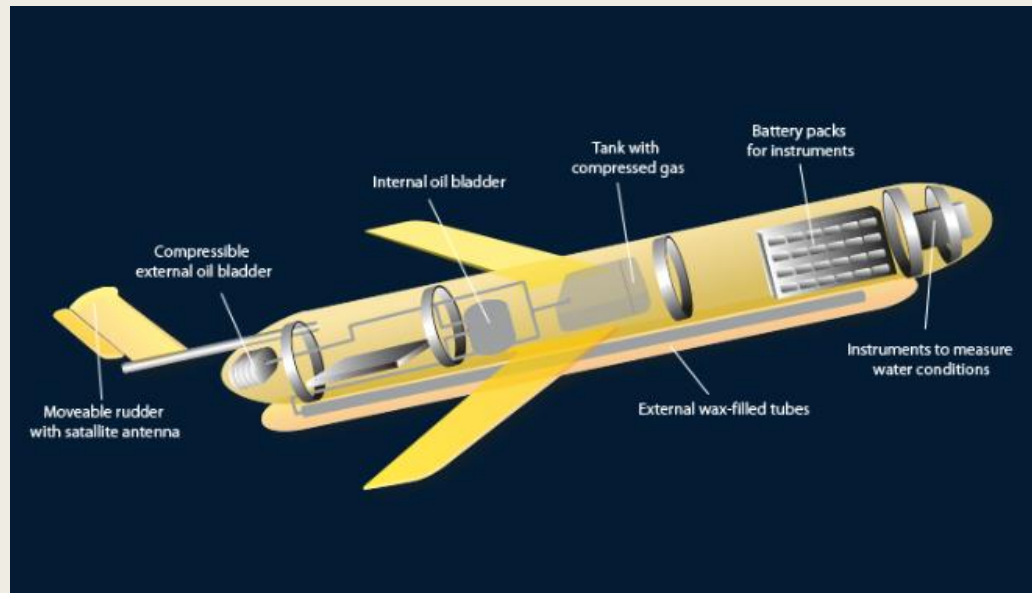
- High Torque DS3235SG 35KG Blue Coreless Motor Digital Servo Metal Gear Stainless Steel Gear Waterproof Servo DS3235 For Robotic
- Price: USD84.55/EA
- High performance digital standard servo
- High-precision metal gears (Stainless steel gear)with hard anodizing
- CNC aluminium middle Shell
- Dual ball bearings



Product Model	DS3235SG Servo
Weight	65g
Size	40x20x38.5mm
Motor type	Coreless motor

b) Underwater glider robot

■ Robot Motion Principle



- A glider uses an internal pump to change its buoyancy, enabling it to move up and down in the water, whereas conventional robotic vehicles or Autonomous Underwater Vehicles (AUVs, such as Autosub) are propeller-driven.
- The movement of internal weights back and forth enables the glider to angle itself to dive or climb in the water column.
- Like an aerial glider moving vertically through the air, underwater gliders use the lift generated by the wings moving through the water to convert vertical force into forward motion.
- Gliders are fitted with an inbuilt compass, which they use to steer a course. Gliders move very slowly, usually at less than a mile per hour, but can maintain this speed for months on end.

■ Robot Actuator



Motor specifications:

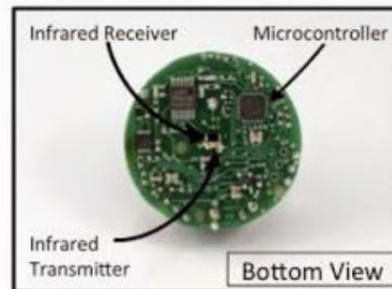
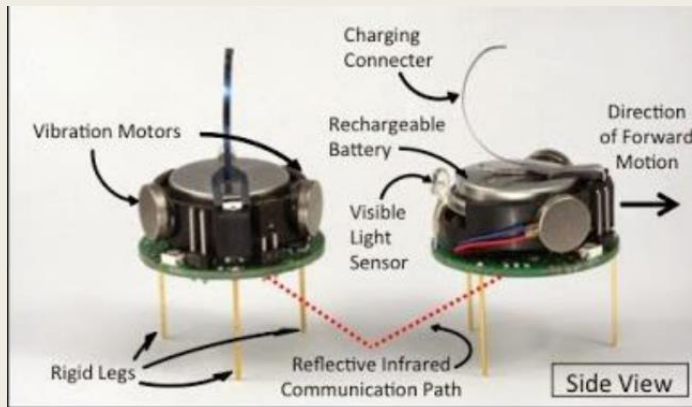
- Control system: +pulse width control 1500 μ s neutral
- Required pulse: 3–5V peak-to-peak square wave
- Operating voltage: 4.8–6V
- Operating temperature range: -20 to +60 °C
- Operating speed (4.8V): 1.68 s/360° at no load
- Operating speed (6V): 1.4 s/360° at no load
- Stall torque at 4.8V: 11 kg/cm
- Stall torque at 6V: 13.2 kg/cm
- Operating angle: 630° one side pulse travelling 400 μ s
- Continuous rotation modifiable: yes
- Direction: clockwise/pulse travelling 1500–1900 μ sec
- Current drain (4.8V): 8 mA idle and 230 mA no load operating
- Current drain (6V): 8.7 mA idle and 285 mA no load operating
- Dead bandwidth: 8 μ s
- Motor type: 3 pole ferrite
- Potentiometer drive: indirect drive
- Bearing type: 1 bearing and 1 Oilite bushing
- Gear type: all karbonite gear
- Connector wire length: 300 mm
- Dimensions: 59 x 29 x 50 mm
- Weight: 110 g

- Hitec HS-785HB servo with the parallel 785 Gear Rack Kit
- This Hitec HS-785HB rotary servo kit (from Servocity) generates a linear motion over a distance of 21.38 cm using a rotary servo. Simply send the appropriate PWM signal with a motor controller (between 850 and 2150 μ s).
- The HS-785HB servo gear rack kit includes robust aluminium and plastic parts and all the necessary hardware.

OTHERS

a) Kilobot

■ Robot Motion Principle



- Kilobot is a low-cost, easy-to-use robotic system for advancing development of “swarms” of robots that can be programmed to perform useful functions by coordinating interactions among many individuals.
- These swarms are inspired by social insects, such as ant colonies, that can efficiently search for and find food sources in large complex environments, collectively transport large objects, and coordinate the building of nests and bridges in such environments.
- It uses vibrations of the system for the movement of the system’s body.
- Collective movement is a way of letting to coordinate a group of robots and making them move together as a group in a cohesive way. It’s a basic way of making some collective tasks done and can be classified into two types of formation and flocking.

■ Robot Actuator



- Seeed Studio 316040001 Mini Vibration Motor for Multipurpose
- Price : RM5.52
- This mini vibration motor worked at 3V can be used for multipurposes.

No. 序号	Item 项目	Measuring Condition 测试条件	Specification 规格
3-1	Rated Speed 额定转速	At Rated Voltage and Rated Load 额定电压及负荷下测试	Min 10,000rpm
3-2	Rated Current 额定电流	At Rated Voltage and Rated Load 额定电压及负荷下测试	80mA or less 80mA 以下
3-3	Starting Voltage 起动电压	At Rated Load and Step Voltage 额定负载及逐渐升高电压法测试	DC2.3V or less DC2.3V 以下
3-4	Insulation Resistance 绝缘电阻	DC100V between Lead wire and Case 引线及电机机身之间的绝缘电阻	10MΩ Min
3-5	Insulation Voltage 绝缘电压	DC50V between Lead wire and Motor Case 引线及电机机身之间施加DC50V电压一分钟	No Destruction Occurs 不被击穿
3-6	Terminal Resistance 端子电阻	Measure between Terminals 端子间电阻	75Ω Max