Robot Components 120

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Class Outline

Objectives
The Components of an Industrial Robot
The Power Supply
Hydraulic Drives
Pneumatic and Electric Drives
Servomotors and Encoders
The Controller and Cabinet
The Teach Pendant
The Axis Control Module
Sensors
The Parts of a Robotic Arm
Degrees of Freedom
End-Effectors
Grippers
Types of Grippers
Robot Safeguards
Summary

Lesson: 1/17

Objectives

- Describe the basic components of an industrial robot.
- Describe the components of a robot's power supply.
- Describe hydraulic drives.
- Distinguish between pneumatic drives and electric drives.
- Describe servomotors and encoders.
- Describe a robot's controller and cabinet.
- Describe the teach pendant.
- Describe the axis control module.
- Describe sensors for robots.
- Describe the parts of a robotic arm.
- Describe the degrees of freedom of a robotic arm.
- Describe the end-effectors of a robotic arm.
- Describe grippers.
- Distinguish between the different types of grippers.
- Describe safeguarding systems for robots.

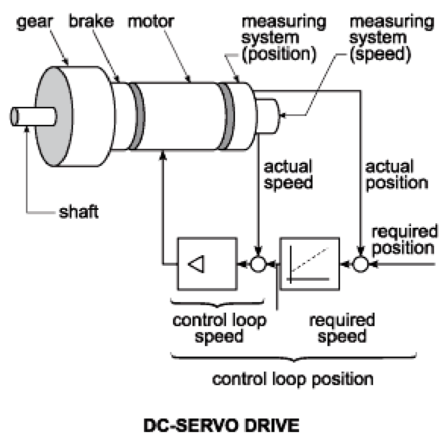

Figure 1. Servomotors are used in robotic applications that require precise motion control.

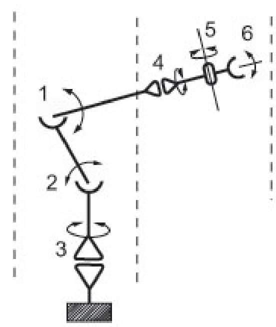

Figure 2. A robot's degrees of freedom are determined by the number of joints on the robotic arm.

Lesson: 2/17

The Components of an Industrial Robot

Robots have been used in industry since the 1960s. An **industrial robot** is a programmable mechanical device that is used in place of a person to perform tedious or dangerous work with a high degree of accuracy. Robots can also lift very heavy objects and perform repetitive tasks for long periods of time without stopping. For example, the palletizing robot in Figure 1 can lift and move heavy boxes all day without getting bored or tired.

As shown in Figure 2, industrial robots are typically composed of a mechanical arm, sometimes called a **manipulator**, and a controller for that arm. Attached to the end of the arm is the robot's work tool, also known as the **end-of-arm tool**. The robotic arm is generally mounted on a platform or suspended from a track while it reaches to various distances and locations. Robotic arms can be large or small and they come in many varieties. In this class you will learn the functions and characteristics of the different components of an industrial robot.

Figure 1. A palletizing robot. [Courtesy of Kawasaki Robotics (USA), Inc.]

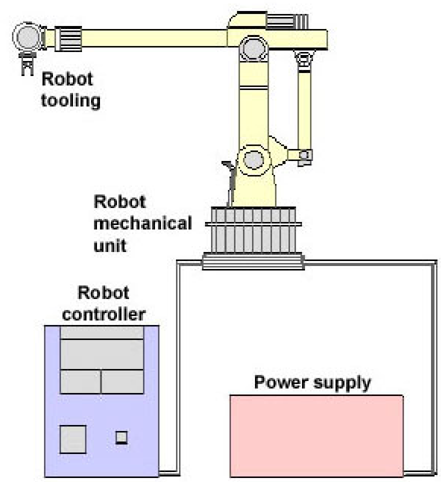

Figure 2. Basic robot components include a controller, a mechanical arm, and a tool at the end of the arm.

Lesson: 3/17

The Power Supply

Most industrial robots today are electric. The robot's **main power supply** provides **voltage** and **current** to the motor. Power is supplied using **alternating current** (AC) run through a **transformer** that transfers power from one **circuit** to another. The transformer alters AC voltage up or down without changing the AC frequency, as shown in Figure 1. This allows the robot to use whatever type of AC power source is being used in the factory.

Circuits connected to the robot's main power supply perform a variety of functions. **Power circuits** provide large amounts of power to the servo amplifiers that power the robot's drives. **Control circuits**, which are lower voltage, coordinate the robot's programming, motion control, and I/Os.

In addition to the main power supply, separate power supplies to the robot can be located in a **cabinet** or in a **power supply unit** (PSU). The PSU provides **direct current** (DC) voltage to the robot's outputs and controller. Fuses and circuit breakers are used to limit the current in the robot's circuits. Some controllers monitor voltage and provide an under/over voltage warning message when there is a problem with the robot's electronics.

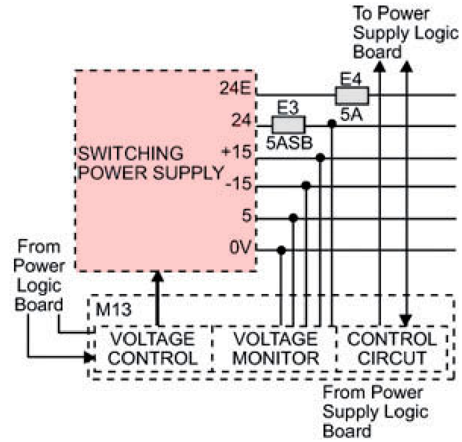

Figure 1. The robot's power supply is run through a transformer that alters AC voltage up or down.

Lesson: 4/17

Hydraulic Drives

Industrial robots use electric power. However, the robot must have an **actuator** to convert this power into mechanical motion. Robots have three main types of actuators: hydraulic drives, pneumatic drives, and electric drives. **Hydraulic drives** use a **hydraulic pump** to move liquids under extreme pressure. Valves control the flow of liquid. Hydraulic pumps require a **prime mover** such as an electric motor to introduce the initial energy needed to perform, as shown in Figure 1.

Hydraulic drives provide high **force multiplication**. Force multiplication allows hydraulic drives to create an exponential increase in available power, as shown in Figure 2. For this reason, hydraulic drives were the preferred actuator for industrial robots in the 1970s and 1980s. At that time, electric motors were not strong enough or prolific enough to be practical. Hydraulic drives enable robots to move extremely heavy **payloads**.

Despite the advantages provided by hydraulic power, it has many drawbacks. Hydraulic fluid systems require extensive maintenance to prevent the downtime associated with contamination and leakage. In addition, hydraulic systems do not have good precision of movement. Valves are needed to turn them on and off and to control speed.

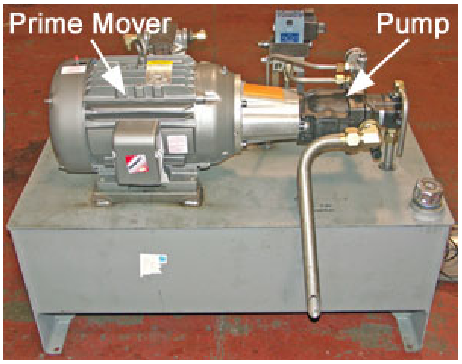

Figure 1. Hydraulic pumps require a prime mover such as an electric motor.

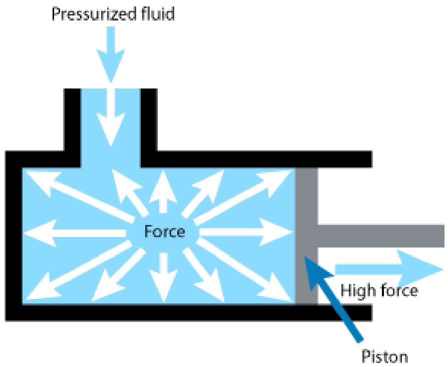

Figure 2. Force multiplication creates an exponential increase in available power.

Lesson: 5/17

Pneumatic and Electric Drives

Pneumatic drives use compressed gases to perform work. The gas is usually air. In a pneumatic system, a **compressor**, shown in Figure 1, squeezes, or compresses, air and moves it under pressure. A pneumatic compressor requires a **prime mover** such as an electric motor.

Pound for pound, pneumatic power offers very high force multiplication. It is relatively clean, lightweight, and it can be safer than electrical or hydraulic energy in many situations. For **Cartesian robots** and **pick-and-place robots**, pneumatic drives are fairly inexpensive and reliable. Grippers and motors on the robot's end-of-arm tooling are usually pneumatic because it is easy to convey the air to the tooling, and fast actuation is desirable for gripping. However, pneumatic drives do not have good positional accuracy.

Electric drives are the most widely used actuator for industrial robots today. They are reliable and accurate and they can lift large loads. Electric drives use **electric motors**, like the one in Figure 2, to convert electricity into mechanical motion. Robots run on direct current (DC) motors.

A DC **servomotor**, is the preferred type of electric motor for high speed applications that require a robot to make multiple movements. DC servomotors also have very high holding torque and strong electrical braking ability, which is useful for robots.

Figure 1. Pneumatic drives use a compressor to move air under pressure.

Figure 2. Electric motors are the most common type of actuator for robots.

Lesson: 6/17

Servomotors and Encoders

A **servomotor**, shown in Figure 1, is a type of motor used for motion control in robots. Servomotors can rotate in both directions, and they accelerate and decelerate quickly and smoothly. For motion control, a measuring device called an **encoder**, shown in Figure 2, is mounted on the servomotor. The encoder is a disc that is divided into a fixed number of increments called **counts**. In a typical encoder, one revolution equals one million counts.

The encoder monitors the position of the robotic arm as it travels from point A to point B. As the servomotor spins one revolution, the encoder makes incremental counts that measure the distance traveled. For some types of robots, such as pick-and-place, a program can be set to tell the robot how much time, or how many counts on the encoder, it should take for the robot to move from point A to point B. If the robot has not reached point B by the maximum number of counts, it is assumed that an error has occurred and the robot automatically comes to a stop.

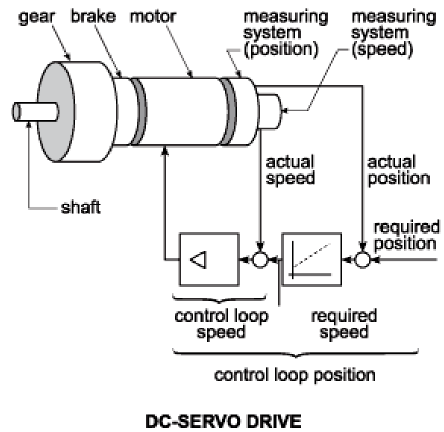

Figure 1. Servomotors are used in applications that require precise motion control.

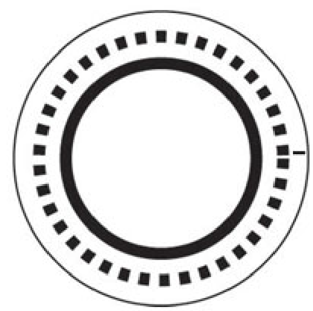

Figure 2. An encoder is divided into a fixed number of counts.

Lesson: 7/17

The Controller and Cabinet

In order to run its program and interface with inputs and outputs, a robot must have a **controller**. The controller is the "brains" of a robot. It gives the robot memory and allows the robot to process sensor **inputs** and **outputs**, as shown in Figure 1. The controller also enables the robot to carry out the commands in its program.

The controller can be located in a microcontroller unit (MCU) inside the robot, but more often it is located inside a **cabinet** that is external to the robot. The cabinet contains the **central processing unit** (CPU) and the **power supply unit** (PSU). The cabinet also holds other components such as the **axis control module** and **input/output modules**.

The components are mounted in separate areas of the cabinet so that they can be removed and replaced easily, as shown in Figure 2. A disconnect switch on the outside of the cabinet shuts off and locks out the power to the robot when the cabinet door is closed. Some controllers have an interface on the front panel that is used by the operator to enter data and program changes.

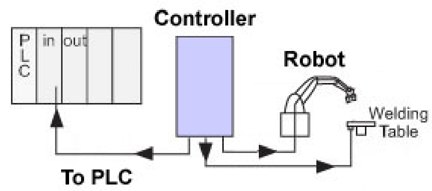

Figure 1. The controller allows the robot to process sensor inputs and outputs.

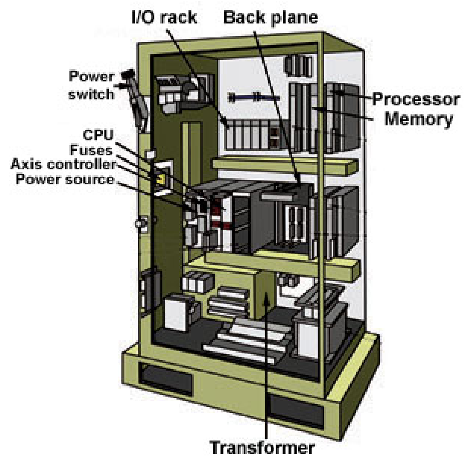

Figure 2. Components are mounted in separate areas of the cabinet so that they can be removed and replaced easily.

Lesson: 8/17

The Teach Pendant

A **teach pendant** is a hand-held device that is used to program a robot. The robot is placed in teach mode while the trainer uses the teach pendant to manipulate the robot through the different steps of the job. The teach pendant also gives a robot technician the freedom to work with the robot either remotely or nearby.

Teach pendants are connected to the robot's controller by a cable, as shown in Figure 1. If the user interface is not built in to the controller cabinet, the teach pendant can be mounted on the front panel and used as an interface. The design of teach pendants can vary between different manufacturers. A very simple teach pendant is illustrated in Figure 2. Note that it has basic programming and motion control keys, as well as an E-stop button. Other features available on teach pendants include:

- **Power on** and **power off** buttons that power up the controller and turn on the servomotor if it has been turned off by an E-stop.
- **Status lamps** or light-emitting diodes (LEDs) that light when errors occur.
- An **LCD screen** for displaying the robot's inputs and outputs, position, and program.
- **Number keys** for entering numeric data such as axes.
- **Motion control keys** for lead-through programming and position adjustment of the robot.
- **Program control keys** for selecting and executing programs.

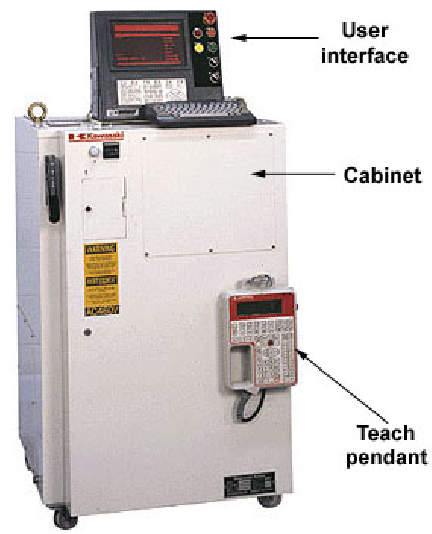

Figure 1. Teach pendants are connected to the controller by a cable. [Courtesy of Kawasaki Robotics (USA), Inc.]

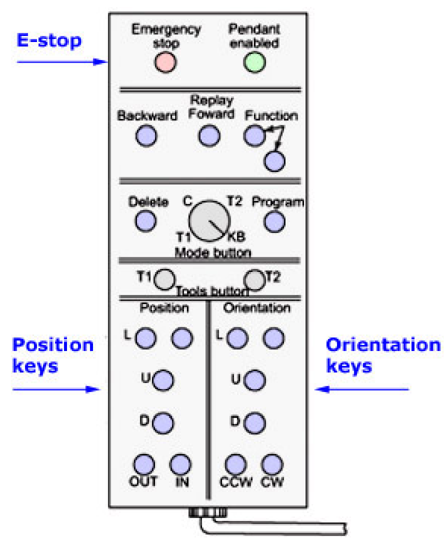

Figure 2. Teach pendants typically have basic programming and motion control keys, as well as an E-stop button.

Lesson: 9/17

The Axis Control Module

The **axis control module** controls the direction and speed of the robot. A manipulator can move through one **axis** or it can move through multiple axes simultaneously. Once the destination **coordinates** have been programmed into the robot, the controller calculates the required movements for each axis. The axis control then sends signals to the motor or amplifier and receives position feedback. The axis control module also coordinates the speed of the motors controlling the robotic arm, allowing it to move smoothly. In Figure 1, the axis control module would be used to direct the robotic arm from point A to point B and to control its acceleration and deceleration.

Typically, a **velocity profile**, shown in Figure 2, is created in the robot′s program to ensure that the **end-effector** reaches the desired coordinates at the programmed speed and along the correct path. The velocity profile controls the acceleration and deceleration of the robotic arm as it moves to its destination. If a robot is moving through more than one axis, a velocity profile has to be created for each axis.

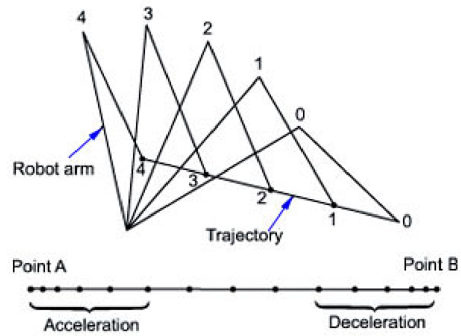

Figure 1. The axis control module controls the direction and speed of the robotic arm.

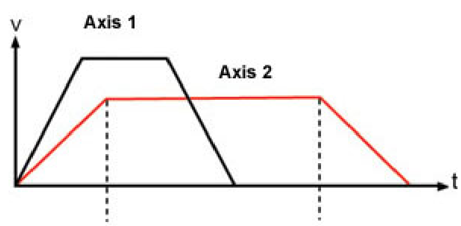

Figure 2. Velocity profiles control a robot's acceleration and deceleration.

Lesson: 10/17

Sensors

Input signals from **sensors** on or near the robot provide information about its surroundings. The robot uses this information to interact with its environment. For example, a collision sensor, shown in Figure 1, allows a robot to adjust its path if it makes contact with an object.

Sensors can be contact or noncontact. **Contact sensors** include tactile, force, and collision sensors. Tactile sensors are used in applications such as arc-welding tracking, handling delicate parts, and parts testing. Force sensors allow robots to precisely insert parts. Pressure sensors tell a robot how much grip strength to apply to hold an object securely without damaging it. Collision sensors prevent the robot's end-effector from being damaged. When the end-effector is subjected to excessive force, the robot stops moving.

Noncontact sensors include proximity sensors and vision sensors such as photosensors and cameras. Vision sensors are used in applications such as sorting, parts-fitting, and parts inspection. Typically the robot's vision comes from an overhead camera, as shown in Figure 2. Robotic vision can be superior to human vision. For example, a vision sensor on a robot can look at two objects and be able to determine that one is .005 in. smaller than the other. The human eye cannot do this.

Contact and noncontact sensors are often used together to accomplish a task. For example, a robot may use both types of sensors to insert a peg into a hole. Vision sensors help the robot to find the hole while force sensors help the robot to insert the peg securely.

Figure 1. Collision sensors allow a robot to adjust its path if it makes contact with an object.

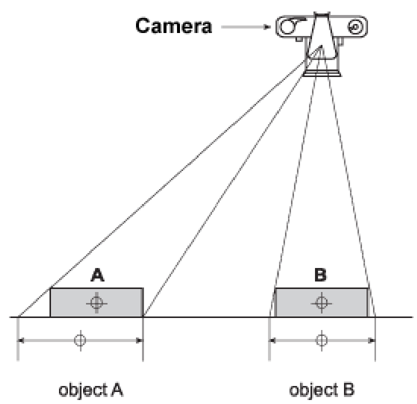

Figure 2. A robot's vision usually comes from an overhead camera.

Lesson: 11/17

The Parts of a Robotic Arm

A robotic arm, shown in Figure 1, can be any combination of the following parts: a base, shoulder, elbow, arm, wrist, and even fingers. An **end-of-arm tool** (EOAT), also known as the **end-effector**, is attached to the end joint of the arm. The end-effector is activated in response to signals that the robot sends and receives through its input/output module.

End-effectors can be shaped like hands or they can be highly specialized tools. Hand-shaped effectors, shown in Figure 2, are called **grippers**. Grippers come in many shapes and sizes. Tools also come in a wide variety and are designed for specific tasks such as welding or grinding.

Robotic arms have two basic types of joints. **Prismatic joints**, also known as **linear joints**, slide in a straight line across one axis. A **revolute joint**, on the other hand, is rotational. Revolute means that a joint revolves as opposed to moving in a straight line. The robot in Figure 3 has two prismatic joints and one revolute joint.

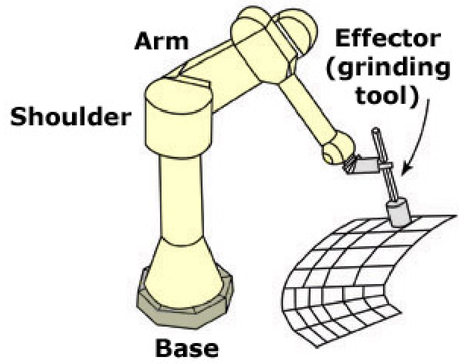

Figure 1. A robotic arm can include a base, shoulder, elbow, arm, and EOAT.

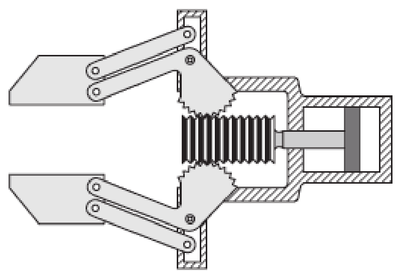

Figure 2. Hand-shaped effectors are called grippers.

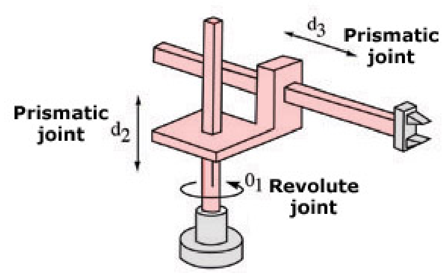

Figure 3. Robotic arms can have prismatic joints or revolute joints.

Lesson: 12/17

Degrees of Freedom

Robotic arms can be broken down into a series of movable parts connected by links and joints. The joints on a robotic arm can move in different directions. In robotics, the direction of movement is defined in terms of an X-, Y-, or Z-axis. The ability of a joint to move through an axis is referred to as a **degree of freedom**.

The degrees of freedom of a robot is determined by the number of joints on the robotic arm. Each joint provides one degree of freedom. Robots usually have three to six degrees of freedom. Less than three would not be very useful, and more than six would be redundant. The robot in Figure 1 has six degrees of freedom.

A degree of freedom allows a robot to move through one of six possible axes:

1. Sliding up and down the Z axis.
2. Sliding back and forth on the Y axis.
3. Sliding from side to side on the X axis.
4. Rotating around the Z axis.
5. Rotating around the Y axis.
6. Rotating around the X axis.

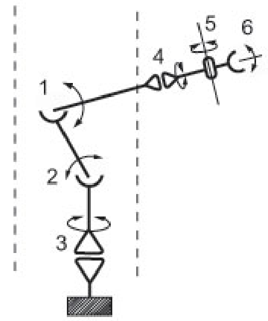

Figure 1. The number of degrees of freedom is determined by the number of joints on the robotic arm.

Lesson: 13/17

End-Effectors

Perhaps the most important component on a robot is the **end-effector**. End-effectors perform the work for which the robot has been programmed. The shape and size of the end-effector depends on its function, including:

- Grasping
- Feeding
- Moving
- Aligning
- Mounting

End-effectors are interchangeable. If the robot is required to perform a different task, a robotic **tool changer** can quickly attach a new end-effector for the job. Some examples of different types of end-effectors include:

- Welding guns
- Blowtorches
- Deburring tools (Figure 1)
- Drills
- Paint guns (Figure 2)
- Vacuum pumps
- Grippers

End-effectors have their own actuators. The actuators are usually pneumatic or they can be mechanical, such as a motor.

Figure 1. A deburring tool for a robotic arm.

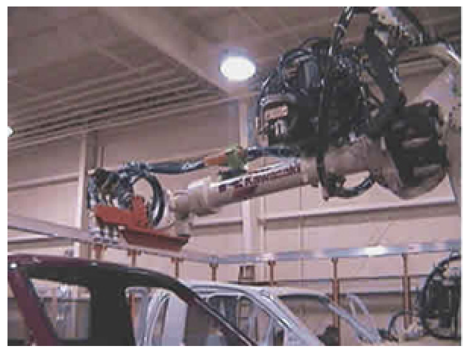

Figure 2. A spray painting robot. [Courtesy of Kawasaki Robotics (USA), Inc.]

Lesson: 14/17

Grippers

A **gripper**, shown in Figure 1, is a type of end-effector that is designed specifically for the purpose of grasping objects. Grippers have at least two moving **fingers**, but three-fingered grippers are also common. Finger movement can be rotary or linear.

To prevent slipping, grippers must have the appropriate level of flexibility to conform to the shape of the object they are grasping. Typically, the more irregular the shape of the object, the more flexibility is required of the gripper. Flexibility is one determiner of how firmly an object is held. Force control is another.

Grippers have their own drives. While some types of grippers use electric drives, most grippers have pneumatic drives that allow air pressure to be adjusted to control the gripping force.

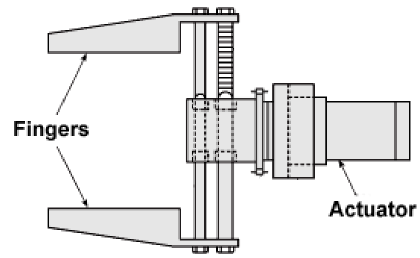

Figure 1. Grippers are designed specifically for grasping objects.

Lesson: 15/17

Types of Grippers

Grippers come in many varieties. A **vacuum gripper**, shown in Figure 1, has **suction cups** for gripping flat objects. The suctions cups can be round or oval, and they are usually made of rubber or plastic. Grip strength may be determined by the size of the suction cups. In addition, it can take time to create a vacuum within the cups, so objects may not be picked up immediately.

A **magnetic gripper**, shown in Figure 2, is used with metallic objects. Magnetic grippers allow for wide variations in part size, and they pick up objects very quickly. However, residual magnetism may remain in a workpiece after it has been handled by a magnetic gripper.

There are two types of magnetic grippers. **Electromagnets** can prevent residual magnetism in a workpiece through reverse polarity. However, electromagnets require a power supply. In contrast, **permanent magnets** do not need a power supply, but they do require a device to release a metallic object from the magnet. For this reason, permanent magnets are of limited usefulness.

An **expanding gripper** is used for grasping hollow objects from the inside. An inflatable **bladder** is inserted into the cavity of the object. When the bladder is inflated, the object can be lifted and moved. The bladder is deflated when the object needs to be released.

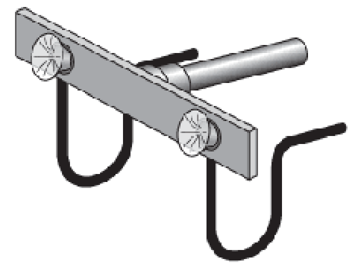

Figure 1. Vacuum grippers have suction cups for gripping flat objects.

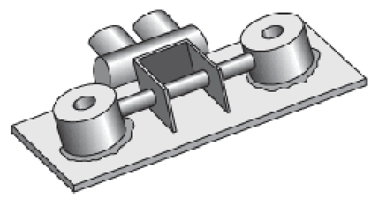

Figure 2. Magnetic grippers are used for gripping metallic objects.

Lesson: 16/17

Robot Safeguards

When installing a robot, the robot technician should incorporate **safeguarding systems** into the design of the work cell to help prevent accidents. A safeguarding system is any device, barrier, or process that protects a worker from being injured by a robot. There are two basic types of safeguarding systems. **Safety devices**, such as the light curtain in Figure 1, prevent the robot from operating when a worker is near a dangerous area. **Safety guards**, such as gates or fences, prevent a worker from entering a dangerous area of the robotic system. Figure 2 shows a safety fence around a robot's work cell.

When installing safeguards, the most important areas are the robot's work envelope and any moving parts. Plan to install locks and passwords to prevent unauthorized workers from accessing the robot's programs. Use a **lockout/tagout** key to prevent the robot from starting up when someone is inside the robot's work envelope. Finally, make sure there is sufficient space around the robot to prevent it from striking nearby workers or objects.

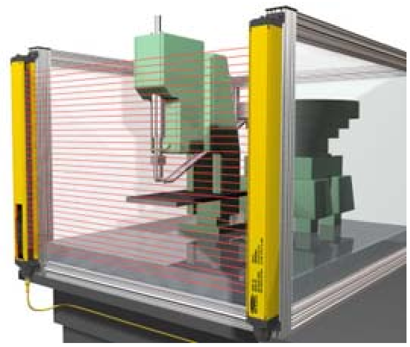

Figure 1. This light curtain causes the robot to stop if an object crosses the light field. (Courtesy of Banner Engineering.)

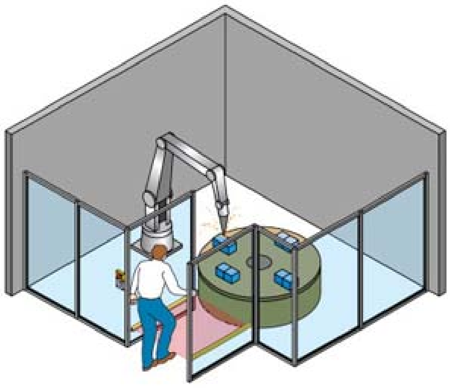

Figure 2. This safety fence prevents workers from entering dangerous areas. (Courtesy of Banner Engineering.)

Lesson: 17/17

Summary

Industrial robots consist of a manipulator and a controller. The main power supply provides voltage and current to the robot's motor. Industrial robots use electric power but need an actuator to convert the power into mechanical motion. Robots have three main types of actuators: hydraulic drives, pneumatic drives, and electric drives. Electric drives are the most widely used. DC servomotors are the preferred type of electric motor for high speed applications that require a robot to make multiple movements.

The controller is the "brains" of a robot. It is usually located inside a cabinet. The cabinet also contains the central processing unit and the power supply unit, as well as the axis control module and input/output modules. A teach pendant is connected to the cabinet by a long cable.

The axis control module controls the direction and speed of the robot. Typically, a velocity profile is created in the robot's program to ensure that the end-effector reaches the desired coordinates at the programmed speed and along the correct path. Sensors are also used to help robots complete their tasks.

A robotic arm can include a base, shoulder, elbow, arm, wrist, and an end-effector. Robotic arms have two basic types of joints. Prismatic joints slide in a straight line across one axis. Revolute joints rotate around an axis. The ability of a joint to move through an axis is called a degree of freedom. Robots usually have three to six degrees of freedom.

A gripper is a type of end-effector that is designed specifically for the purpose of grasping objects. Vacuum grippers have suction cups for gripping flat objects. Magnetic grippers are used with metallic objects. Expanding grippers are used for grasping hollow objects. When installing a robot, the robot technician should incorporate safeguarding systems into the design of the work cell to help prevent accidents.

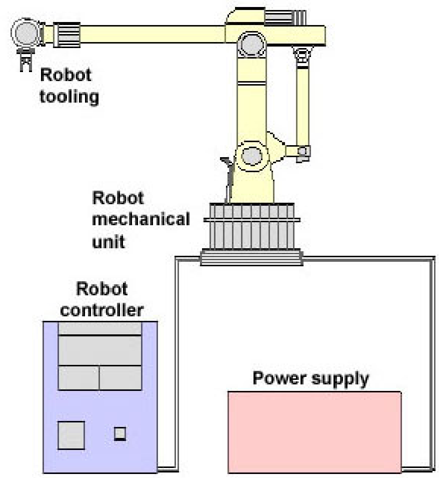

Figure 1. Basic robot components include a controller, a mechanical arm, and a tool at the end of the arm.

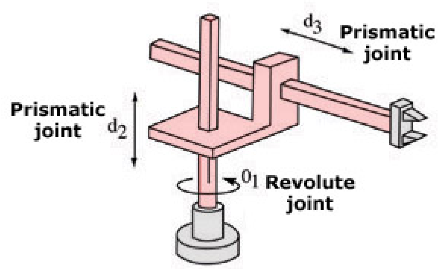

Figure 2. Robots can have prismatic joints or revolute joints.

Class Vocabulary

actuator A device that converts an electrical control signal into mechanical motion.

alternating current Current that regularly reverses the direction of its flow in a repeating, cyclical pattern. Power is supplied to robots using AC run through a transformer.

axis An imaginary straight line or circle used to describe the location or movement of an object in the Cartesian coordinate system.

axis control module A component that allows a robot to move in different directions. The axis control module also controls the velocity and torque of the robotic arm.

bladder An expandable sac that can be inflated with air or filled with fluid.

cabinet An enclosure containing a robot's controller, axis control module, input/output module, and power supplies.

Cartesian robot A type of robotic arm that has prismatic joints only. The linear movement of the joints gives the Cartesian robot a highly rigid structure that allows it to lift heavy objects.

central processing unit The main device that processes information and carries out instructions in a robot. Also known as the controller or processor.

circuit A controlled path for electricity. A circuit includes a source, path, load, and control.

compressor A component that pressurizes ambient air and directs it into a pneumatic system.

contact sensor A type of sensor that detects physical contact with an object or surface. Contact sensors for robots include tactile, force, and collision sensors.

control circuit A circuit in the robot's power supply that coordinates the robot's programming, motion control, and I/Os.

controller The main device that processes information and carries out instructions in a robot. Also known as the CPU or processor.

coordinate A specific location in three-dimensional space.

count An increment on an encoder that measures the distance a robotic arm has traveled.

current The flow of electricity. Current is measured in amps.

degree of freedom The available ways a component can move in three-dimensional space. Robots typically have three to six degrees of freedom.

direct current Current that travels in one direction. Robots run on DC motors.

electric drive An actuator that uses electricity to create mechanical motion.

electric motor A machine that converts electricity into mechanical energy or motion. An electric motor is a type of prime mover for a hydraulic system.

electromagnet A powerful magnet that gains an attractive force only when current passes through it.

encoder A measuring device for motion control that is divided into a fixed number of increments called counts. In a typical encoder, one revolution equals one million counts.

end-effector The end component of a robotic arm that is shaped like a hand or like a specialized tool. Also known as end-of-arm tool (EOAT).

end-of-arm tool The end component of a robotic arm that can be shaped like a hand or a specialized tool. Also known as an end-effector.

expanding gripper A type of EOAT that uses an inflatable bladder to lift hollow objects from the inside.

finger The part of a gripper that grasps an object.

force multiplication The exponential increase in available power. Hydraulic drives and pneumatic drives provide high force multiplication.

gripper A hand-shaped end-effector designed for seizing and holding.

hydraulic drive An actuator that uses pumps, valves, and pressurized liquids to create mechanical motion.

hydraulic pump A mechanical device used to move liquids. The hydraulic pump introduces pressure into the system.

industrial robot A programmable mechanical device that is used in place of a person to perform dangerous or repetitive tasks with a high degree of accuracy.

input A device, usually a type of sensor, that sends information into a robot.

input/output module The jack where an input/output device is physically connected to a robot. Inputs and outputs allow the robot to interact with its environment.

LCD screen A screen on a teach pendant for displaying the robot′s inputs and outputs, position, and program.

linear joint A joint that moves in a straight line across one axis. Also known as a prismatic joint.

lockout/tagout A method of protecting employees from accidental robot startup through proper locking and labeling of robots that are undergoing maintenance.

magnetic gripper A type of EOAT that uses electromagnets or permanent magnets to pick up metallic objects.

main power supply The power supply that provides voltage and current to a robot′s motor. A robot's main power supply is AC run through a transformer.

manipulator A robotic arm. A manipulator is generally mounted on a platform or suspended from a track while the arm reaches to various distances and locations.

motion control key A type of key on a teach pendant for lead-through programming and position adjustment of the robot.

noncontact sensor A type of sensor that detects changes in light or an electromagnetic field. Noncontact sensors for robots include proximity sensors and vision sensors such as photosensors and cameras.

number key A type of key on a teach pendant for entering numeric data such as axes.

output A device that performs a mechanical action after receiving the electrical signal to do so from the robot.

payload The maximum load that a robot can manipulate.

permanent magnet A magnet that retains its attractive force once it is removed from a magnetic field.

pick-and-place robot A robot designed to transfer objects from one place to another.

pneumatic drive An actuator that uses pressurized air to create mechanical motion.

power circuit The circuit for the power supply. Power circuits for robots provide large amounts of power to the servo amplifiers that power the robot's drives.

power off A button on a teach pendant that powers off the controller.

power on A button on a teach pendant that powers up the controller and turns on the servomotor if it has been turned off by an E-stop.

power supply unit A separate power supply that provides DC voltage to a robot's outputs and controller.

prime mover A device supplying the force necessary to turn the shaft of a generator or alternator. Hydraulic drives and pneumatic drives require prime movers.

prismatic joint A joint that moves in a straight line across one axis. Also known as a linear joint.

program control key A type of key on a teach pendant for selecting and executing programs.

revolute joint A joint that rotates around more than one axis.

safeguarding system Any device, barrier, or process that protects a worker from being injured by a robot. The two basic types of safeguarding systems are safety devices and safety guards.

safety device A mechanism that prevents the robot from operating when a worker is near a dangerous area.

safety guard An obstacle that prevents a worker from entering a dangerous area of the robotic system.

sensor A device that detects the presence or absence of an object, or certain properties of that object, and provides feedback. Robots use sensors to interact with their environment.

servomotor A type of motor used in applications that require precise positioning. Many robots use DC servomotors.

status lamp A LED on a teach pendant that lights up when errors occur.

suction cup A rubber or plastic device that sticks to smooth, nonporous surfaces. A robot's grip strength may be determined by the size of the suction cups.

teach pendant A hand-held device that can be used to program a robot and control its movements.

tool changer A device used for changing the end-effector on a robotic arm.

transformer A device that transfers electrical energy from one circuit to another, without changing the frequency, using electromagnetic induction. A transformer is most often used to change the line voltage.

vacuum gripper A type of EOAT that uses suction cups for gripping flat objects.

velocity profile A profile in the robot's program that controls the acceleration and deceleration of the robotic arm as it moves to its destination.

voltage A measure of electrical pressure or potential. Voltage is measured in volts.