Robotics II

Encoders

Feedback Devices, Encoders

An encoder is an electrical mechanical device that can monitor motion or position. A typical encoder uses optical sensors to provide a series of pulses that can be translated into motion, position, or direction.

2 main types of encoders are:

1) **Absolute encoders**
2) **Incremental encoders**

Within our lab we can see examples of the different robot feedback systems.

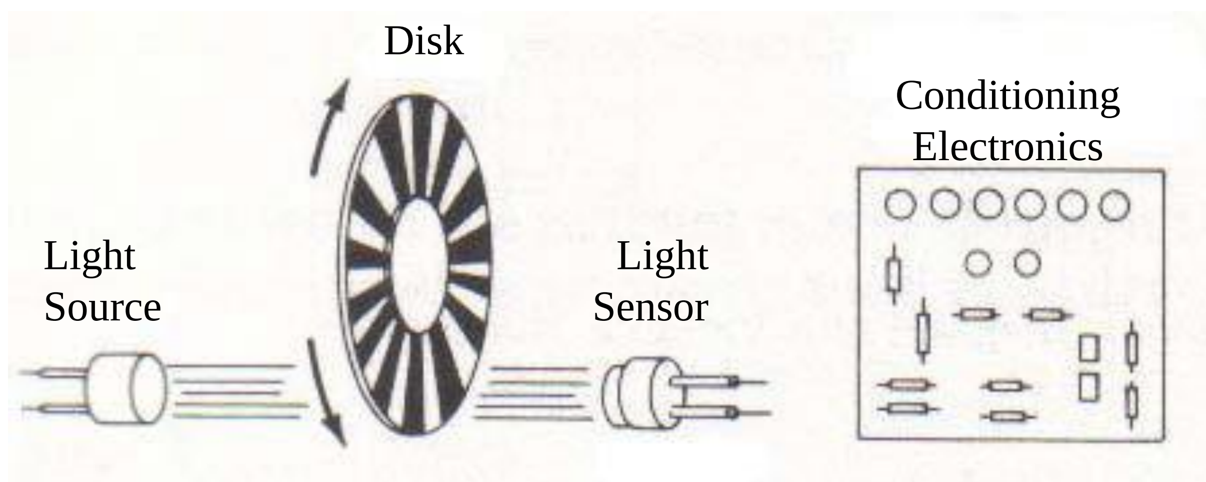
Motoman, Denso and **Fanuc** are robots that remember there position and do not need to be taken to a home position at power up.

Wittmann robot that must be taken to a home position before they are aware of there location.

Keep these differences in mind as to read through the next few pages.

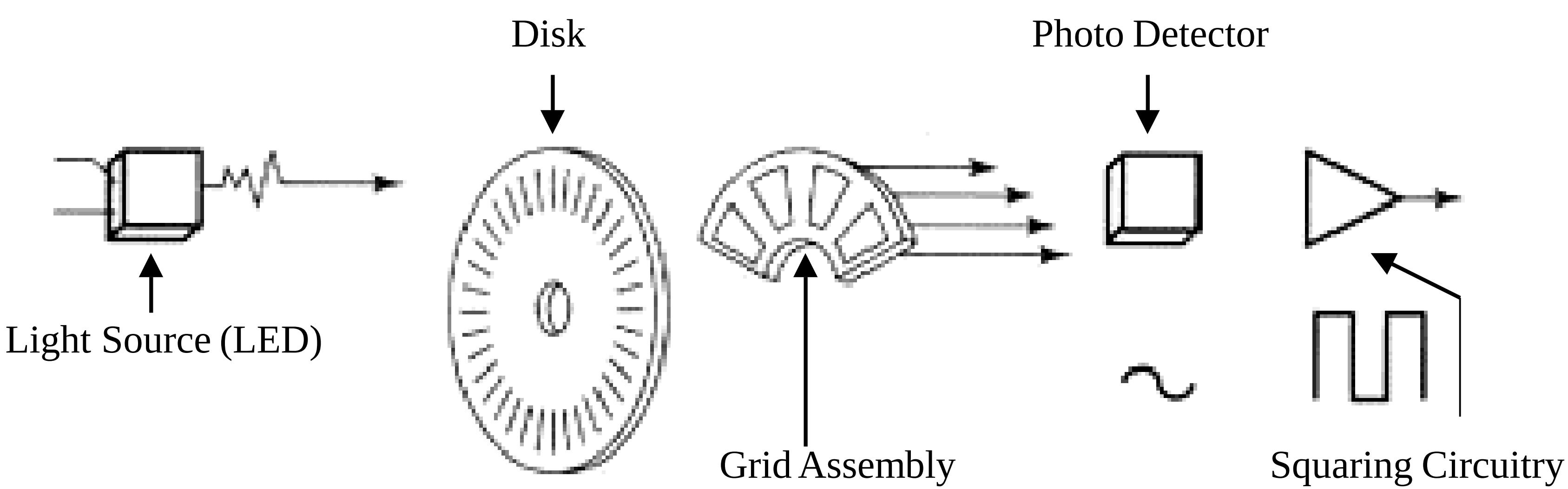
Feedback Devices, Encoders

Encoder wheels are made from clear glass that has opaque segments etched in them like bars. As the encoder wheel spins, the opaque segments block the light and where the glass is clear, light is allowed to pass. This provides a pulse train similar to a disk that has holes drilled in it. Typical glass encoders have from 100 to 80000 segments. An encoder with 100 segments can provide 3.6° (360/100=3.6) of resolution. The more segments the encoder has the more accurate it is. If the shaft of the encoder is connected to a drive shaft for a motor that is connected to a ball screw or a reduction gear, the number of degrees of resolution can be converted into linear position.

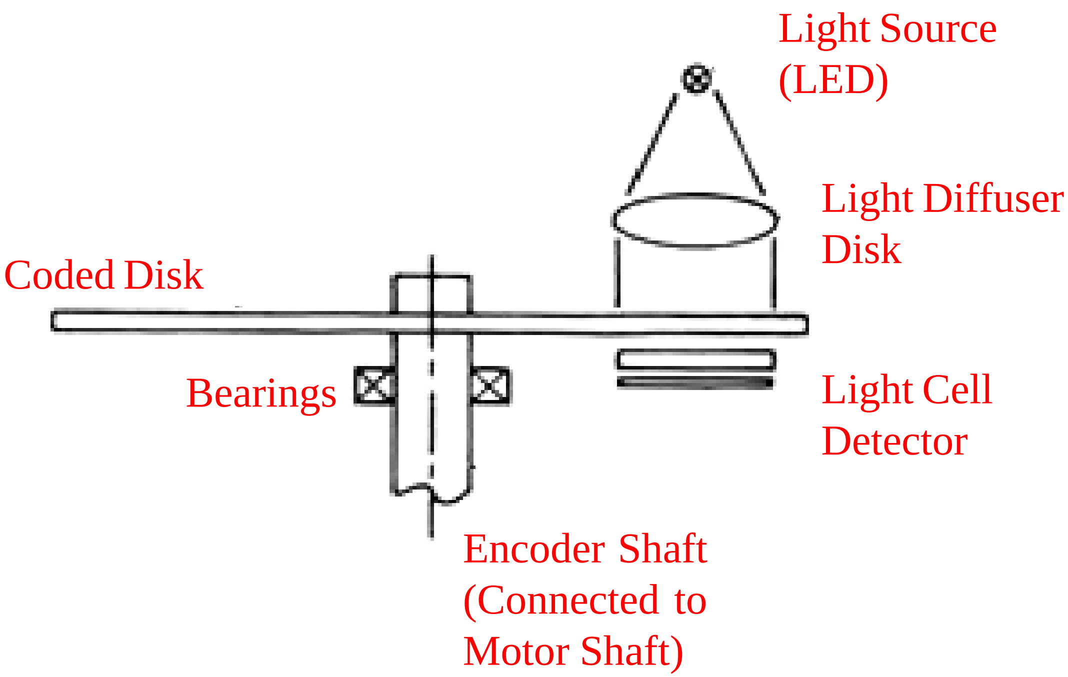


Feedback Devices, Encoders

The diagram shows that the disk is very thin, and a stationary light-emitting diode (LED) is mounted so that its light will continually be focused through the glass disk. A light-activated transistor is mounted on the other side of the disk so that it can detect the light from the LED. The disk is mounted to the shaft of a motor or other device whose position is being sensed, so that when the shaft turns, the disk turns. When the disk lines up so the light from the LED is focused on the phototransistor, the phototransistor will go into saturation and an electrical square wave pulse will be produced. This figure shows an example of the square wave pulses that are produced by the rotary encoder.

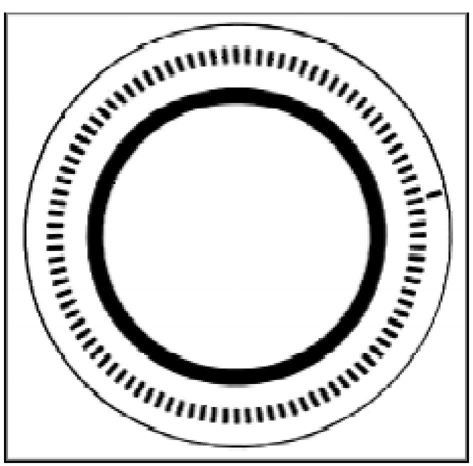


Incremental Rotary Encoder



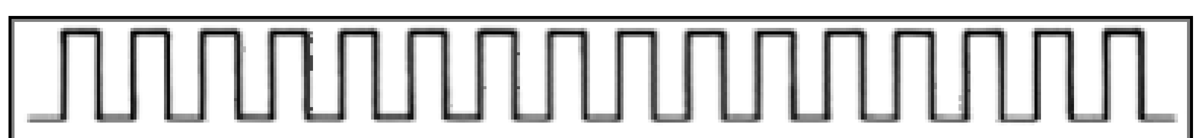
An incremental rotary encoder generates a square wave pulse pattern as the encoder disk turns. The disk is coupled directly to the motor shaft. If the motor turns so does the encoder, producing a square wave signal. If the square wave is monitored we can determine both the speed of motor rotation and amount of motor rotation.

This information can then be used to calculate the manipulator location.



Shown is an example of a simplified basic incremental encoder construction, a coded disk and the produced square wave.

Incremental Rotary Encoders are sometimes called Pulse Generators.



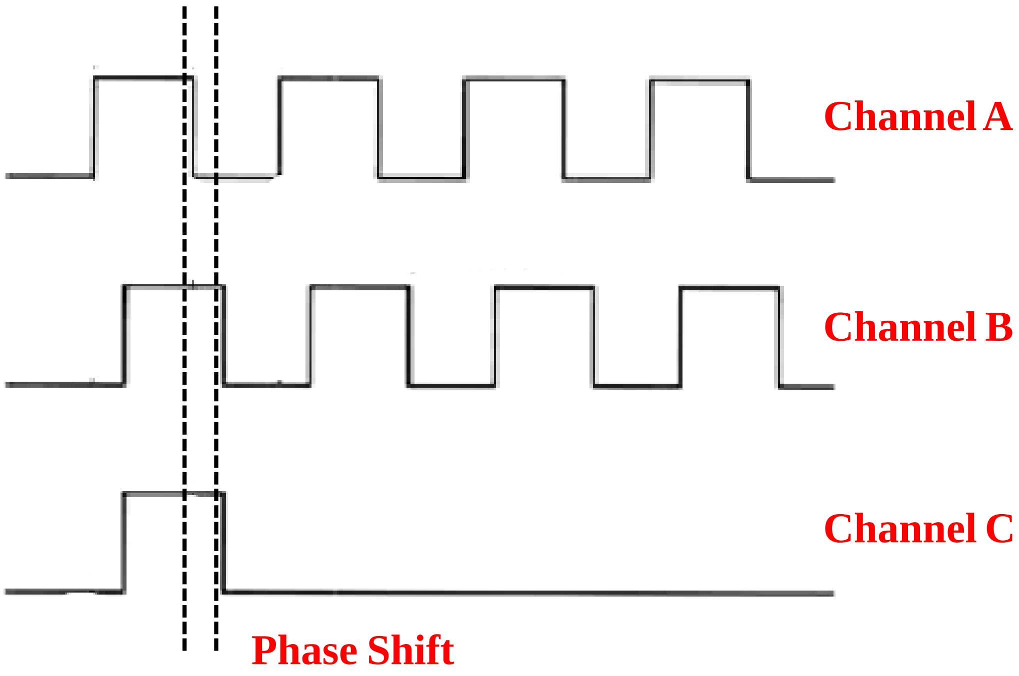
Incremental Rotary Encoder

An encoder with one set of pulses would not be useful since it could not indicate the direction of rotation. Most incremental encoders have a second set of pulses that is offset (out of phase) from the first set of pulses, and a single pulse that indicates each time the encoder wheel has made one complete revolution.

Since the two sets of pulses are out of phase from each other, it is possible to determine which direction the shaft is rotating by the amount of phase shift between the first set and second set of pulses.

The first set of pulses are called the A pulses, and the second set of pulses are called the B pulses. A third light source is used to detect a single pulse that appears once per revolution. Below is shown an example of the two sets of pulses that are offset.

This pulse is called the *command pulse,* which is used to count revolutions of the shaft where the encoder is connected.



Incremental Rotary Encoder

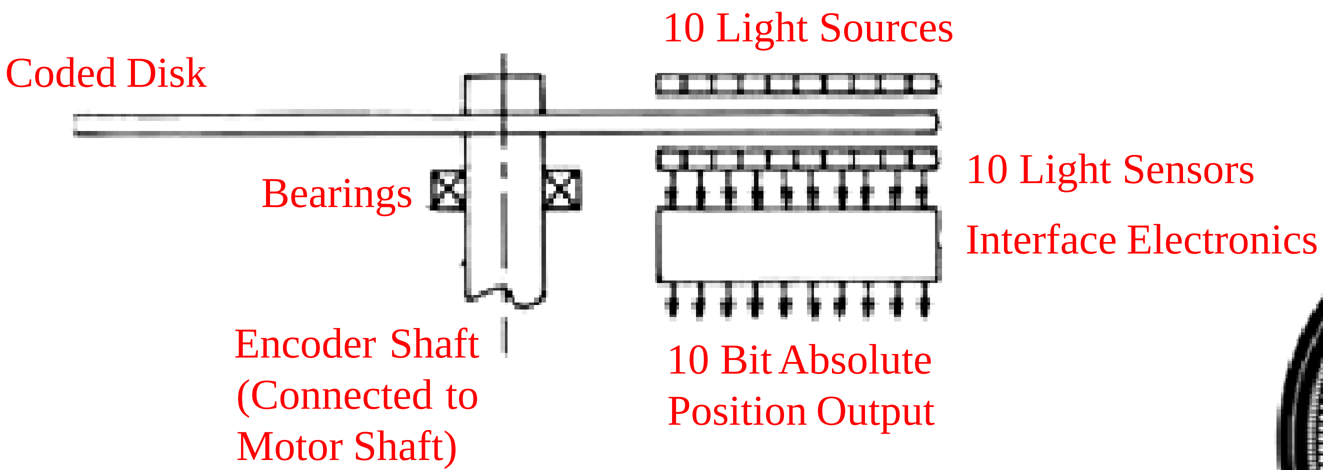
One of the major drawbacks of the incremental encoder is that the number of pulses that are counted are stored in a buffer or external counter. If power loss occurs, the count will be lost. This means that if a machine with an encoder has its electricity turned off each night or for maintenance, the encoder will not know its exact position when power is restored. The encoder must use a home-detection switch to indicate the correct machine position. The incremental encoder uses a *homing routine* that forces the motor to move until a home limit switch is activated. When the home limit switch is activated, the buffer or counter is zeroed and the system knows where it is relative to fixed positional points.

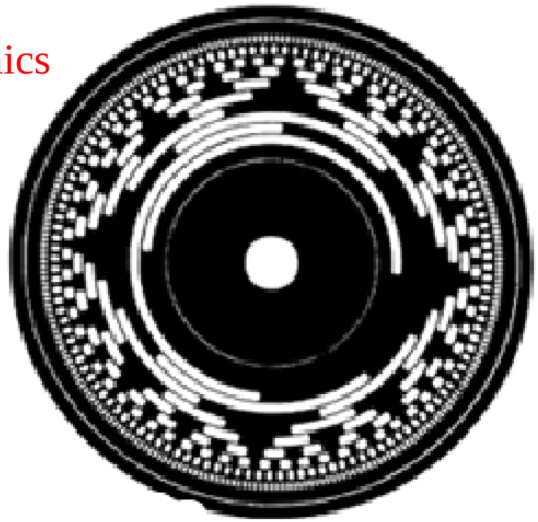
Absolute Encoders

Absolute Encoders have been designed to address the problem of position loss on power failure. It is designed in such a way that the machine will always know its location. Absolute encoders are probably the most common type of encoder used on modern industrial robots.

Absolute Encoders

Show below is an example of an absolute encoder. From this figure you can see that this type of encoder has alternating opaque and transparent segments like the incremental encoder, but the absolute encoder uses multiple groups of segments that form concentric circles on the encoder wheel like a "bull's eye" on a target or dartboard. The concentric circles start in the middle of the encoder wheel and as the rings go out toward the outside of the ring they each have double the number of segments than the previous inner ring. The first ring, which is the innermost ring, has one transparent and one opaque segment. The second ring out from the middle has two transparent and two opaque segments, and the third ring has four of each segment. If the encoder has 10 rings, its outermost ring will have 512 segments, and if it has 16 rings it will have 32,767 segments.





Absolute Encoders

Since each ring of the absolute encoder has double the number of segments of the prior ring, the values form numbers for a binary counting system. In this type of encoder there will be a light source and receiver for every ring on the encoder wheel. This means that the encoder with 10 rings has 10 sets of light sources and receivers, and the encoder with 16 rings has 16 light sources and receivers.

The advantage of the absolute encoder is that it can be geared down so that the encoder wheel makes one revolution during the full length of machine travel. If the length of machine travel is 10 inches and its encoder has 16-bit resolution, the resolution of the machine will be 10/65,536, which is 0.00015 inch. If the travel for the machine is longer, such as 6 feet, a *coarse resolver* can keep track of each foot of travel, and a second resolver called the *fine resolver* can keep track of the position within 1 foot. This means the coarse encoder can be geared so that it makes one revolution over the entire 6-foot distance, while the fine encoder is geared so that its entire resolution is spread across 1 foot (12 inches).

Since the absolute encoder produces only one distinct number or *bit pattern* for each position within its range, it knows where it is at every point between the two ends of its travel, and it does not need to be homed to the machine each time its power is turned off and on.

Grey Code

The encoder output bit count is not the same as the standard binary count you would expect. The standard encoder count shown below (a) has time where more that one bit is changing at a time. This increases the odds that there could be a time when the robot is not clear on the count. To reduce this risk a new form of binary count was designed that only the robot controller would understand. In this new code no more than one bit ever changes at a time and reduces the risk of an improper count. This encoder count is called grey code.

You will seldom need to deal with grey code in industrial robot applications, but not knowing it exists could lead to thinking it is an incorrect binary count should you have to deal with it. You may also run into grey code when programming PLC'S.

Binary Code	Grey Code
0000	0000
0001	0001
0010	0011
0011	0010
0100	0110
0101	0111
0110	0101
0111	0100
1000	1100
1001	1101
1010	1111
1100	1110

Batteries

If your thinking that this is leading toward saying that some industrial robots run on batteries, it's not. There are some robots that do use batteries as a source of electricity for there power supply (see below). The batteries we are dealing with are within the manipulator and/or controller on almost all industrial robots.

The reason for these batteries is to keep the RAM (Random Access Memory) that stores the encoder count and offset energized. If power is removed from the robot the encoder count and offset are stored in the RAM. When power is returned the controller knows where the manipulator is due to the information stored in RAM. Typically the replacement of these batteries is part of a predictive maintenance program. Normally the batteries must be purchased through the robot manufacturer.

If the batteries are dead or removed when the power is shut off encoder count and offset are lost. It is understandable that battery replacement is one of the few maintenance job that is performed on a robot when the power is on.

Many AGV (Automatically Guided Vehicles) use batteries as a power source to move the AGV around within the facility. Somewhere within the facility is a docking station for battery charging.