A CNC control system includes a velocity loop within an axis drive system and a position loop external to the axis drive system.

**Position Feedback Options**

- **Potentiometers**
  - Linear
  - Rotary
- **Resolvers**
  - Linear
  - Rotary
- **Encoders**
  - Linear
  - Rotary

**What are Potentiometers?**

Material with constant resistance per unit length properties.

\[ \delta = \frac{V}{V_0} \]

Position can be computed from voltage ratios.

**What are Encoders?**

A device used to convert linear or rotational position information into an electrical output signal.

- Magnetic (LVDT)
- Contacting
- Capacitive
- Optical
How Does a Rotary Optical Encoder Work?

- Outer track is used to determine position.
- Middle track is used to measure direction of rotation.
- Inner track is used to indicate a complete revolution.
- Integrated counter circuits are used to count leading or falling edges of pulses.

Incremental Encoders

Incremental Encoder - Produces equally spaced pulses from one or more concentric tracks on the code disk. Position is determined by counting pulses.

Incremental Encoder must be calibrated. Power loss will lead to loss of position information unless a backup power source is used.

Absolute Encoders

Absolute Encoder – produces a binary number that uniquely identifies each position on the code disk.

- Absolute encoders do not have to be recalibrated after a power loss.
- Absolute encoders are more expensive than incremental encoders.

Gray Binary Code

Compliments of BMC Buckbee-Mears St. Paul

How Does a Linear Optical Encoder Work?

- Linear instead of rotary scale.
- Glass is used because of low sensitivity to temperature changes.

MTD Bridgeport

Typical Acu-lite Encoder Accuracy

± 5 ±m /m

or

± 0.0002 ±m/in

Acu-lite Glass Scale Encoder

Compliments of BMC Buckbee-Mears St. Paul
Industrial Applications

Rotary Encoders are widely used with robotics.

Linear encoders are widely used with machine tools.

What are Resolvers?

A resolver is a rotary transformer that produces an output signal that is a function of the rotor position.

Servomotor with Resolver

Parker, Fig. 1-44

Operational Features of CNC Machine

Dugan, Figure 29-10.

Velocity Feedback

Tachometers

Electrical output is proportional to rate of angular rotation.

Encoders, Resolvers, Potentiometers

Number of pulses per time is proportional to rate change of position.

Rotary Encoder Velocity (Example)

\[
S = \frac{60C}{NT_c}
\]

What is velocity resolution?

S = shaft speed, rpm
N = number of pulses per shaft revolution
C = total count during time interval T_c
T_c = counter time interval, seconds
A CNC control system includes a velocity loop within an axis drive system and a position loop external to the axis drive system.

**CNC Programming Methods**

- **Manual**
- **Computer Aided Manufacturing (CAM)**

**Main Control Unit**

**Types of CNC Programming Languages**

<table>
<thead>
<tr>
<th>Standard</th>
<th>Proprietary (Conversational)</th>
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<tbody>
<tr>
<td>ISO 6983</td>
<td>Respond to prompts</td>
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<tr>
<td>EIA RS274</td>
<td>Typically proprietary</td>
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<td>Command List</td>
<td></td>
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</tbody>
</table>

**Who and what is EIA?**

- Electronic Industries Association
- U.S. Manufacturers of electronic equipment.

**Who and What is ISO?**

- World wide standards organization
- ISO – means one

[www.eia.org/eng/published.htm](www.eia.org/eng/published.htm)
**ISO 6983 and EIA RS274**

- Standards are very similar
- EIA in most cases will adopt an ISO standard with only minor changes and issue the standard under an EIA number.
- CAD/CAM programs support these standards

---

**Example of ISO 6983 and EIA RS274 Standard Code**

```
H5 G90 G20
H10 M64 D2
H15 M63 D1250
H20 G00 X1 Y1
H25 T0.1
H35 G01 X-0.125 F5
H35 X3 Y2 F10
H40 G00 X1
H45 X0 Y0
H50 M5
H55 M30
```

(Hello #5, Absolute in inches)

(Tool change to Tool #0)

(Rapid to X,Y)

(Rapid down to Z)

(Rapid down to Z at 150rpm)

(Rapid diagonal to X2,Y2 at 10rpm)

(Rapid up to Z1)

(Spindle Off)

(Program End)

*Often referred to as M-code or G-code*

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**Major Manufacturers of ISO and EIA Main Controllers**

- **Fanuc**
- **General Electric**
- **Cincinnati Milicron**
- **Bendix**
- **Giddings and Lewis**

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**Steps in the CNC Process**

**(Manual Programming)**

1. Review part drawing
2. Decide which machine will produce the part
3. Choose the tooling required
4. Decide on the machining sequence
5. Do math calculations to find part coordinates
6. Calculate the spindle speeds and feed rates required for the tooling and part material
7. Write the CNC program
8. Prepare setup sheets and tool lists
9. Verify the program using a CNC simulator or the actual machine
10. Edit the program if necessary
11. Run the program and produce the part

---

**Steps in the CNC Process**

**(CAM)**

1. Develop the three-dimensional geometric model of the part using CAD
2. Decide which machining operations are required to produce the part
3. Choose the tooling to be used
4. Run a CAM software program to generate the CNC part program, including the setup sheets and list of tools
5. Verify the program on a machine simulator
6. Download the part program(s) to the appropriate machine(s)
7. Verify the program(s) on the actual machine(s) and edit if necessary
8. Run the program(s) and produce the part

---

**What is a 3-D CAD model?**

- A 3-D cad model is a computer representation of an actual part.
- The computer representation contains all of the physical information about the part (material, dimensions, etc.).
- The mathematical descriptions of the model’s surfaces can be used to create CNC code.
A good designer must know how a part will be produced and what tooling will be used to make it.

- This part is made using sand casting technology.
- The patterns are machined using a three-axis CNC mill.
- Finish machining is done using a three-axis CNC mill.

Assignment

Review information about ISO and EIA on the web.