

## WHAT IS COMPUTER NUMERICAL CONTROL (CNC)? MEANING, FUNCTIONALITY, AND APPLICATIONS

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ABSTRACT	KEY WORDS
Computer Numerical Control (CNC) technology revolutionizes manufacturing by automating machine operations with computer systems, eliminating the need for constant human involvement. This article explores the fundamentals of CNC, highlighting its ability to manage tool movements with unparalleled precision using G-code instructions. Key functionalities include operations such as milling, turning, laser cutting, and 3D printing, enabling the production of complex and high-precision components. Essential considerations like material selection, tool maintenance, and workflow optimization are discussed to ensure efficient operation. Applications span industries such as aerospace, automotive, and architecture, showcasing CNC's role in creating highly accurate, customizable, and scalable products.	CNC technology, Computer Numerical Control, manufacturing automation, G-code, precision machining, milling, turning, laser cutting, plasma cutting, 3D printing, aerospace components, automotive parts, machining applications, rapid prototyping, mass production, high-precision manufacturing.

### Introduction

In traditional manufacturing, skilled workers manually operate machines to create parts. This can be risky, especially when handling heavy equipment or dangerous materials, and it can also lead to fatigue due to repetitive tasks. Computer Numerical Control (CNC) technology eliminates the need for constant human involvement, speeds up production, and reduces errors caused by human fatigue.

### What Is Computer Numerical Control (CNC)?

Computer Numerical Control (CNC) is a technology that uses computer systems to control machines during the manufacturing process. With CNC, computers manage the movement of tools and machinery with great precision. The machine follows instructions, much like a recipe, to determine how it should move, at what speed it should operate, and where it should cut. These instructions are written in a code called G-code.

For example, when using a CNC milling machine, a worker loads a digital design into the system. The machine then reads the design and follows the instructions to carve out the desired shape from a block

of material. CNC machines are highly accurate, able to make cuts at a scale smaller than the width of a human hair. This precision, often measured in micrometres ( $\mu\text{m}$ ) or thousandths of an inch, is essential in fields like aerospace and medical device manufacturing, where exact components are required.

Some CNC systems use sensors to constantly monitor the machining process. If the tool deviates from its expected position, the system automatically makes adjustments, ensuring consistent quality, especially in mass production. CNC also allows for rapid prototyping and customization, as engineers can easily modify instructions without having to physically alter the machine setup.

CNC technology is used across many industries, including aerospace, automotive, electronics, and even by hobbyists in metalworking, woodworking, and 3D printing.

## How Does CNC Work?

CNC systems work by converting a digital design into machine-readable instructions. Here's a breakdown of how a CNC machine operates:

1. **Design the Part:** The part is first designed using CAD (Computer-Aided Design) software.
2. **Write Instructions (G-code):** The design is translated into G-code, a language the machine can understand, specifying how the machine should move and cut.
3. **Set Up the Machine:** The worker loads the material (like metal or plastic) into the CNC machine and attaches the necessary cutting tool.
4. **Run the Program:** The CNC machine reads the G-code and begins executing the instructions.
5. **Make the Cuts:** The cutting tool moves in various directions, making precise cuts according to the design.
6. **Admire the Results:** The machine finishes the process, and the part is complete, replicating the design accurately.

CNC machines can repeat this process many times, producing identical parts with high consistency. This is especially useful for manufacturing complex components that would be difficult to make by hand, such as car engine parts or intricate jewellery designs.

## Types of CNC Operations

Different types of CNC machines perform specific operations depending on the required part. Some of the most common CNC operations include:

1. **Milling:** Uses rotating cutting tools to remove material and shape the work piece into the desired form. Milling machines can handle both 2D and 3D designs, making them versatile for industries like aerospace and automotive.
2. **Turning:** The work piece is rotated while a stationary cutting tool shapes it. This operation is typically used for cylindrical parts, such as shafts and bolts.
3. **Drilling:** CNC drilling machines are used to create precise holes in various materials.
4. **Laser Cutting:** A laser beam is used to cut or engrave patterns into material with high precision.
5. **Plasma Cutting:** Uses a jet of superheated plasma to cut through metals, often used for thicker materials.

6. **Waterjet Cutting:** High-pressure water mixed with abrasive particles cuts through materials. This method is heat-free, making it suitable for delicate materials and thick sections.
7. **Routing:** CNC routers carve out patterns or hollow areas in materials like wood and plastic.
8. **3D Printing/Additive Manufacturing:** While not strictly CNC, 3D printing uses an additive process to build up material layer by layer to create complex objects.
9. **Electrical Discharge Machining (EDM):** Uses electrical discharges to remove material, typically from hard metals.

## Key Considerations in CNC Systems

To ensure CNC machines operate effectively, manufacturers need to consider several factors:

1. **Design and Programming:** The design needs to be accurately translated into G-code for the machine to follow. CAD and CAM (Computer-Aided Manufacturing) software play a key role in this.
2. **Material Selection:** The material used for the workpiece affects the choice of tools and the machining process. Harder materials, for example, may require different tools or cutting speeds.
3. **Tool Selection and Maintenance:** Choosing the right tools for cutting and maintaining them regularly is crucial to ensuring the accuracy and efficiency of the machining process.
4. **Workholding:** Properly securing the material is essential to avoid misalignment during machining, which could result in wasted material or faulty parts.
5. **Speeds and Feeds:** The cutting speed and feed rate must be optimized to prevent excessive wear on tools and ensure smooth operation.
6. **Precision and Tolerances:** CNC machines offer high precision, but it's essential to understand the required tolerances to ensure that parts function correctly.
7. **Fixture and Setup:** The workpiece must be properly positioned to avoid errors during the machining process.
8. **Safety Measures:** CNC machines often involve high-speed moving parts, so safety protocols and protective barriers are important.
9. **Prototyping and Testing:** Before mass production, it's helpful to create prototypes and conduct test runs to identify any potential issues.
10. **Quality Control:** Regular checks throughout the machining process ensure that the final product meets specifications.
11. **Workflow Optimization:** Efficient integration of design, software, and machine tools can improve productivity and reduce errors.

## Applications of CNC Technology

CNC technology has a wide range of applications across multiple industries, helping to produce high-precision parts at scale. Some key areas of CNC application include:

1. **Aerospace:** CNC is used to create highly precise components like turbine blades, engine parts, and structural components for aircraft and spacecraft.
  - **Example:** Designing airfoil shapes for jet engine blades.

2. **Automotive:** CNC machines manufacture critical components such as engine blocks, crankshafts, and cylinder heads.
  - **Example:** Producing parts with tight tolerances, such as engine components.
3. **Architecture and Construction:** CNC is used to produce detailed architectural models, decorative building elements, and large-scale construction parts.
  - **Example:** Creating decorative facades and structural components.
4. **Art and Sculpture:** Artists use CNC technology to create detailed sculptures and carvings in materials such as wood, metal, or stone.
  - **Example:** Carving intricate designs into various materials for artistic purposes.

In summary, CNC technology has transformed the way industries produce components by offering greater precision, efficiency, and customization. Its ability to handle complex tasks with high accuracy has made it indispensable in industries ranging from aerospace to healthcare, while also enabling faster prototyping and mass production.