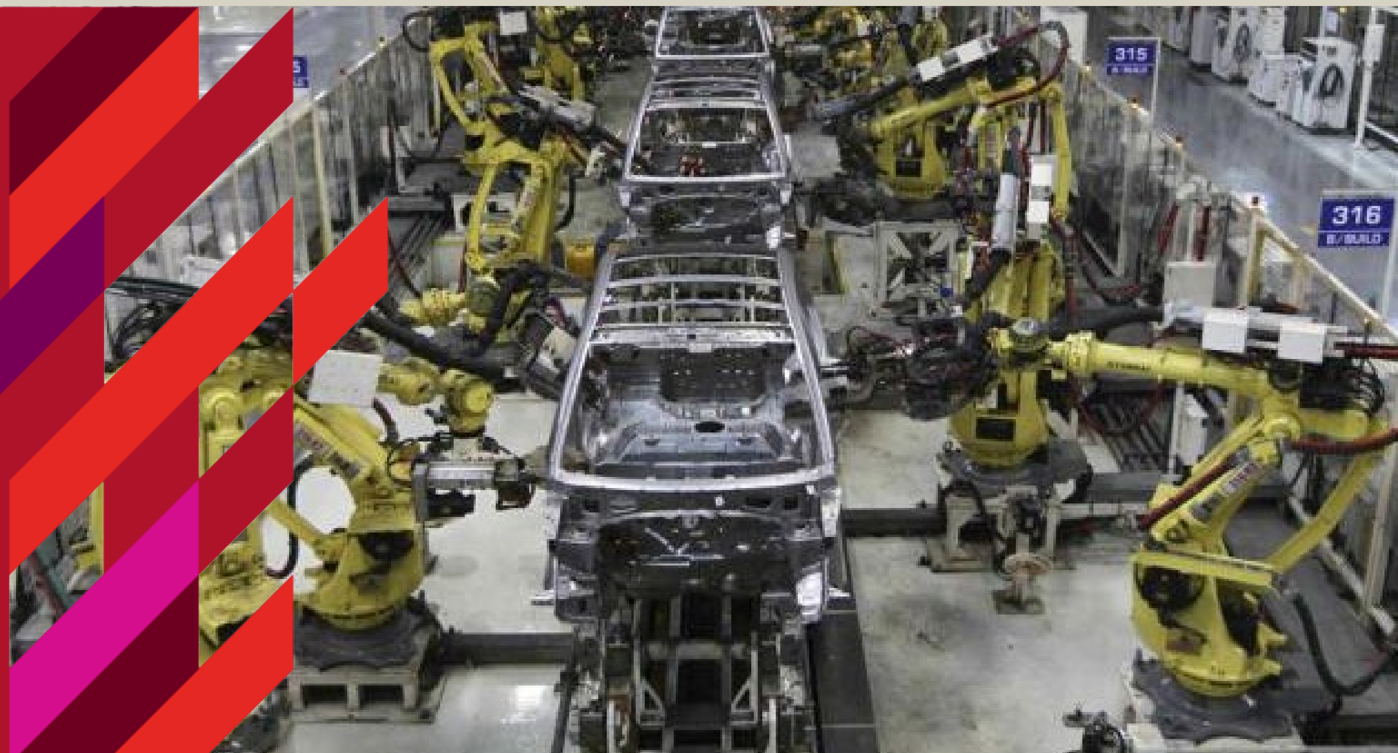
MACQUARIE University

MECH203 – Mechanical Engineering Design
Manufacturing Automation



Manufacturing Automation

Week 8 will be the mid session test. There will be no lecture that week.

The test will be available on iLearn from 9am until 5pm, Wednesday April 26th.

It will consist a mixture of multiple choice and short answer questions.

The test will cover material from week 1 to 7 and be a mix of multiple choice and calculation based questions.

It will be 60 minutes in duration.

Test instructions are provided before the test begins, please read them carefully!

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Week 9 will be the second CAD test. This will be conducted during your specific tutorial time slot and everybody is required to attend. There will be no alternative test time so please do not ask!

You are only permitted to attend the tutorial at the location that corresponds with your enrolment in e-student. Only the enrolled students will have access in ilearn to the instructions and required files. Anybody not attending the correct tutorial will be penalised for not doing so regardless of the reason! If you can not make the tutorial that you are currently enrolled in, try enrolling into a different tutorial in e-student.

The test will cover the tutorial exercises from week 6 to 8. It will have a very similar format to that of the first CAD test assessing your ability to complete specific tasks and the time required to complete them.

To perform well in the CAD test, you are expected to practice the exercises at home or in your own time!

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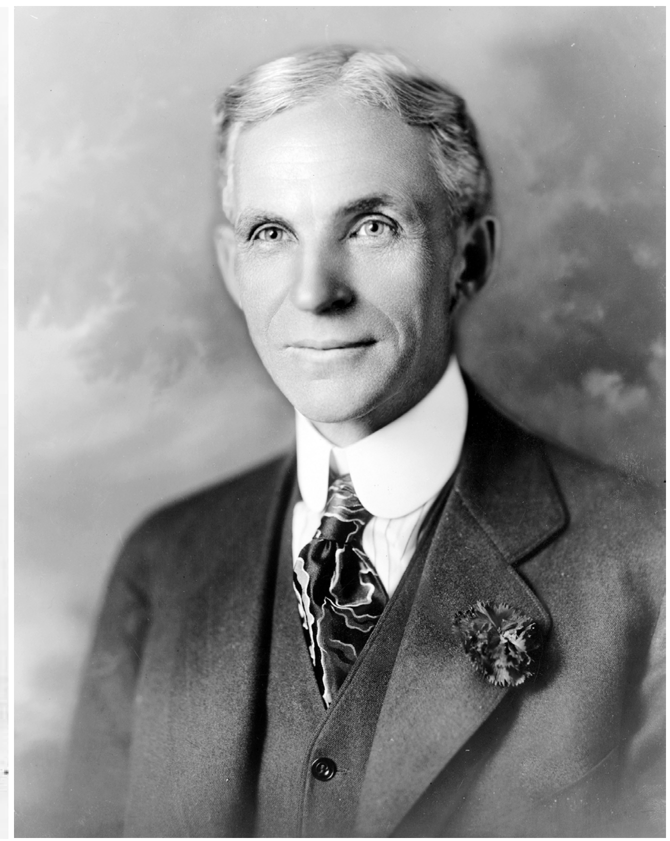
Introduction

What is this vehicle, who is this person and what has been their contribution to your life?



Manufacturing Automation

Introduction

What is this vehicle, who is this person and what has been there contribution to your life?

Manufacturing Automation

Introduction

Manufacturing automation is a vital part of reducing the cost of products and therefore makes them affordable.

$19,990

Manufacturing Automation

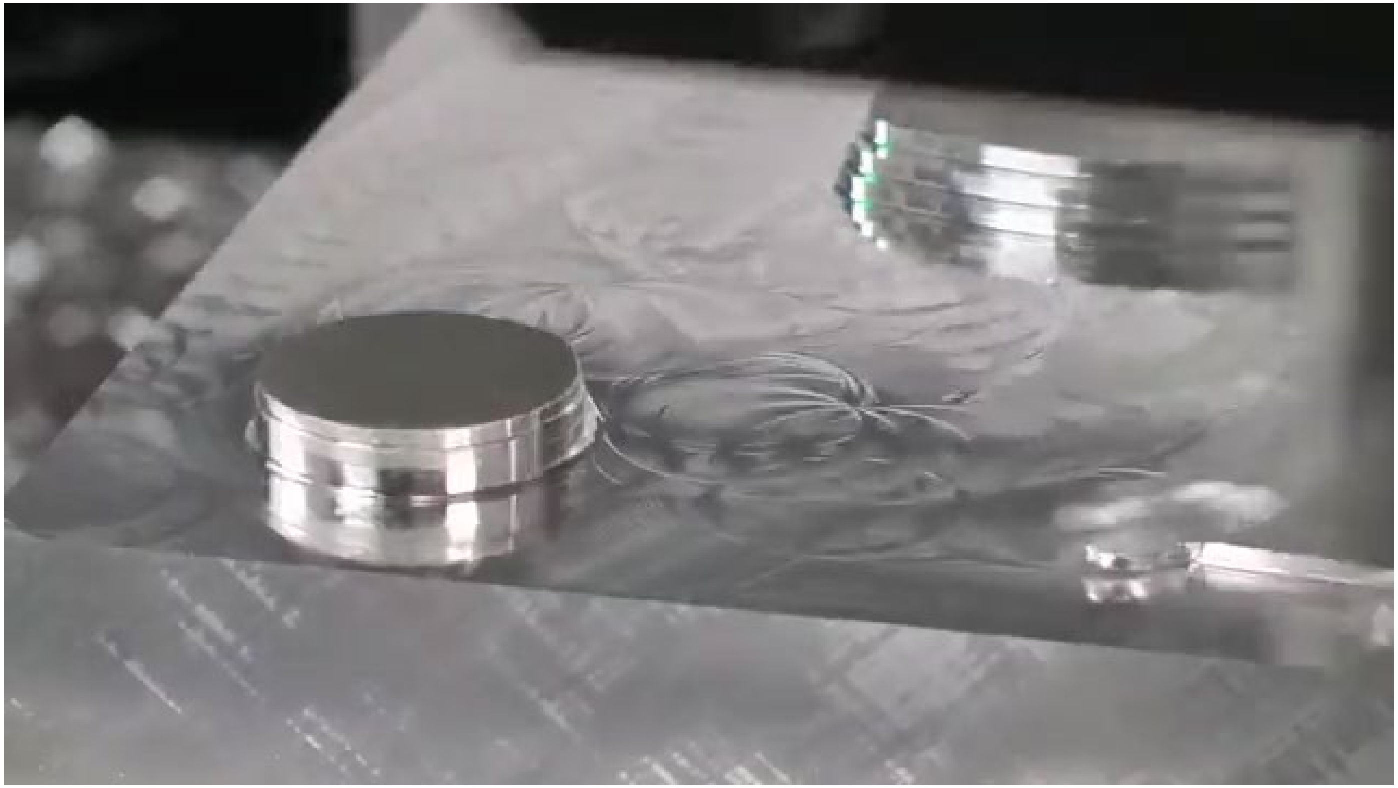
Introduction

This also includes products such as common electronic goods. A study has conducted has estimated the cost of producing an iPhone 5C for example to be only $US185. They were retailing for $US 364…

Manufacturing Automation

Introduction

Computer Numerically Controlled (CNC) milling is one example of manufacturing automation. These machines allow material to be removed in complex shapes that would not have been possible on a manually operated mill.



Manufacturing Automation

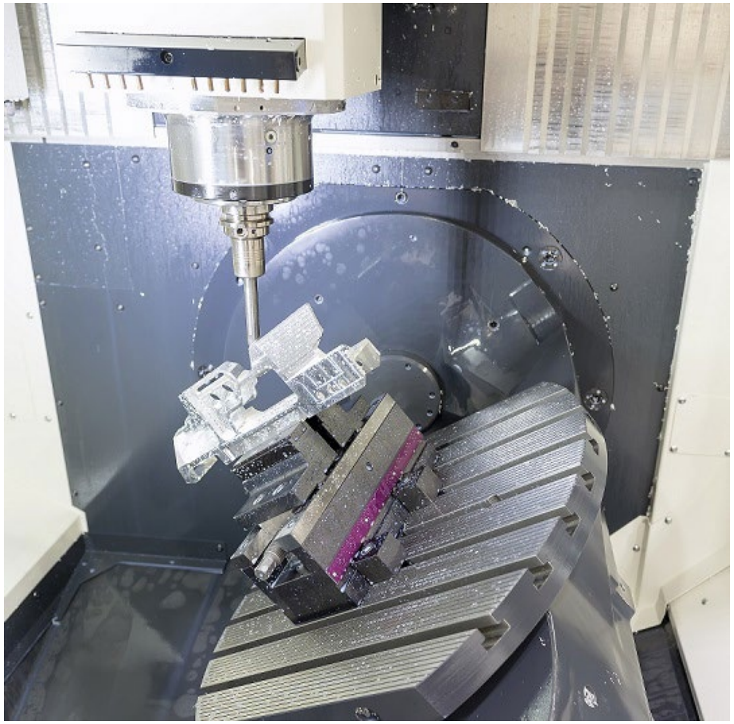
Numerically Controlled Machines

CNC mills come in various levels of complexity based on the number of axis that the milling head or the material can be moved in automatically. A 3-axis CNC mill allows for motion in three directions, the x, y and z linear directions.

Manufacturing Automation

Numerically Controlled Machines

A 5-axis CNC mill allows for movement about five directions, the x, y and z linear motions and rotations about an additional two axis. This allows for almost unlimited axis to the component for more complex machining.



Typical CNC machines can include:

Lathes

Mills

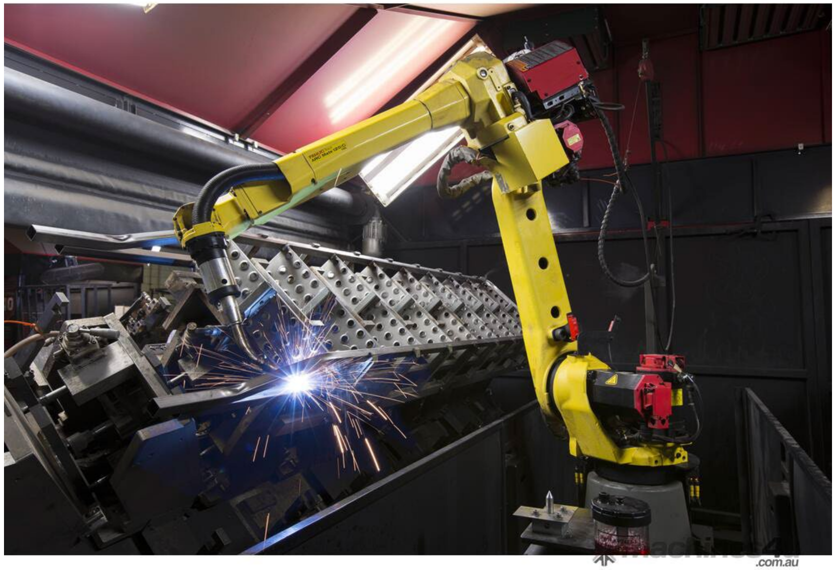
Routers

Laser and water jet cutters

Manufacturing Automation

Numerically Controlled Machines

There are also: CNC welding machines



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All these machines share one thing in common. They are fundamentally made of three components:

1) Part program
2) Machine control unit
3) Processing equipment

Numerically Controlled Machines

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1) Part program – *list of instructions specific to a part that the machine must execute in order to create the part. Each instruction is either a position or motion which the machine must achieve usually defined using x, y and z coordinates and/or rotations.*
2) Machine control unit
3) Processing equipment

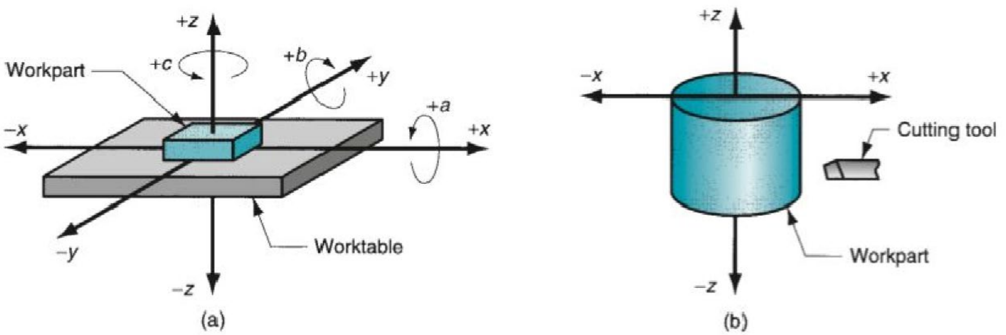

FIGURE 29.1 Coordinate systems used in numerical control: (a) for flat and prismatic work, and (b) for rotational work. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

Manufacturing Automation

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1) Part program – *list of instructions specific to a part that the machine must execute in order to create the part. Each instruction is either a position or motion which the machine must achieve usually defined using x, y and z coordinates.*
2) Machine control unit – *a microcomputer that receives, stores and processors the list of instructions that have been generated by the Part program.*
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Manufacturing Automation

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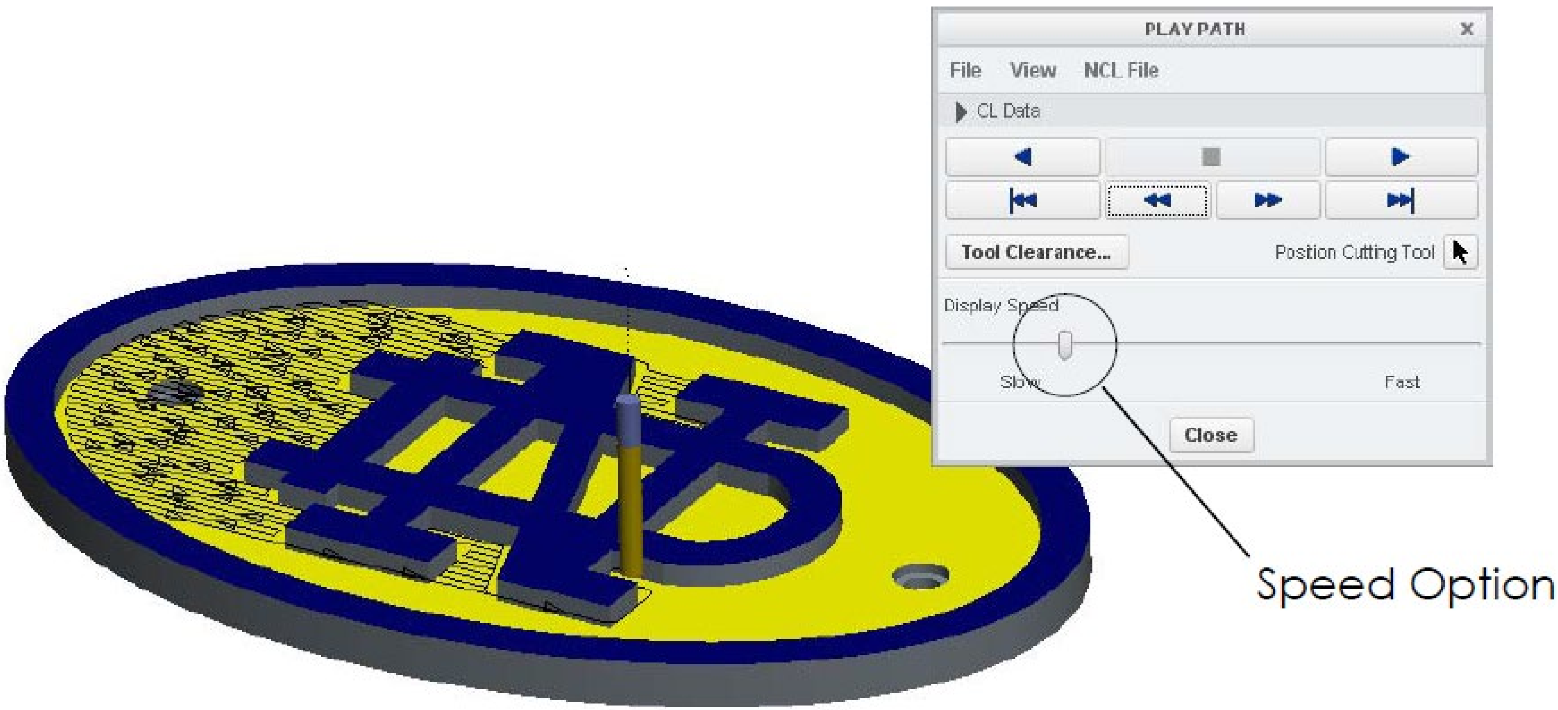
2) Machine control unit – *a microcomputer that receives, stores and processors the list of instructions that have been generated by the Part program.*
3) Processing equipment – *the machine that actually undertakes the work that the part program is requesting. This could be a lathe, mill, router, etc…*

Manufacturing Automation

Introduction

Your tutorial exercises this week will allow you to learn how to prepare a part program, or a CNC coding path using CREO to manufacture a component using a CNC mill..



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Numerically Controlled Machines

A 5-axis CNC mill allows for movement about five directions, the x, y and z linear motions and rotations about an additional two axis. This allows for almost unlimited axis to the component for more complex machining.

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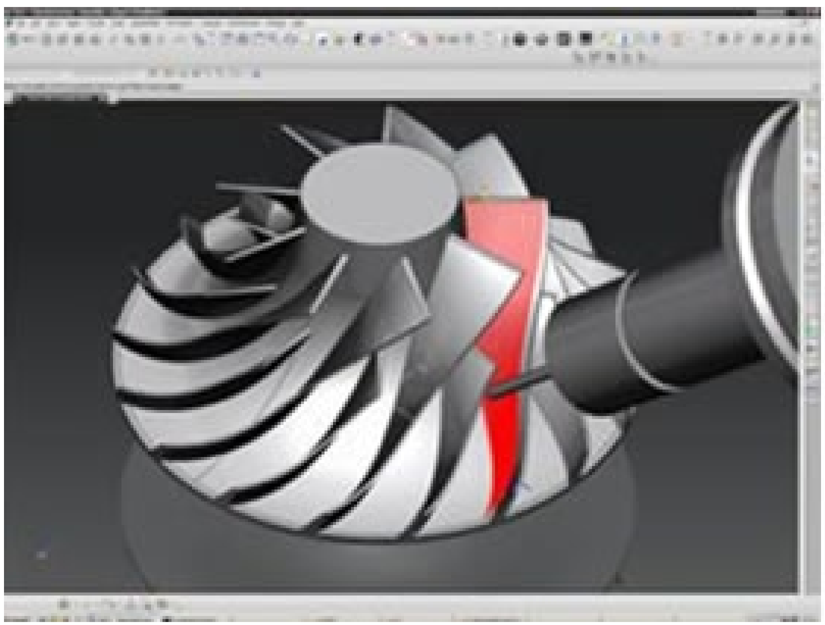
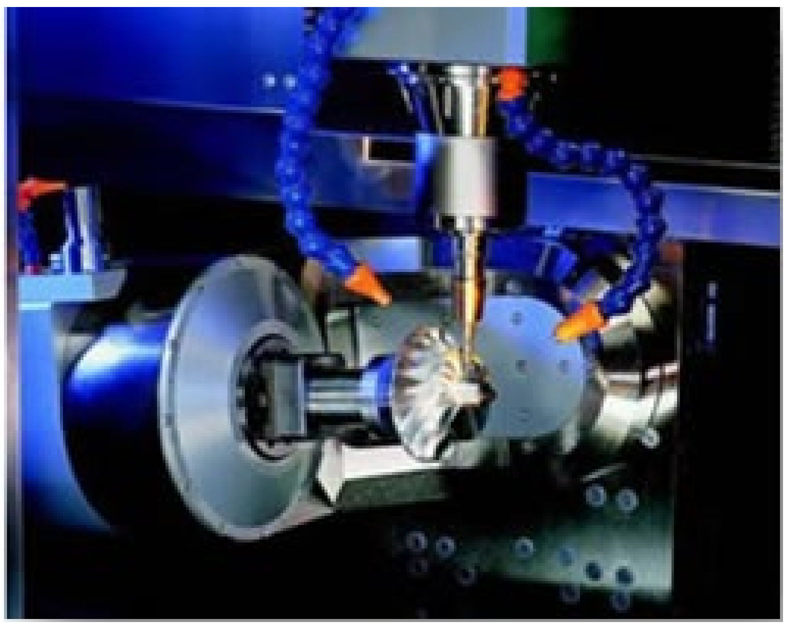
Numerically Controlled Machines

What is the process, method or technology required to achieve numerically controlled machines? How is it possible to go from a computer model of a component to a completed component with minimal input from a person?





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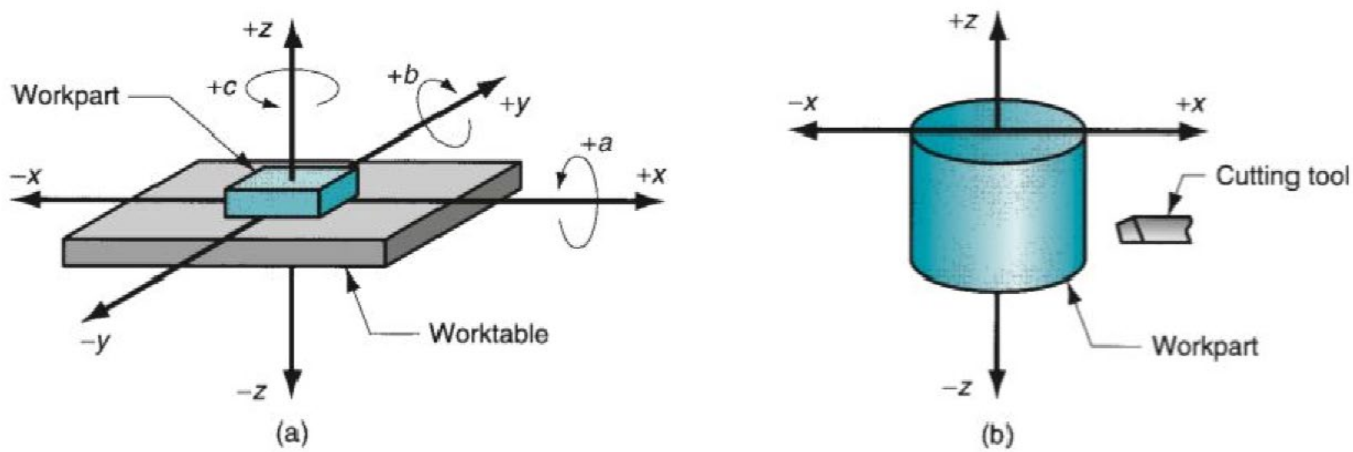
Coordinate System and Motion Control

A standard coordinate system is used to control the position of an NC machine. Three linear axes (x,y,z) and three rotational axes (a,b,c) are used.

Coordinates change for rotational NC systems with one less linear direction required. The simplest NC machines use only two of these axes.



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Coordinate System and Motion Control

The simplest NC machines use only two axes, these include plotters, CNC routers and component insertion machines. To control these machines, only a series of x and y coordinates are required. The addition of further axes allows for more complex work to be undertaken. Three axes systems require x, y and z coordinates to be specified.

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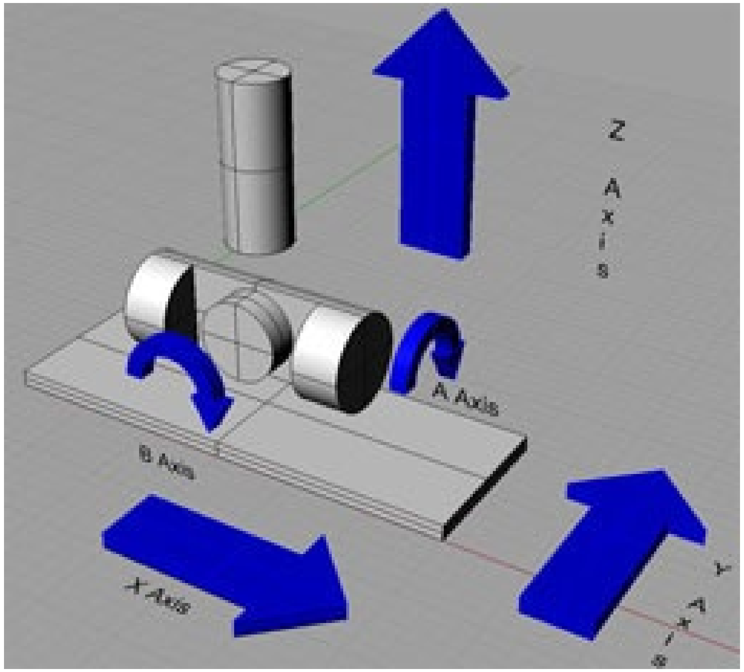
Coordinate System and Motion Control

Five axis machines allow the relative position of the work part and the processing tool to be altered. As depicted in this diagram, there are 5 separate motions that can be conducted either independently or in unison.



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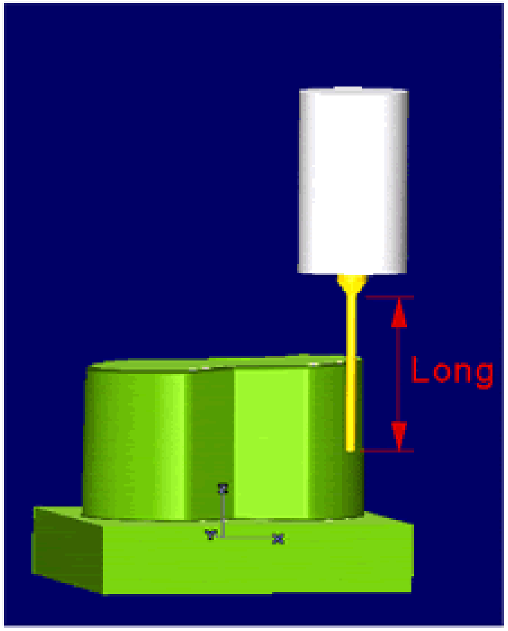
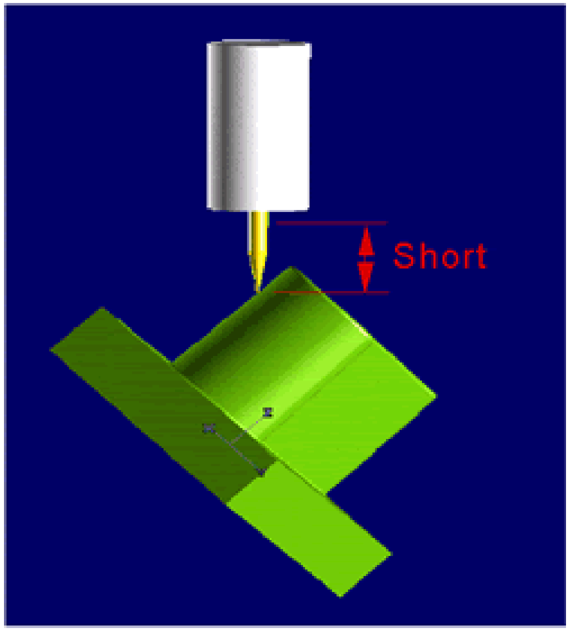
Coordinate System and Motion Control

This allows for access to be achieved using alternative configurations depending on the tool being used. In some cases, it can improve the accuracy with which a component is manufactured.



3-axis machining



5-axis machining

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There are two types of motion control employed by NC machines. They are:

1) Point to point systems
2) Continuous path systems

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1) Point to point systems *– also called positioning systems, they move the workhead to a position with no regard for the path taken to achieve that location. Once at the location, an operation is completed such as drilling, welding, etc…*
2) Continuous path systems

Manufacturing Automation

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1) Point to point systems – *also called positioning systems, they move the workhead to a position with no regard for the path taken to achieve that location. Once at the location, an operation is completed such as drilling, welding, etc…*
2) Continuous path systems – *undertake simultaneous control of more than a single axis and as a result have some control over the path taken . This is critical for achieving angled lines and two or three dimensional curves.*

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In order to be able to achieve a continuous path motion, some interpolation technique is required. Two alternative techniques are employed depending on the required path which are:

1) Linear interpolation
2) Circular interpolation

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2) Circular interpolation

Manufacturing Automation

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1) Linear interpolation *– is used for straight line paths. To determine the motion, a start and end point are required as well as a feed rate (speed).*
2) Circular interpolation *– is used when a curve needs to be followed. A start and end point is once again required, but the path between the two is described by a series of radii. The interpolator then generates a series of points which satisfy this path moving along a series of long straight segments that at no time deviate between the desired path and teh actual path by more than a pre determined tolerance.*

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Coordinate System and Motion Control

One additional consideration for defining an NC path is how the position is specified. This may be either:

1) Absolute positioning
2) Incremental positioning

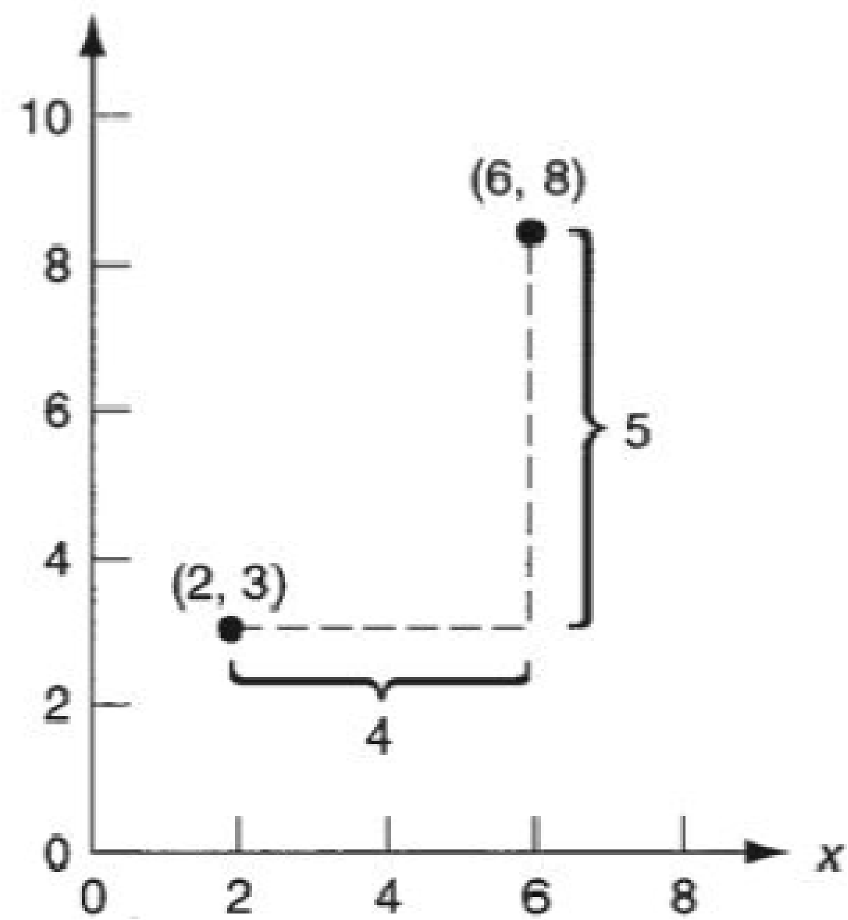

FIGURE 29.2 Absolute vs. incremental positioning. The workhead is at point (2,3) and is to be moved to point (6,8). In absolute positioning, the move is specified by $x = 6$, $y = 8$; while in incremental positioning, the move is specified by $x = 4$, $y = 5$. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

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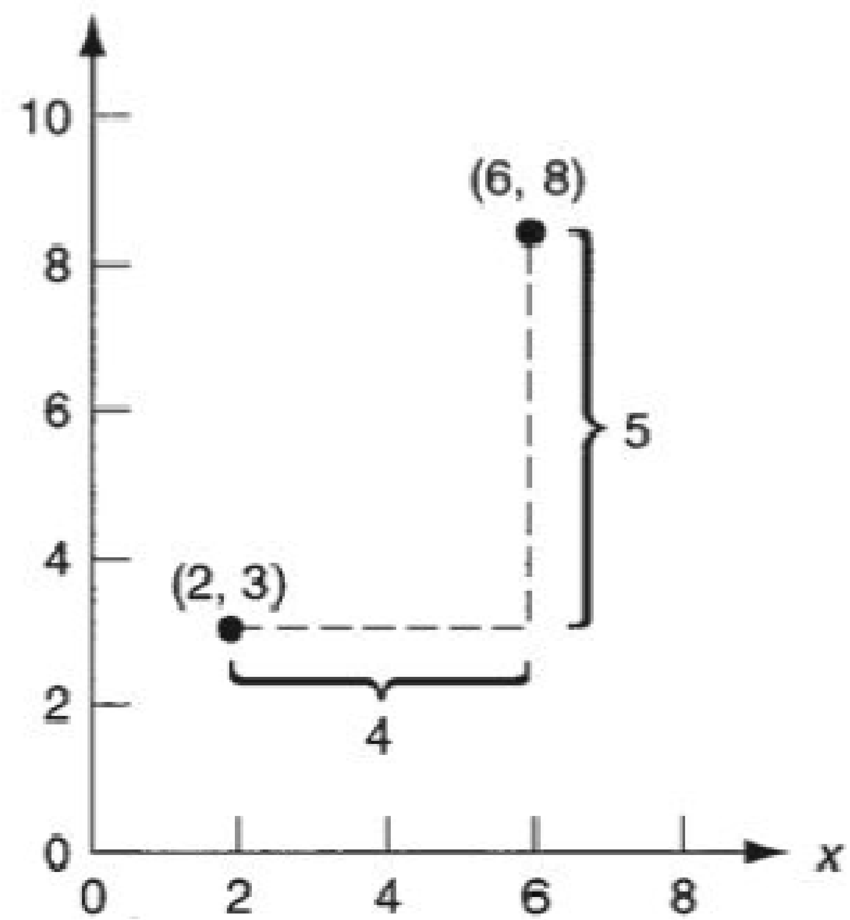
Coordinate System and Motion Control

One additional consideration for defining an NC path is how the position is specified. This may be either:

1) Absolute positioning *– the tool location is all ways defined relative to the origin of the axis system.*
2) Incremental positioning



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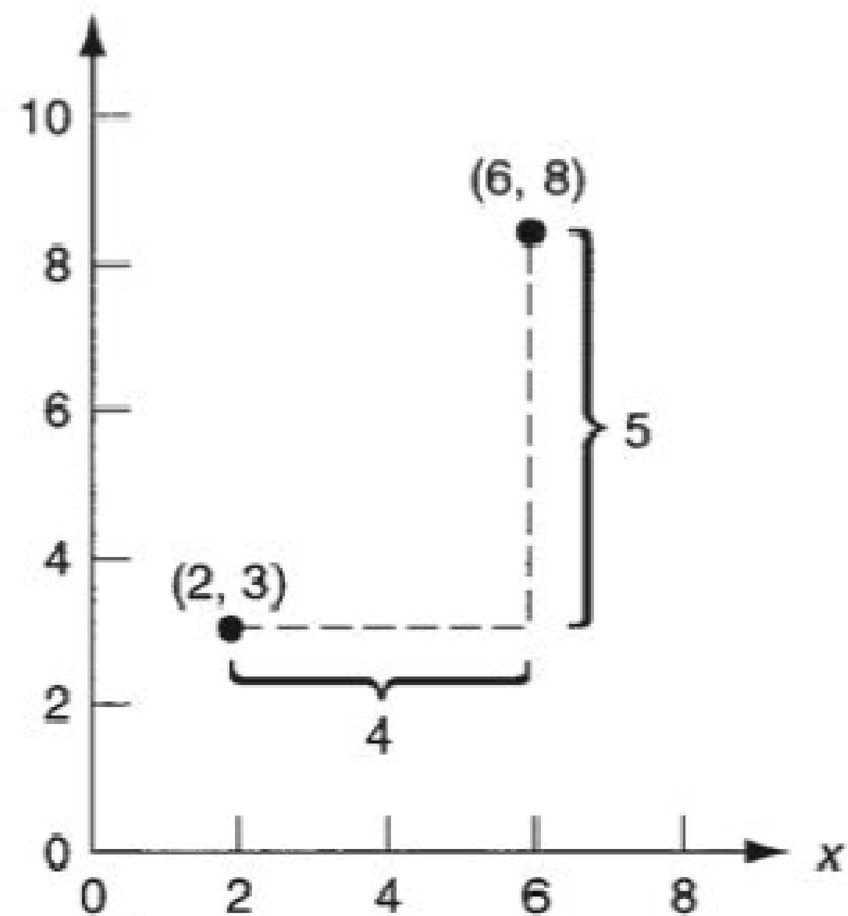
Coordinate System and Motion Control

One additional consideration for defining an NC path is how the position is specified. This may be either:

1) Absolute positioning *– the tool location is all ways defined relative to the origin of the axis system.*
2) Incremental positioning *– the subsequent location is defined relative to the previous location.*



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Example 1

Using an absolute referencing system, determine the 3 coordinates systems that a 2 axes CNC machine would traverse if it employed linear interpolation to travel from point A(150,250) to point B(200, 300).

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Coordinate System and Motion Control

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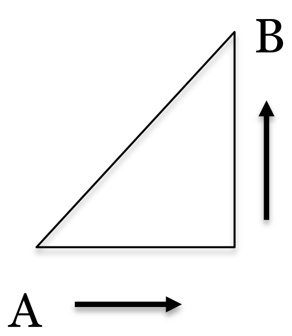

$$x_b - x_a = 200 - 150 = 50$$
$$y_b - y_a = 300 - 250 = 50$$

$$n = 3 + 1 = 4$$
$$\Delta x = \frac{50}{4} = 12.5 \qquad \Delta y = \frac{50}{4} = 12.5$$

$$A(150,250), A_1(162.5,262.5), A_2(175,275), A_3(187.5,287.5), B(200,300)$$

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Example 2

Using an incremental referencing system, determine the 4 coordinates points that a 2 axes CNC machine would traverse if it employed linear interpolation to travel from point A(100,200) to point B(500, 200).

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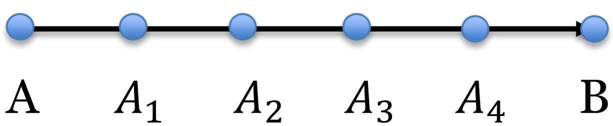
Coordinate System and Motion Control

Example 2

Using an incremental referencing system, determine the 4 coordinates points that a 2 axes CNC machine would traverse if it employed linear interpolation to travel from point A(100,200) to point B(500, 200).



$$x_b - x_a = 500 - 100 = 400$$

$$n = 4 + 1 = 5$$

$$x = \frac{400}{5} = 80$$

$$\therefore A_{x,i} = (80,0)$$

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Example 3

A CNC machine is required to traverse along a 90 degrees arc with radius 100mm. If at no point the tool is permitted to deviate from the required path by more than 0.1mm, how many interpolations would be required to achieve this?

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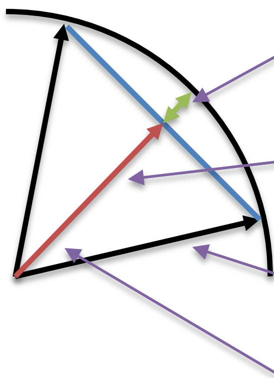

$$\cos\frac{\alpha}{2} = \frac{r-d}{r}$$

$$n = \frac{90°}{\alpha}$$

$$n = \frac{90°}{2\cos^{-1}\frac{r-d}{r}}$$

$$n = \frac{90°}{2\cos^{-1}\frac{100-0.1}{100}}$$

$$n = 17.56 = 18\ iterpolations$$

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Can you think of a way to reduce the number of interpolations but still achieve the desired accuracy?

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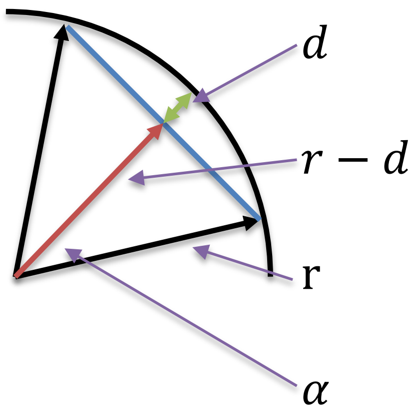

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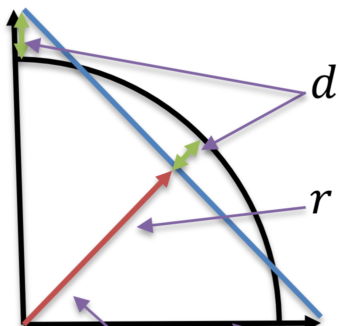

Can you think of a way to reduce the number of interpolations but still achieve the desired accuracy?

$$\cos\frac{\alpha}{2} = \frac{r-d}{r+r}$$

$$n = \frac{90°}{\beta}$$

$$n = \frac{90°}{2\cos^{-1}\frac{r-d}{r+r}}$$

$$n = \frac{90°}{2\cos^{-1}\frac{100-0.1}{100+0.1}}$$

$$n = 12.4 = 13\ iterpolations$$

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Example 4

A CNC machine is required to traverse along a 90 degrees arc with radius 100mm. If at no point the tool is permitted to deviate from the required path by more than 0.01mm, how many interpolations would be required to achieve this?

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A CNC machine is required to traverse along a 90 degrees arc with radius 100mm. If at no point the tool is permitted to deviate from the required path by more than 0.01mm, how many interpolations would be required to achieve this?

Using the first method from example 3:

$$n = 56\ interpolations$$

Using the second method from example 3:

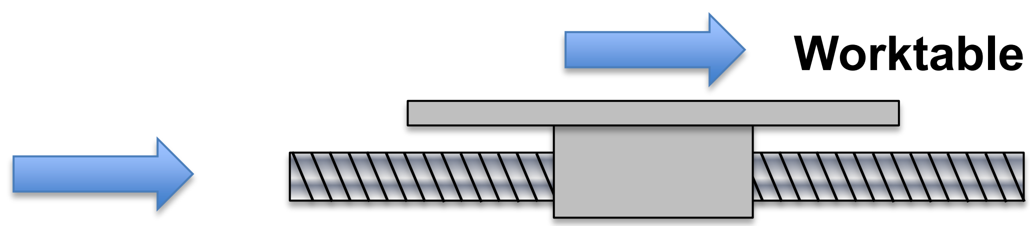
$$n = 40\ inpterpolations$$

Manufacturing Automation

Analysis of NC Positioning Systems

Now that we know how to define the path that is required for an NC machine to travel along, it is necessary to determine a method that will allow these values to be converted into a physical movement.

X100, Y200, Z0
X120, Y200, Z0
X120, Y250, Z0
X120, Y250, Z100
X120, Y200, Z100
X100, Y200, Z100



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Analysis of NC Positioning Systems

If we consider a single linear axis only to begin with, the most common arrangement to achieve motion includes a motor that drives a lead screw attached to a worktable. As the lead screw is rotated, the worktable is translated.

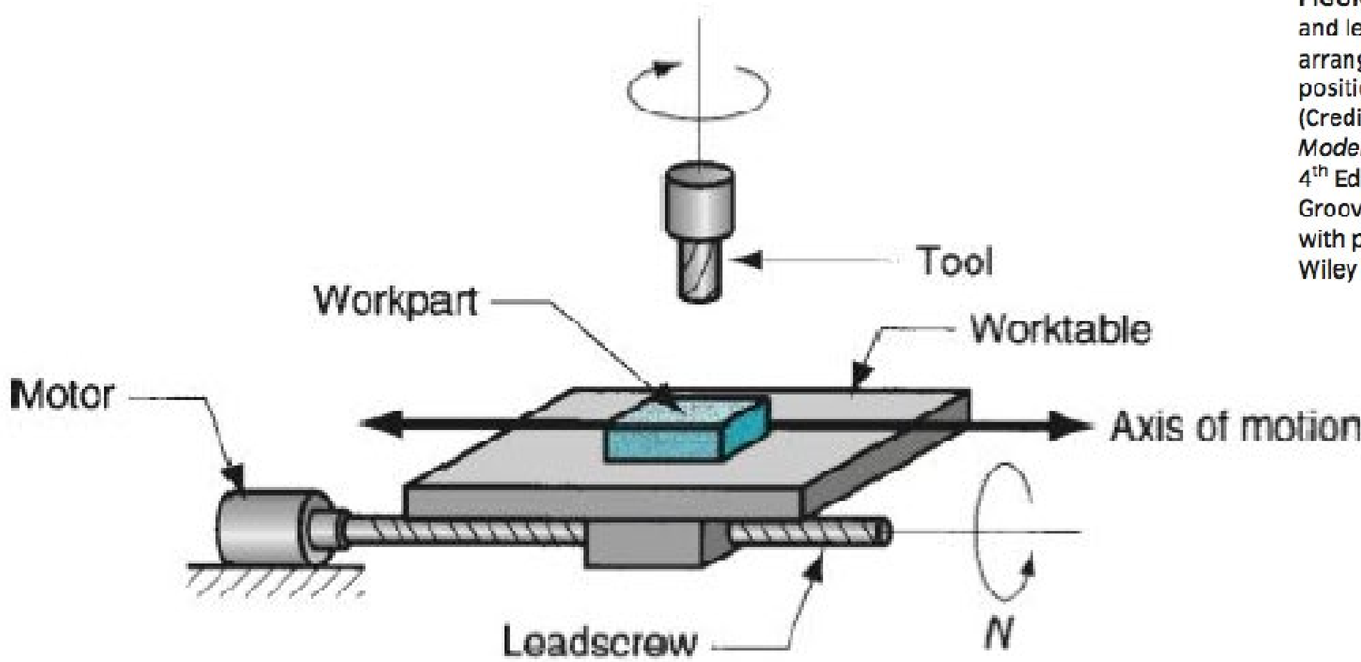

FIGURE 29.3 Motor and leadscrew arrangement in an NC positioning system. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

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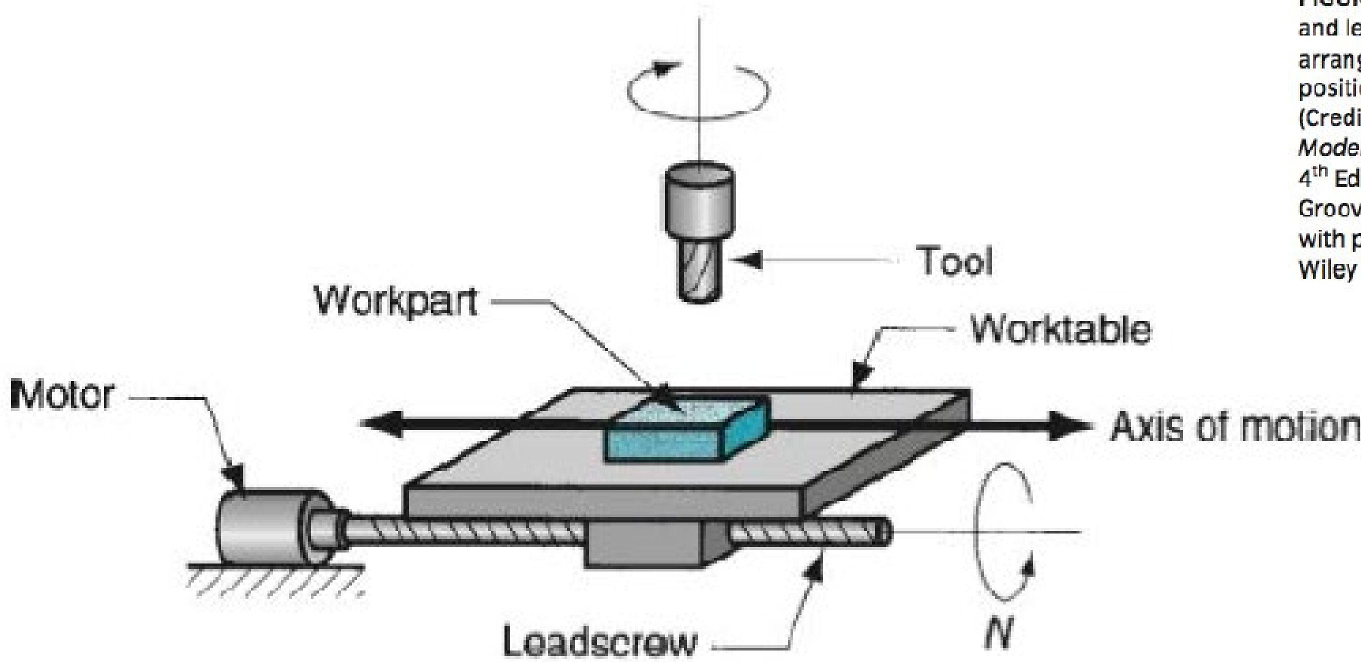
Analysis of NC Positioning Systems

While the image below depicts only a single axis, a two axis system is created by mounting the shown arrangement on a second similar system positioned normal to the first.



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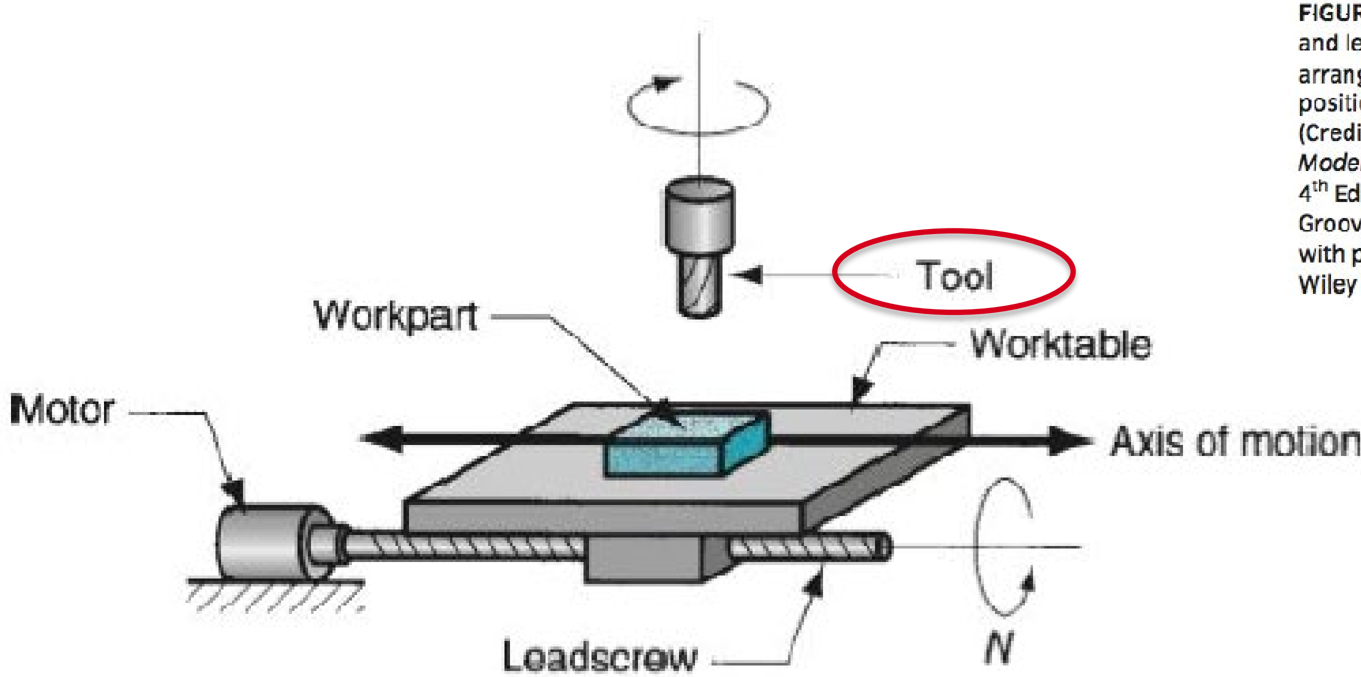
Analysis of NC Positioning Systems

The **tool** is dependant on the required processing equipment, it may be a spindle to undertake milling, a welding probe or a laser cutter. In this particular example, a mill is shown.



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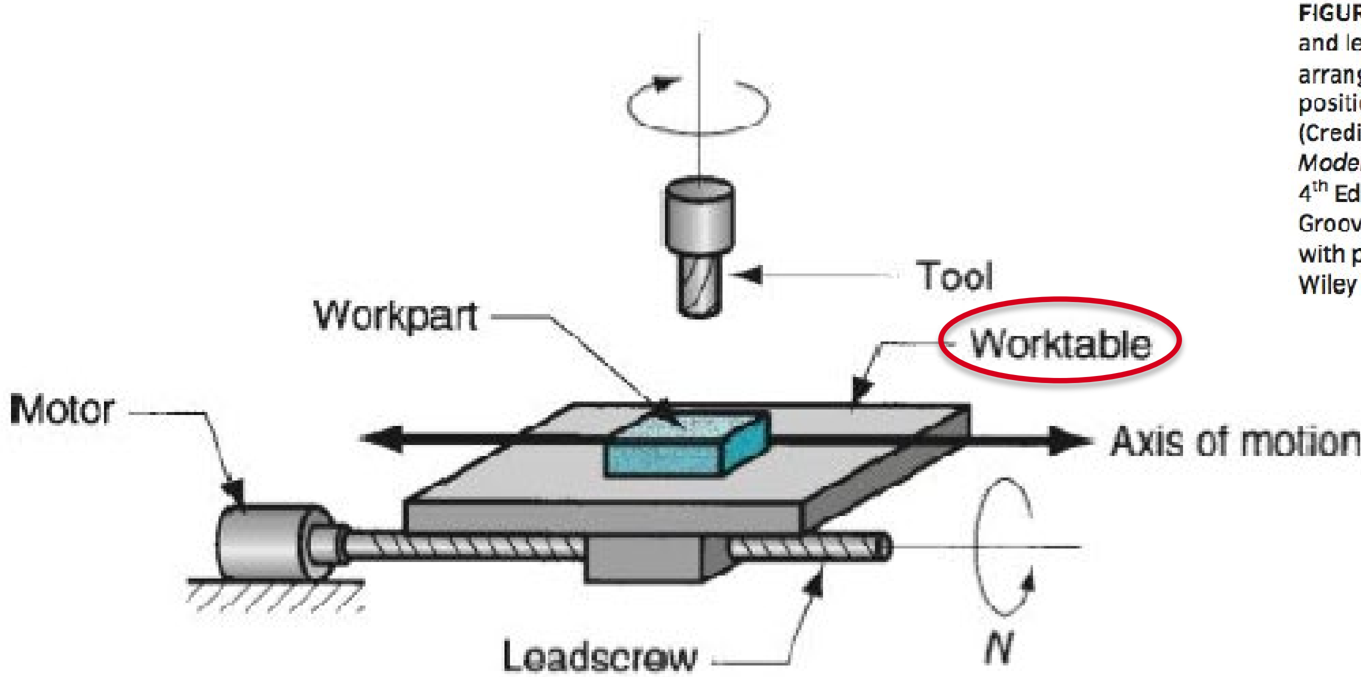
Analysis of NC Positioning Systems

The **worktable** is where the workpart is fixed while the manufacturing operation is undertaken. The worktable may be moved in order to translate the workpart otherwise the tool can be moved instead. The relative motion between the workpart and the tool is the desired outcome of the operation.



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Analysis of NC Positioning Systems

Motion is controlled using one of two positioning systems, **open loop** or **closed loop**. The fundamental difference between the two is whether or not the feedback is used to determine the position.

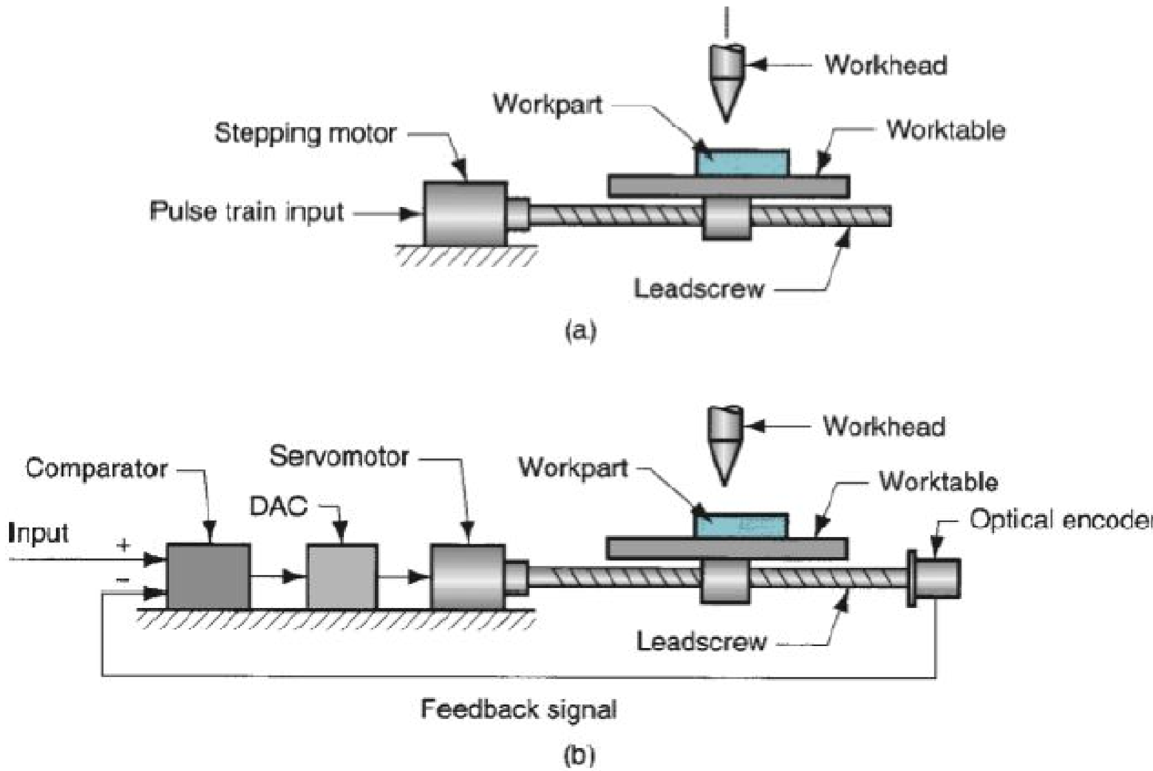

FIGURE 29.4 Two types of motion control in NC: (a) open loop and (b) closed loop. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

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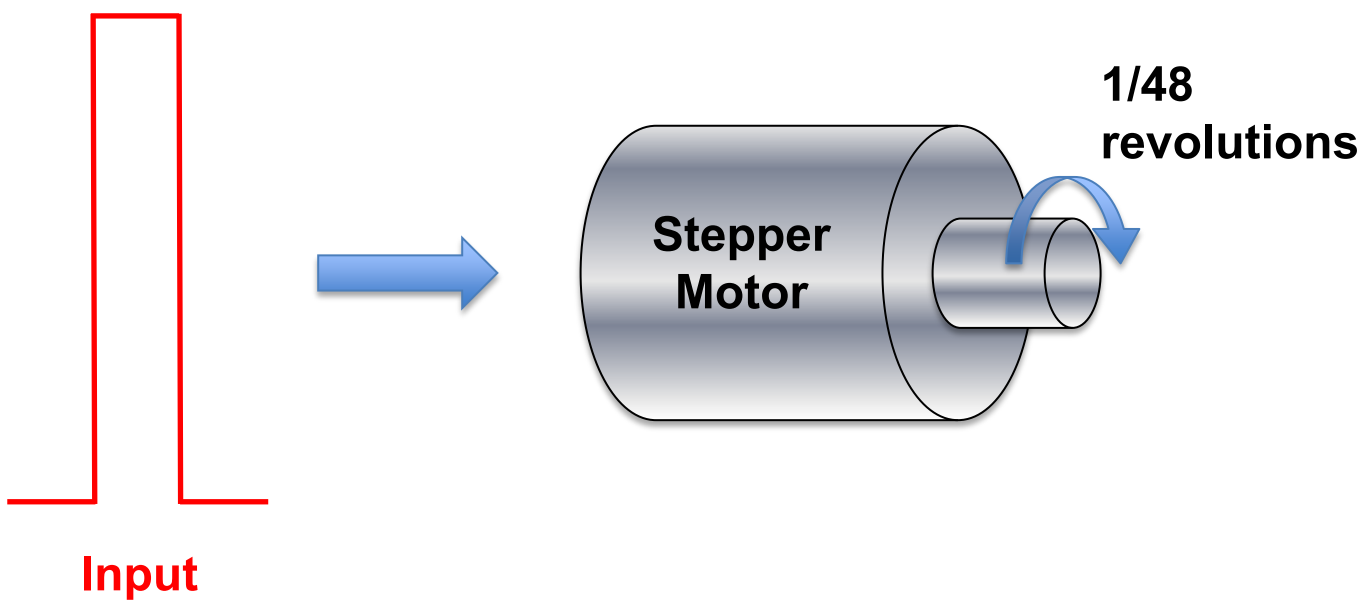
Analysis of NC Positioning Systems

The leadscrew for an **open loop positioning systems** is driven by a stepping motor (a.k.a. Stepper motor). For every pulse that is sent to the motor, the motor turns a fraction of a rotation called the stepping angle. To complete one revolution, usually 48 steps are required.



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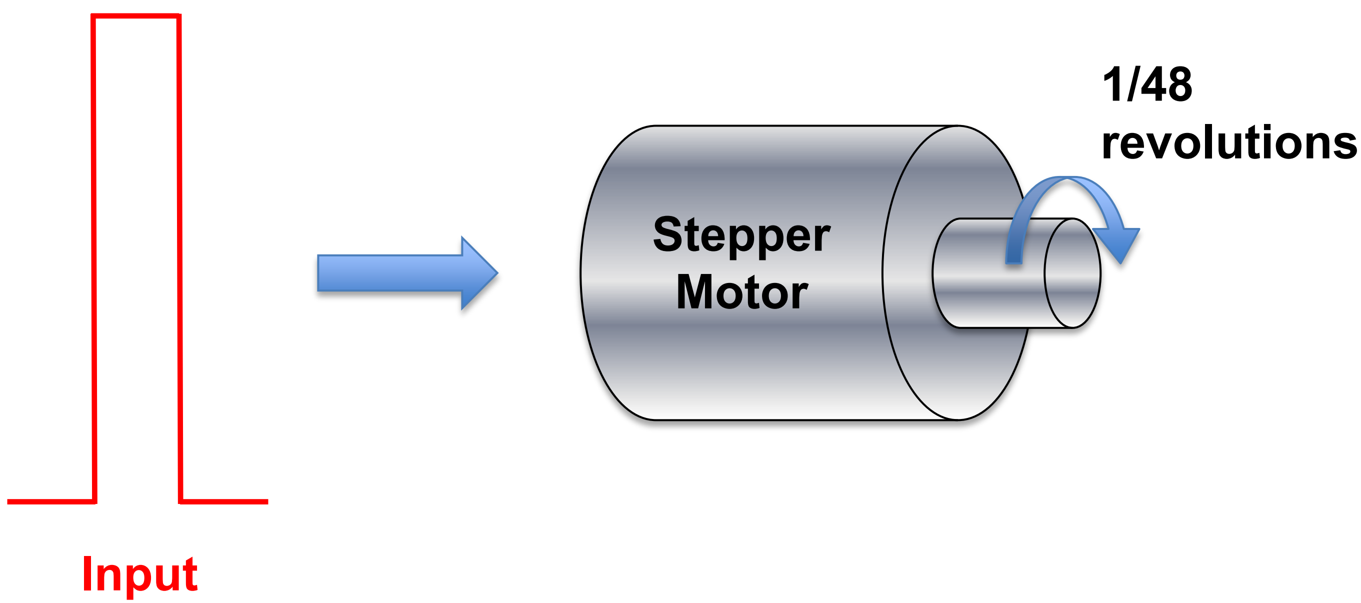
Analysis of NC Positioning Systems

The step angle that is achieved by each pulse can be determined by using the following equation:

$$\alpha = \frac{360}{n_s}$$

Where:
α = step angle achieved (degrees)
N_s = number of steps per revolution (must be an integer)



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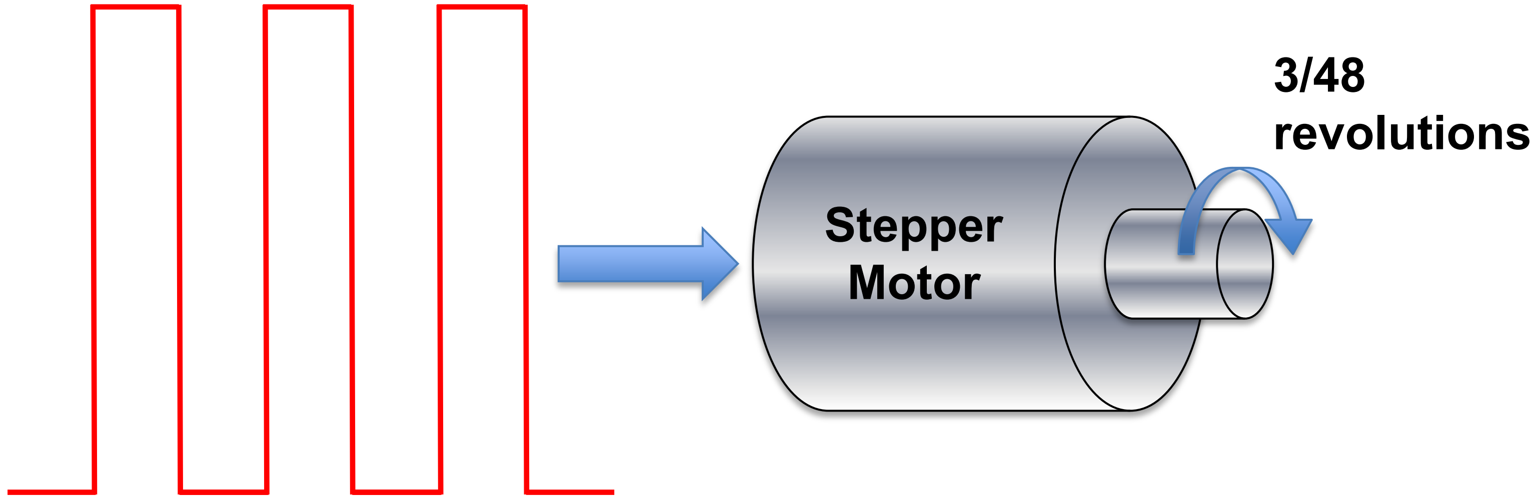
Analysis of NC Positioning Systems

For an open loop system, the number of pulses inputted into the stepper motor controls the position of the worktable. The more pulses provided, the greater the translation that will be achieved in a specific direction.



Input

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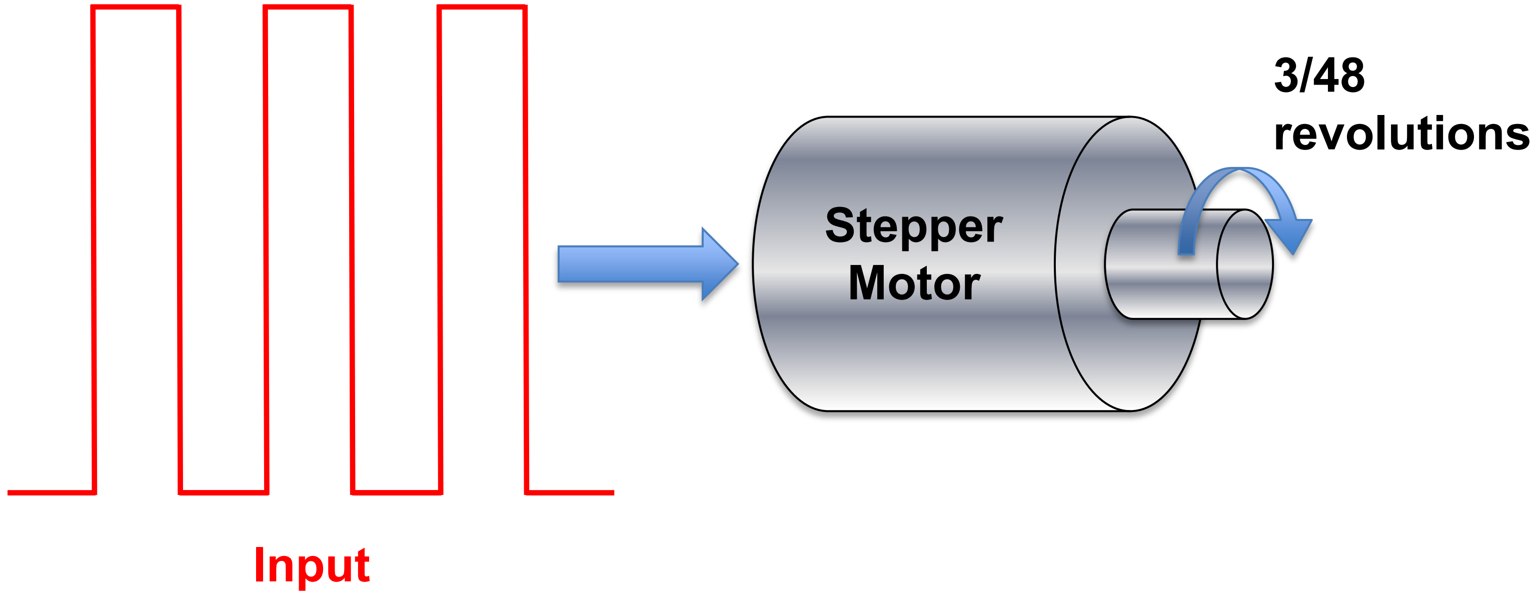
Analysis of NC Positioning Systems

The rotation that is achieved by the motor for any number of pulses can be determined by:

$$A_m = \alpha n_p$$

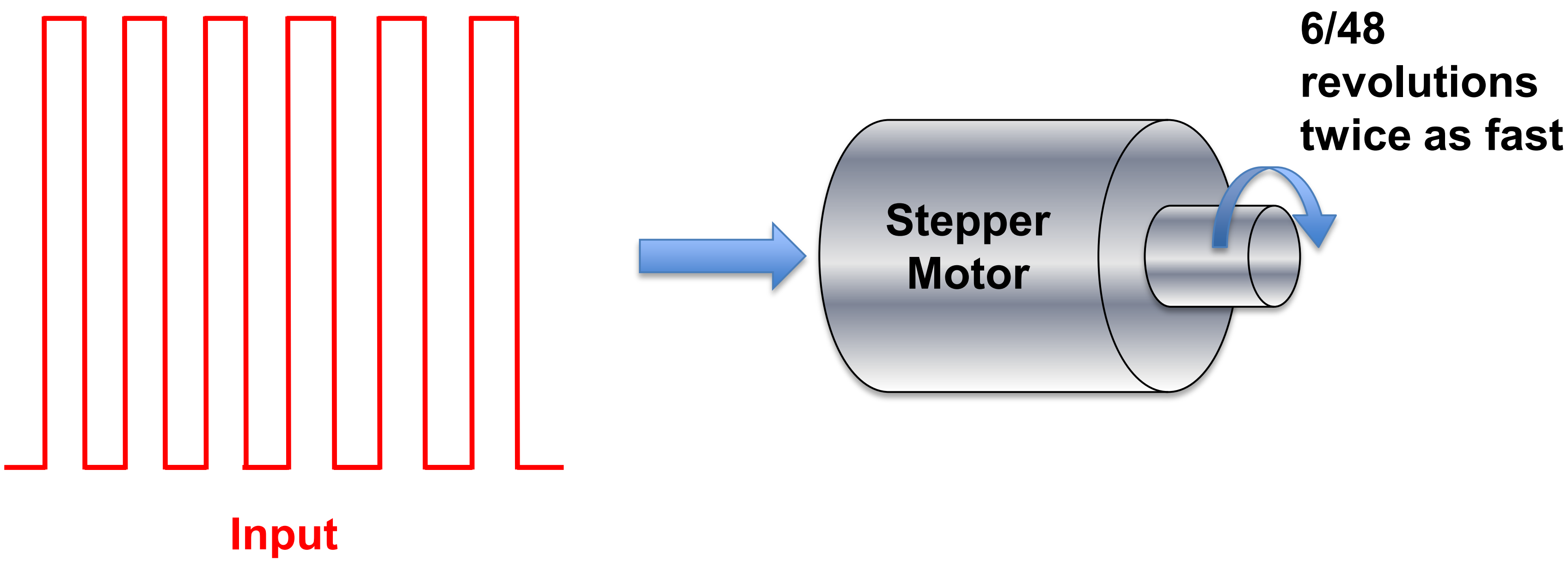
Where:
A_m = angle of motor shaft rotation (degrees)
α = step angle achieved (degrees)
n_p = number of pulses sent to the motor (must be an integer)



Manufacturing Automation

Analysis of NC Positioning Systems

Varying the frequency with which pulses are sent to the motor alters the speed with which the motor is driven. Increasing the frequency of the pulses will increase the speed with which the worktable is driven.



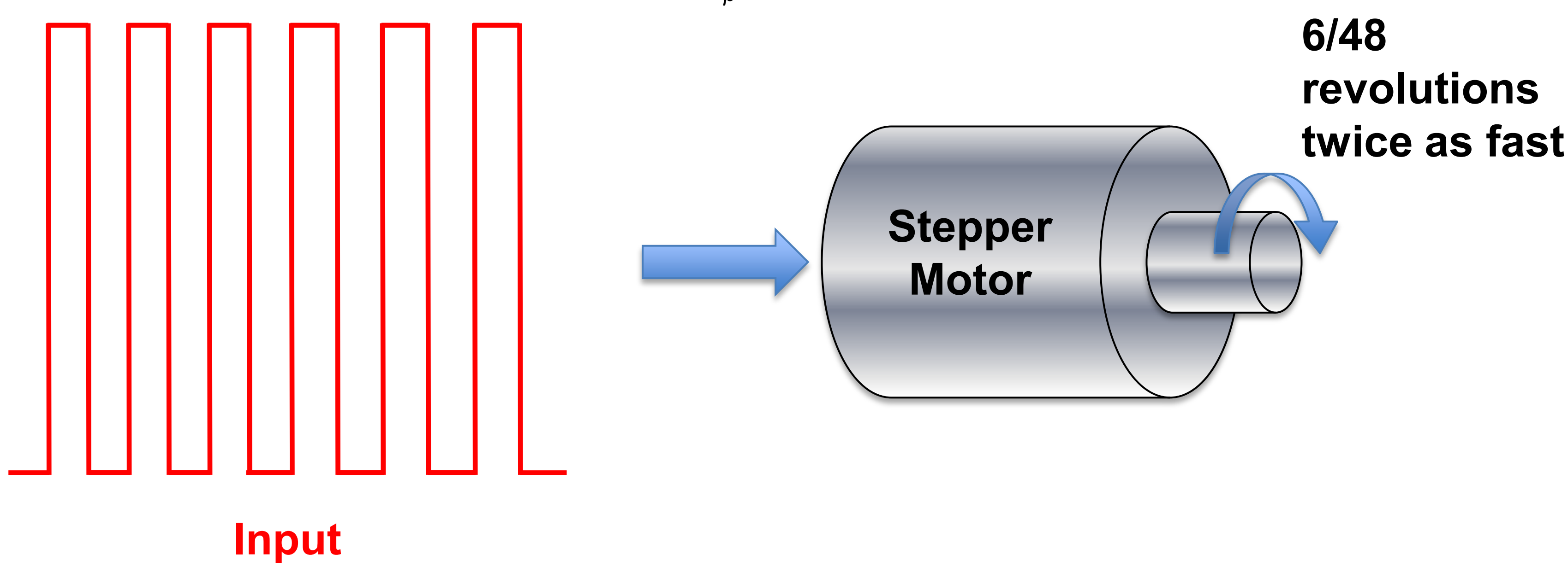
Manufacturing Automation

Analysis of NC Positioning Systems

The speed that the shaft rotation will achieve can be determined by the following equation:

$$N_m = \frac{60 \alpha f_p}{360}$$

Where:
N_m = *speed of motor shaft rotation (rev/min)*
α = *step angle achieved (degrees)*
f_p = *frequency of pulses sent to the stepper motor (Hz)*



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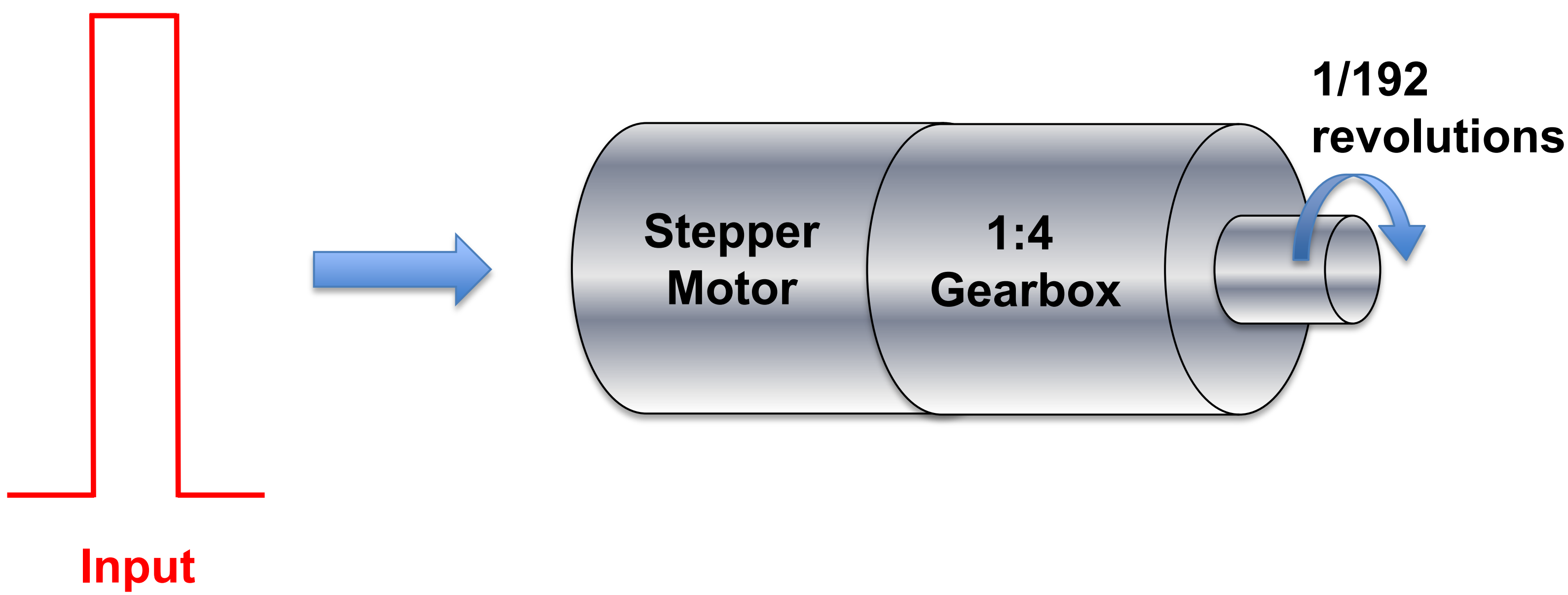
Analysis of NC Positioning Systems

Gearboxes can be mounted to further increase the resolution that can be achieved by a stepper motor. This will also reduce the speed with which the worktable can move with and increase the torque being provided to the leadscrew.



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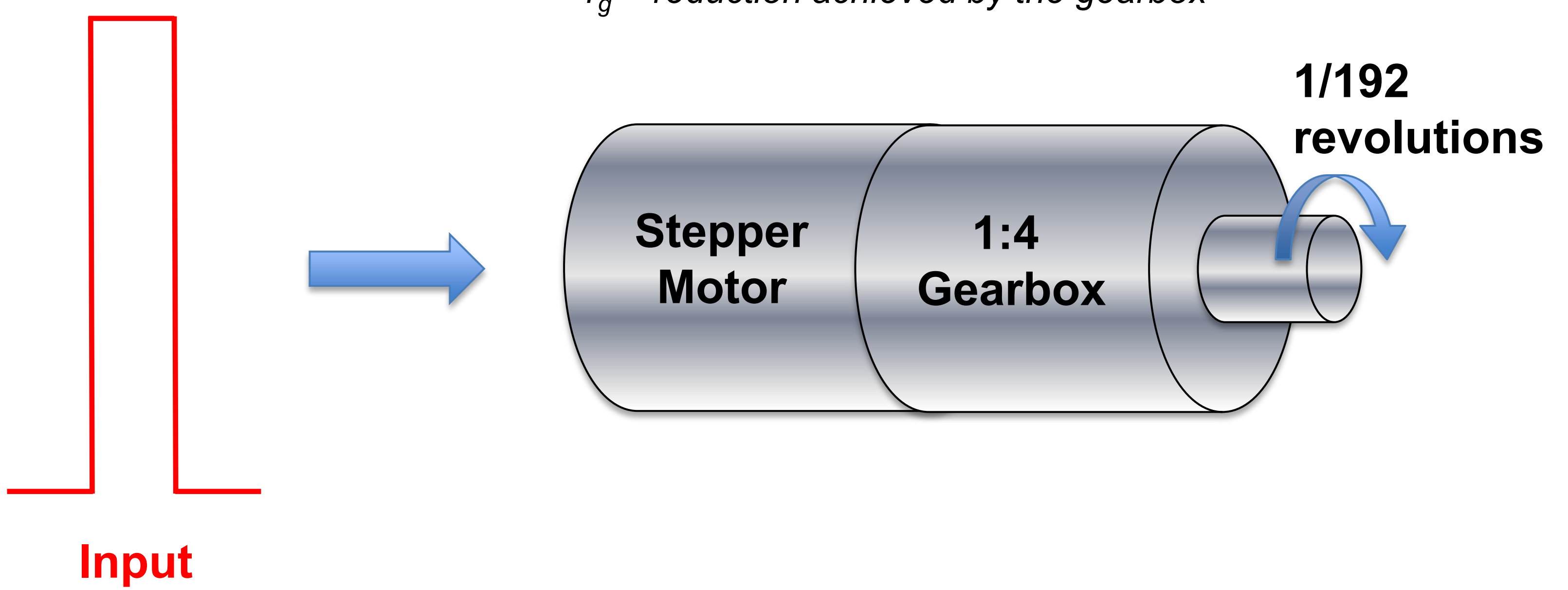
Analysis of NC Positioning Systems

The effect that the gear reduction has on the rotation and speed of the leadscrew relative to the stepper motor output can be determined by:

$$N_m = r_g N_{ls} \qquad A_m = r_g A_{ls}$$

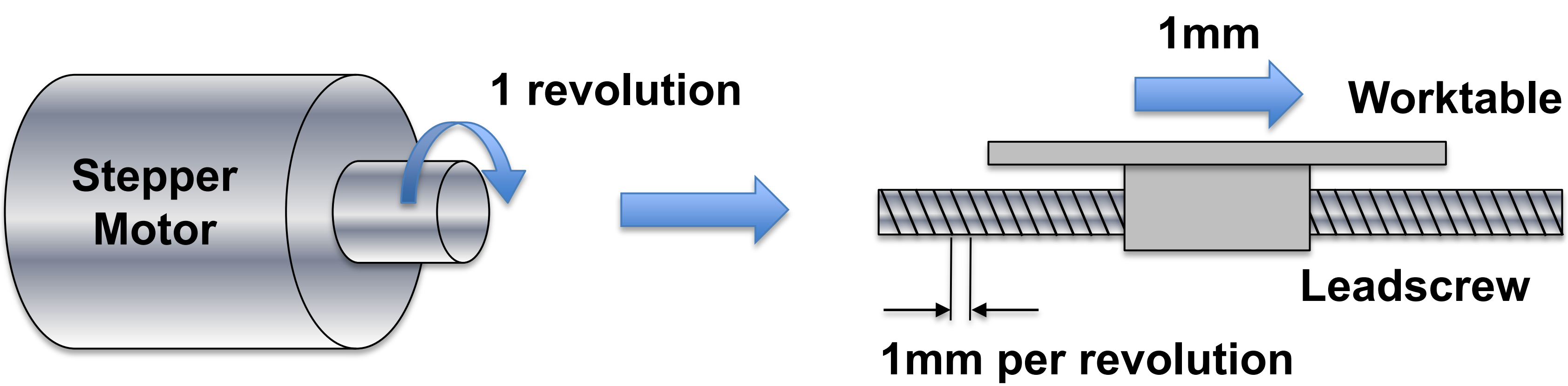
Where:
A_{ls} = angle of rotation of the leadscrew (degrees)
N_{ls} = speed of rotation of the leadscrew (rpm)
r_g = reduction achieved by the gearbox



Manufacturing Automation

Analysis of NC Positioning Systems

The movement achieved by each rotation of the stepper motor is dependant on the pitch of the leadscrew used. If a 1mm pitch is used, then each complete revolution of the leadscrew will result in a 1mm variation in position of the worktable.



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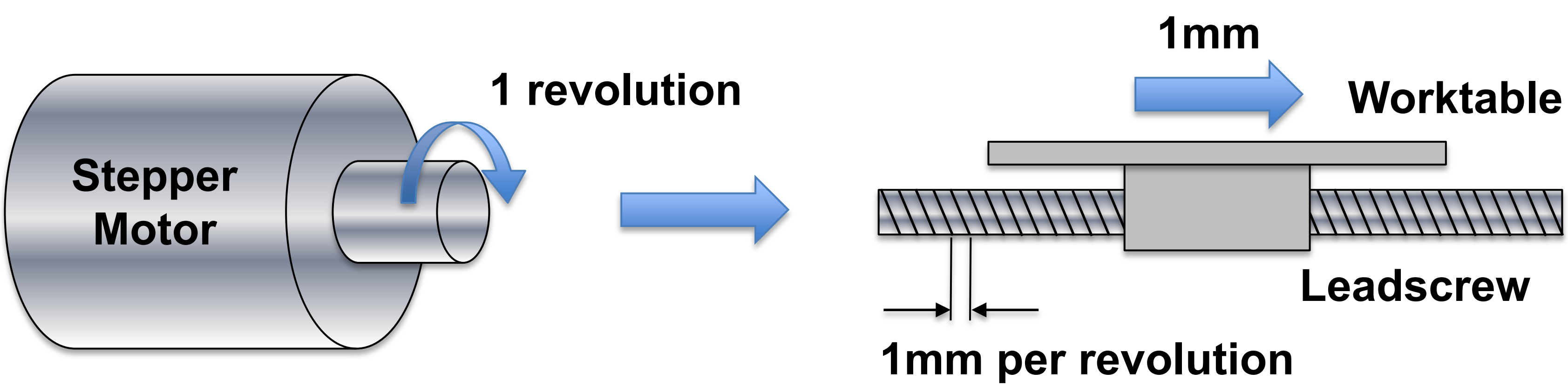
Analysis of NC Positioning Systems

The translation that would be achieved for any rotation of the leadscrew can be determined using the following equation:

$$x = \frac{pA_{ls}}{360}$$

Where:
A_{ls} = angle of rotation of the leadscrew (degrees)
p = pitch of the leadscrew (mm per revolution)



$$n_p = \frac{360 r_g x}{p\alpha} = \frac{r_g n_s A_{ls}}{360}$$

Manufacturing Automation

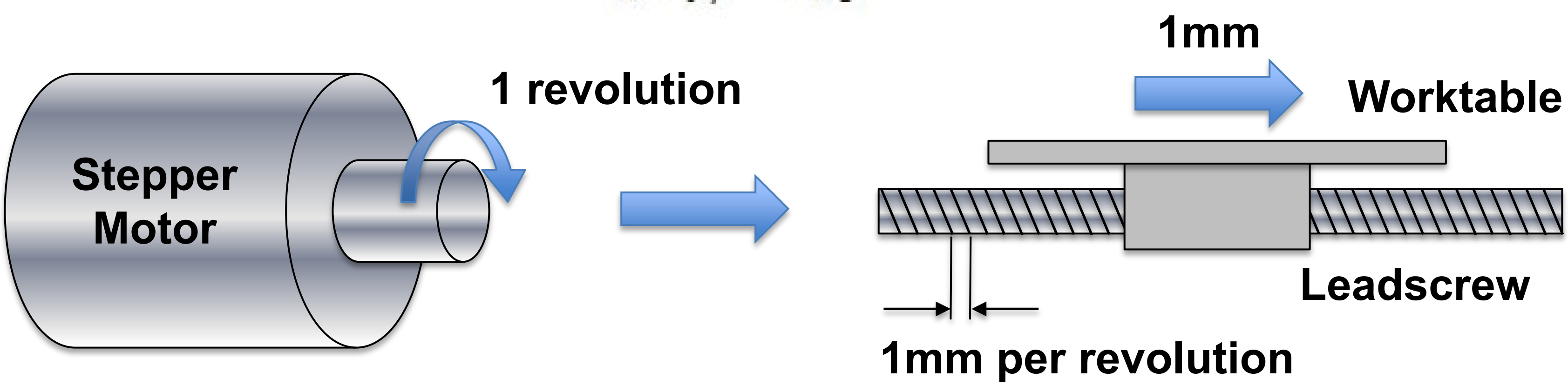
Analysis of NC Positioning Systems

The number of rotations required to achieve a given translation can be determined using the following equation:

$$n_p = \frac{360 r_g x}{p\alpha} = \frac{r_g n_s A_{ls}}{360}$$

Where:
A_{ls} = angle of rotation of the leadscrew (degrees)
p = pitch of the leadscrew (mm per revolution)

$$v_t = f_r = N_{ls}\, p$$



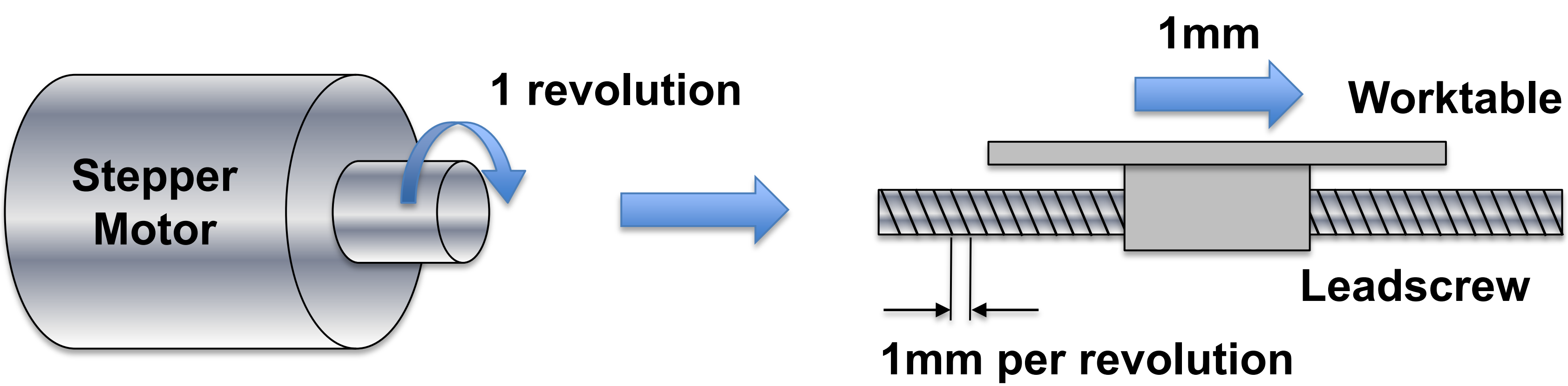
Manufacturing Automation

Analysis of NC Positioning Systems

The speed that can be achieved for any given rotation speed of the leadscrew can be calculated by using the following equation:

$$v_t = f_r = N_{ls} p$$

Where:
v_t = table travel speed (mm/min)
f_r = federate (mm/min)
N_{ls} = rotational speed of the leadscrew (rev/min)
p = leadscrew pitch (mm per revolution)



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Analysis of NC Positioning Systems

The rotational speed of the leadscrew depends on the frequency of pulses driving the stepping motor:

$$N_{ls} = \frac{60 f_p}{n_s r_g}$$

Where:
N_{ls} = rotational speed of the leadscrew (rev/min)
f_p = pulse train frequency (Hz)
n_s = steps per revolution
r_g = gear reduction between the motor and the leadscrew

Rearranging to solve for f_p, it is possible to determine the frequency required to achieve a desired speed.

$$f_p = \frac{v_t n_s r_g}{60p} = \frac{f_r n_s r_g}{60p} = \frac{N_{ls} n_s r_g}{60} = \frac{N_m n_s}{60}$$

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Analysis of NC Positioning Systems

Recall that a **closed loop** requires feedback is used to determine the position.

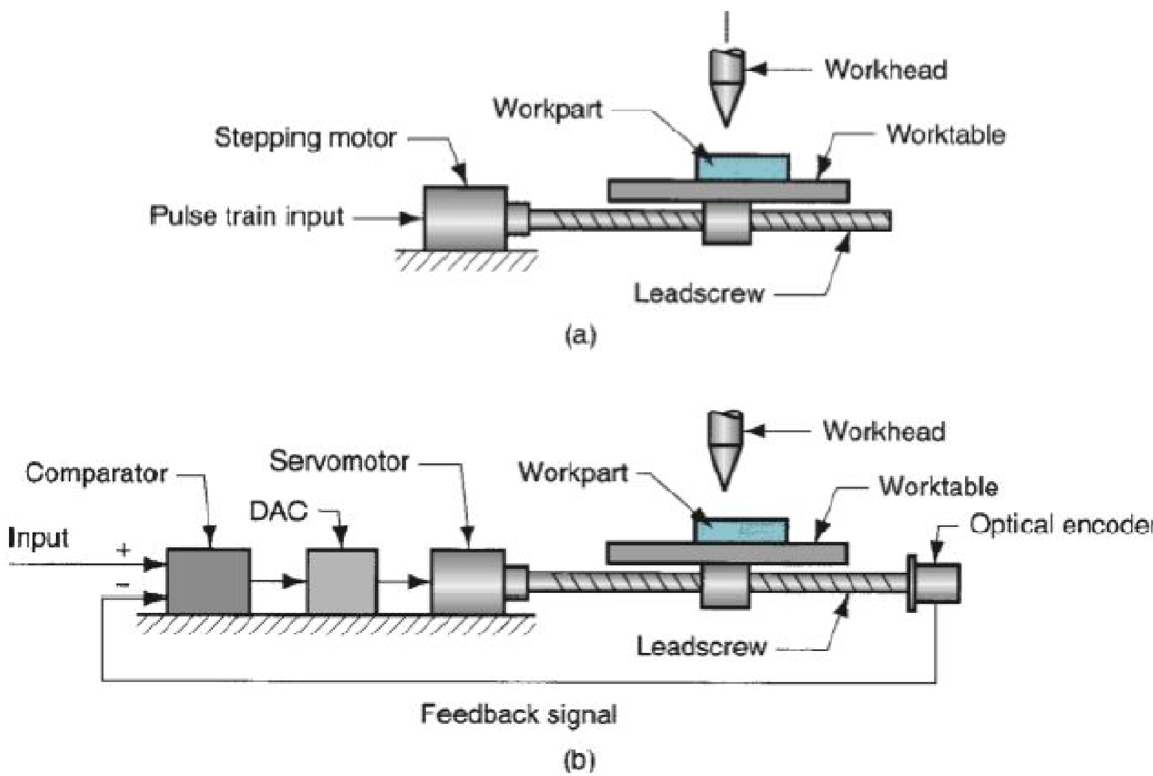


FIGURE 29.4 Two types of motion control in NC: (a) open loop and (b) closed loop. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

Analysis of NC Positioning Systems

When considering a closed loop system, a common sensor used to determine the number of rotations achieved is a rotary encoder. This measures the number of pulses detected by a photocell that is created by a light source and encoder wheel.

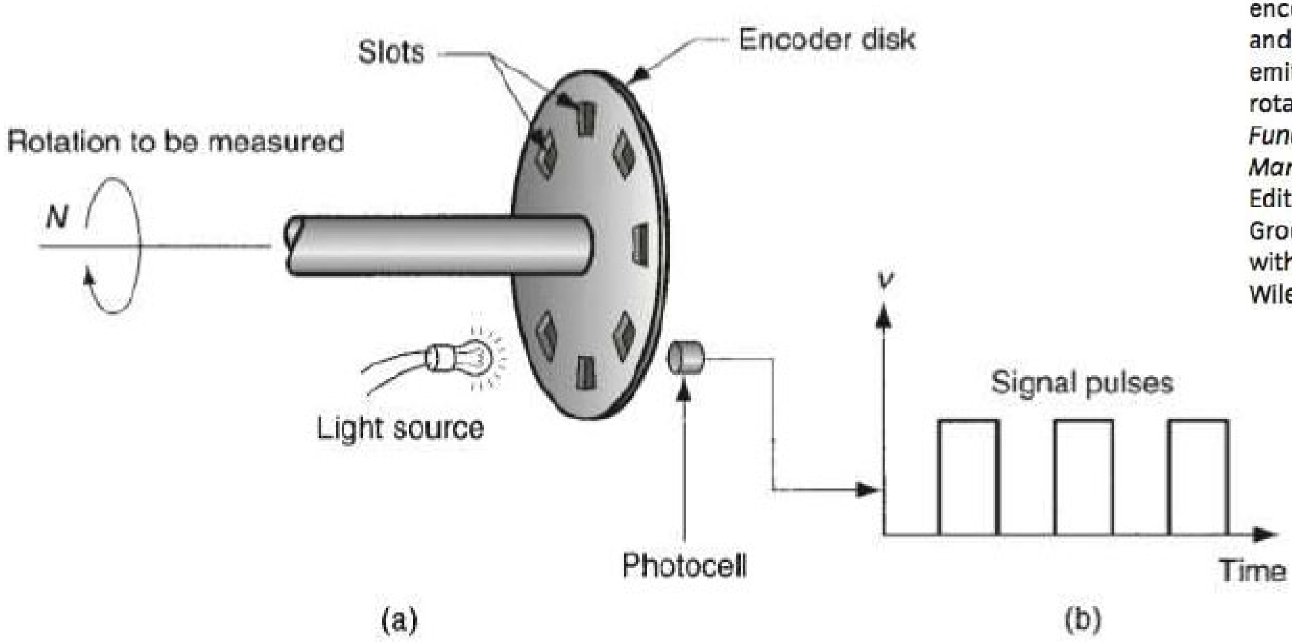


FIGURE 29.5 Optical encoder: (a) apparatus, and (b) series of pulses emitted to measure rotation of disk. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

Manufacturing Automation

Analysis of NC Positioning Systems

Given that a number of pulses are now measured for each rotation, the equations required to determine the position of the worktable ae very similar to the ones used for an open loop system.

$$\alpha = \frac{360}{n_s}$$

$$n_p = \frac{A_{ls}}{\alpha} = \frac{A_{ls} n_s}{360}$$

$$x = \frac{p n_p}{n_s} = \frac{p A_{ls}}{360}$$

$$v_t = f_r = \frac{60 p f_p}{n_s}$$

Where:
N_{ls} = rotational speed of the leadscrew (rev/min)
f_p = pulse train frequency (Hz)
n_s = steps per revolution
r_g = gear reduction between the motor and the leadscrew
v_t = table travel speed (mm/min)
f_r = federate (mm/min)
p = leadscrew pitch (mm per revolution)
α = step angle achieved (degrees)
n_p = number of pulses sent to the motor (must be an integer)
A_{ls} = angle of rotation of the leadscrew (degrees)

Example 5

A stepping motor has 48 step angles. Its output shaft is coupled to a lead screw with a 4:1 gear reduction. The lead screw which drives the worktable has a pitch = 5mm. The table must move a distance of 75mm from its current position at a travel speed of 400mm/min. Determine:

a) How many pulses are required to move the table the specified distance.

b) The motor speed

c) Pulse frequency required to achieve the desired table speed.

Example 5

A stepping motor has 48 step angles. Its output shaft is coupled to a lead screw with a 4:1 gear reduction. The lead screw which drives the worktable has a pitch = 5mm. The table must move a distance of 75mm from its current position at a travel speed of 400mm/min. Determine:

a) How many pulses are required to move the table the specified distance.

$$A_{ls} = \frac{360x}{p} = \frac{360 \times 75}{5} = 5{,}400°$$

$$n_p = \frac{A_{ls} n_s r_g}{360} = \frac{5400 \times 48 \times 4}{360} = 2{,}880\ pulses$$

Manufacturing Automation

Analysis of NC Positioning Systems

Example 5

A stepping motor has 48 step angles. Its output shaft is coupled to a lead screw with a 4:1 gear reduction. The lead screw which drives the worktable has a pitch = 5mm. The table must move a distance of 75mm from its current position at a travel speed of 400mm/min. Determine:

b) The motor speed

$$N_{ls} = \frac{v_t}{p} = \frac{400}{5} = 80\, rpm$$

$$N_m = N_{ls} r_g = 80 \times 4 = 320\, rpm$$

Manufacturing Automation

Analysis of NC Positioning Systems

Example 5

A stepping motor has 48 step angles. Its output shaft is coupled to a lead screw with a 4:1 gear reduction. The lead screw which drives the worktable has a pitch = 5mm. The table must move a distance of 75mm from its current position at a travel speed of 400mm/min. Determine:

c) Pulse frequency required to achieve the desired table speed.

$$f_p = \frac{N_m n_s}{60} = \frac{320 \times 48}{60} = 256\ Hz$$

Example 6

An NC worktable is driven by a closed-loop positioning system consisting of a servomotor, leadscrew and optical encoder. The leadscrew has a pitch of 3mm and is coupled to the motor with a gear ratio of 5:1. The optical encoder generates 100 pulses per revolution of the leadscrew. The table has been programed to move a distance of 95mm at a feed rate = 300mm/min. Determine:

a) How many pulses are received by the control system to verify that the table has moved exactly 95mm
b) The pulse rate, and
c) Motor speed that corresponds to the required feed rate.

Manufacturing Automation

Analysis of NC Positioning Systems

Example 6

An NC worktable is driven by a closed-loop positioning system consisting of a servomotor, leadscrew and optical encoder. The leadscrew has a pitch of 3mm and is coupled to the motor with a gear ratio of 5:1. The optical encoder generates 100 pulses per revolution of the leadscrew. The table has been programed to move a distance of 95mm at a feed rate = 300mm/min. Determine:

a) How many pulses are received by the control system to verify that the table has moved exactly 95mm

$$A_{ls} = \frac{360x}{p} = \frac{360 \times 95}{5} = 11{,}400°$$

$$n_p = A_{ls} n_s r_g = \frac{11400 \times 100 \times 5}{360} = 15833.3 = 15833\ pulses$$

Manufacturing Automation

Analysis of NC Positioning Systems

Example 6

An NC worktable is driven by a closed-loop positioning system consisting of a servomotor, leadscrew and optical encoder. The leadscrew has a pitch of 3mm and is coupled to the motor with a gear ratio of 5:1. The optical encoder generates 100 pulses per revolution of the leadscrew. The table has been programed to move a distance of 95mm at a feed rate = 300mm/min. Determine:

b) The pulse rate, and

$$N_{ls} = \frac{v_t}{p} = \frac{300}{3} = 100\ rpm$$

$$N_m = N_{ls} r_g = 100 \times 5 = 500\ rpm$$

$$f_p = \frac{N_m n_s}{60} = \frac{500 \times 100}{60} = 833.33\ Hz$$

Example 6

An NC worktable is driven by a closed-loop positioning system consisting of a servomotor, leadscrew and optical encoder. The leadscrew has a pitch of 3mm and is coupled to the motor with a gear ratio of 5:1. The optical encoder generates 100 pulses per revolution of the leadscrew. The table has been programed to move a distance of 95mm at a feed rate = 300mm/min. Determine:

c) Motor speed that corresponds to the required feed rate.

Calculated in previous step:

$$N_m = N_{ls} r_g = 100 \times 5 = 500\ rpm$$

Manufacturing Automation

Analysis of NC Positioning Systems

Example 7

Each axis of a two axes CNC router utilise a stepping motor that has 48 step angles and its output shaft is coupled to a lead screw with a 10:1 gear reduction. The leadscrew which drives the worktable in each axis has a a pitch = 2.0mm. The table is required to travel along a linear trajectory with neither axis exceeding a travel speed of 200mm/min. To achieve an incremental position of 25mm, 45mm, determine for each axis:

a) How many pulses are required to move the table the specified distance.

b) The motor speed required for each axis, and

c) Pulse frequency required to achieve the desired table speed.

Manufacturing Automation

Analysis of NC Positioning Systems

Example 7

Each axis of a two axes CNC router utilise a stepping motor that has 48 step angles and its output shaft is coupled to a lead screw with a 10:1 gear reduction. The leadscrew which drives the worktable in each axis has a a pitch = 2.0mm. The table is required to travel along a linear trajectory with neither axis exceeding a travel speed of 200mm/min. To achieve an incremental position of 25mm, 45mm, determine for each axis:

a) How many pulses are required to move the table the specified distance.

$$A_{ls_x} = \frac{360x}{p} = \frac{360 \times 25}{2} = 4{,}500°, \qquad A_{ls_y} = \frac{360y}{p} = \frac{360 \times 45}{2} = 8{,}100°$$

$$n_{p_x} = \frac{A_{ls_x} n_s r_g}{360} = \frac{4500 \times 48 \times 10}{360}, \qquad n_{p_y} = \frac{A_{ls_x} n_s r_g}{360} = \frac{8100 \times 48 \times 10}{360}$$

$$n_{p_x} = 6{,}000\ pulses, \qquad n_{p_y} = 10{,}800\ pulses$$

Manufacturing Automation

Analysis of NC Positioning Systems

Example 7

Each axis of a two axes CNC router utilise a stepping motor that has 48 step angles and its output shaft is coupled to a lead screw with a 10:1 gear reduction. The leadscrew which drives the worktable in each axis has a a pitch = 2.0mm. The table is required to travel along a linear trajectory with neither axis exceeding a travel speed of 200mm/min. To achieve an incremental position of 25mm, 45mm, determine for each axis:

b) The motor speed required for each axis, and

$$N_{m_y} = r_g \frac{v_{t_y}}{p} = \frac{10 \times 200}{2} = 1{,}000\, rpm$$

$$N_{m_x} = N_{m_y} \frac{x}{y} = 1000 \times \frac{25}{45} = 555.6\, rpm$$

Manufacturing Automation

Analysis of NC Positioning Systems

Example 7

Each axis of a two axes CNC router utilise a stepping motor that has 48 step angles and its output shaft is coupled to a lead screw with a 10:1 gear reduction. The leadscrew which drives the worktable in each axis has a a pitch = 2.0mm. The table is required to travel along a linear trajectory with neither axis exceeding a travel speed of 200mm/min. To achieve an incremental position of 25mm, 45mm, determine for each axis:

c) Pulse frequency required to achieve the desired table speed.

$$f_{p_x} = \frac{N_{m_x} n_s}{60} = \frac{555.555 \times 48}{60} = 444.4\ Hz$$

$$f_{p_y} = \frac{N_{m_y} n_s}{60} = \frac{1000 \times 48}{60} = 800\ Hz$$

Manufacturing Automation

Analysis of NC Positioning Systems

Example 8

Each axis of a two axes CNC router utilise a stepping motor that has 48 step angles and its output shaft is coupled to a lead screw with a 8:1 gear reduction. The leadscrew which drives the worktable in each axis has a pitch = 1.0mm. The table is required to travel along a linear trajectory with neither axis exceeding a travel speed of 200mm/min. Determine for each axis:

a) The minimum translation that can be achieved (or resolution).

b) What modification is required to double the resolution.

Manufacturing Automation

Analysis of NC Positioning Systems

Example 8

Each axis of a two axes CNC router utilise a stepping motor that has 48 step angles and its output shaft is coupled to a lead screw with a 8:1 gear reduction. The leadscrew which drives the worktable in each axis has a pitch = 1.0mm. The table is required to travel along a linear trajectory with neither axis exceeding a travel speed of 200mm/min. Determine for each axis:

a) The minimum translation that can be achieved (or resolution).

$$A_{ls_x} = \frac{360x}{p}, \qquad n_{p_x} = \frac{A_{ls_x} n_s r_g}{360}$$

$$x = \frac{n_{p_x} p}{n_s r_g} = \frac{1 \times 1}{48 \times 8} = 2.604mm$$

Remember, minimum translation will be for a signle pulse.

Manufacturing Automation

Analysis of NC Positioning Systems

Example 8

Each axis of a two axes CNC router utilise a stepping motor that has 48 step angles and its output shaft is coupled to a lead screw with a 8:1 gear reduction. The leadscrew which drives the worktable in each axis has a pitch = 1.0mm. The table is required to travel along a linear trajectory with neither axis exceeding a travel speed of 200mm/min. Determine for each axis:

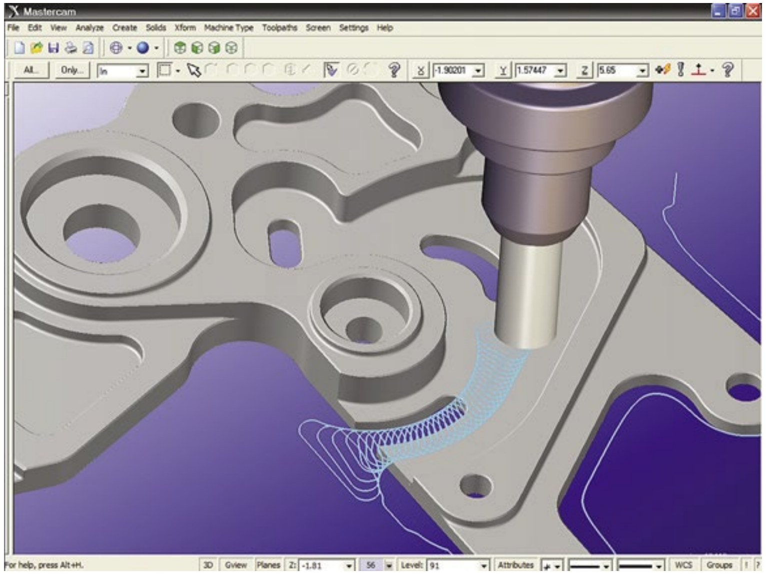
b) What modification is required to double the resolution.

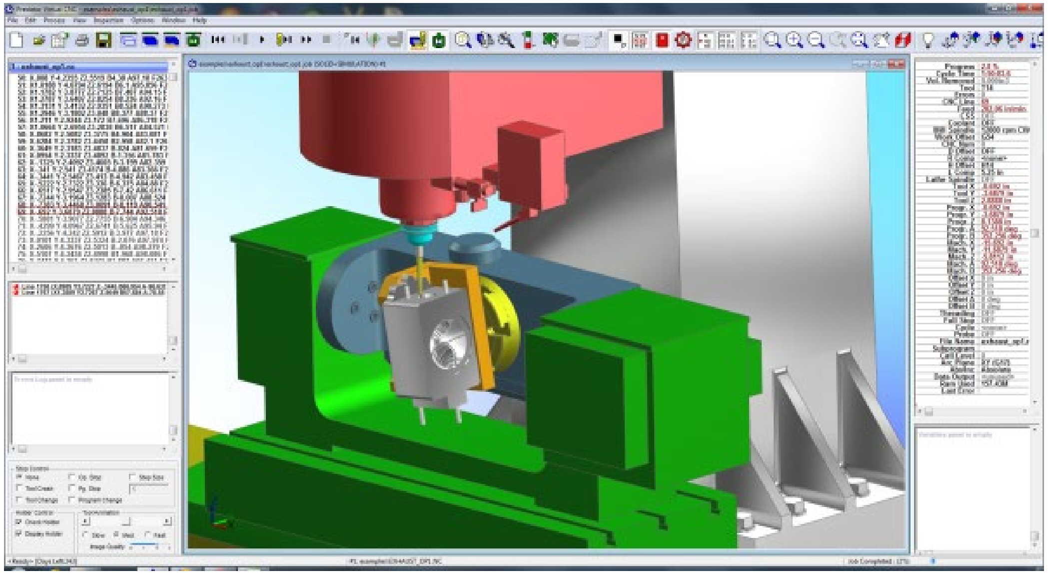
- Double the pulses
- Double the gear ration
- Halve the leadscrew pitch

Manufacturing Automation

Part Programming

Part programing refers to the programming that would be prepared for a specific part. It is usually prepared by somebody that is familiar with the operation that is required to be undertaken. Computer software is typically used to assist with this.





Manufacturing Automation

Part Programming

Part programming requires the programmer to define points, lines and surfaces of the workpart in the axis system and to control the movement of the tool relative to the defined part features. These include:

1) Manual part programing
2) Computer assisted part programming
3) CAD/CAM assisted part programming
4) Manual data input

Manufacturing Automation

Part Programming

Manual part programming is used for jobs such as drilling operations. It requires basic numerical data and special alphanumeric codes to define the steps in the process.

N010 x70.0 y85 f175 s500

Each word in the statement specified a detail in the drilling operation. The n word is a sequence number, the x and y words indicate the x and y coordinate positions. The f and s words specify the feed rate and spindle speed.

Manufacturing Automation

Part Programming

Computer Assisted Part Programming requires the programmer to first enter a series of geometric features that define the part. This is undertaken using APT motion statements which take the following form:

```
P1 = POINT/25.0, 150.0
L1 = LINE/P1, P2
```

These descriptions are then used to generate the path that is required. Terms exist to achieve lines, circles and planes. They can also be used to control feed rates, spindle speeds, tool sizes and tolerances.

Manufacturing Automation

Part Programming

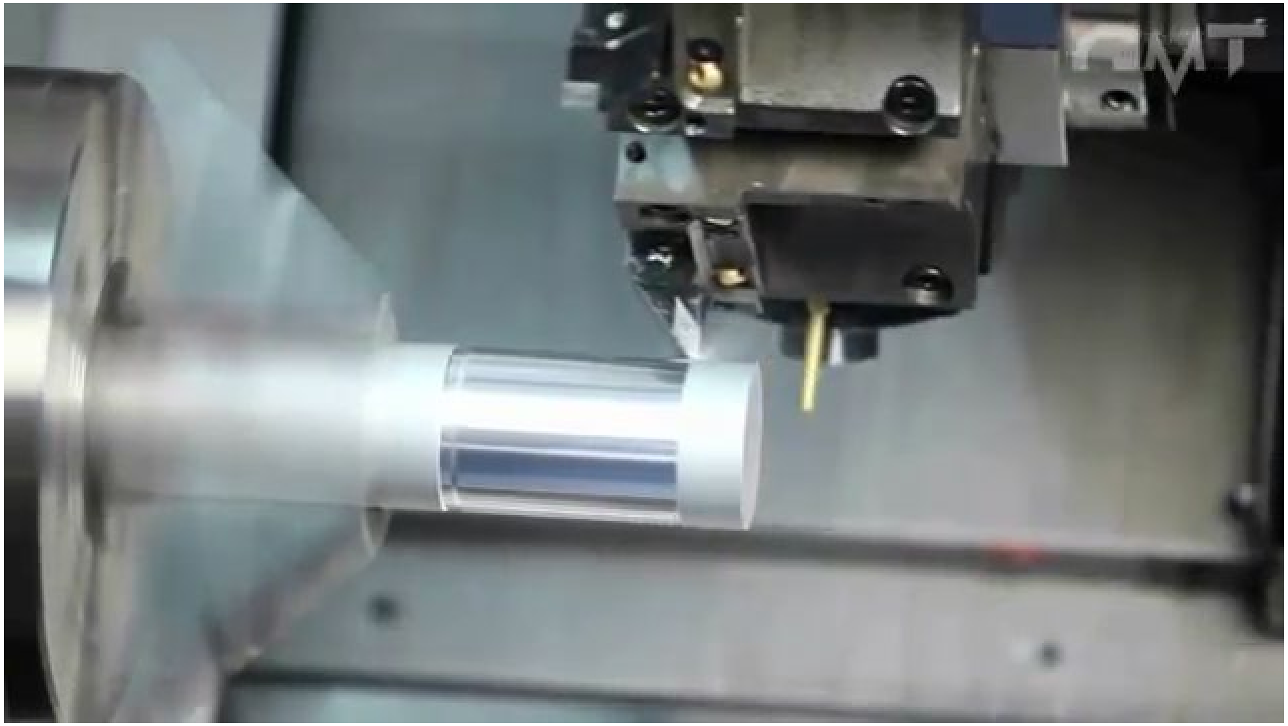
CAD-CAM Assisted Part Programming utilises software that allows the for the most complex of operations to be controlled easily and conveniently and with the aid of a visual feedback prior to the operation being undertaken. This allows for many errors to be determined prior to the operation being conducted for the first time.

Manual Data Input is when the operator directly enters data into the machine that is being controlled. The machine would therefore have some ability to display and enter data.

Manufacturing Automation

Applications of Numerical Control

CNC machines can be categorised into two main categories. These are either **machining** operations or **non-machining operations**. Many examples have been given thus far of machining operations such as CNC mills, lathes, routers, etc…



Manufacturing Automation

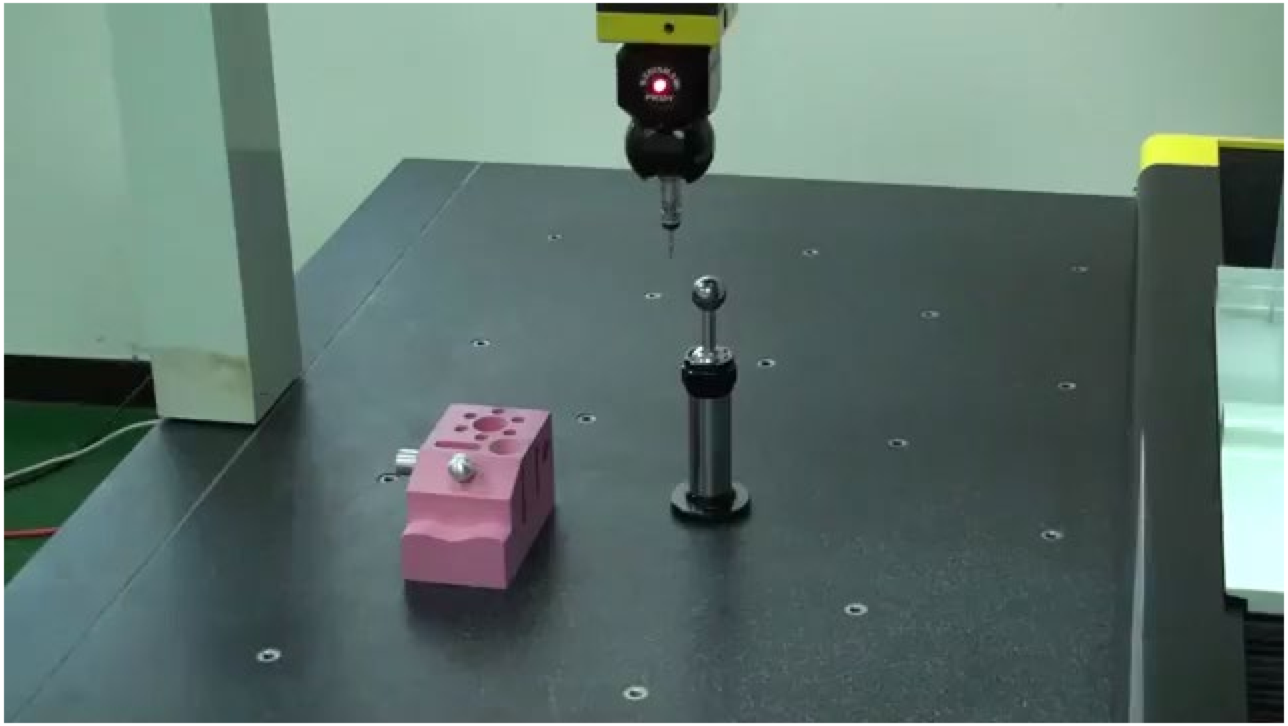
Applications of Numerical Control

N**on-machining operations** that have already been shown include; component insertion machines and welding. These can also include: Tape laying machines in composite manufacturing.

Manufacturing Automation

Applications of Numerical Control

N**on-machining operations** that have already been shown include; component insertion machines and welding. These can also include:
Coordinate measuring machines.



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Applications of Numerical Control

N**on-machining operations** that have already been shown include; component insertion machines and welding. These can also include: Drawing plotters.