COMPUTER AIDED MANUFACTURING (CAM)

UNIT 3

(INTERPOLATORS and CONTROL ON NC SYSTEM)

INTRODUCTION

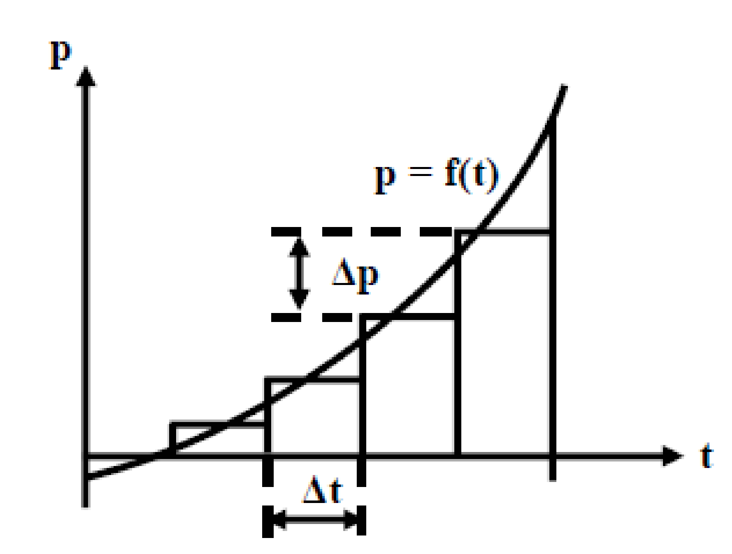
The most critical and specialised activity in a CNC is axis management, which involves interpolation, servo control and drive of the motion axes. Axis management tasks can be processed by one or more dedicated CPUs. Often, the interpolation and the servo control tasks for the several motion axes can be split between the various CPUs. Both point-to-point (PTP) interpolators and contouring interpolators are available on a machine.

Contour Generation by Interpolation

In contouring systems the machining path is usually constructed from a combination of linear and circular segments. It is only necessary to specify the coordinates of the initial and final points of each segment, and the feed rate. The operation of producing the required shape based on this information is termed interpolation and the corresponding unit is the “interpolator”. The interpolator coordinates the motion along the machine axes, which are separately driven, by providing reference positions instant by instant for the position-and velocity-control loops, to generate the required machining path. Typical interpolators are capable of generating linear and circular paths.

DDA Algorithm

DDA is essentially an algorithm for digital integration and generates a pulse train varying in frequency. Digital integration is performed by successive additions using an Euler approximation method shown in figure.



From the above, let,

$$z(t) = \int_0^t p\, dt$$

The value of z at $t = k\Delta t$ is denoted by z_k, which may be written as:

$$z_k = z_{k-1} + \Delta z_k$$

where

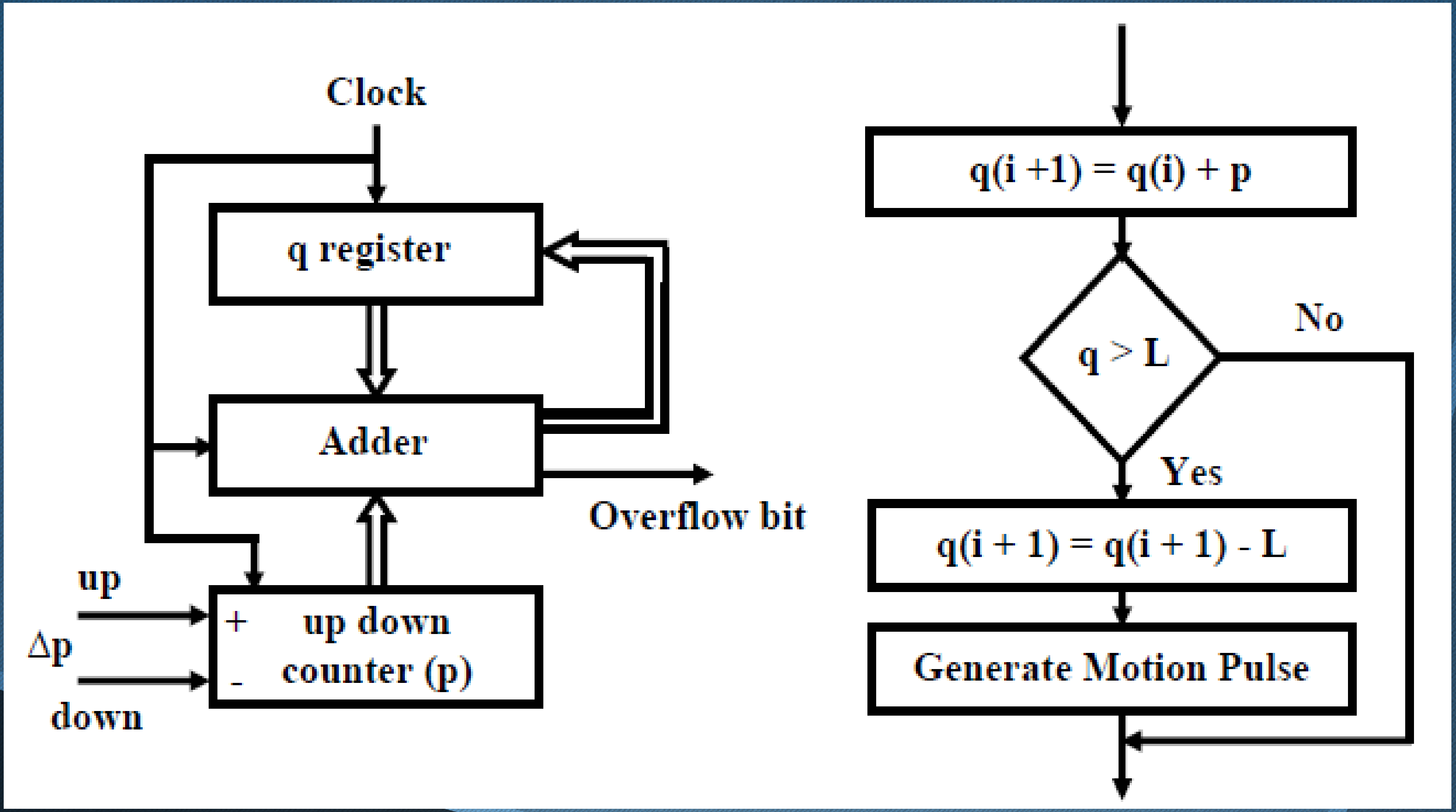
$$\Delta z_k = p_k\ \Delta t$$

The value of p_k can in turn be modified by incrementing or decrementing it by Δp, which is either 1 or 0. The DDA integrator operates cyclically at a frequency f provided by an external clock. At each iteration the variable p is added to the register q so that,

$$q_k = q_{k-1} + p_k$$

At intervals this addition would generate an overflow bit, which is fed as the output reference pulse. Obviously, the higher the value of p the higher would be the frequency of generation of an

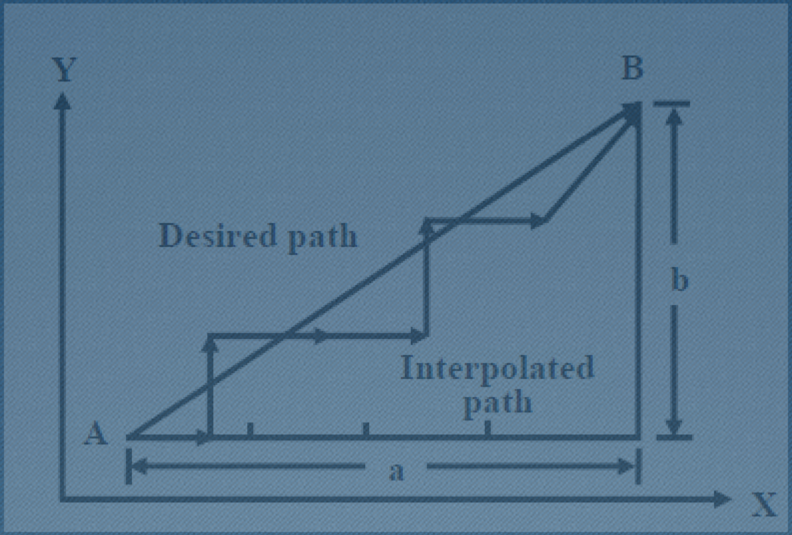
overflow and a reference pulse. Thus the rate of generartion of the reference pulse would be proportional to the value of p.



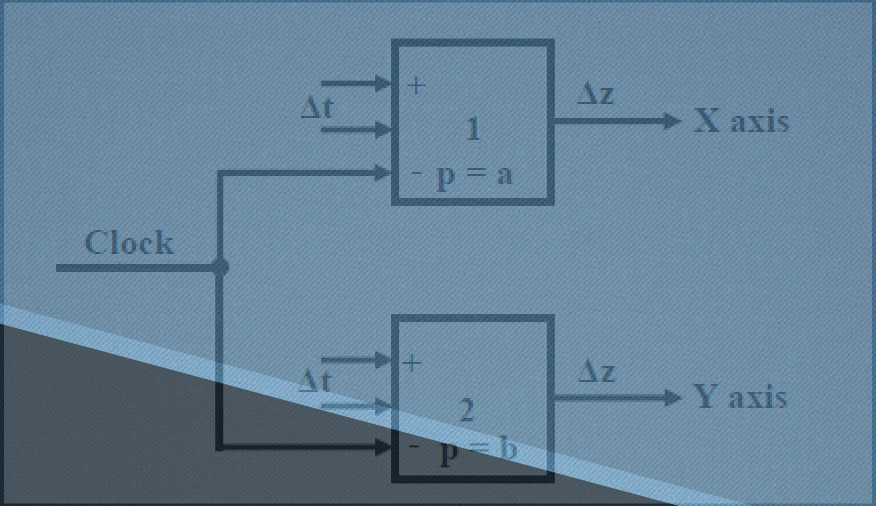
DDA Integrator Schematics and Flowchart

Linear Reference Pulse Interpolation

The ability to control the movement along a straight line between given initial and final coordinates is termed linear interpolation. In this lesson only 2-D linear interpolators are discussed. A 2-D linear interpolator supplies velocity commands, in pulses per second, simultaneously to two machine axes, and adjusts the ratio between the pulse frequencies depending on the slope of the trajectory., where a straight path has to be cut between points A and B. Note that movement along each axis takes place by 1 BLU for every reference pulse along the axis. The interpolator therefore has to provide pulses to each axis at definite rates, a and b pulses per second, along X and y axes respectively) with respect to time.



2D linear interpolation



DDA-based Linear Reference Pulse Interpolator.

Reference-word Circular Interpolators

In reference pulse systems a pulse train of varying frequency is output to the servo control module. The servo system for an axis causes an incremental displacement along the axis, for each pulse. As mentioned before, this can cause a speed limitation for the CNC, depending on the execution speed of the interpolation loop. In contrast, in reference word interpolation systems the maximum velocity is not limited by the execution speed of the processor. . The interpolation subroutines continuously provide velocity set points to the servo system, which realizes it through the drive. In this lesson we discuss a circular interpolation using the reference word method. This require the use of a “controlled speed drive” rather then a “position servo”.

In circular interpolation, at a constant tangential velocity, *V* and radius *R*, the axial velocities satisfy the following equations:

$$\mathrm{Vxsin} = \theta xVtV\ t$$

$$\mathrm{Vycos} = \theta yVtV\ t$$

The velocity components V^x and V^y are computed by the circular interpolator and are supplied as reference inputs to the computer closed loops. Actually what is generated is a polygon inscribed on a circle. At the beginning of each side the interpolator provides new velocity references to the axes. The more the number of sides of the polygon, the better is the accuracy of the generated circle. The optimal number of sides is the smallest one for which the path error is within one BLU.

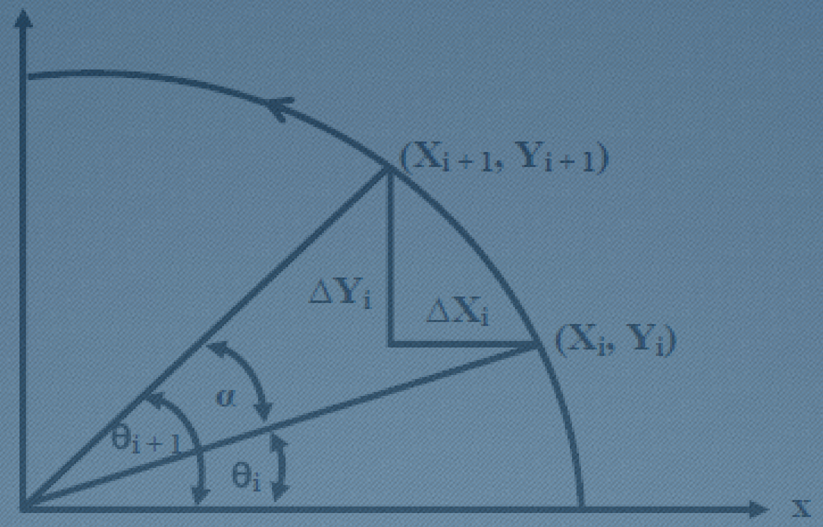


Fig. 24.6 Position and velocities at two successive points on a circle

From Fig. 24.6 one can derive the following recursive update eqns. for the two coordinate axes.

$$X(i+1) = AX(i) - BY(i)$$

$$Y(i+1) = AY(i) + BX(i)$$

where, $A = \cos\alpha$ and $B = \sin\alpha$. The velocity set points for the axis drives are computed as follows.

$$\Delta X(i) = X(i+1) - X(i) = (A-1)X(i) - BY(i)$$

$$\Delta Y(i) = Y(i+1) - Y(i) = (A-1)Y(i) + BX(i)$$

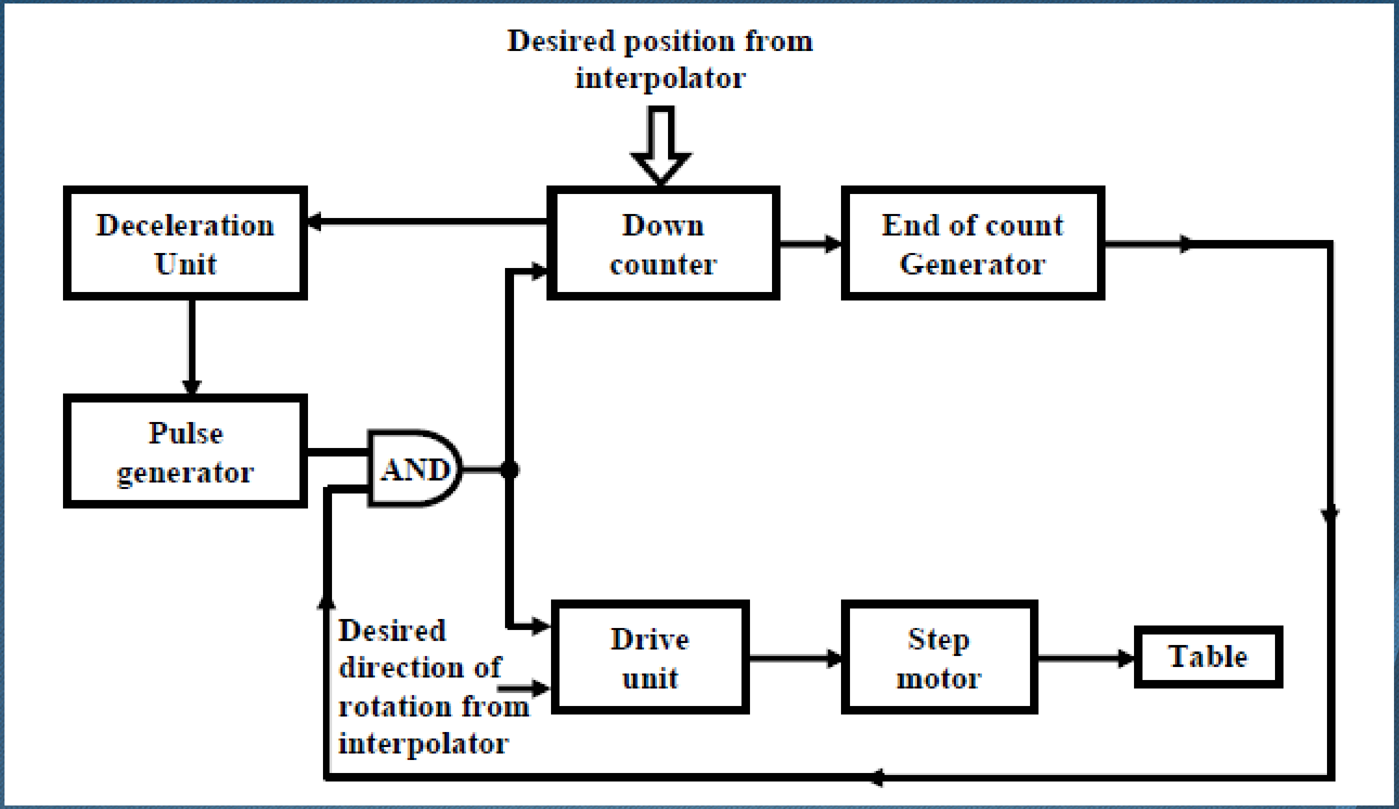
$$V_x(i) = K\,\Delta X(i)$$

$$V_y(i) = K\,\Delta Y(i)$$

where $K = V/R\alpha$. These velocity set points are provided to the servo control systems which are described below.

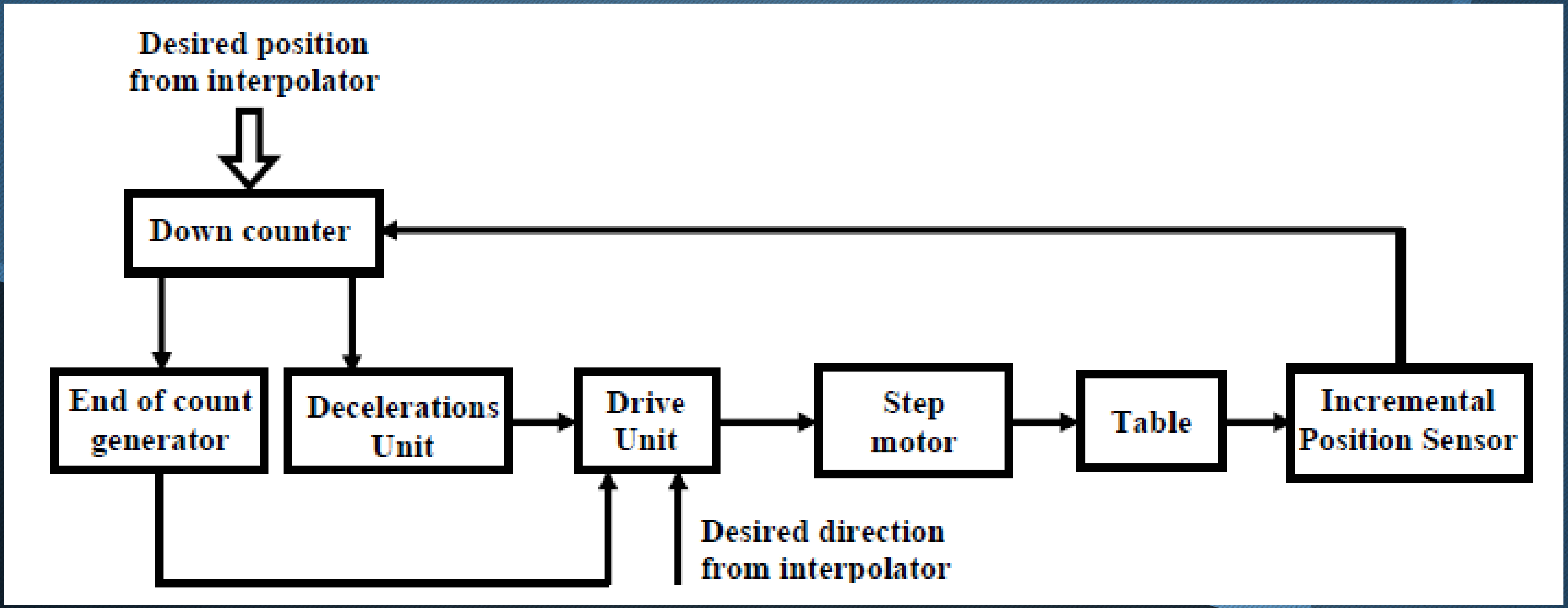
Control of PTP Systems

In PTP systems only the final position of the table is controlled and the trajectory of motion in between the final and initial points are of no concern, since the tool is not cutting metal during motion. Open-loop controls using stepping motors as the drive devices of the machine table can be utilized in on small-sized point-to-point systems in which the load torque is small and constant. To save machine time, the table travels at high velocities. However, in open loop control there is no feedback of the actual position of the table. Therefore, the velocity must be gradually reduced towards the end, to avoid overshooting the final position, due to the limited braking torque compared to the momentum of the drive system and the table at high speed. PTP systems can use incremental or absolute programming. In incremental point-to-point systems a counter is loaded with the incremental coordinate of the destination by the interpolator. In closed loop systems it is decremented by pulses from the encoder, which indicate actual axis motion. In open loop control it is decremented at a suitable rate, by a pulse generator, as the step motor has turns by one step angle for each pulse. The motor is decelerated based on the content of the counter, which represents the distance to the destination point. A block diagram of an open-loop point-to-point control system for incremental programming for a single axis. When the motor axis reaches the destination point, counter content is zero.



Incremental open-loop control for PTP systems

In open loop control, it is implicitly assumed that the shaft rotates by 1 BLU for every command pulse applied to the drive. Thus the pulse generator frequency cannot be increased beyond a certain level, which depends on the load, since then the stepper motor would not be able to turn under the load with each pulse. To obviate this difficulty, feedback is used. The incremental change in the shaft position is taken from an incremental position sensor, such as an encoder, on the lead screw .



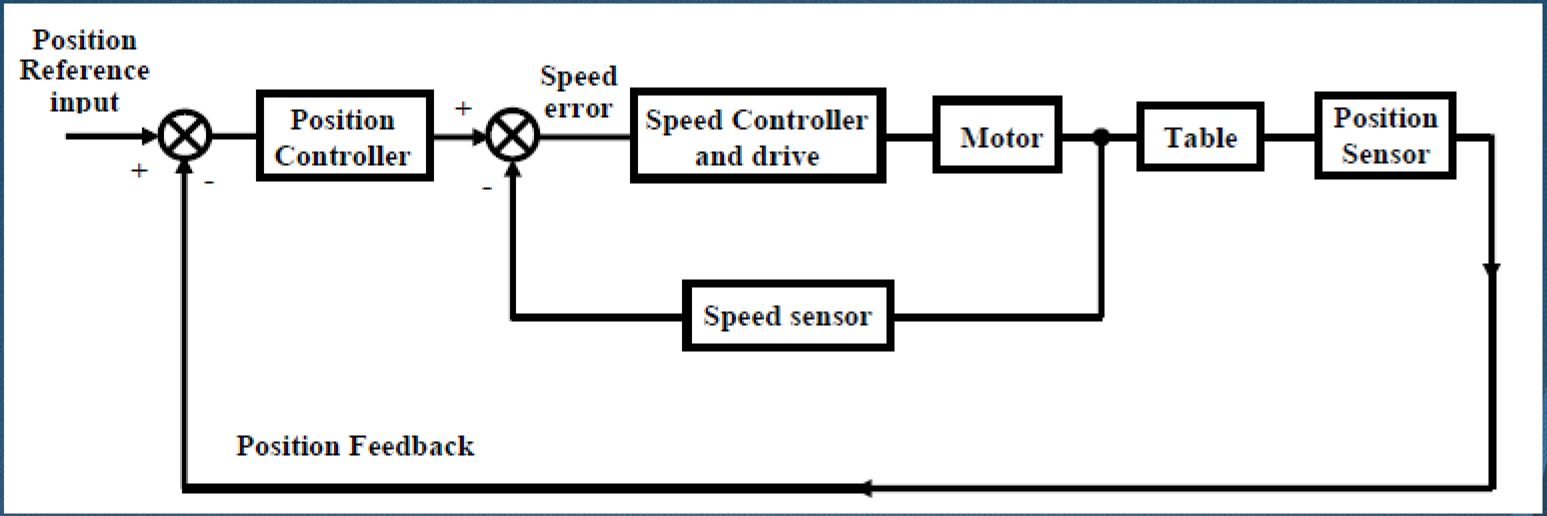
Block diagram of closed-loop incremental PTP system pulses, which represent the actual motion, feed the down counter rather than the command pulses produced by the pulse generator in the open-loop control. The decelerator circuit slows down the motor before the target point in order to avoid overshoot. Note that, even in a closed loop system, to avoid errors due to backlash in gears, an overshoot is to be avoided. When the table is at a close distance of the target point, the table “creeps” toward the final point at very low velocity, before it stops.

In absolute positioning systems utilizing an incremental feedback device, two alternative sequences of pulses from the incremental encoder, one for each direction of motion, feed the up and down inputs of a *position counter*. Thus, its contents are incremented for a rightward movement of the corresponding axis and are decremented for a leftward motion. The position counter value, therefore, indicate the actual absolute position of the axis. A *command register* is loaded with the required absolute destination position of the axis, by the interpolator. The *subtractor unit* indicates the instantaneous actual difference between the required and actual position, which is the distance to the target point. The subtractor output is the position error of the loop. Till the subtractor output is zero, pulses are fed through a deceleration circuit to the motor.

Control of Contouring Systems

In contouring systems the tool is cutting while the machine axes are moving. The contour of the part is determined by the ratio between the velocities, along the two axes. The control in contouring systems operates in closed loop. Therefore, a contouring system uses a cascade control structure involving an inner velocity loop and an outer position loop for each feed axis improved dynamic response. In such systems the interpolator generate reference signals (in form of a sequence pulses or position words) for each axis of motion, in a coordinated manner so that a desired contour is generated.

Typical cascade control structure of contouring systems is shown in figure. It uses an inner velocity feedback loops incorporating a tachometer usually mounted directly on the motor shaft and an outer position feedback loop which is capable of measuring incremental (such as from an incremental encoder) or absolute angular position of the leadscrew shaft (such as a resolver or inductosyn).



Control loop of a contouring system

In encoder-based systems each pulse indicates a motion of 1 BLU of axis travel. Therefore, the number of pulses over a period represents incremental change in position over the period and the encoder pulse frequency is proportional to the axis velocity. In such a system, fed from a reference pulse interpolator the comparison is done by an up-down counter which is fed by two sequences of pulses: reference pulses from the interpolator and feedback pulses generated by the encoder. The counter produces a number representing the instantaneous *position error* in pulse units. This number can be converted by the DAC and fed to an analog position control system.