Direct Numerical Control

Direct Numerical Control, also known as **Distributed Numerical Control**, (both DNC) is a common manufacturing term for networking CNC machine tools. On some CNC machine controllers, the available memory is too small to contain the machining program (for example machining complex surfaces), so in this case the program is stored in a separate computer and sent **Direct** to the machine, one block at a time. If the computer is connected to a number of machines it can **Distribute** programs to different machines as required. Usually, the manufacturer of the control provides suitable DNC software. However, if this provision is not possible, some software companies provide DNC applications that fulfill the purpose. DNC networking or DNC communication is always required when CAM programs are to run on some CNC Machine control.

1950s-1970s

Programs had to be walked to NC controls, generally on paper tape. NC controls had paper tape readers precisely for this purpose. Many companies were still punching programs on paper tape well into the 1980s, more than twenty-five years after its elimination in the computer industry.

1980s

The focus in the 1980s was mainly on reliably transferring NC programs between a host computer and the control. The Host computers would frequently be Sun, HP, Prime, DEC or IBM type computers running a variety of CAD/CAM software. DNC companies offered machine tool links using rugged proprietary terminals and networks. For example, DLog offered an x86 based terminal, and NCPC had one based on the 6809. The host software would be responsible for tracking and authorising NC program modifications. Depending on program size, for the first time operators had the opportunity to modify programs at the DNC terminal. No time was lost due to broken tapes, and if the software was correctly used, an operator running incorrect or out of date programs became a thing of the past.

Older controls frequently had no port capable of receiving programs such as an RS232 or RS422 connector. In these cases, a device known as a Behind The Reader or BTR card was used. The connection between the control's tape reader and the internal processor was interrupted by a microprocessor based device which emulated the paper tape reader's signals, but which had a serial port connected to the DNC system. As far as the control was concerned, it was receiving from the paper tape unit as it always had; in fact it was the BTR or Reader Emulation card which was transmitting. A switch was frequently added to permit the paper tape reader to be used as a backup.

1990s and beyond

The PC explosion in the late 1980s and early 1990s signalled the end of the road for proprietary DNC terminals. With some exceptions, CNC manufacturers began migrating to PC-based controls running Windows or OS/2 which could be linked in to existing networks using standard protocols. Customers began migrating away from expensive minicomputer and workstation based CAD/CAM toward more cost-effective PC-based solutions. Users began to demand more from their DNC systems than secure upload/download and editing. PC-based systems which could accomplish these tasks based on standard networks began to be available at minimal or no cost. In many cases, users no longer needed a DNC "expert" to implement shop floor networking, and could do it themselves.

To remain competitive, therefore, DNC companies moved their offerings upmarket into Advanced DNC, sometimes called Manufacturing Execution Systems or MES. These terms encompass concepts such as real-time Machine Monitoring, Graphics, Tool Management, and Scheduling. Instead of merely acting as a repository for programs, Advanced DNC systems aim to give operators at the machine an integrated view of all the information (both textual and graphical) they require in order to carry out a manufacturing operation, and give management timely information as to the progress of each step. Advanced DNC systems are frequently directly integrated with corporate CAD/CAM, ERP and Process Planning systems.

Special Protocols

A challenge when interfacing into machine tools is that in some cases special protocols are used. Two well-known examples are Mazatrol and Heidenhain. Many DNC systems offer support for these protocols. Another protocol is DNC2 or LSV2 which is found on Fanuc controls. DNC2 allows advanced interchange of data with the control, such as tooling offsets, tool life information and machine status as well as automated transfer without operator intervention.

Machine Monitoring

One of the issues involved in machine monitoring is whether or not it can be accomplished automatically. In the 1980s monitoring was typically done by having a menu on the DNC terminal where the operator had to manually indicate what was being done by selecting from a menu, which has obvious drawbacks. There have been advances in passive monitoring systems where the machine condition can determined by hardware attached in such a way as not to interfere with machine operations (and potentially void warranties). Many modern controls allow external applications to query their status using a special protocol.

Alternatives

Smaller facilities will typically use a portable PC, palmtop or laptop to avoid the expense of a fully networked DNC system. In the past Facit Walk Disk and a similar device from Mazak were very popular.

Uses a few methods,

- the oldest methods used modems, and a mainframe which emulated a tape reader, to control the NC machine (no storage)
- A more recent advance used a local computer which acts as a storage buffer. Programs are downloaded from the main DNC computer, and then the local controller feeds instructions to the hardwired NC machine, as if they have been read from tape.
- the newer methods use a central computer which communicates with local CNC computers (also called Direct Numerical Control)

- DNC controllers came before CNC machines, but as computer technology improved it became practical to place a computer beside the NC machine, and DNC changed in form.

Characteristics of modern DNC systems are,

- uses a server (with large storage capacity) to store a large number of part programs
- the server will download part programs on demand to local machines
- may have abilities to,
  - display and edit part programs
  - transmit operator instructions and other data needed at the machines
  - collect and process machine status information for management purposes

Advantages are,

- eliminates the need for NC tapes (the advantages are obvious)
- design changes are immediate
- NC programs may be edited quickly
- can be used to support an FMS system
- increase efficiency of individual machine tools
- more shop up-time than with stand alone machines
- simplifies implementation of group technology, computer aided process planning, and other CIM concepts
- reduces peripheral costs with NC tapes

A Brief History,

- Mid 60's
  - Concept proved by Cincinnati Milacron and G.E.
  - Telephone links used to send instructions from large computers to hard wired NC machines. Basically replaced a tape reader.
- 1970
  - Several commercial DNC systems announced.
- Mid 70's
  - Aerospace companies used DNC because of the large number of distributed machines in their facilities.

Initial resistance to DNC technology was (previously) based on,

- ❖ high cost of computer hardware
- ❖ the number of machines which could be controlled by one computer was limited
- ❖ computer software was limited for maintenance, scheduling, control, and data collection
- ❖ a backup computer was usually required
- ❖ was hard to justify on the basis of downloading parts programs

- ❖ when downloading programs there are two popular opinions,
- ❖ A program should only be downloaded in part, this accommodates easy engineering changes in a real-time environment.
- ❖ Many programs should be downloaded to the local controller to provide protection against system failure, and eliminating the cost of real-time response in the DNC central computer.

While it's been a protracted and rocky road for numerical control, the latest breakthroughs indicate DNC has truly come of age. Recent developments in software and client/server networking lay to rest the old misconceptions of prohibitive expense, complexity and inefficiency. Instead, they provide a sophisticated, cost-effective technology that is more than living up to early expectations.

The Road To Perfection

The first NC systems were hard-wired circuits connecting the machine tool servo motors to the machine control unit (MCU). After initial developmental bugs were worked out in the 1950s, these early NC machines increased production and made it possible to do the types of jobs that a manual worker could never accomplish—jobs such as forming dies, molding cavities, airfoils and other aircraft components. Then came computer numerical control (CNC) which utilized an on-board computer as the MCU, allowing the machine tool to repeat work from its own memory. The greater output of CNC expanded the new technology into automation of small batch production traditionally done by manual machines. Yet many problems remained, not the least of which was dealing with paper tape programs that continued to be the primary medium for program transfer.

Then came direct numerical control (DNC) which provided the ability to connect machine tools to a common, centrally located computer that stored the part programs and, on demand, distributed the machining data to the different MCUs. Direct NC kept the operator at the machine, bypassing the need for paper tape, and substantially reduced setup time. But one drawback remained; if the computer went down, all its machines were inoperative.

Now there's distributed numerical control, which employs a network of computers to coordinate the operation of multiple machines by feeding a program to the CNC memory where it can remain and function independently. The operator can collect, edit and return the program. This is a significant advantage over direct NC machines which were unidirectional and dependent on a central computer. Thus, the term DNC has come to mean both direct and distributed numerical control, though the later term is more representative of the dominant application in today's modern machine shop.

State-Of-The-Art DNC

State-of-the-art DNC systems today can do much more than just send and receive NC programs. They can transmit part programs in blocks (drip feed), administer sub-programs and allow for re-entry into interrupted programs. In addition, some systems can relay data to third-party systems, offer a surprising level of configurability, and even execute "background processing" where multiple activities are handled simultaneously. Some systems also are equipped with quality control features such as a gage port interfaces and can establish the connection to electronic measuring equipment, displaying "measured data" as a control chart.

The capabilities of DNC have been greatly expanded over the last few years to include more functions that simplify operations. In the past, hardware determined the capability of the system. Nowadays, software innovation leads the way. Here are some of the key features of modern DNC systems:

- Editing—It is possible to run one NC program while others are being edited (background processing), providing shop floor people the ability to work with multiple programs at any given moment.
- Compare—This takes an edited version of an NC program, compares it to the original and marks the differences in color so that a process engineer can evaluate the changes.
- Restart Function—In older equipment, if a tool broke or wore out halfway through a program, the whole program had to be re-run after the tool change, wasting hours of work. Now a program can be stopped, the tool changed, and the program re-started where it left off.
- Job Tracking—With some DNC systems, there is no longer a need to clock in jobs at some shop control system terminal far away from an operator's work area. A worker can do it right at his machine, and at the same time record what job is being worked on, how long setups take, and so on.

- Video Hook-Up—It is now possible to watch a video on site that demonstrates how to operate and set up a machine, as well as run any specified job.
- Diagnostics—Maintenance is made much easier by a system of diagnostic coding that isolates what's wrong with a particular machine, saving hit-and-miss troubleshooting that otherwise could take days.
- Displaying Drawings—Photos, graphics and CAD drawings of tools, fixtures and finished parts are readily available in various formats.
- Advanced Database Management—Residing on the network server, such software organizes and maintains data, and allows for the retrieval, view and update of information. It provides fast, consistent and predictable response to database queries and report generation.
- Touch Screen Interfaces—One touch of the fingertip is all that is needed for the machinist to select the desired function.

Machine Tool Monitoring

Most managers don't find out about downtime until well after the fact, regardless of what computer system they use. Lengthy job setups and unexpected stoppages can go on for hours before word of the downtime makes its way upstairs.

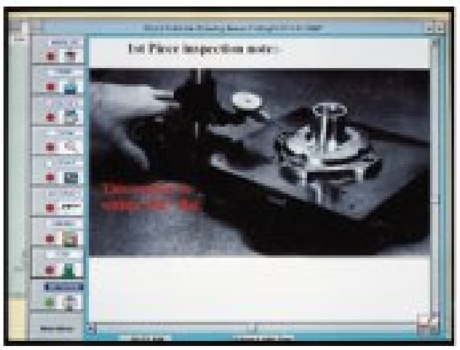
Machine tool monitoring, probably the most significant advance in software to complement DNC, is essentially a means of transforming a complex, unwieldy jumble of information into a smaller database, fully isolated from the main shop floor data. It provides automatic report generation of machine tool utilization, work order status and labor reporting. The system has the ability to collect specified facts and figures from in-process transactions being recorded moment by moment on the shop floor. It enables personnel to analyze data, generate standard and ad hoc reports, as well as to pass information off to MRP II and financial systems.

In the case of DLoG's machine monitoring capability, it makes use of a binary logbook rather than a database. This allows for significantly faster processing. For instance, if the primary database has five million entries and a query involves 500, the "DC Engine" gathers only the data relevant to that query. Since the DNC system doesn't have to deal with thousands of unrelated records, it brings fast, uncomplicated access to the information without costly databases or other types of administrative overheads.

DNC In The Workplace

Pat Collins is a manufacturing engineer for Allied Signal Aerospace in South Bend, Indiana. According to Mr. Collins, his company had an outmoded NC program management system that didn't function properly as a network. He notes, "Our hardware was obsolete, with four or five different centers of control. We had two different types of NC programs running and had to remember to store updates in four or five places manually. If you forgot, you ended up with some machines running on the new version and others on the old."

The solution to this problem was to install a new DNC system that gave timely distribution of information between planning and the shop floor. According to Mr. Collins, this upgrade resulted in a substantial reduction in downtime and increased productivity by fifteen percent. "Part of the plant was storing programs on floppy disks," he says. "Each operator had his own disk, modifying it as he went along. One worker would have a different program than his shift replacement, causing confusion on the machines involved. In other areas, we were using a paper tape punch that took fifteen minutes to load each time. Sometimes it contained reader errors. The readers and punches were aging, causing machine malfunctions and damage.



"Another problem was operators spending too much time on setups. Besides the time it took to download programs, the operators didn't have all the data at their fingertips to get the job done. So it often required trips to the engineering department to get everything straightened out.

"We now have file integrity using one server. The new DNC system takes less than a minute to do what took fifteen in the old sys-tem. With seventy uploads and downloads per day, this is a significant saving."

Brendan Kowalski, Computer Operations Manager at American Mold Technologies in Harrison Township, Michigan, has seen many changes in technology during his fourteen years in the business. At American Mold, Mr. Kowalski was charged among other things to lead the company's investigation and acquisition of the latest DNC technology. He says, "We were a new firm, starting out from scratch, and I was hired to research, install and run the computer network."

That investigation found that DNC technology had indeed made major advances in the last decade. As Mr. Kowalski puts it, "In older systems, you could use no more than 50 feet of wire before you needed a booster. We would have needed 20 booster boxes for our three-quarter mile of networking line. With our new system we use only one. It has a 10-megabit transfer rate, and in four years of operation, we've never lost a bit of data in 30,000 to 40,000 transfers. That's phenomenal.

"We do high speed cutting at 400 inches per minute at 12,000-rpm spindle speeds. A tremendous amount of data is being fed down the lines to keep up with that, but our DNC system handles it excellently."

The Paperless Shop

While the goal of eradicating paper from the workplace has been with us for decades, the achievement of this dream is closer than most people realize. It has been estimated that US corporations spend eleven percent of their gross income on generating, controlling and retrieving paper. In the manufacturing environment, elimination of paper though the introduction of a broadly functioning DNC shop floor network can offer a huge payback. Indeed, installation of a modern DNC system can result in an immediate eighty percent reduction in paper. And it isn't just the direct costs of managing information that can be dramatically reduced. Shops that utilize this technology properly should also see lower costs in NC programming, setup, supervision and even maintenance as well.

Moreover, initial system cost is no longer a significant barrier to building a paperless manufacturing environment. Early DNC equipment was an extremely costly investment, and only the larger firms were able to afford it. But with the price of computers steadily falling, a DNC system is available to most manufacturers at a fraction of the former investment.

The Future of DNC

The future of DNC is headed toward multimedia access via the Internet. A user may simply log onto a DNC server whenever needed and then be charged for the time used. This will make the technology more affordable because users pay only for the time they use the system. That means that the DNC of the future must be Internet enabled and must work on any hardware. DNC providers will have to adapt from handling a few large, expensive orders to servicing millions of customers, each paying a relatively small amount. It's likely that each operator will have his or her own multimedia PC, something that's coming much faster than most people believe. In the meantime, the use of DNC will increase in prototype and small job shops due to the arrival of lower cost controllers containing many of the advanced programming features.

"Another wave of change could involve PCs taking over part of the role of a CNC controller," With the bugs that have plagued numerical control over almost half a century, and the perpetual wave of optimism about its potential from its creators and developers, it is hardly surprising that some misconceptions exist about the performance rates of DNC. But one only has to see the latest DNC systems in action to know that this technology has finally come of age. It is no longer the case that DNC needs to develop further to be able to fully handle the needs of the machine shop. With the speed and capabilities of current systems, it is the machines themselves that need upgrading to keep up with the work rate potential of DNC.

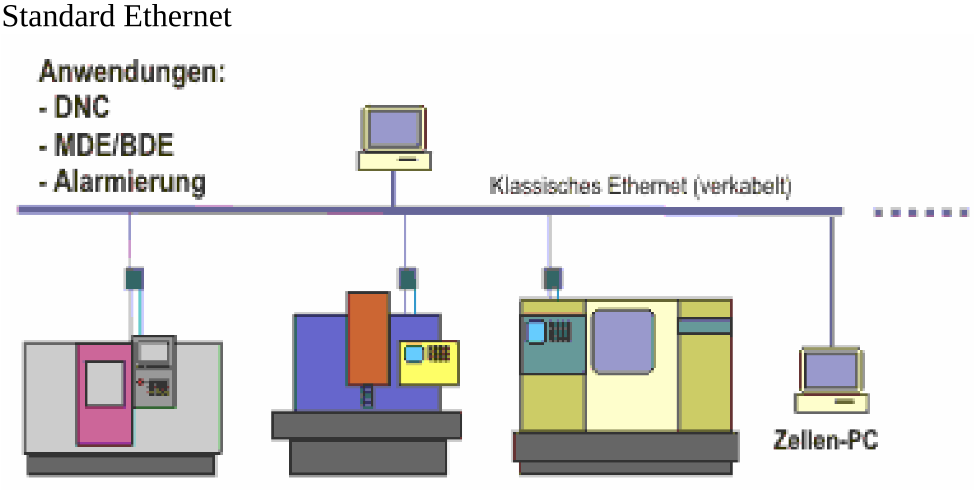
In the early 90s we were the first to connect machine tool controls to networks using Ethernet adapters. At the same time we introduced the technique of program request from the controller's keyboard, using a dummy program. These were important factors to reduce the cost of ownership and allowed our system to become the standard of network-DNC in teh market.

Older controllers without a built-in Ethernet card still need a device server (= Ethernet adapter) to connect their RS232 interface to the network. Although newer controllers have an Ethernet card, they still use the data management of the DNC system for data storage and backup. All Network DNC systems can use either the special Network network adapters with DNC-In-The-Box® firmware, but can as well use standard terminal servers, device servers or com-servers, such as produced by Lantronix, W&T, Moxa and others.

Standard Ethernet or Wireless LAN

All Network DNC systems can be used in "classic" Ethernet LANs or in wireless LANs (WLAN).

The LAN of your choice
Standard Ethernet



Program request from controller's keyboard

An other significant feature is the use of a dummy program, sent from the controller, to request a NC program that is stored on the computer. This allows the operator of the machine to call and save programs from his controller without leaving his work place. The DNC system recognizes whether a saved program has been modified and in such a case, it stores it in the duplicates where it can be compared to the original with a simple mouse click.

As our DNC systems use a comment line for identification of a part program, the restrictions of 4 digit-Ids does not apply and you can work with smart Ids, such as: part number, design numbers or even combinations.

Safe data transfer

Our Ethernet adapters work with TCP/IP protocol which assures a safe data transfer over any distance. As the network adapter is built in the cabinet of the controller, the RS232 cable can be kept very short. This allows to transfer part programs with the maximum speed that is supported by the controller.

Machine Data Collection/Monitoring

- MM Machine Monitoring
- MDC Machine Data Collection
- PDC Production Data Collection

Machine Data Collection

MDC/MM is a network based system that monitors the status (e.g. the start and stop of cycle, etc.) of machines and automatically records changes in their status. The premise of the system's design is that changes in machine status should be collected automatically by a central PC - and that user intervention should be limited to an absolute minimum. In addition to the status change, new production orders can be entered via barcode reader or handheld terminals.

Whenn a Network DNC system is used, the same adapter (SCD) can be used to gather digital signals from the machine's PLC and send them to the MDC/MM server program. DNC and MDC server can share the same computer or can be installed on different PCs. The MDC/MM server software updates automatically all client PCs with any change in status.

In a second step you can collect the production time and downtimes, e.g. by part# or order#, what makes MDC/MM to a perfect production data collection system (PDC).

All these data can be enterd by the operator on the machine, using a barcode reader or a handheld terminal.

Machine Monitoring

MDC/MM is also a **machine-monitoring system** that provides a maximum of information on machines and their productivity, with a minimum of effort. The system allows you to recognize bottlenecks and malfunctions quickly so that you can take remedial actions immediately.

Using MDC/MM, all authorized users can do the following work:

Production Data Collection

- define downtime reasons
- view in real-time, all productive and non-productive machines
- view all up-time and down-time details per machine over the past 90 days
- display productivity statistics per order#, part#, machine#, department or plant - and compare them to the preceding month, quarter or year.

SCD - Smart Communication Device

Network adapter of the latest generation, 48 MHz 16-Bit DSTni communications processor, includes PCMCIA slot for WLAN (IEEE802.11b) and/or Compact Flash card, expandable with digital I/Os and audio exit. The SCD family has a soft-configurable RS232 (300 - 115'000) and a 2nd serial port for barcode reader or handheld terminal. These devices are supported in the DNC version. A serial line monitor can be activated via browser and allows to trace the data traffic on the serial interfaces.

SCD-M

for application in MDC/MM with controllers with built-in Ethernet interface or with machines that dont need DNC functions.

All tools included

The network adapters SCD-D and SCD-DM possess all the tools you need to network numerical controllers. The problems are normally related to the RS-232 of which you have to know well how they work, which pins have to be connected and which (invisible) control characters the controllers expect during an upload. Together with the SCD you get all the tools to network machine controllers easily:

- **NetworkConfig**, a configuration program for easy configuration of the serial interfaces, helps you to configure the DNC parameters and the digital I/Os.
- **RS232 DNC.** Allows you to configure without necessity of solderin. This function reduces considerably installation times, work hours and costs.
- **RS232** for barcode reader or handheld terminal. These media are supported by the firmware and need no extra software. **Line**

- **Embedded Line Monitor.** With the browser it is possible to vizualize all the printable and even the non-visible characters during an upload or download. This function is a great help and is necessary to connect controllers via RS-232. It saves you an expensive special program for this purpose.
- **Part Counter.** The digital I/Os can be used as part counters. The adapter counts any change of a signal and delivers on request the result to the PC. Theis function reduces the traffic on the network.

PC-DNC Plus

Most powerful DNC software, PC-DNC Plus provides simultaneous communications with up to 256 CNCs. PC-DNC Plus lets you call up files with "remote" commands from your CNCs keyboard, and can also be used as a manual file queuing system. Optional software modules are available for machine cycle monitoring, automatic paging, in-process gauging, paperless factory, and FTP data server.

- ✓ All 32-bit code for Windows 95/98/NT/ME/2000/XP
- ✓ Uses standard COM ports (COM1 to COM128)
- ✓ Optional FTP server support
- ✓ Full support for UUP (Ethernet) port
- ✓ Simultaneous drip-feeding at up to 115,200 baud
- ✓ Easy drag & drop file queuing
- ✓ Operate from anywhere on your network (monitor CNCs too!)
- ✓ Easy mid-file (tool break) startup
- ✓ Upload & download using remote commands from CNC
- ✓ Mazatrol CMT file I/O
- ✓ Includes **PC-DNC Editor**
- ✓ Each port configurable for baud rate, disk directories, etc...

System Overview

PC-DNC Plus is a totally new concept in multi-port DNC software. Most other DNC systems are designed to run as a single application, in which there are multiple "threads" to handle the simultaneous communications with multiple CNC machines. PC-DNC Plus is different in that it consists of a "main window" application, and multiple 1-port DNC applications running concurrently.

At start-up, a main command window (shown above) opens, which then launches a separate 1-port DNC application for each CNC machine on your system. PC-DNC Plus can be configured to communicate with any number of ports (from 1 to 256). Since each DNC window is simply another iteration of the same 1-port DNC application, there is far less complexity to the software design. Each DNC window functions independently of all other applications. You can open, close, or reset each DNC window individually, or you can control them all as a group from the main command window. Since each DNC window is a separate Windows application, a fatal error that might occur in one DNC window is isolated to one element of the system, and does not affect other DNC windows or the main command window.

Client/Server capabilities

A PC-DNC Plus "server" can communicate with up to 256 CNC machines. A PC-DNC Plus "client" can connect with any PC-DNC Plus server on your network, and can be used to perform any manual operation that can be performed from the server. Our "floating client" licensing method permits many clients to connect with each server, regardless of where they are located on the network. If your facility has multiple PC-DNC Plus servers in operation, any client can connect with any server that is currently running.

Types of Communications Ports

Serial (RS232):

PC-DNC Plus can communicate with CNC controls, BTR devices, or paper tape punch/readers using any logical COM port (RS232 or RS422) on the PC-DNC Plus Server PC. These ports can be native COM ports (COM1 to COM4), or the COM ports provided on a Multi-Port Serial board, such as Control Rocket Port boards. PC-DNC Plus can also use serial network hubs, such as the Control SI serial hub. Baud rates from 110 to 115,200 are available, along with a multitude of configuration options for tape codes, leader/trailer, character masking, etc.

Wireless Ethernet:

Our new Wireless Ethernet Adapter can be used to connect almost any RS232 equipped CNC to your PC-DNC Plus system through a **wireless** shop network. The Wireless Adapter is connected to your CNCs serial port, and is powered by a 5vdc power cube. Once connected, the Wireless Adapter connects automatically with any 802.11b compatible access point, and can then be configured on your DNC computer to function just like a standard COM port. PC-DNC Plus can then communicate with the CNC control as if it were connected with a conventional "wired" RS232 port. For more information on our Wireless Ethernet Adapter, please click **here**.

FTP Server:

PC-DNC Plus has an optional FTP (File Transfer Protocol) server capability. You can configure multiple FTP ports for individual CNCs, and assign different root directories on the PC-DNC Plus Server PC for each CNC machine.

Hitachi Seiki UUP:

Currently, PC-DNC Plus is the **only** DNC system that supports the new Hitachi Seiki UUP (Universal User Port). This unique new ethernet port permits fully interactive communications between the CNC and the DNC system. With a UUP port connection, PC-DNC Plus can display data on the CNC screen, define and monitor "soft" function keys on the CNC, and perform fully intrusive machine monitoring, right down to each macro variable and each I/O flag in the CNCs internal programmable controller. The UUP port also permits the transfer of files into or out of the CNC (from the PC-DNC Plus PC) while the CNC is in automatic operation.

BTR boards:

PC-DNC Plus can transmit serial data to nearly all BTR (Behind the Tape Reader) boards. We recommend the BTR boards manufactured by ADR Corporation because of their extreme flexibility and ease of use. To transmit to an ADR board, simply connect an RS232 cable to an available PC-DNC Plus serial port, and set the DNC option to "Send program w/o Xon in (x) seconds"

Direct BTR connections:

PC-DNC Plus and PC-DNC Editor can be configured to transmit data directly to the CNCs tape reader port using a parallel (LPTn) printer port. With certain model CNCs that use 5v TTL signals for the tape reader, this direct BTR link can be used instead of a BTR board. The cable length limit between the PC-DNC Plus server PC and the CNCs CPU board is approximately 16 feet (5 meters).

RS232 Operation

PC-DNC Plus lets you upload & download files using remote commands from the CNCs keyboard, or you can manually "queue" files for sequential output to the CNC. Remote commands are freely programmable so that you can easily accommodate the keyboard restrictions on various CNC controls. When a file is requested from the CNCs keyboard, PC-DNC Plus can be configured to search for the requested file in any sequence of subdirectories (folders) or sub-folders.

Files can be queued directly from a file list box with a toolbar button, or by dragging & dropping the file from the file list to the CNC control’s window. You can also use OLE (Object Linking and Embedding) to drag & drop files from other applications, such as Windows Explorer. You can easily edit or re-arrange the queue list if the sequence of files needs to be changed. Files that are manually queued can be sent automatically after a specified time delay. This way, you can configure PC-DNC Plus to download a file to a BTR board or tape punch/reader as soon as it is queued on the PC-DNC Plus system.

An automatic queue function lets PC-DNC Plus "find" any file that is placed in a designated subdirectory (folder), and queue it for output to the CNC control. When combined with the PC-DNC Plus Paperless Factory Option, PC-DNC Plus will also transmit the associated setup files (Tooling list, Setup data, File list, and Blueprint) to the specified PC for viewing with the PC-DNC Plus Viewer.

PC-DNC Plus can also upload files from the CNCs using automatic tape code recognition and automatic program ID recognition. Uploaded files can be stored in separate "upload" directories to prevent confusion with proven files. An automatic versioning system can also assign version numbers to uploaded files.

Mazatrol CMT files in binary format can be sent to PC-DNC Plus at any time. Remote requests for CMT files can also be sent to PC-DNC Plus using the Mazaks EIA port, and CMT file requests can be re-directed to a different serial port. This lets Mazak users connect TWO serial ports (one for EIA programs and one for CMT files), and have all the remote file request features available for both EIA and CMT files. CMT files can also be manually queued for sequential output to Mazatrol CNCs.

Remote Monitoring of the DNC System

PC-DNC Plus contains a powerful remote diagnostic capability. If you have access to the PC-DNC Plus server through your network, then remote troubleshooting and diagnostics are easy. If a remote network connection (WAN) is not available, you can connect one of the PC-DNC Plus serial ports to a Hayes compatible MODEM, which is then connected to a standard analog phone line, and set to "auto-answer." A service technician can then dial-up that MODEM connect to the PC-DNC Plus server, and perform a wide variety of maintenance tasks.

Typical remote service tasks include the downloading of activity log files, security log files, clearing and resetting error conditions, and replacing or updating the .EXE files that compose the PC-DNC Plus system itself.

Paperless Factory Option

The Paperless Factory Option lets you define operator messages and setup files, which the CNC operator can view on any PC on the network. Once a "Job" has been defined, the CNC operator can use the optional PC-DNC Plus viewer program to view setup files, tooling lists, operator messages, and graphic blueprint files. The viewer also provides a toolbar button to automatically queue all the files in the job’s "File list".

At the PC-DNC Plus Viewer screen, the operator can view the setup files for past, present, and future jobs, and report the machines status, such as "Normal", "Setup", "Maintenance", "Lunch Break", etc.

F**eatures for "Drip-Feed" DNC**

Most DNC systems let you "drip-feed" long programs to your CNC controls. PC-DNC Plus also lets you call **disk files** like subroutines within your part programs. With PC-DNC Plus, you can use a "CALL" statement in your part programs which will automatically merge an entire file into the data stream. Files that are CALLED can also include CALL statements (up to 7 levels deep). You can also CALL multiple iterations of the same file. For example, the command "CALL <filename> (5 TIMES)" will merge the same file 5 times in succession into the data stream being transmitted to the CNC control.

PC-DNC Plus also includes a powerful "Tool Break Editing" feature. If a DNC cycle is interrupted for any reason, you can quickly highlight the portions of the file you want to run again, stitching together any segments of the file into a special "one-time" sequence. You can then cycle start your CNC again to run only those selected blocks of data. Once the edited sequence has executed, the DNC window discards the edited sequence and returns to normal DNC operation.

PC-DNC Editor

Each PC-DNC Plus system includes our powerful **PC-DNC Editor** for quick & easy editing of your NC data files. Toolbar buttons on the PC-DNC Plus main window permit a quick-link to PC-DNC Editor and to the editor's powerful File/Compare function. PC-DNC Editor includes many powerful functions for modifying G-code files, as well as a variety of pop-up calculators and reference files. A more detailed description of the PC-DNC Editor is shown in a subsequent section.

Security System

PC-DNC Plus has a comprehensive "logon" security system, which can be disabled for those shops not requiring user logon security. With the system activated, you can restrict individual users to the use of certain specified manual operations on a specified group of machines. Users are required to log on and log off using their own names and passwords. A Security Manager program lets the system administrator enter user names, passwords, and machine access privileges. All password information is encrypted and stored in a "fail-safe" mode, which restricts all access by anyone but the administrator if tampered with.

Machine Cycle Monitoring

An optional machine cycle monitoring feature lets you automatically record "Cycle-start" and "Cycle-end" events from any machine on your system. Information collected can then be analyzed and displayed as a bar-graph/time chart, and relevant statistics such as the number of cycles, average cycle time, average load time, and uptime/downtime ratios are calculated for you. Once a time period has been selected for analysis, the Cycle Time Analysis module will let you select any "Job" that was run within that time period for further analysis.

Automatic Paging and E-mail Systems

PC-DNC Plus is available with an optional paging and E-mail system, which can be programmed to automatically page or E-mail you when an important machine event occurs. Since it shares information with the machine monitoring function (above), the paging/e-mail system can also notify you of part cycle activity. Events such as the beginning of the n^{th} part cycle, the end of the n^{th} cycle, a remote operator's message, etc. can trigger a page or an e-mail automatically. The system can also be programmed to notify you if a machine has been idle for more than a specified number of minutes, or to give you a parts count or machine status report at a specified time-of-day. Up to 128 paging event scenarios can be programmed, each one having its own trigger event, pager number or e-mail address, and message text.

In-Process Gauging System

Also available with PC-DNC Plus is a powerful in-process gauging system. Any COM port on the system can be configured as a gauging port. Most any measuring device with an RS232 output can then feed numeric data to that port, which is accumulated in a file. Once a specified number of measurements are collected, the gauging system will use a sequence of programmed calculations to generate a tool offset command. Tool offset commands can be automatically "Called" like subroutines from any CNC on the PC-DNC Plus system. This provides a powerful feedback loop for updating tool offsets automatically, without any operator intervention.

Tooling Control System

The PC-DNC Plus Tooling Control System uses barcodes to identify qualified (pre-measured) tools. When a qualified tool is loaded into a CNC machine, PC-DNC Plus will automatically generate the correct tool offset commands and load them into the CNC control. The system can also be used to control your tool inventory, and to actively monitor the usage of each tool during production. This powerful new feature works through the PC-DNC Plus communications system, and can be added to existing systems currently in operation.

The qualified tooling features can be used with any CNC control that is capable of executing a program command to set tool offset values (such as the Fanuc "G10" command). Features for active tool life monitoring require that the CNC control have "macro" programming features (similar to the Fanuc Macro B option.) The only hardware items required are barcode wands or readers, and some inexpensive (pre-printed) barcode tags and machine placards.

Predator WIRELESS DNC™

Networking your CNC machines just got even easier!

Predator Software is leading the way with Wireless DNC™ technology. You can still choose between our Plug & Play Grizzly Cables™ or a wireless network for your machines.

Using Wireless means the cost of stringing cable is removed, machines with overhead cranes, traveling gantry's or those that are simply too far to cable can be quickly, efficiently and reliably networked. Should you want to move machines there is no need to change cable or re-configure the software. Best of all just about any CNC machine can be connected to wireless DNC and being wireless doesn't cost extra!

System Features:

- Uses a standard IP Address / Communication Port.
- Basic Model with 128 bit Encryption, Plus Model with WPA Support!
- Need Protocol Support or high speed baud rate? Use our Flex/W Plus Model.
- Standard 110v power pack included or wire directly into your CNC power.
- Protect your investment and place the unit inside your machine cabinet and use our external antenna!
  No additional cost for external antenna - other vendors charge for it!
- 6 Foot RS232 cable included from Wireless Unit to Machine's RS232 Port.
- Basic Model with 128 bit Encryption starts at $250.00!
- Works with Predator DNC Software or CNC Editor (Comm Port Required).
- Access Points sold separately and can be provided by SFA. Can also be integrated with clients existing Access Points, contact SFA for recommendations.
- Add benefits of a wireless system:
  - - Integrate wireless bar code readers to swipe bar codes to download or save programs to PC.
  - - Use laptops on the shop floor to transfer files or access existing shop floor documents.
  - - Prevent data lost with using short RS232 connections to the CNC - 6ft from Wireless CNC Adapter!
  - - Eliminate hardware repairs on your CNCs - no RS232 surges or blown ports!
  - - Generally IT Departments are familiar with the concept and can help with integration / support.
  - - Quickly establish high-speed connectivity between buildings without the inconvenience of installing cable

How does it work?

Predator Wireless DNC™ is run over an IEE 802.11b wireless Ethernet network. This is made up from one or more access points (shown below) which are networked to your existing LAN/WAN to a DNC server. The Wireless Access Point (WAP) directs the NC data to each CNC machine's unique Wireless Client address / comm port. The WAP can be located in the office or out on the shop floor depending on the manufacturing environment. One or more of the Wireless Access Points maybe required based on your plant configuration. SFA can provide Access Points that will cover 300 feet from 1 unit assuming direct line of sight to the WAP.

Each CNC machine has a wireless device (shown right) mounted on it that links to the Wireless Access Point to form a virtual cable. The Wireless Client (WC) receives the NC data, transmits the program into the CNC machines serial port via a short serial cable. Typically, we recommend the unit to be mounted inside the CNC machine cabinet and linked to an external antenna mounted on the top of the machine (like a CB Antenna). The WC can be powered by the 110v power supply or wired directly into the CNC Machine 3-9 volt power source.

As part of this wireless network, any PC with a WiFi compliant network card can be configured to access the wider PC network. Of course all data is secure thanks to 128bit encryption or WPA with our Flex/N Plus Models. Using encryption and spread spectrum technology means wireless DNC is now the most secure and most interference resistant way to network your CNC machines.

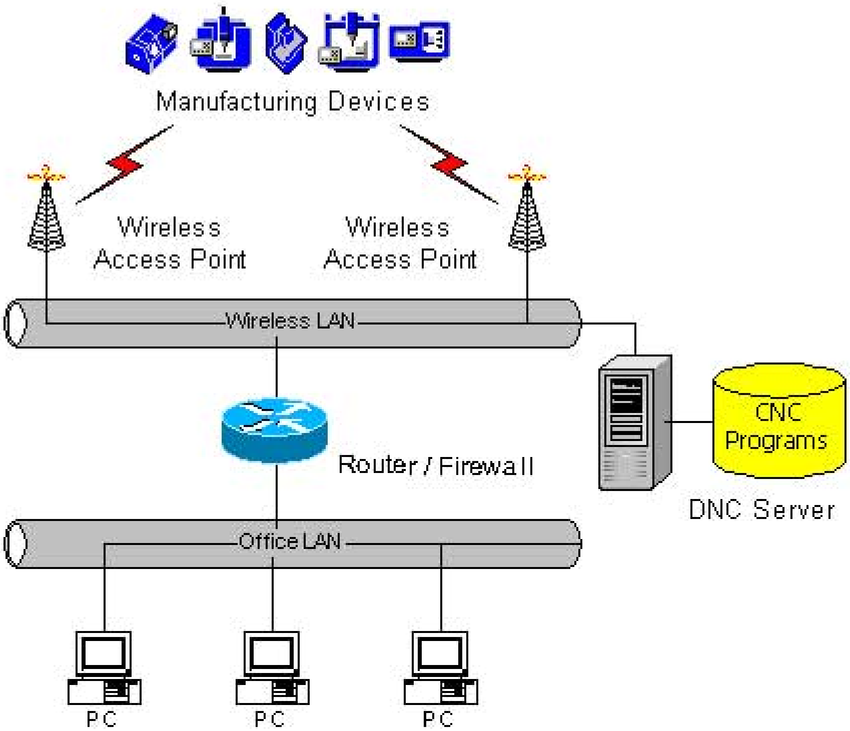
Still Not Convinced Wireless Is For You?

Tired of re-running cable when you move CNC machines? Looking to move to more of a lean environment? The Predator Wireless DNC system is your answer. Affordable wireless DNC is possible since Predator uses industry standard wireless Ethernet (802.11) which allows for an affordable installation or to leverage an existing wireless Ethernet infrastructure.

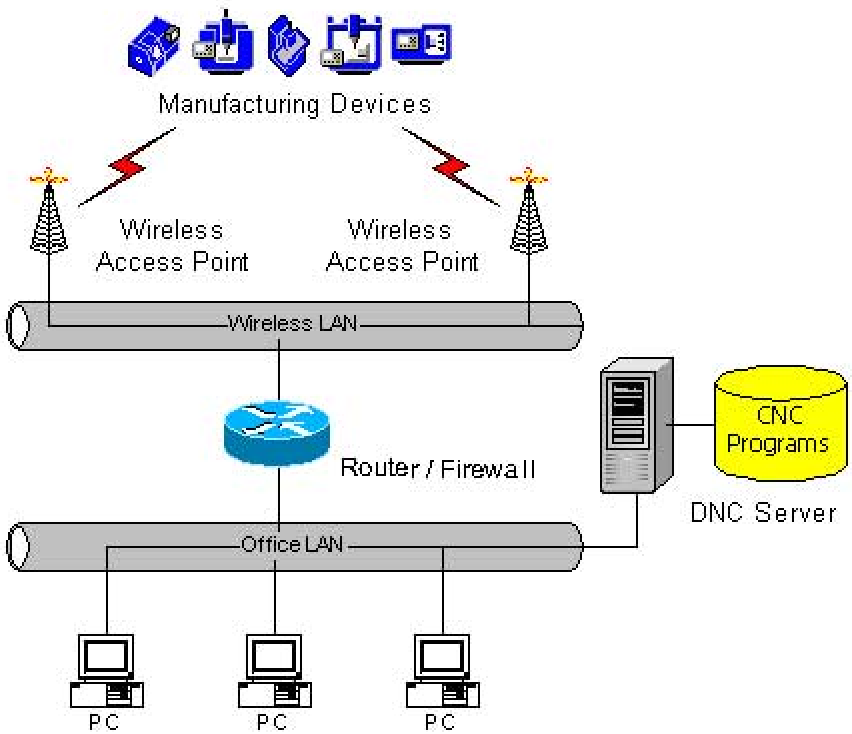
Concerned about data integrity of CNC programs with wireless Ethernet to serial conversion? Predator uses wireless CNC adapters connected to each CNC with built in buffering and the ability to still use flow control. This unique solution allows specialized CNC protocols to still be used and doesn't hinder the advanced features such as the ability to drip feed to the CNC over the wireless network. All other standard and advanced DNC functionality is also available include remote request.

Worried about setting up a wireless network? SFA can help you determine the best network and DNC configuration based on your current network infrastructure, security policies, and shop floor usage. The options will vary depending partly on the capabilities of the firewall being used and the IP architecture, but there are a few options listed below as examples

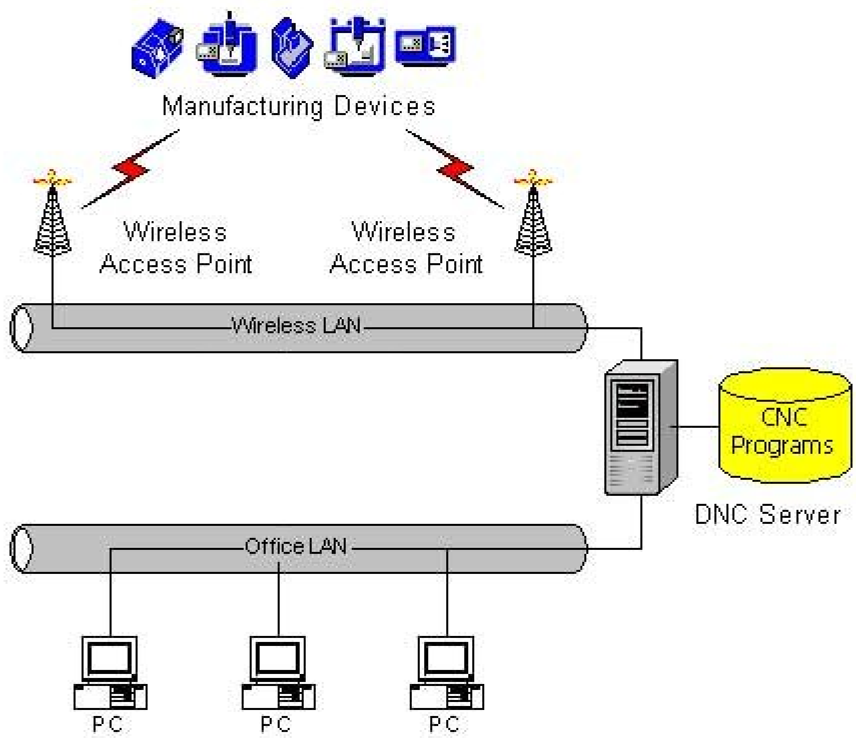
One possible solution is to use a firewall to separate the wireless shop floor network from the office network where sensitive information is stored. The DNC server and the CNC programs are located on the wireless shop floor network.



Another solution is to have the DNC server and the CNC programs on the secure office LAN and just the CNC machines on the wireless shop floor network.



A third option is to use a firewall to completely separate the wireless shop floor network from the office network. The DNC server is dual homed (two network cards) to allow access to both the wireless shop floor network and the office LAN.



Predator MDC (Manufacturing Data Collection) Adapters

Predator MDC Adapters™ provide automatic input to the Predator MDC system from CNC machines or factory equipment. Input to the MDC Adapter comes from either digital or analog signals and then sent to Predator MDC via RS232 or RS485 messages.Ý Traditionally this could also be done via a PLC but often a PLC is overkill for data collection.

Inputs
Predator MDC Adapters offer the following inputs:

- 4 Analog 0-5 Volt Inputs with 10-Bit
- Resolution 4 Digital 5-12 Volt Inputs or 15-36 Volt Inputs
- 1 RS232 Serial Port

Outputs
Predator MDC Adapters offer the following outputs:

- 8 Digital Outputs at a maximum of 50 Volts and 500mA
- 1 RS232 or RS485 Serial Port

Other Specifications

- Rugged Industrial Case
- Power Supply 9-16 Volts DC and 90mA
- Dimensions 4.5"x3.5"x2"

Predator MDC (Manufacturing Data Collection) Features

Monitor up to 256 Machines

Have an entire shop floor of CNC machines?

Predator MDC™ (Manufacturing Data Collection) supports up to 256 machines per PC for simultaneous cycle starts, cycle ends, spindle time, and an unlimited number of user defined input events. Track machines, personnel, parts, and processes in real-time. Organize your machines by grouping them per building or cell. Connect your PC's and create an entire real-time shop floor machine monitoring and data collection network.

Software-Enabled And Hardware-Enabled

Frustrated with installing and maintaining proprietary hardware-based machine monitoring and running the risks of voiding your CNC machine's warranty?

Predator MDC provides software and hardware based solutions and works with the machines existing RS232, RS422, or Ethernet input and output capabilities. Supports most major CNC machine and control builders, including Allen Bradley, Cincinnati, Fanuc, Fadal, Haas, Mazak, Mitsubishi, Mori Seiki, Okuma, Siemens, Yasnac and many others.

Monitor an Unlimited # of Events

Need to monitor more than 4 or 8 events per machine?

Since Predator MDC is a software and hardware based solution, an unlimited number of machine events can be monitored. An unlimited number of user-defined events can be added to any machine or just selected machines. Time, operator, or process/program studies can be made by customizing the events that are monitored on each machine.

Reports & Graphs

Need to generate summary reports and graphs?

Predator MDC includes over 80 standard reports. Custom reports can be created with numerous third party applications, such as Crystal Reports. Examples of available reports and graphs (links open in new window):

- Shift Summary Report gives detailed shift information regarding good parts, scraped parts, scheduled and unscheduled downtimes, and much more.
- Production Detail Report lists by resource (in this case by department), good parts, scrap parts, quality percentage, scheduled parts per hour, production parts per hour, and production percentage achieved for the time period selected.
- Production Detail by Part Report similar to the Production Detail Report listed above, this report utilizes the part number as the resource.
- Production Detail by User Report similar to the Production Detail Report listed above, this report utilizes the user as the resource.
- Machine Time Report lists totals by resource (in this case by department) for logon time, cycle time, setup time, down time, and idle time for the time period you select.
- Machine Time by User Report similar to the Machine Time Report listed above, this report utilizes the user as the resource.
- Productivity Summary Graph is viewed by the resource selected and compares production time, planned downtime, unplanned downtime, and setup time as an overall percentage for the resource and time period selected.
- Good vs. Scrap Summary Graph is viewed by resource (in this case by department), compares the good parts run by each shift for the the time period you select.
- Good Parts Summary Graph is viewed by resource (in this case by department), compares the good parts run by each shift for the the time period you select.
- Hours Summary Graph for a department, compares the total scheduled shift hours, actual production hours, and actual cycle hours, against the total number of shift hours available.
- Downtime Summary Graph for a department, details all scheduled and non-scheduled downtimes as a percentage of the overall downtime for any time period you select.

Feature Article DNC:

With the greater availability of computers in the shop, more manufacturers are relying on computer aided design (CAD), computer aided manufacturing (CAM), and digitizing systems to create part programs. Parts are getting more complicated, and the programs are getting longer. It is not uncommon for a CAD/CAM system to create a program with a half-million moves. Many of today's computer numerical controls (CNCs) cannot store programs that have a half-million moves. Instead, the CNC must execute each move as it is received. This "drip feeding" process of sending a move at a time is commonly known as DNC, short for direct numerical control.

A Typical Program

A typical program requiring DNC is made of many point-to-point moves. CAD/CAM and digitizing systems create programs that might take thousands of moves to machine a single pass of your part. Let's say, for example, that currently your CNC machines 100 moves per second (one move every 10 milliseconds) or 6,000 moves each minute (100 moves/second x 60 seconds/minute). Sounds impressive, doesn't it? Or is it?

If a part with a high tolerance has an average move of 0.001 inch, 6,000 moves per minute would result in an effective feed rate of 6,000 x 0.001 or 6 ipm. Most materials can be machined at speeds much greater than 6 ipm. Your parts, then, could be taking much longer to machine than necessary. As the old saying goes, "Time is money." The faster you DNC your parts, the more parts you can produce in the same amount of time.

That's what this article is about: using DNC faster and better than you are currently. The tips suggested here are practical. You can take them right into the shop with you.

DNC From The Inside

In order to DNC faster and better, you need to understand DNC as more than just running a program from a computer. By understanding DNC as a process, you can make improvements that will yield real benefits.

There are three components required for DNC: the CNC, a computer and a serial line connecting them. The program to be machined will be sent by the computer a move at a time to the CNC via the serial line. When a full move has been received by the CNC, the move is processed and added to what is called the Look-Ahead buffer. Processing a move includes executing fixed cycles, computing cutter radius compensation, and making any other calculations necessary to convert the NC code into machine moves.

An important detail to keep in mind is that while the CNC is machining a move, it is also processing upcoming moves. In other words, the CNC is dividing its attention between actually machining the part and calculating what it is going to machine next. In this way, there is no break between the machining of moves; there is a continuous flow of motion. The Look-Ahead buffer is where these next moves are stored.

What is the Look-Ahead buffer? A buffer is something that lessens or absorbs the shock of an impact. By looking ahead, or processing moves to come, the CNC is buffered against actually coming to a stop between moves. Unbuffered motion can cause the CNC to vibrate, as the CNC moves to a location, stops, then moves to another location. The faster the moves, the more violent the vibration. Such vibration can affect the finish and accuracy of your final part. When moves are buffered, the CNC doesn't stop between moves. It moves to a location, and, because it knows where the next location is, it can immediately begin moving to that next location. Instead of vibrating, the CNC flows smoothly between moves, yielding a more accurate part with a better finish.

The serial line is also buffered. While the CNC is machining the current move and processing the next move, the serial line is downloading the moves after that. In the same way that unbuffered moves vibrate the CNC, unbuffered serial input may also cause vibration. The CNC, then, is really doing three things simultaneously during DNC: loading moves, processing moves and machining moves.

The Three Bottlenecks

The key to increasing DNC speed is to increase the speeds at which the CNC loads, processes and machines moves. Note that improving just one or two of these does not increase overall DNC speed. Loading, processing and machining are dependent operations. The faster the CNC loads moves, the faster it needs to process them. And the faster the CNC processes moves, the faster it needs to machine them. Thus, in order to make your DNC faster and better, we need to improve all three of these operations.

The Serial Line

Today, loading programs for DNC consists of a computer sending the CNC a move at a time over a serial line. The serial line (also commonly referred to as an RS-232 line) is like a telephone line between the computer and the CNC; it's how the computer "talks" with the CNC. The speed that moves are sent over a serial line, or downloaded, is called the baud rate.

Typical industry baud rates are 9600, 19,200, and 38,400. What do these numbers mean? The baud rate generally corresponds to the number of bits per second that can be transferred between the computer and the CNC. In general, for each character (letter or number) in a move, 10 bits are sent over the serial line. (It takes ten bits because the character is eight bits long, and then there's usually one start bit and one stop bit. Your computer will take care of this for you.) So at 9600 baud, 960 characters per second are transferred, and at 38,400 baud, 3840 characters per second are transferred. As you can see, 38,400 baud sends four times as many characters as 9600 baud.

Fast Tip 1: Use the highest reliable baud rate your CNC allows.

Remember, we want to send moves to the CNC as fast as possible. For example, if the average move is 10 characters long, at 9600 baud you can send only 960 characters for a maximum of 96 moves per second. Even if your CNC can process 1,000 moves per second, at 9600 baud you will be able to machine only 96 moves. At 38,400 baud, however, you could send 3840 characters for a maximum of 384 moves per second. You're still not up to 1,000 moves per second, but you're a lot closer.

You may have been told that your CNC requires something like "seven data bits, even parity and one stop bit." These settings are required so that the computer and the CNC talk with what we might call the same accent. Changing these settings, say from even parity to odd parity, will not improve your DNC speed because ten bits are still going to be sent over the serial line; the same number of moves will be sent over the serial line using even parity as will be using odd parity.

Protocol

A protocol is the set of rules observed when a computer and a CNC "talk" over a serial line. Protocol is also known as hand-shaking. The reason for a protocol is to make sure that the computer and the CNC aren't trying to send each other information at the same time. When the CNC is sending information, it is not listening to information that is being sent to it. This is how information is lost. To avoid losing information, the computer and CNC follow a protocol to make sure that they don't try to communicate at the same time.

There are two popular protocols used today: XON/XOFF and XModem. XON/XOFF protocol is the faster of the two protocols. The sender, or computer in the case of DNC, talks as fast as it can to the receiver, or the CNC. If the computer talks faster than the CNC can listen, the CNC sends an XOFF to the computer, telling the computer to stop sending until it can catch up. When the CNC has caught up, it sends an XON, and the computer begins sending again.

Serial Errors

The most frustrating part of using XON/XOFF is that you don't know whether or not the serial line had a failure until after you've finished machining the part. Serial communications are not 100 percent reliable. When the computer is sending 38,400 bits per second, it is possible that a few bits might drop off if your shop has a lot of electrical noise or the serial cable you are using is very long. This will result in errors in your parts. Because the CNC has no way of detecting and preventing errors, if an error does occur, your part is possibly scrapped.

Fast Tip 2: Position the computer near the CNC and use a cable that is as short as possible.

Besides being easy to trip over, serial cables are susceptible to electrical noise. Electrical noise is interference from other electrical equipment that is "louder" than the signal you are sending. One of our customers, for example, was unable to implement DNC. When our service engineer inspected the serial cable, he discovered that the cable showed high voltage present without the cable even being hooked up! Upon further investigation, the service engineer noticed that the cable had been suspended from the ceiling by wrapping it aroundother wires used in the shop.

Harmless as it seemed, the other wires were high voltage and through inductance caused an electrical current through the serial cable. This current was stronger than the signal being sent by the computer, and the program was garbled. Rerouting the serial cable away from the high voltage wires fixed the problem.

Error Recovery

XModem protocol allows the CNC to detect and prevent errors by breaking up the program into smaller packets, or pieces. Each packet has a checksum. The checksum is computed by totaling the ASCII value of every character in the packet. The computer computes this checksum while sending the characters, and the CNC computes this checksum while receiving the characters. After an entire packet has been sent, the computer sends the checksum it computed, which the CNC compares to the checksum it computed. If the checksums match, (that is, the checksum is good) then no errors were detected while sending, and the CNC sends an ACK (ACKnowledge) signal to the computer requesting the computer to send the next packet. If the checksum is bad, which means the packet has an error, the CNC sends a NAK (Not AcKnowledged) signal to the computer requesting the computer to resend the packet, thus preventing the error from occurring. In this way, most errors are detected and prevented, protecting your part.

Fast Tip 3: Always use XModem.

With all of the ACKs and NAKs, XModem is slightly slower than XON/XOFF. However, it is still strongly recommended that you use XModem instead of XON/XOFF because of error detection and prevention. Figure it this way: One scrapped part and your time savings are worthless. There are smarter, more reliable ways to improve your DNC.

Sending Only What You Need

There are often alternate ways to program the CNC. Because we're trying to send moves as fast as we can, the shorter the program, the faster we can send it. The rule is that if there is more than one way to program a move, choose the way that uses fewer characters.

Fast Tip 4: Drop all N-words.

N-words usually don't do anything in DNC. They are extra characters being sent over the serial line when machinable codes could be sent instead. If you currently have N-words in your program, you could DNC significantly faster without them.

Fast Tip 5: Remove excessive comments.

Comments, like N-words, don't do anything in DNC. A comment here or there will have no real effect on machining time, but comments on every line will. (Note: Do keep the comments at the beginning and end of your program. They will help you remember what the program is supposed to do.)

Fast Tip 6: Use X5 instead of X0.0005.

Most CNCs accept NC words in two formats: in tenths and in decimal formats. Always use the tenths format. For example, X5 is only two characters whereas X0.0005 is 7 characters, yet to the CNC they are the same move.

Fast Tip 7: Use modal codes.

Modal codes are codes that once you use them in your program, the CNC will stay in that mode until you change it with another modal code from the same group. Examples of modal codes are G0, G1 and F100. Don't include a G1 on every line; that's just extra characters that have to be sent over the serial line.

Preprocessing And Compression

Many CNCs offer the option of preprocessing and compressing your program before sending it over the serial line. Preprocessing means that the computer does part of the processing job that the CNC normally does before the CNC gets the program. This can save your CNC time and speed up DNC. Compressing means that the computer shrinks the program before it sends it over the serial line, and the CNC expands it once it has been received.

Preprocessing, by itself, can actually make your program larger and take longer to send, but it processes faster in the CNC. Compressing, on the other hand, makes your program smaller and takes less time to send, but it processes slower in the CNC. The decision of which to use is ultimately based on how quickly your CNC processes.

In general, most CNCs are buffer-starved. Buffer-starved means that the CNC processes moves so quickly that the moves are processed as soon as they are received. In other words, the CNC is waiting for moves to arrive. Compression is the best option in this case because more moves can be sent. The CNC has to take a little longer with each move in order to decompress it, but the CNC is waiting anyway. The basic rule is that if your CNC is waiting and doing nothing part of the time, give it more to do (compressing); and if your CNC is overloaded and has too much to do, let the computer take some of the burden (preprocessing).

One of the best options is a CNC that preprocesses and compresses the moves. For example, in one of its high-speed modes, Fadal CNCs can DNC up to 1,000 three-axis moves per second. The NC code for an average three-axis move is about 21 characters (X#.####Y#.####Z#.####). Normally, to send 1,000 such moves would require a baud rate of 210,000 (21 characters x ten bits per character x 1,000 moves). Using compression, the Fadal control can send 1,000 three-axis moves per second at a baud rate of 38,400.

Fast Tip 8: Preprocess and/or compress your program.

Your DNC Software

A critical part of achieving faster and better DNC is having good DNC software on your computer. There are at least two questions you should ask yourself when you choose your DNC software: "Is it efficient?" and "Is it easy to use?"

Is It Efficient?

If your DNC software says that it can DNC at 38,400 baud, is it really going 38,400 baud? Here's a way you can measure the effective baud rate, or the baud rate at which your program is really being downloaded. Write an incremental program that has the move:

"X0.0001Y0.0001Z0.0001*COMMENTS SLOW DOWN DNC"
repeated 10,000 times. With a carriage return and linefeed, each move has 46 characters, for a total program size of 460,000 characters. Remember that at 38,400 baud, 3840 characters are sent each second, so it should take about 120 seconds (460,000 divided by 3840) to send this program. This is equivalent to 83 moves per second.

If your CNC takes longer than 150 seconds, then either your CNC cannot machine 83 moves per second or your computer is not running at 38,400 baud. If the Look-Ahead buffer is full, then your CNC is the bottleneck: It doesn't matter how much faster you send the program because the CNC can't process it fast enough. If the Look-Ahead buffer always has only one or two moves in it, then your computer is the bottleneck.

Fast Tip 9: If your computer is too slow, try a faster one.

Don't let a slow computer slow down your DNC. Ideally, the computer should be sending your program as fast or faster than the CNC can receive it. Many times you don't need a whole new computer. Sometimes a faster hard drive or a higher quality serial board can make a significant difference.

You can also slow down your computer by trying to make it do too many things. One of our customers was trying to write a DNC program for Windows that would allow him to DNC to four machines simultaneously using one computer. He also wanted to be able to use his spreadsheet program at the same time. At best, each CNC was receiving less than fifty moves per second. Why would you run your CNC at fifty moves per second when you could run it significantly faster?

Fast Tip 10: Use the computer for DNC only and with only one CNC.

Computers are inexpensive enough that each CNC should have its own computer. Slowing down your DNC just to have the ease of running all of your CNCs from one computer will sacrifice performance. If many CNCs need to access the same programs, then consider setting up a network.

Is The DNC Software Easy To Use?

DNC is not without its problems. Tools break. People trip on cables and disconnect them. The power goes out. These kinds of problems happen often enough to make them a consideration in choosing your DNC software. The basic question is: How easy is it to recover? You've replaced the broken tool. Now you want to continue machining.

Fast Tip 11: Your DNC software must have a Mid-Program Start Option.

Think of all the time you'll be cutting air if you have to start back at the beginning of your program. The DNC software should let you easily find the move from which you want to resume machining.

You should also be able to enter preparatory data. Preparatory data is one or two moves that you can type in to be sent before resuming your program. The purpose of preparatory data is to allow you to set modal codes and feed rates back to what they were when the tool broke. This frees you from having to continue DNC from a move that has these codes, which might be thousands of moves away from where you optimally want to resume machining.

Fast Tip 12: Experiment with your DNC software.

Your DNC software may have features that will make your jobs easier to run. If you don't look for them, you'll never know about them.

High-Tech Alternatives

Recently, options have appeared for CNCs that give them megabytes of memory, allowing CNCs to load up to 16 megabytes of programs. The capacity to run such large programs may one day eliminate the need for DNC. Huge memory options offer greater reliability than serial DNC. They are not vulnerable to people tripping on cables and disconnecting them like DNC is. Recovery after tool breakage is much simpler.

However, huge memory options still have limitations. Being new technology, they are expensive. They also require long download times--it may take an hour to download a program with 1,000,000 moves. It can also be difficult to work with a single program that is so large. Many editors and word processors cannot handle such large files. One possible solution may be to break your program into more manageable pieces.

In general, huge memory options are more suited for production runs than for development or single parts. Imagine taking the time to download a program and then discovering that there is a mathematical error.

Transmitting NC data from a computer to a CNC is the chief function of a DNC (direct numerical control) system. How efficiently the system performs this function is based partly on how the data is prepared before transmission. Likewise, how the receiving CNC is prepared will affect how the incoming data is processed and executed as machine moves to make the part.

Most discussions of DNC do not adequately address what happens at the CNC, the receiving end of a DNC system. This is unfortunate because therein lay some of the most valuable opportunities for improving the productivity of a machine tool. As our first installment stressed, the key to increasing DNC speed is to increase the speeds at which the CNC loads, processes and machines moves. All three of these aspects must improve to increase overall DNC speed.

The two bottlenecks to be addressed in this article impact not only the speed of the DNC system, but also the quality of the finished workpieces.

Processing From The Inside

The second bottleneck of DNC is how fast the CNC processes moves once they have been loaded. In its simplest terms, processing is the conversion of moves from a form you understand (that is, an NC program) into a form the CNC motors understand (that is, axis motor commands). For example, the simple move "X1." may require a great many calculations to convert it into actual table motion. In general, the CNC must consider several factors when processing moves:

- Is a fixture offset active?
- Is cutter radius compensation in use?
- Is the move in inch or millimeter units?
- Is this an incremental position or an absolute position?
- Are any special modes (fixed cycles, and so on) in effect?

Once the CNC calculates a move-to position after taking all of these factors into consideration, the move-to position must be converted into digital motor pulses. The motor pulse size and number of pulses are based on the programmed feed rate. For example, if the X axis is to move 1 inch at a feed of 60 ipm, then it will take the axis motor 1 second to move the table 1 inch. If the axis motor is pulsed at a rate of 10 milliseconds (which means the motor pulses 100 times a second), then each pulse of the motor must advance the table 0.01 inch (pulse size = 0.01 inch).

Thus, for this move, the processor controlling the axis motor will calibrate the motor pulse size to 0.01 inch. Every 10 milliseconds for the next second, the processor will pulse the axis to move another 0.01 inch. When the axis has reached its destination, it is ready for another move.

Reducing Complexity

If processing requires too many calculations, it will become a bottleneck. You can see the effects of a processor bottleneck by running a program with very short moves using cutter radius compensation. The program will run significantly slower than if cutter radius compensation were not in use.

Fast Tip 13: Do not use cutter radius compensation.

The fewer calculations that the processor has to make to convert a move into motor pulses, the more moves that can be processed in the same time. Cutter radius compensation requires the most calculations of any mode and can slow down even normal machining significantly.

Fast Tip 14: Do not use fixture offsets.

Avoid using a fixture offset by setting your zero position to the fixture offset zero. This change may possibly eliminate the fixture offset calculation during all processing.

Absolute Vs. Incremental/Inch Vs. Millimeter

The mode in which you are programming also may have a significant impact on processing time. Your CNC calculates moves in either absolute values or incremental values. In the absolute mode of programming, the end points for all motions are specified from the program zero point. In the incremental mode, end points for motions are specified from the tool's current position, not from program zero.

Which mode you should use depends upon the manufacturer of your control and how it is set up to make calculations. In other words, regardless of the mode your program is written in, the CNC will make its calculations in the same mode it always does. For example, if your CNC does all of its calculations in absolute mode, all of your incremental moves will be converted to absolute values before calculations begin. Therefore, if your program is in absolute mode to begin with, you avoid the conversion from incremental to absolute.

The same applies to inch and millimeter modes. Your CNC performs all table motion in either inch or millimeter units, regardless of the mode your program is written in. If your control performs table motion in inch units, then any program in millimeter units will have to be converted into inch units. If your program is in inch mode to begin with, you avoid the conversion from millimeter to inch.

Fast Tip 15: Determine whether your CNC calculates in absolute or incremental mode, and program in the same mode (unless you are using a special high speed mode as discussed below).

Fast Tip 16: Determine whether your CNC performs table motion in inches or millimeters, and program in the same mode.

You can determine if your CNC uses absolute or incremental mode internally by running two point-to-point programs that machine the same part in both modes and see which runs faster. To determine if your CNC uses inch or millimeter units, compare the run times of a part written in both inch units and millimeter units. Depending upon your control, it may make a significant difference as to which modes you use.

High Speed Processing Modes

Many CNCs offer special processing modes. Special processing modes allow you to tell the CNC that it can make certain assumptions about your program, and therefore process it faster. There are many special processing modes, and most CNCs have modes that are unique to themselves. Some modes offer more accuracy, others offer more speed.

In general, the modes you are going to be interested in for faster and better DNC are the high speed modes. The modes that offer more accuracy and higher quality tend to run slower than the high speed modes. We will explore these modes later in the discussion of the third bottleneck, machining.

Fast Tip 17: Use a high speed mode, if available.

CNC Architecture And Multiple Processors

The most important feature of your CNC, regarding processing speeds, is the architecture of your CNC control. The architecture of your control is the way the various components of your control are built to work together. A CNC's speed depends upon how its components interact.

A common misconception is that the fastest computer chip will make the best machine or that a 32-bit processor makes a better control than a 16-bit processor. This is not necessarily true. For example, a 32-bit processor that drives up the cost of a CNC will not necessarily control a 2048-line encoder better than a 16-bit processor. In fact, an 8-bit processor might do the job just as well for less money. What really matters is how these components are used together.

One important aspect of a CNC's architecture is whether it has multiple processors. Having multiple processors simply means that it has more than one processor. In general, the more processors a CNC has, up to a point, the faster it can process moves.

However, there are two basic processor designs: time-slicing or in-parallel. Time-slicing means that a processor works on many tasks, switching from task to task hundreds, or even thousands, of times per second. Examples of tasks might be updating the axes positions on the screen, pulsing a motor, and checking the keyboard for a key press.

Parallel processing means that many processors work on their own set of tasks, separately and independently from the other processors. Tasks are performed in parallel, that is, at the same time. Whereas time-slicing processors update the screen, then pulse the motors, then check the keyboard; in parallel processing, one processor updates the screen while another processor pulses the motors, while a third processor checks the keyboard.

Of course, a single processor might handle several tasks, and a CNC system might be a combination of time-slicing and parallel-processing elements. However, each CNC usually depends upon one type of processing more than another. One cannot say whether one method is better than the other in every case.

Nevertheless, parallel processing generally can achieve higher DNC speeds than time-slicing, using equal technology when a system is being pushed to its limits. A time-slicing system has certain recurring tasks that always compete against your program for processor time. The screen must be updated, the keyboard checked, the motors pulsed, and so on. Even if it takes only 5 milliseconds to process a move, a time-slicing system may be unable to machine moves this quickly because of system tasks that need to be done on a regular basis. Because it has to allow time for system tasks, the control may be able to pulse moves only every 7 or 8 milliseconds. In addition, lower priority tasks, such as screen updates, will suffer.

Parallel Processing And Pipelining

In a parallel-processing system, your program is not competing with as many other tasks for processor time. The screen might have its own processor. The keyboard might have its own processor. And the motors might each have their own processors. And these processors can function simultaneously.

A parallel system is also capable of pipelining. Pipelining is a method by which your program is handled by different processors, each performing a specific task. An example of pipelining in DNC might involve a serial processor, the main processor and an axis processor. The serial processor's job is to receive the program over the serial line. The main processor converts the program into motor pulses. The axis processor sends the pulses to the motor. When a processor has finished with a move (for example, the serial processor receives an entire move), the move is passed on to the next processor to handle.

The rate at which such a system will process moves is based on how fast the slowest step in the pipeline processes. We can illustrate this by following a few moves through the pipeline. Suppose that each processor requires 5 milliseconds to complete its task. First a move is loaded in by the serial processor. This step takes 5 milliseconds. Then, while the main processor converts the move into pulses, the serial processor loads another move. While the axis processor pulses the motor, the main processor converts the second move and the serial processor loads a third. Every 5 milliseconds, a move is pulsed by the axis processor. Thus, even though the entire processing time for a move is 15 milliseconds (3 x 5 milliseconds), a move is completed every 5 milliseconds because of pipelining.

In reality, the process inside a CNC is much more complicated, but the general principle is the same. Moreover, because CNC system tasks are being handled by their own processors, no compensation is necessary for CNC system tasks. Moves can be consistently pulsed every 5 milliseconds.

Fast Tip 18: If your CNC uses time-slicing, turn off and disable any features you are not using.

For example, turn off the screen display during DNC to reduce the processing time required by CNC system tasks.

Upgrading Your CNC

Many people think that buying a faster processor option for their machine will improve their DNC. It's definitely something to look into. Your CNC manufacturer may have added new hardware or software features since you bought your machine. Some manufacturers design their products to be backwards compatible so that new features can be installed on older machines as these improvements are developed. Obviously, a point may come when technology has pushed so far ahead that an older machine can no longer be upgraded; but this may be years after the machine is installed.

Fast Tip 19: Check with your dealer every couple of months about new options for your CNC.

Machining And Physical Limitations

The third bottleneck of DNC is the physical limitations of machining. Whereas you might be able to machine an aluminum part at 300 ipm, you certainly wouldn't cut titanium at that speed. Dealing with this limitation is mostly a matter of experience and insight into the nature of the workpiece being machined. Machining too quickly can adversely affect final finish and accuracy.

Resolution

Resolution is the detail of your part. The chief factor in determining the resolution of a part is the size of the point-to-point moves. For example, an arc made of long segments tends to look more like a dot-to-dot drawing than a smooth curve. In this case, the resolution is low. On the other hand, the shorter and more numerous the segments, the smoother the arc appears. Resolution is high in this case.

Resolution also plays a role in digitized parts. Digitized parts are cut in cross sections. A digitized part may represent thousands of cross-sections to machine. The thickness of the cross sections affects the resolution. The higher the resolution, the thinner the cross sections (and the more cross sections that will have to be machined).

In general, the lower the resolution of the part, the faster it will machine. For example, a program with cross sections 0.001 inch thick will take ten times as long to machine as a part with cross sections 0.01 inch thick. Resolution affects quality: You can see and feel 0.01-inch thick cross sections but you may not be able to notice cross sections 0.001 inch thick.

The advantage of faster DNC is that resolution can be managed intelligently. Because more moves are being processed and machined, you can lower resolution and machine parts faster, or you can increase resolution and get parts with smoother surfaces. If you are machining an injection mold, you probably want the increased resolution. If you are machining high volume parts, you probably want the increased speed.

Fast Tip 20: Before you begin to program and run your part, decide whether quality or speed is more important for this job.

Inside An Axis Motor

The highest priority of a CNC during DNC should be managing axis motors. These motors have a direct effect on the quality of the finished part. Motors are driven; that is, they receive electrical pulses at a set rate. The larger the pulses, the faster the motor is driven.

Let's look at a motor that's stopped. All of a sudden, it receives a pulse to move 0.01 inch. The motor immediately begins to advance to the new position. However, before it can finish moving the entire 0.01 inch, a pulse to move another 0.01 inch arrives. The motor is now more than 0.01 inch but less than 0.02 inch from where it should be. The motor moves faster than it did after the first pulse because it has to catch up. Eventually, the motor ramps up to speed and machines 0.01 inch per pulse.

From this example we can see that the distance the motor has to go to get into position is what drives the motor. The larger the distance to go, the faster the motor must go to catch up. If the distance to go is 0, then the motor is in position and doesn't need to move.

Overshooting And Undershooting

Two problems can occur when driving a motor. Overshooting occurs when the motor is quick to respond to changes in distance to go but the distance to go is updated slowly. In other words, the motor has already reached the position it was commanded to reach, but the distance to go hasn't been updated, so the motor keeps on going. Undershooting occurs when a motor is slow to respond to changes in the distance to go. In other words, the distance to go is updated before the motor has a chance to move to position. Undershooting is most apparent on axis reversals: The distance to go reflects the axis reversal before the motor reaches the point of the reversal.

The best system is one that both responds quickly and updates often. Some CNCs are sluggish: Motors are updated every 20 milliseconds (50 times a second). Some multiple-processor CNCs can update motors every millisecond (1,000 times a second).

CNCs with a slow update rate cannot machine high resolution parts quickly. Details may be lost because several moves are added together into one update. Consider two machines cutting at the same feed rate. Which can have more detail--the one which has 50 updates a second or the one with 1,000 updates a second?

Fast Tip 21: If your CNC has a slow update rate, favor lower resolution parts for this machine.

Backlash

Another aspect of CNC that will affect the final quality of a part is backlash. Backlash occurs when the ballscrew moving the CNC table along an axis reverses direction. The screw may turn for a few "tenths" before the table begins moving in the new direction before the thread catches and the table begins to move also. CNCs compensate for backlash by commanding the axis to move those extra "tenths" whenever the axis reverses direction.

Backlash can be a problem particularly when an NC program is created by a CAD/CAM system. Some systems may create a program that has very small moves in the Z axis on flat surfaces, even when tolerances are very low, such as 0.0002 inch. These moves, even though they are very small, cause axis reversals, with the control unit attempting to compensate for backlash at each reversal. Inaccurate backlash settings can magnify these slight variations, causing ridges and valleys in what should be a flat surface. Fine-tuning the backlash settings will eliminate this problem most of the time.

Fast Tip 22: Make sure that your backlash settings are accurate.

Special Processing Modes

High speed DNC can push the limits of the accuracy of machining. Just as an automobile does not stop instantly when the brakes are applied, axis motors cannot start and stop instantly at high speeds. Imagine cutting a corner at 200 ipm. Even though you programmed a corner cut, what you may get on the part is an overshoot and a gouge.

For accuracy's sake, the CNC must automatically compensate when coming to a corner or during any direction change. Normal processing modes offer the option of compensating for every move, but not every move needs compensation, so processing speed slows down unnecessarily. Fine-tuning the compensation yourself is extremely time-consuming, and it may not be possible at all on some controls. Another option is to run at slower feed rates to reduce error to an acceptable level. None of these choices is attractive for high speed DNC.

Many CNCs offer special processing modes to handle high speed DNC. These modes use what is commonly called feed forward. Feed forward allows the CNC to look ahead a number of moves and determine how to avoid overshooting and undershooting. For example, the CNC can determine that the tool will be cutting too quickly for a particular series of moves, so the CNC reduces the feed rate automatically. These modes can significantly improve the quality and resolution of your parts. However, they will increase processing time.

Fast Tip 23: Check if your CNC manufacturer has high speed DNC preprocessing software.

You can use special processing modes without the processing penalty if you can preprocess the program. Preprocessing is a means by which the DNC computer does some of the calculations that the CNC would do before the DNC computer sends the program to the CNC. Preprocessing software is offered by suppliers of CNC machine tools as an option. By preprocessing the program off-line (away from the CNC, that is), you can avoid using valuable CNC processing time. Preprocessing your program off-line allows you to ensure the quality of your part and maintain the high speed.