

**CALIFORNIA SOFTWARE SYSTEMS**  
COMPUTER SYSTEMS FOR MANUFACTURING PRINTED CIRCUIT BOARDS

**How to Replace Your Old DNC Network  
With Modern Computers and Software**

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## Acknowledgments

After a few minutes on the phone with Mike Banks, I suspected the customer in trouble was the same company in Silicon Valley that Jim Warholic had taken me to about a month earlier. Jim is one of the owners of Probe Industries which is an independent company providing machine maintenance and repair. He is also a recent contributor the Circuitree Magazine (August 2007 Measuring Spindle Runout)

I hadn't met Mike before but Jim and I were old friends going back many years. The customer was Nova Drilling Services and the problem was a dead DNC server. Little did I know that the old Excellon Miniserver was just the tip of the iceberg.

My special thanks goes out to Mike Doherty, V.P. of Nova Drilling. Not only was he the customer who ultimately paid the bills, he is also a nice guy. He tolerated our mistakes with good humor and our successes with reserved dignity. Mike believes what you say. He just needs to see it work for a while before he's convinced you've found the right answer.

Mike Banks was the network brains for the project. Not only did he select the new hardware including the serials hubs, he kept all the other computers at Nova up and running while the drill room network was down. Mike knows more about Domains, Workgroups, TCP/IP, and the differences between Windows 2000 and Windows XP than anyone I've ever had the pleasure of working with.

Ruben Gonzales is the production manager at Nova. He ran the Cat 5 cables and setup the new hubs. He also personally tested everything including the machines and the network, and at the same time kept his crew working efficiently. Here's a guy who can really keep his cool under pressure.

Jeff Penney, now System Specialist with Mania Technologies, is the best Hitachi technician I've ever met. He's the one who provided the insight and software drivers need to switch Nova's machines from DNC to Ethernet. Jeff also provided most of the information about networking Hitachi machines which will be included in future chapters of this saga

My part of the project was taking the ideas and concepts expressed by the other guys and writing software to make them work.

If you're considering updating your DNC Network you probably can't find a more knowledgeable group of people in the world today. Fortunately, they've all agreed to try and answer questions about the project from you, the readers of Circuitree Magazine.

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## **Preface:**

My first article on connecting printed circuit board drills to a local area network appeared in the July 1991 issue of Printed Circuit Fabrication Magazine. At that time computer networks were replacing punched paper tapes on the production floor. Today, most NC machines in service at that time, if they've been properly maintained, are still drilling and routing boards. However, both the hardware and software technologies of 20 years ago are becoming bottlenecks in the production process. Worse yet, with respect to DNC systems, in many cases there is no practical alternative for computer to machine communication. We have to keep this obsolete communication protocol – or scrap our machines. The fundamental problem is that there are essentially no remaining sources for the original hardware and software. This series of articles tells independent shop owners, production managers, and drill room supervisors, how to solve this problem with inexpensive, readily available, modern computer technology.

Russell W. Walton  
February 2008

## **How To Replace Your Old DNC Network With Modern Computers and Software**

### **Introduction**

For at least the past 20 years printed circuit board drilling and routing machines have been connected to a central computer using what is called a “DNC System”. This started well before the introduction of the first “Personal Computer” by IBM in the 1980's. Since then both computers and networks have evolved exponentially. The result is DNC is now both technically obsolete and completely incompatible with today's LANS, WANS, and Wireless networks. In addition, the computers and special serial communications boards originally used for DNC networks are no longer available. In fact, you probably can't even find good, working hardware anymore. The result is, if your DNC Network goes down your shop can be in very serious trouble.

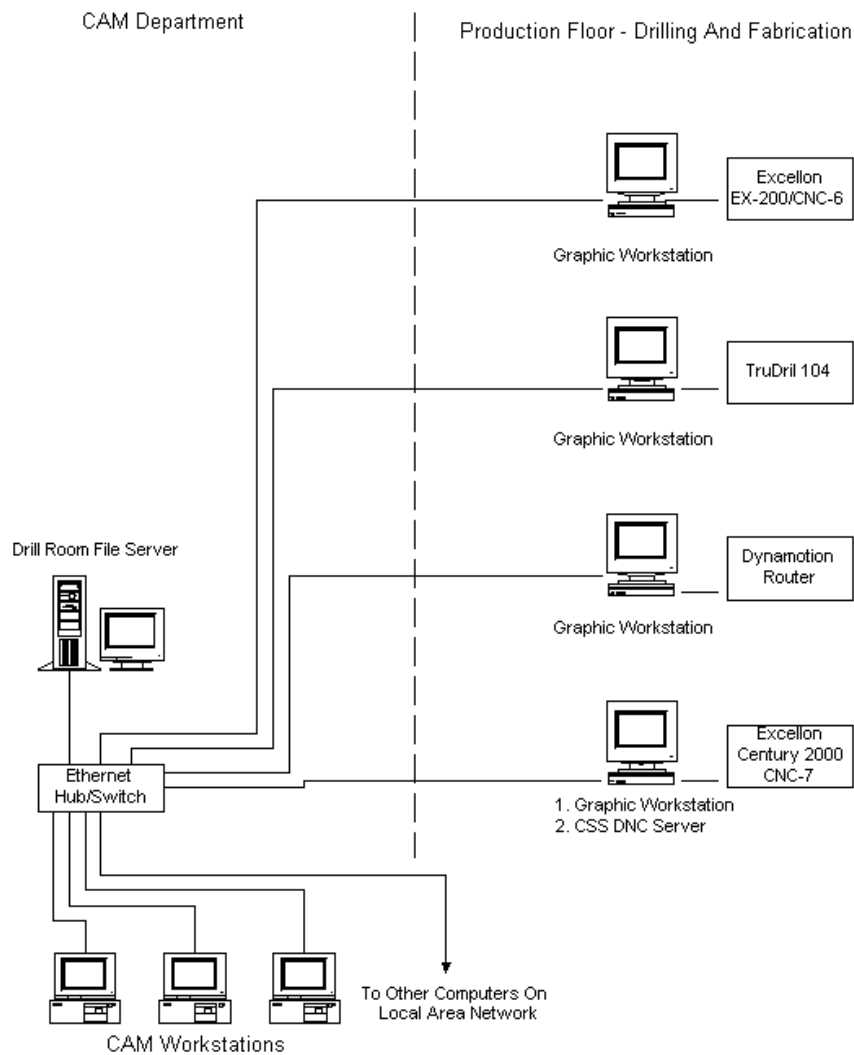
It is essentially impossible as well as completely impractical to connect perfectly good, older, machines directly to a modern Ethernet based network. If your DNC network breaks you really only have two practical alternatives: (1.) Install a PC on each machine and network the PC's or (2.) Find some way to replace your DNC Server with modern hardware and software.

This series of articles will show you how to create a new DNC Server with any modern computer capable of running Microsoft Windows and how to connect that Server to your machines using your existing cables and modems. Not only will this eliminate the

weakest and most frail link in your drill room network, it can also significantly improve the capabilities of all your machines and their operators by adding computer graphics to your drilling and fabrication operations.

### Small Shop With Microsoft Network

Figure 1 shows a small shop with separate PC's connected to each of four machines. The type of machines really doesn't matter as long as they are NC controlled. DNC capability is not required. This includes essentially all types of printed circuit board drills and routers in service today. They can be Excellon, TruDril, Hitachi, Posalux, Pluritec, Dynamotion, Wessell, ATI, PDA, Mania, etc.



- Notes
1. This configuration expandable to any number of machines.
  2. Drill Room File Server function may be moved to another computer.
  3. Graphic workstations required on all machines.
  4. DNC capability not required

**Small Shop  
with  
Microsoft Network  
On Production Floor**

## Figure 1

All of these machines originally had provisions for a paper tape reader. Therefore, normally the easiest way to connect a modern PC to the machine is to make the computer act like a paper tape reader. This means the voltage levels, timing, and encoding of the information coming from the computer is made to accurately represent the output of the original reader. The machine “thinks” it is still running from paper tape even though the actual machine language drill/route program is really being created and formatted by the computer.

All you need to connect Drilling and Fabrication to your CAM department is to extend your office network into Production. This can be done using standard Ethernet network interface cards (NIC’s), Hubs/Switches, and cables available from your local computer store. The process is exactly the same as setting up a network in your accounting department.

Incidentally, don’t immediately reject this networking solution because it requires a computer at each machine. By the use of computer graphics to display drill and route programs you can probably substantially increase the productivity of both your machines and your machine operators. In addition, by simplifying operator dependent tasks such as entering tool parameters, drilling selected holes, or routing test coupons from a panel, you should be able to better control the quality and consistency of your product – and reduce scrap losses. Excellent, inexpensive, parts (both new and used) are readily available. Lastly, in addition to factory support, there are lots of trained technical people who know how to setup and maintain Microsoft networks.

***Historical Note:*** Driving machines through their paper tape reader ports requires precise delays in the data stream to emulate the response of the original paper tape reader. Most of the early suppliers of “BTR” (Behind The Reader) equipment used hardware generated delays. Typically this was done by digitally dividing down the master clock for the CPU in the computer. This was fine in the days when the IBM AT was state-of-the-art with a 4.7 Mhz clock. Today’s computers are easily 1000 times faster which makes the original digitally generated delays so small that they are absolutely useless. This is why if you have a Centrum Research or a Fox system and the computer dies, you can’t simply buy a new one. It will not work. You have to try and find another old computer which is still working and - that’s getting harder and harder to do.

The best solution is to replace both your hardware and software with modern components that don’t rely on the speed of the computer. California Software Systems is one of the suppliers which uses software rather than hardware generated delays to communicate with the machine. This guarantees that their products will work with the latest and greatest personal computers – regardless of how fast they become.



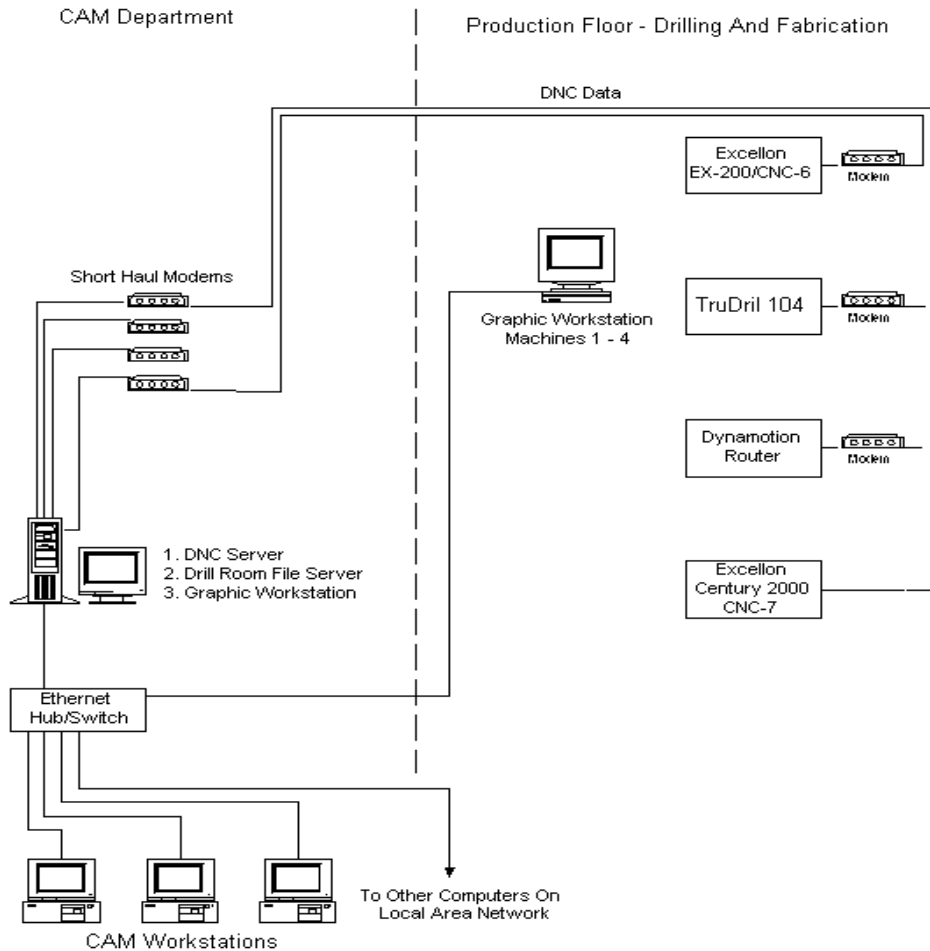
Figure 2. Excellon CNC-6 with computer connected via paper tape reader port



Figure 3. TruDril 104 with computer connected via paper tape reader port

## Small Shop With DNC Network

Figure 4 shows the same shop as Figure 1 except all four machines have DNC capability installed and working. An Add-on card with two additional COM ports has been plugged into a PCI slot in the motherboard of the Drill Room File Server computer. The computer originally included two COM ports. The add-on card provides a total of four ports – one for each machine. The computers operating system is a current version of Microsoft Windows. This means it can simultaneously function as both a normal Network File Server and a DNC File Server for the machines – provided the software is “Windows Compatible”.



- Notes
1. This configuration expandable to 16 machines maximum.
  2. Drill Room File Server function may be moved to another computer.
  3. Graphic workstations in Drilling and Fabrication are optional.
  4. Requires one COM port in DNC Server for each machine.
  5. Requires DNC capability in all machines.

**Small Shop  
with  
DNC Network  
On Production Floor**

Figure 4

Given the right software, full graphics capability can be provided for all machines, drills and routers, from a single computer on the production floor. This Graphic Workstation only requires a connection to the Microsoft network so it can communicate with the DNC server in the CAM department.

A computer on the production floor enables the machine operators to view any drill or route program either graphically or as an ASCII text file. They can select holes to drill, segments to route, scale the panel, offset individual parts within a panel, and perform a number of other tasks which are often necessary but difficult to do without a computer connected to the machine. If you wish, the more powerful capabilities like Optimizing and Scaling can be hidden from the operator or password protected.

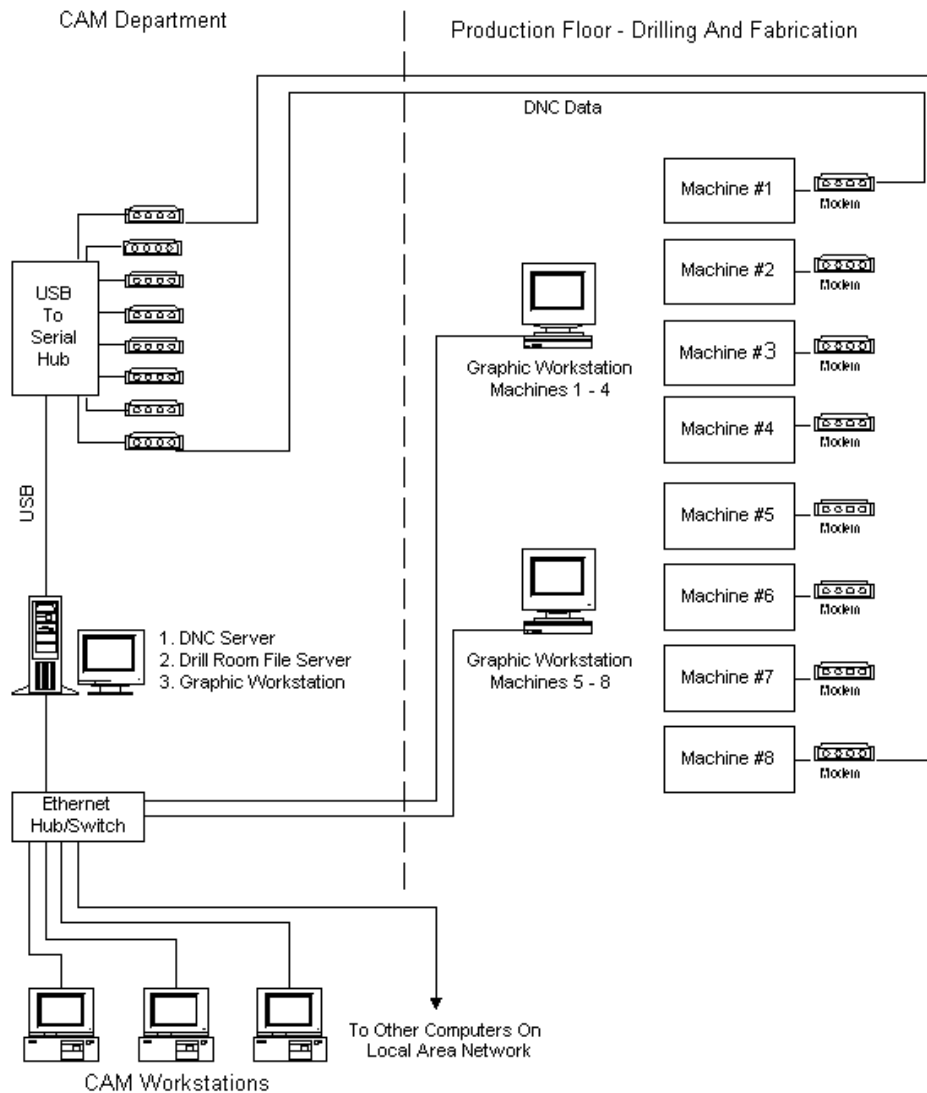
Limiting what the operator can do is something most owners and managers worry about when they first consider employing the power of computer graphics in production. It is reasonable to be concerned about the machine operator making unauthorized changes that can ruin the product. However, based on more than 10 years of practical experience in more than 100 shops world wide, this has proven not to be a significant problem. In fact, once people become familiar with the power of computer graphics in production, they never want to go back to the old ways of drilling and routing boards.

#### **Larger Shop With DNC Network (USB to Serial Hub)**

Figure 6 shows a facility which could include up to 16 machines running from a single DNC Server. The 16 machine limit is set by Microsoft Windows which can only handle 16 COM ports simultaneously in one computer. If there are more machines, a second DNC Server can be added in parallel.



Figure 5. 16 Port USB to Serial Hub



Notes

1. This configuration expandable to 16 machines maximum.
2. Drill Room File Server function may be moved to another computer.
3. Graphic workstations in Drilling and Fabrication are optional.
4. External USB to Serial Hub must be within 30 feet of DNC Server.

**Basic DNC Network  
with  
USB to Serial Hub  
Off Production Floor**

Figure 6

In this example I have chosen to use a USB to Serial Hub. This is a self-contained unit with either 8 or 16 COM ports. The principal advantage of the USB Hub is that it only requires 1 cable plugged into the computer to drive up to 16 COM ports. Also the Hub and the necessary Short Haul Modems can be located up to about 30 feet away from the computer which can help to keep the work area reasonably neat, clean, and free of tangled cables.

Normally each machine requires two short haul modems – one at each end of its’ DNC cable. In a perfect world the modems would not be necessary. It is technically possible to connect the machines directly to the COM Ports on the USB Hub. However, in the real world this is normally a very bad thing to do. Technically the only purpose of the modems is to provide electrical isolation between the machines and the computer. If all the machines and the computer are tightly connected to the same electrical ground there will be no problem. However, the electrical grounds in most shops degrade over time. If the machines are not properly grounded an electrical potential (voltage) can develop between them. The simple act of connecting everything together through the wires in the modem cables can destroy electronic components in the machines and the computer. Don’t take this possibility lightly. If you don’t have the electrical isolation provided by the modems, it is easy to do thousands of dollars of damage to your machines in a fraction of a second by merely plugging in the DNC cables!

The computer in the CAM room can perform three separate functions. First it properly formats the data being sent to and from the machines using DNC protocol. This is what a DNC Server does. It packages bytes of data in a way that is understood by the machine. It also responds to specific requests from the machine such as sending a duplicate packet of data to replace one that was corrupted during transmission. This is a type of automatic error correction and is accomplished by electronic “hand shaking” between the computer and the machine.

Secondly, the computer can store all of the drill and route programs created in the CAM department and used in production. It works as a normal, standard, Network File Server. It doesn’t matter whether the network is configured as Peer-to-Peer or Client/Server. It stores your files on its hard disk and makes them available over the network to other computers.

This Network File Server function does not necessarily have to be done on the same computer that is acting as a DNC File Server. Data files can be stored in multiple locations on the network and automatically retrieved by the DNC Server - if it’s configured to do so. However, normally all your drill and route programs should be stored in a single network subdirectory so they can be easily found and backed up to prevent loss of critical information needed to manufacture your product.

Thirdly, the computer can act as a “Graphical Workstation” for all of your machines. You can call up any drill or route program stored on your Drill Room File Server and display it either as a computer generated picture of the panel being processed or as an ASCII text file of the machine language program. You can zoom in and out, instantly identify any hole, verify total hole counts for each tool, select specific holes to drill, scale the entire panel, offset individual parts, and easily do many other tasks which are difficult, if not impossible, without the computer. When you are satisfied with what you see you can send the drill/route program to any machine on your DNC network through your DNC File Server. This is a great tool for easily finding and correcting problems before you run the job and ruin the panels. See Table 1 for a list of some of the more useful things your can do with a Graphic Workstation connected to your machines.

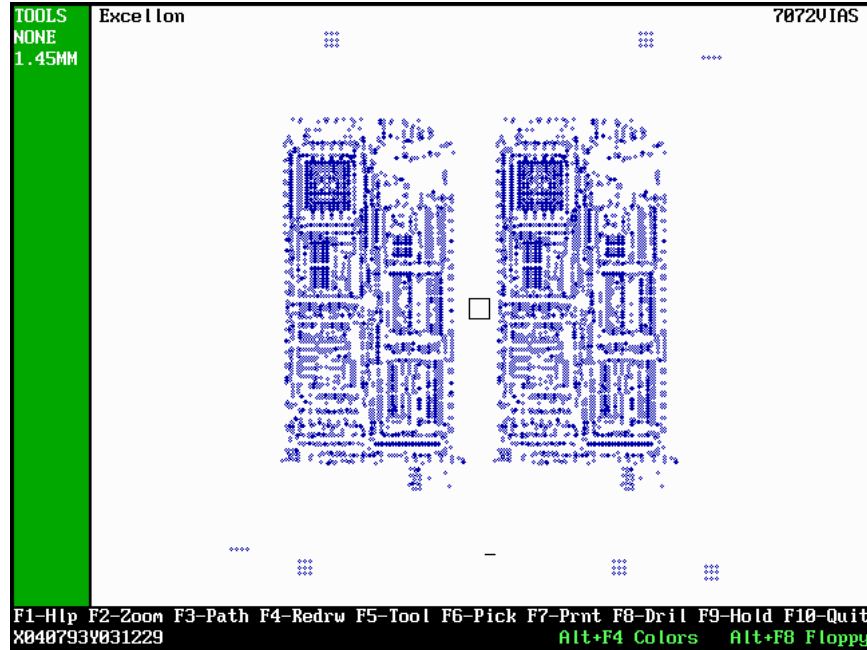


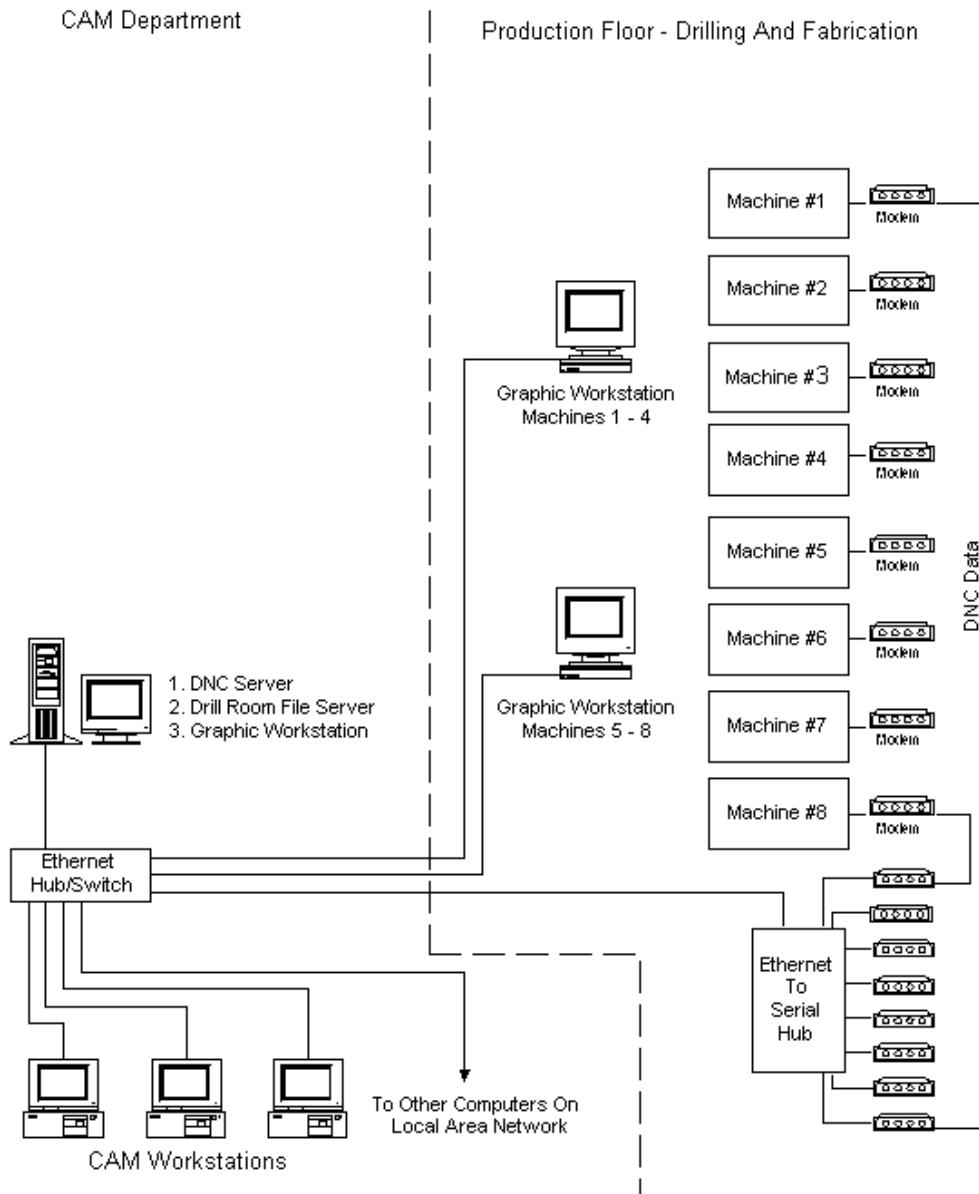
Figure 7. Typical Graphic Image Of Drilling Program

Figure 6 shows two computers on the production floor which function as Graphic Workstations. This really makes better sense than running the same software on the DNC Server in your CAM room where you probably already have other tools which do essentially the same thing. The real advantage of a Graphic Workstation for drilling and fabrication is in what it can help your machine operators accomplish. It can truly make their jobs easier and enable them to do more in less time. In other words, computer graphics can make both your machines and your machine operators more productive.

Note that you only need a single network cable to a Graphic Workstation. It does not have to be connected directly to your machines or to your DNC Server.- only to your Ethernet hub. This makes it relatively easy to install Graphic Workstation computers in convenient locations on your production floor.

## Alternate Configuration For Larger Shops (Ethernet To Serial Hub)

Figure 8 is the functional equivalent to figure 6. However, the USB to Serial Hub has been complete removed from the CAM department and replaced by an Ethernet To Serial Hub on the production floor.



### Notes

1. This configuration expandable to 16 machines maximum.
2. Drill Room File Server function may be moved to another computer.
3. Graphic workstations in Drilling and Fabrication are optional.

**Basic DNC Network  
with  
Ethernet to Serial Hub  
On Production Floor**

Eight 8

USB Hubs are limited by the distance they can be located from the computer. Ethernet to Serial Hubs are more like computers. They can be located almost any distance from each other and can work through daisy chained network hubs, switches, and routers.

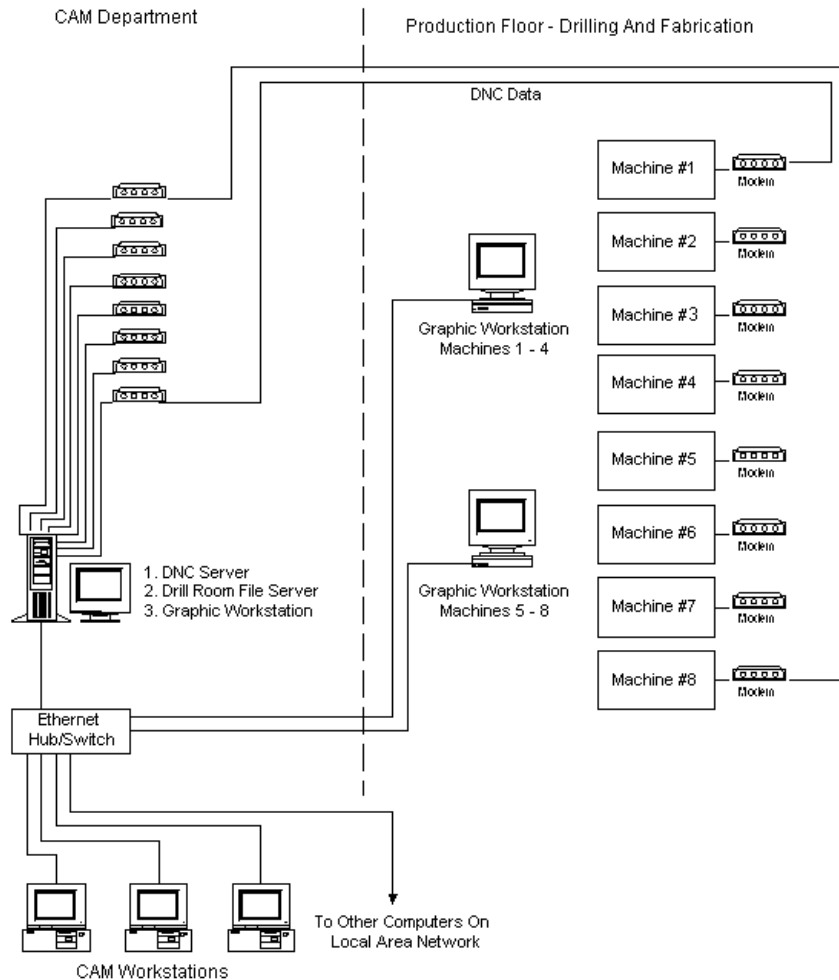


Figure 9. Eight Port Ethernet To Serial Hub

Normally one of the advantages of using an Ethernet to Serial Hub located in drilling or fabrication is fewer and shorter cables running back and forth everywhere in your facility. Where you originally had 16 or more DNC cables running out of CAM you now only have one. In addition, you don't have an unsightly stack of short haul modems and cables cluttering up office space. The only significant disadvantage is the dust which accumulates in production. You should try to place the Ethernet to Serial Hub and associated modems in a relatively clean location where they can be easily reached for service but are out-of-the-way for other purposes. In general, installing computer hardware above false ceilings is not a good thing to do. However, it is very common and only causes problems for the technicians who have to keep it running.

### **Moving Your DNC Server To The Production Floor**

Figure 10 is essentially identical to figure 6 except, instead of using an external USB to Serial Hub, it uses Add-on PCI serial cards to install the needed COM ports physically inside the computer. This works fine. However, the cabling can become an unsightly mess. If that's not a problem you can save several hundred dollars in hardware because Add-on cards are less expensive than free standing hubs. They are also normally available at local retail computer stores while hubs must be special ordered or purchased on-line and shipped to you.

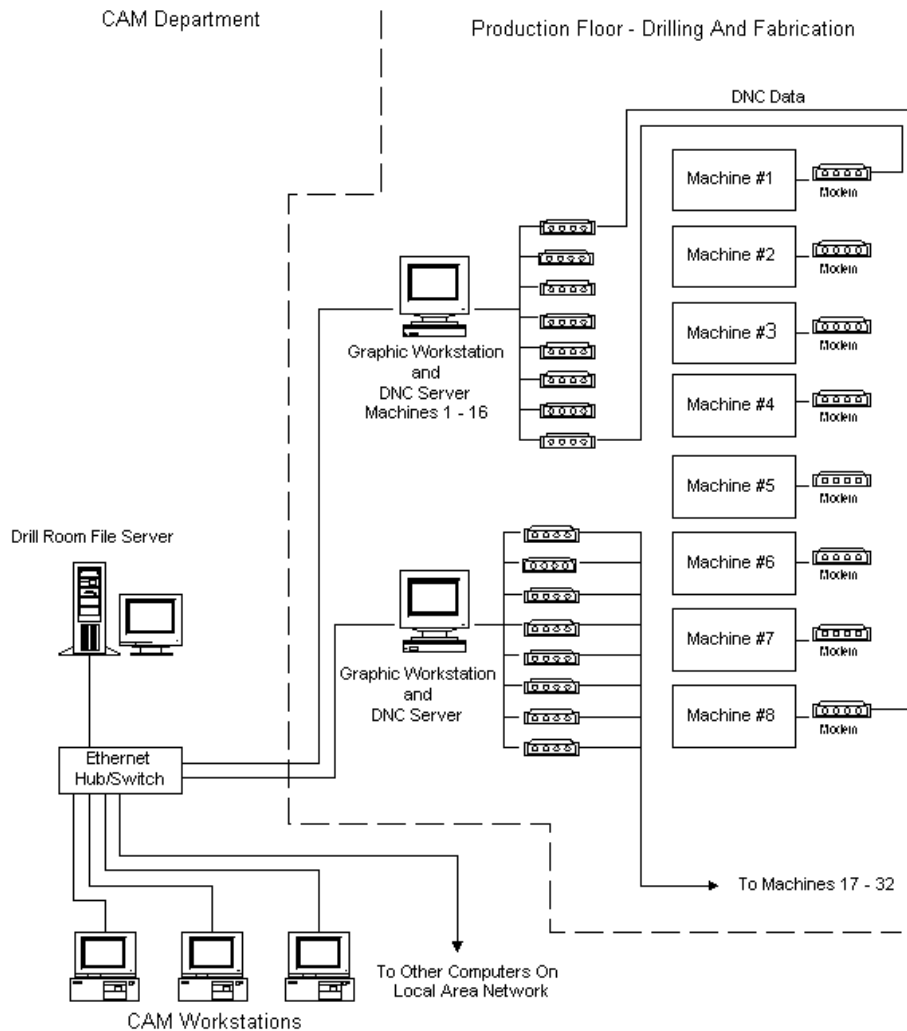


- Notes
1. This configuration expandable to 16 machines maximum.
  2. Drill Room File Server function may be moved to another computer.
  3. Graphic workstations in Drilling and Fabrication are optional.
  4. Requires one serial port (COM port) in DNC Server for each machine.
  5. PCI and PCI-Express Add-On serial cards currently available.

**Basic DNC Network  
Using  
Internal COM Ports  
in  
DNC Server**

Figure 10

Figure 11 shows what is often a better solution. The DNC Server computers have been moved into the production floor where they also function as Graphic Workstations for drilling and routing. One major advantage of this configuration is that everything else in your facility can be left exactly “as-is”. No additional computers, hubs, modems, cables, etc. need clutter up your CAM or MIS departments. All you need is one CAT 5 network cable brought into Production. If you install more than one DNC Server you will also need an inexpensive Ethernet hub/switch to connect all the computers to this single line.



**Notes**

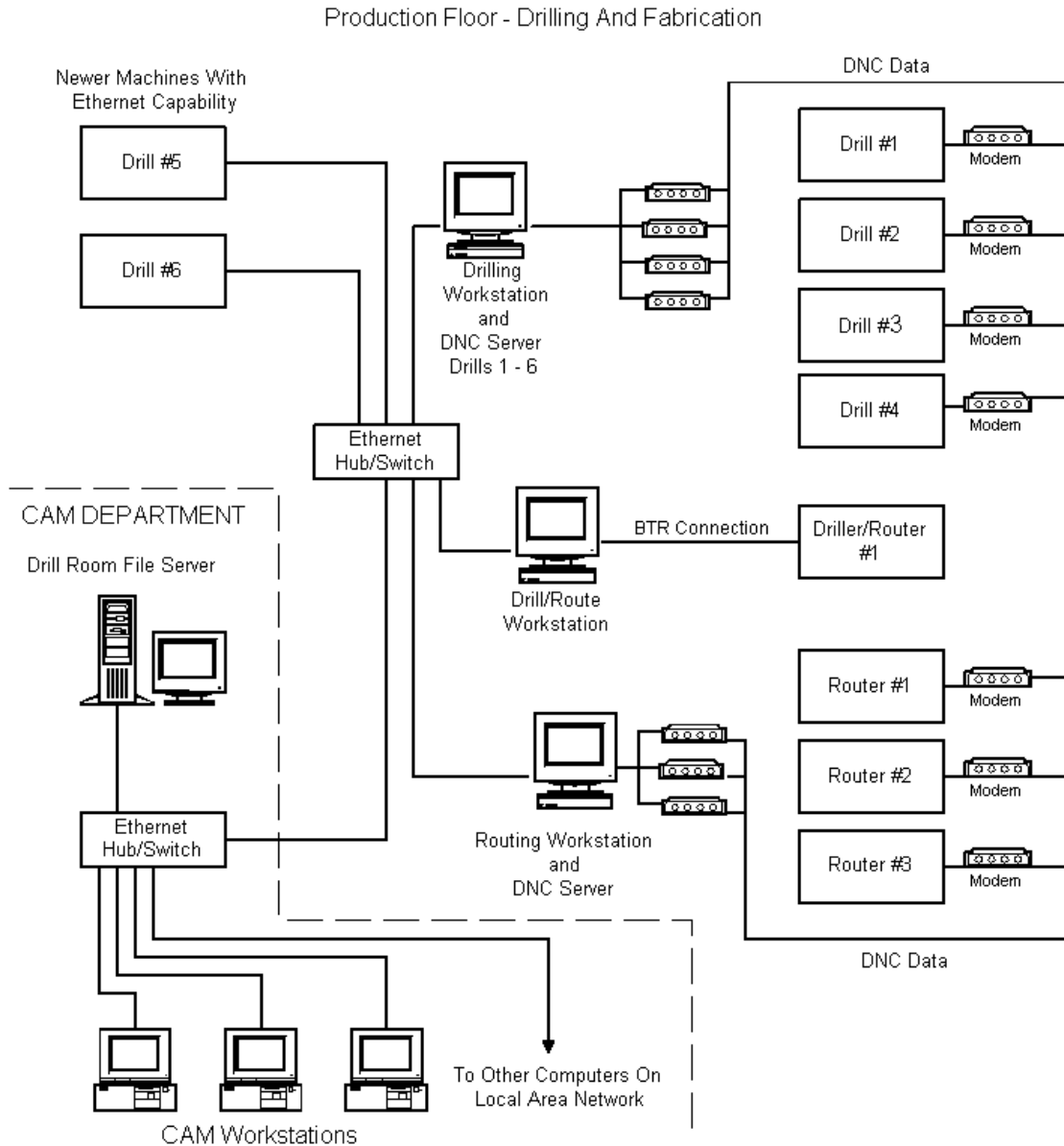
1. This configuration expandable to 16 machines per DNC Server.
2. Normally uses internal PCI or PCI-e serial cards in DNC Servers
3. Could be built with USB or Ethernet to Serial Hubs.
4. As many DNC Servers as needed may be added to production floor.
5. Requires fast response from Drill Room File Server Computer to DNC Servers.
6. Response times of large networks are often too slow for machines.

**Basic DNC Network  
with  
DNC Servers  
On Production Floor**

Figure 11

There are two DNC Servers shown in 11. Each Server can support up to sixteen machines. However, that's probably not the way you should setup your shop. The controlling factor should be the location and usage of the computers for drilling and routing panels. For example if you had ten drills and three routers it would probably be better to locate one DNC Server/Graphic Workstation in the drilling department and the other in the fabrication. The machines and associated short haul modems would be connected to the computers according to their function.

## BTR, DNC, and Ethernet Machines All On The Same Network



**Notes**

1. This configuration expandable to any number of machines.
2. DNC Servers could be built with external USB or Ethernet to Serial Hubs.
3. As many DNC Servers as needed may be added.
4. As many Graphic Workstations as desired may be added.

**Three Ways  
To Network  
Printed Circuit Board  
Drills and Routers**

Figure 12

There are three practical ways to connect printed circuit drills and routers to a network. The first is via a paper tape reader port as previously described. This is a parallel, BTR, connection and is often the best way to go for older machines.

The second method is through a serial port on a computer running DNC 1.3 or 1.4. The serial (COM) port can be physically in the computer or remotely implemented with an Ethernet or USB to serial hub. This has been discussed above and is illustrated in figures 2 thru 11.

The third way is with a direct Ethernet network connection. Newer machines from Excellon, Hitachi, Mania, and others are built around controllers using a Microsoft Windows 95/98/Me/xp/2000 operating system. Both the operation system and the machine hardware include all the networking capability included by Microsoft in their standard product. This enables the machine to be directly connected to a modern network typically using NetBUEI or TCP/IP protocol just like another computer. Network drives can be mapped, user privileges established, and anti-virus protection enabled. Clearly, this is the way of the future and, in our opinion, should have been seen 15 years ago by the machine manufacturers. However, it wasn't which is why networking machines today is more complicated than it should be.

The configuration shown in 12 can be expanded to any number of machines. The only practical limiting factor is the fact that Microsoft Windows can only control a maximum of 16 COM ports in a single computer. Therefore a single DNC Server is limited to 16 machines. However, you can add as many computers as necessary, in parallel, downloading from any combination of network file servers you desire. The fact is you combine machines using a paper tape interface, machines requiring DNC connections, and those with built-in Ethernet capability all in the same facility and working on the same LAN. You could even connect or extend LANS in different facilities around the world using high speed DSL over telephone lines. It's now easy to build your prototypes in Los Angeles and your production in China using data files created and stored in Silicon Valley.

### **Wireless Networks In Production**

Today it is possible to replace wired Ethernet network hubs with wireless access points. You can then install wireless NICs (network interface cards) in your computers and eliminate most of the network cables running around your facility. We have seen this done successfully in production, on a small scale, in one shop. However, we are still very skeptical of wireless networks on the production floor.

Your Drilling and Fabrication departments are machine shop environments. The machines and associated equipment such as vacuum systems and air compressors require a lot of electrical power. When they are running they also create a substantial amount of electrical noise. This electrical noise can enter a wireless network two ways (1.) through the AC power lines to which it is connected, and (2) via RFI (radio frequency interference). Electrical noise can substantially reduce the speed of a wireless network. It can also severely affect the accuracy of the data being passed from one computer to another. If a machine receives bad data it will either stop or make a mistake. Mistakes

are often very costly because they ruin the panels being processed. For this reasons it is our opinion that wireless networks should not be used in drilling and routing printed circuit boards. 100 Mb, wired networks using CAT 5 cables are completely safe, inexpensive, and easy to maintain. Eliminating copper wire cables is not worth the risk in an industrial machine shop environment.

### Web Sites Of Interest

<a href="http://www.bbdsoft.com/iocard_serial.html">www.bbdsoft.com/iocard_serial.html</a>	List of Serial Port Card Manufacturers
<a href="http://www.neteon.net/">www.neteon.net/</a>	<a href="#">16-Port USB to RS-232/422/485 Serial Hub</a>
<a href="http://www.comtrol.com">www.comtrol.com</a>	Ethernet Connected Device Servers
<a href="http://www.specialix.bix">www.specialix.bix</a>	PCI Express Serial Port Cards
<a href="http://www.californiasoftwaresystems.com">www.californiasoftwaresystems.com</a>	Graphic Software for manufacturing PCBs
<a href="http://www.blackbox.com">www.blackbox.com</a>	Short Haul Modems

### DNC – A Simple, Error Correcting, Communications Protocol

First, the minute details of DNC are very hairy and, unless you intend to write your own communications program, you don't need to know everything. All we're trying to do right now is cover the basics of how DNC works and how it's used.

DNC transmits a file by packaging it's content into small strings of data and adding the length of the string and two different check sums to each packet. The format of a DNC 1.3 packet is this:

Stx + Size + Data String + CHKSUM1 + CHKSUM2

Text files created on an IBM compatible computer have each line terminated by two characters which represent a line feed and a carriage return. This is analogous to a typewriter where, when you reach the end of a line, you throw the handle which returns the carriage to the left margin and rolls the paper up one line. For purposes of writing computer code, Carriage Returns are shown as CHR\$(13) and Line Feeds are CHR\$(10). In other words, the ASCII code for a line feed has the decimal value of 10. Carriage Returns have a value of 13.

When forming strings of data into packets, DNC eliminates Line Feeds. The end of each line of text in the file is marked only by CHR\$(13). In the example below this is shown as "Cr" which means one 8 bit byte with a value of 13 for the first 7 bits plus 128 for the fixed 8<sup>th</sup> bit.

When creating DNC packets it is necessary to establish the maximum allowable length of the Data String. In our industry, this maximum is 80 characters. However, for simplicities sake, lets assume a maximum of 25 characters and then manually create a couple of complete DNC packets.

### *Original Drilling Program*

M48  
T01C.125  
%  
T01  
X01Y02  
M30

Packet #1  
Stx Chr\$(21) D, M48 Cr T01C.125 Cr % Cr T01 Cr ADDSum XORSum

Packet #2  
Stx chr\$(13) D, X01Y02 Cr M30 Cr ADDSum XORSum

Certain ASCII control codes have special meaning in DNC.

<u>Name</u>	<u>Decimal Value</u>	<u>Character</u>	<u>Meaning</u>
STX	2 + 128	^B (Control + B)	Start Of Text
ENQ	5 + 128	^E (Control + E)	Enquire
ACK	6 + 128	^F (Control + F)	Acknowledge
ACKP	15 + 128	^O (Control + 0)	Packet ACK – DNC 1.4 only
NAK	21 + 128	^U (Control + U)	Negative Acknowledge
WAK	24 + 128	^X (Control + X)	Wait Acknowledge

All data packets containing text must start with “Stx” as shown in the two example packets given above. Again, this is an 8 bit byte with the first 7 bits having a decimal value of 2 and a fixed 8<sup>th</sup> bit corresponding to a value of 128. If you like you could write Stx as CHR\$(130) but the name “Stx” is more understandable.

In example packet #1 the length of the data string is shown as Chr\$(21) which means there are 21 ASCII characters in this Data String. If we would have included the next line of text from the file (X01Y02) the Data String would have been 28 characters long which exceeds our example limit of only 25. The length of the Data String in packet #2 is shown as Chr\$(13) which does not indicate a Carriage Return but rather a length of 13 bytes.

#### **Check Sums**

The two check sum bytes are calculated using the logical “Add” and “Exclusive OR” operators for binary arithmetic. For those who are familiar with the programming language “Basic” here’s how they are calculated.

```
AddSum = 0: XorSum = 0  
FOR I = 1 TO LEN(DataString)
```

ASCI = ASC(MID\$(DataString, I, 1)	Get each ASCII character
AddSum = AddSum + ASCI	Calculate Sum Check Byte
XorSum = XorSum XOR ASCI	Calculate Xor Check Byte
NEXT	
AddSum = AddSum AND 255	Use only lower byte
XorSum = XorSum AND 255	Use only lower byte

Here's what the computer is doing.

- (1.) Read the ASCII code for the first byte in the Data String for the packet
- (2.) Read the ASCII code for the second byte and add it to the first byte. Save the result.
- (3.) Using the same two ASCII codes perform an Exclusive OR and save the result.
- (4.) Continue reading, Adding, and Exclusive Or-ing bytes until the end of the string.

The results may be numbers which are too big to be expressed in only 8 binary bits. They will be 16 bit binary numbers. Disregard the 8 most significant bits. This leaves only one 8 bit byte (the least significant byte) which is the check sum you are looking for.

#### **Sending A Packet To The Machine**

DNC requires both the computer and the machine be able to send and receive data packets. The error correcting aspect of the protocol works like this.

1. The computer sends a DNC control code to the machine (^E Enquire)
2. If the machine is ready, it responds by returning another control code (^F Acknowledge)
3. The computer then sends the first data packet to the machine.
4. The machine reads the Data String in the packet and re-calculates the AddSum and XorSum totals.
5. If the check sums calculated by the machine are the same as those included in the packet by the computer, the machine has received the Data String correctly. The machine returns a positive response (^F Acknowledge)
6. If the two sets of checksums do not agree then there has been an error and the machine responds negatively (^U Negative Acknowledge).
7. If there is an error the computer will resend the same packet again and the machine will do the calculations and compare results a second time.
8. If there is an error the 2<sup>nd</sup> time the computer will try resending a 3<sup>rd</sup> time.
9. If the 3<sup>rd</sup> attempt is also a failure the computer and machine abort the operation.



3. Machine sends 1 packet with Data String containing Operator Message
4. Computer sends ^F (Acknowledge) if the check sums match

If the check sums don't match, Computer sends ^U (Negative Acknowledge) and the sequence begins again.

#### **Loading A New Program Into A Machine**

I'm going to again use Excellon as an example. However, behind the scene at the DNC level, all machines send and receive the same control codes and data packets even though the method of starting the file transfer may be different. Here's an outline of the sequence of events required for an operator to download a drill/route program from a DNC Server using only the keyboard of the machine.

Operator types	SI, FileName	On machine keyboard
Machine sends	^E (Enquire)	Wake up!
Computer responds	^F (Acknowledge)	OK – I know you're there
Machine sends	SEN?,FileName,XM( )	Do you have the file?
Computer responds	^F (Acknowledge)	Yes
Machine sends	SEND,Filename,XM( )	OK – Send it to me

From here on it's a matter of sending Data Packets, verifying Check Sums, and resending misunderstood packets until the entire file has been correctly received by the machine.

Be aware that normally things are not quite this simple. Generally there is a flurry of Enquire – Acknowledge control codes sent back and forth until the machine and the computer get organized. Then the file transfer actually begins.

In the above example the file transfer was initiated by the operator at the keyboard of the machine. It is also possible for the DNC Server to initiate the file transfer. In this case the sequence of events is the following:

Computer Sends	^E (Enguire)	Wake up
Machine Sends	^F (Acknowledge)	OK
Computer Sends	RECV,XM( ),FileName	Here it comes
Machine Sends	^F (Acknowledge)	OK – I'm ready
File transfer begins		

#### **The Differences Between DNC 1.3 and DNC 1.4**

Under DNC 1.3 the Data String in the packet begins with the characters "D," (No quotes). The actual content of the file begins at the fourth byte immediately following the comma.

The Data String in the packet under DNC 1.4 begins with “D#” where # is the number of the packet starting with 1 and incrementing. When packet #127 has been successfully received the packet number is automatically reset to 1 and the packet numbering sequence begins again.

Under DNC 1.4 the receiving entity can look at the packet numbers and determine if a packet has been lost or duplicated. If so, corrections can be made automatically and the file transfer can continue. DNC 1.3 does not have this capability. Either the error may be missed completely or the file transfer may shut down due to unspecified errors. This is seldom a problem in the real world but it is a theoretical possibility.

In addition to the control code ACK (Acknowledge), DNC 1.4 also uses ACKP (Acknowledge Packet). Again, theoretically, when ENQ and ACK codes are flying back and forth, it is possible for the server computer and the machine to get out of sync. The computer may be enquiring about one event and the machine responding about another. ACKP is used to help minimize this possibility.

I personally have never experienced a situation in which there was a difference on the drill room floor between using DNC 1.3 and 1.4. In addition, some machine manufacturers only offer DNC 1.3. If you are an “All Excellon” shop DNC 1.4 is fine. If not, you should probably stick to DNC 1.3 to maintain compatibility between all your machines.

#### **What Are Short Haul Modems And Why Are They Used?**

*Words Of Wisdom: If you can make a direct Ethernet connection to your machine don't even consider DNC and short haul modems! Go with a modern local area network.*

The modems typically used in a DNC network are different beasts from the modems we use in our computers to communicate over telephone lines. Basically analog telephone modems generate tone pulses which can be sent over ordinary voice quality telephone lines. DSL and other high speed data transmission techniques also use modems that are much more sophisticated. However, we don't need to concern our selves with any type of telephone modem because the technical details are simply not relevant to DNC systems.



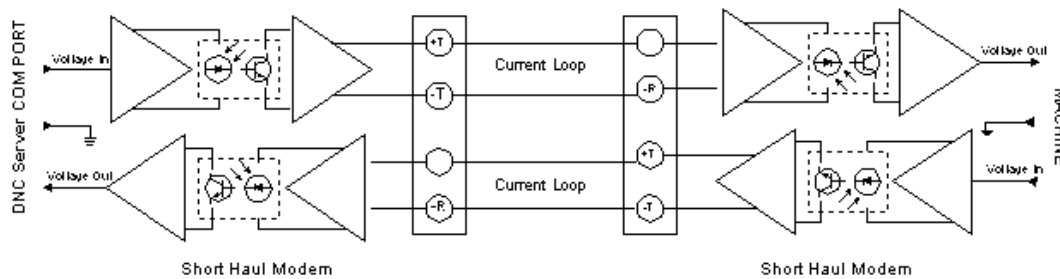
Modem In Case With Power Supply



Modem Without Case

Figure 13. Short Haul Modems

Fundamentally, short haul modems receive voltage pulses and convert them to current pulses and vice versa. This provides electrical isolation, noise immunity, and minimizes signal degradation. The electrical isolation helps prevent burning out our machines when they are all connected together. The noise immunity enables the computer and the machine to communicate over distances up to about 4 miles.



Notes:

1. Current loop cable between modems should be #26 AWG or larger, unshielded, twisted pair.
2. Input/Output Voltage Levels: "Low" = -3 to -25V. "High" = +3 to +25V RS-232-C interface.

Figure 14. Functional diagram of two short haul modems communicating with each other

Figure 14 is a functional diagram of two short haul modems as they are typically connected in a DNC network. This diagram is meant to illustrate the concept. Certain details regarding the optical isolation are not absolutely precise - but they don't have to be for our purposes.

The first and most important reasons for using short haul modems is to prevent your machines and computers from destroying each other when everything is connected together. If the machines and computers are not properly grounded there can be a voltage difference between them. This voltage differential can easily be large enough to burn out electronic components such as transistors and integrated circuits. In fact, it is not unusual to burn traces off a PC board! Short haul modems minimize this possibility by electrically isolating their inputs from outputs by the use of optical isolators (Light Emitting Diodes + photo sensors)

The second reason for using short haul modems is to minimize the amount of electrical noise picked up in the wires between the computer and the machine as they run up, over, and around your shop. Induced electrical noise can easily distort the data so badly that it becomes unintelligible. In addition, electrical signals dissipate as they travel down a wire. The amplitude drops off and rise times decrease. At some distance the signal becomes so weak and distorted that the machine can no longer understand what the computer is sending.

You cannot simply look at the electrical grounds in your shop and tell whether they're good. In many facilities electrical power is distributed by wires which run thru metal tubing (EMT conduit) from a junction box on the wall to the machines. It is common practice to use the tubing as an electrical ground. When everything is new this will often work. However, over time, the fittings used to connect the tubing corrode. This corrosion causes partial or even complete electrical disconnection between sections of electrical conduit. In other words, what looks like a perfectly good and safe electrical ground may be totally useless when your machines are connected together.

The subject of electrical grounds can quickly become complicated. If you are not absolutely certain all your grounds are mechanically and electrically good, and that there's no more than approximately 1 Volt RMS between them, don't try setting up a DNC network without short haul modems.



Figure 15. Typical rack of short haul modems, power supplies, and cables for DNC network driving 20 machines

Short haul modems have problems, not the least of which is they act like light bulbs. You install a new one and turn it ON. Some time later you turn it OFF. The next time you turn it back ON it flashes for an instant and then burns out.

Short haul modems also have a propensity for dieing any time you plug or unplug their data cables. If your modems are mounted in a rack, never simply remove one unit while the power is ON. Turn OFF the power to the entire rack before you unplug any modems or change any cables. If you don't it is very likely that at least one of your modems will die - for no apparent reason.

### **Short Haul Modem Advantages**

1. Provides optical isolation between computers and machines which can minimize possibility of electrical damage and failure
2. Enables communication between machines and computers over long distances.
3. Any machine with DNC capability will work with short haul modems including Excellon, Hitachi, and Kennard.
4. For some older machines they are the only way to make a direct connection to an external file server computer.

### **Short Haul Modem Disadvantages**

1. Requires two modems per machine
2. Requires space to install and electrical power for each modem
3. Invariably results in unsightly rats' nests of cables
4. Often difficult to tell which of the two modems, or both, are not working properly
5. Unreliable – Modems die for no apparent reason
6. Very slow compared to modern Ethernet network connections

### **Testing Short Haul Modems**

One of the joys of short haul modems occurs when the machine stops talking to the DNC Server. Historically you solved this problem by trying different ports on the computer, replacing modems, moving jumpers and switches, and swapping cables until you found a combination that worked. This guessing game can be very time consuming. It is not

unusual to spend two hours, or more, trying to correct a problem which is the result of a failed short haul modem.

After fighting this problem several different times I decided there had to be a better way. Ruben Gonzalez, production manager for Nova Drilling, loaned me several new short haul modems. Anticipating problems, he had wisely ordered ten new units (\$150.00 each) from Black Box before we started the project.

I setup two computers connected by two short haul modems in our lab at California Software Systems. One computer functioned as the DNC Server. The other computer emulated the machine.

If you look carefully at figure 13 you will see a push button switch which protrudes out the front of the black plastic case labeled "Normal/Loopback". On the printed circuit board, near the front left corner is a slide switch identified as "S1". The front position of S1 is labeled DTE which means "Data Terminal Equipment". The rear position is DCE which is the abbreviation for "Data Communication Equipment". At the right rear of the board there is a jumper labeled "J1 RTS/DTR Control" (Request To Send/Data Terminal Ready).

The proper settings for the switches and jumper when the modems are installed in a working DNC system are shown in table 1.

	Modem <u>At Server</u>	Modem <u>At Machine</u>
Normal/Loopback	Normal	Normal
S1	DCE (Back)	DCE (Back)
J1	DIS (Disabled – forward)	EN (Enable – back)

Table 1. Switch and jumper setting for short haul modems

By reading the manual which comes with new short haul modems and experimenting with the switches and jumper I was able to figure out a way to test the modems while they are installed in a DNC network. If the Normal/Loopback switch is pressed "In", a properly working modem will return back to the computer anything that it receives rather than sending it on to the next modem or the machine. Each data bit coming in is looped back out to the computer which sent it.

We are using one serial communications port (COM Port) on the computer for each machine. The data is being sent and received at 9600 baud as ASCII codes using RS-232 voltage levels. From a software standpoint, this a terminal emulation problem. We can program the computer to send and receive text data. By itself this is no big deal. The catch is, if we send the wrong data during a loop back test which accidentally gets to the machine, we can have serious problems. DNC is very unforgiving. If you send the machine ASCII characters which it does not understand it may make a mistake, drill a

hole in the wrong place, or lockup. Normally this requires you to perform a cold boot to get it back up and running again.

I modified our DNC File Server For Windows to perform loopback tests on the short haul modems while they are still installed in a DNC network. The trick was to block DNC codes which can cause problems in the machine. Figure 16 shows the short haul modem test screen.



Figure 16. Installed modem for Excellon Mark-6 tested good

We can now easily test the modems for any of the sixteen machines that can be connected to one DNC server computer. The test procedure is as follows.

1. Press the Loopback switch on the short haul modem at the DNC server.
2. Send a test message to the modem.
3. If this first modem tests good, press the switch to return it to "Normal" operation
4. Press the Loopback switch on the second short haul modem at the machine
5. Send a test message to the second modem through the first modem.

If the short haul modem is working correctly the exact same message will reappear on the computer screen. If the outgoing message does not reappear the computer indicates "Modem Not Responding" which normally means the modem is bad. This is fast and easy. In a matter of minutes you have tested the DNC Server Computer, the short haul modems, the cables, and ultimately, the machine – all without disassembling anything.

We found one other major advantage of this software. You can easily test any short haul modem before it's wired into your DNC network. You don't need to remove the case, cut off the power supply, connect the four wires to the terminal block, and install the modem in a rack to find out if it works. Just plug-in the data cable and let the computer determine if the modems good or bad - before you start making changes.

For more information about short haul modems contact Black Box Network Services at [www.blackbox.com](http://www.blackbox.com) or (877) 877-2269.

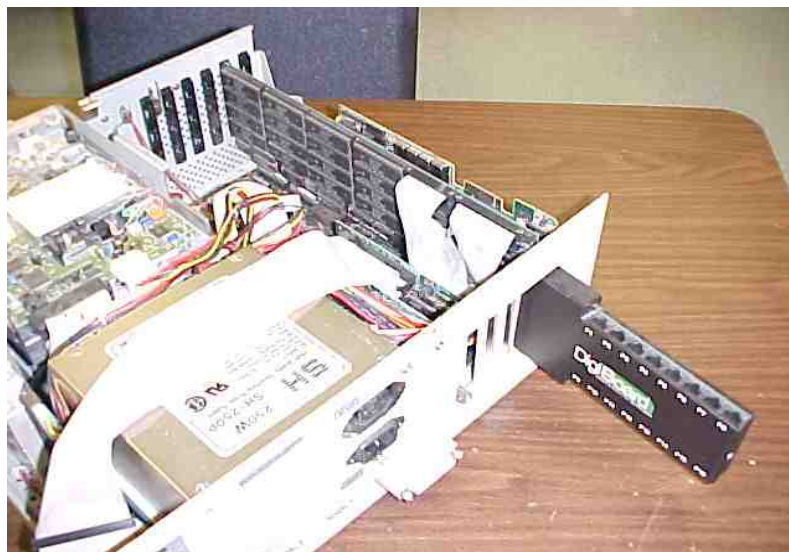
**The Original Excellon DNC Miniserver**

If I remember correctly, the first DNC system was the Excellon Data Workshop which appeared in the 1970's prior to the introduction of the IBM personal computer. I haven't seen one of these for years so we'll jump ahead to the 1980's.

The Excellon Miniserver and Miniserver Plus were developed to run under Microsoft DOS (MS-DOS) on an IBM XT or AT compatible computer. One COM port was required in the computer for each machine. The additional COM ports were provided on Digi Boards which is a generic name for serial cards manufactured solely by Digi Board Corporation. To the best of our knowledge, there was never a second source. It now appears that the Corporation has changed it's name to DIGI International and can be found on the web at [www.digi.com](http://www.digi.com).



**Figure 17. 16 Port Digiboard use in original Excellon Miniserver**



**Figure 18. Excellon Miniserver computer with cover removed**

Excellon software only supported the Digiboard PC/X family of non-intelligent multiport serial communication boards. These boards were available with 4, 8, and 16 ports for computer with ISA and EISA hardware busses. There may have also been a version for the “MC” buss (what ever that may have been) and the original PCI buss. However, the PCI version required a CPU embedded on the serial I/O card! None of these old boards from the late 1980’s is available today.

Figure 17 shows a 16 port Digi board with its extender. Figure 18 shows the same card installed in an old computer. Not only are the original Digiboards not available, you can’t even get parts any more for the computers they require. Still, today many printed circuit board manufacturing facilities are dependent on this old hardware because, until recently, there was nothing else available.

### **How To Build A Modern DNC Server**

The basic approach to building a DNC Server still requires a computer, one COM port for each machine, and the right software. However, we want it built with modern, standard, hardware which is readily available from multiple sources. In addition, the software should be, for all practical purposes, hardware independent.

Today there are three practical ways to add multiple COM ports to a computer.

1. Internal Add-on serial port cards
2. A USB to Serial Port Hub
3. An Ethernet to Serial Port Hub

*Internal cards* are readily available from many different vendors for the PCI and PCI-Express buss with 2, 4 and , 8 COM ports. They can be found at almost any retail computer store and 100’s of sources on the Internet. They range in price from about \$15.00 (Figure 19) for a two port card to approximately \$250.00 for an 8 port version.

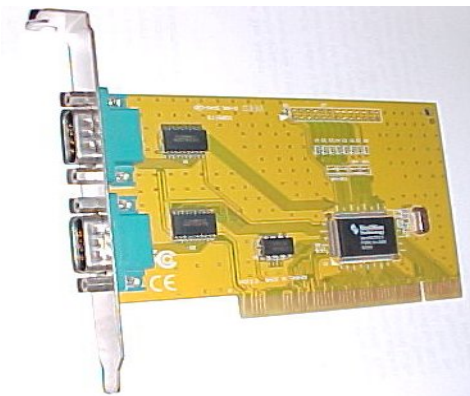


Figure 19. Add-on Card With Two Serial Ports For PCI Buss

*USB to Serial Hubs* (Figure 5) have an advantage with respect to cabling. Internal add-on cards require multiple cables plugged directly into the back of the computer. This can create a tangled mess and a problem when it is necessary to open the computer case. USB hubs only require one cable plugged into the computer. The hub can be located anywhere within about 30 feet. USB is a very high speed serial protocol. Signal degradation in the cable is a significant problem. This is why a relatively short distance must be maintained between the computer and the hub.

Eight port USB hubs are available for about \$650.00. Sixteen port hubs are priced in the range from approximately \$1,500.00. to \$2,500.00. USB hubs are not normally available from retail computer stores except by special order. At least three major sources can be found on the web.

An *Ethernet to Serial Hub* (Figure 9) is a very interesting device for several reasons. First, it does not require a direct cable to its' computer. It only requires a connection to a network hub or switch just like another computer. Second, it can be physically located anywhere on a LAN including in your drilling or fabrication departments near the machines it supports. The hardware does not have to clutter up your CAM or MIS areas. Even though an Ethernet To Serial Hub may be located across the hall, or in a different building on a different network, it acts like it's part of the computer which drives it. .

Ethernet to serial hub prices are similar to USB hubs. Again multiple suppliers can be found on the web and again, hubs normally must be special ordered.

### **Selecting The New Computer**

The steps in selecting the hardware for your new DNC server are relatively simple.

1. Select the operating system for the computer. We recommend Windows xp for any installation but prefer Windows ME where possible because it is easier to setup and keep running in this dedicated environment.
2. Select the method of adding serial communication ports. Internal add-on cards are the least expensive and Ethernet to serial hubs are probably the most eloquent.
3. If your master drill and route programs are to be stored on your DNC server computer select the backup technique to be used to prevent catastrophic loss of your critical manufacturing data
4. Select a computer which matches your operation system and, if necessary, has enough slots in the mother board for the add-on serial cards you need. Drill and route programs are typically less than 100K in size which is very small by today's standards. Therefore, if you plan to store your drill and route files on the hard disk of your DNC server computer we suggest a 20 GB hard drive (or larger). If all the computer is doing is acting as a DNC server then a 2 GB hard drive is more than adequate.

Building the DNC Server computer is straight forward.

1. Load the Windows operating systems
2. Configure your network connections
3. Connect your serial ports and install the drivers into the operating system.
4. Load and configure DNC Server Software
5. Connect to Short Haul Modems and Test\Trouble Shoot Connections to machines
6. Load your virus protection software

#### **DNC Server Software**

The original Excellon Miniserver software was named DNC1.EXE, DNC8,EXE, DNC16,EXE, DNC24.EXE, and DNC32.EXE. corresponding to the number of ports being supported. DNC1 can still be run under DOS or Windows for a single machine using one of the standard serial ports generally included in a PC. ( COM1 or COM2 ). It is available free from Excellon and no hardware key is required. A similar but earlier free version called PCDNC can also be found on the web. All other version which support multiple machines require both a specific Digi board and a hardware key available only from Excellon. Because the software is hardware specific it will only work with a Digi board. However, the old Digi boards are not plug and play and no software drivers are available for current versions of Microsoft Windows. In addition the necessary hardware keys are probably not compatible with Windows. The result is a complicated mess that is probably not worth your time to try and correct.

California Software Systems has solved all of the above problems by writing DNC Server software specifically for Microsoft Windows. It will run under Windows 95/98/Me/Xp/2000. It will probably also work under Vista but has not yet been tested. CSS DNC File Server For Windows was written in Visual Basic and uses active-x controls to simultaneously access up to 16 COM ports. The COM ports are installed in the Windows operating system using software drivers provided by the serial port hardware developer. California Software Systems DNC File Server For Windows (CSSDNC.EXE) is completely hardware independent. It will work correctly on any computer running any version of Microsoft Windows starting with Windows 95.

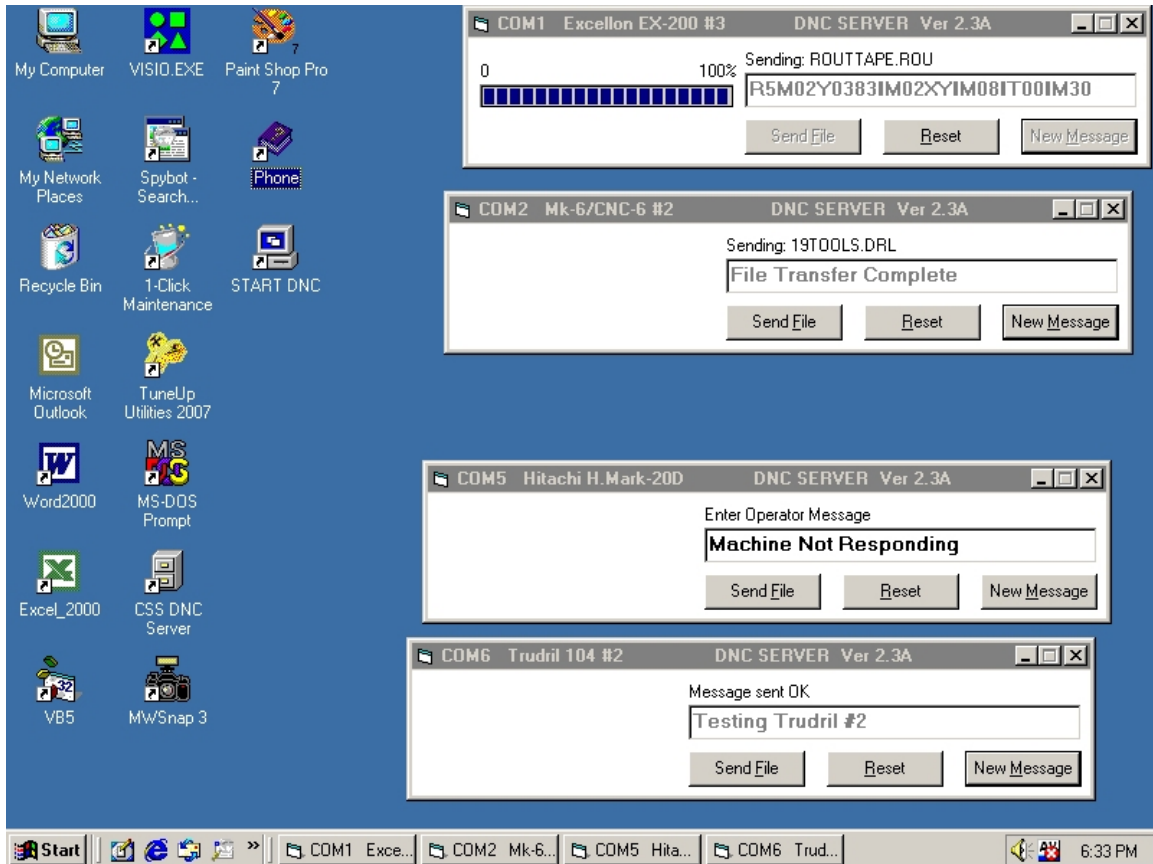


Figure 20. CSSDNC Server display for 4 of 16 machine network

The CSSDNC File Server For Windows does not directly access the serial hardware ports. It simply reads and writes predefined memory locations in the computer. The Windows operating system handles the problem of moving the data from memory to the physical port using the software drivers mentioned above. It doesn't matter what hardware buss is being used in the computer or where the COM ports are physically located. Basically all the DNC Server software has to know is which COM port number to communicate with and the DNC parameters being used by the machine

Regardless of what changes Microsoft may make in the future, as long as they maintain backward compatibility with Windows xp, this DNC Server software will work Your guess is as good as ours as to how long this will be. However, a minimum of 10 years seems like a good bet.

## Updating An Old DNC Network - A Case History

Nova Drilling Services, Inc. in Santa Clara California has provided drilling and fabrication services to the printed circuit board manufacturing industry for more than 30 years. Mike Banks, a local computer consultant and networking specialist originally installed an AppleTalk network in their facility in the late 1980's. Since then their production network had evolved into a DNC system composed of a somewhat haphazard collection of computers, monitors, cables, short haul modems, Ethernet hubs, printers, and power strips. All of this hardware was spread over, under, around, and through a stack of metal shelves in their CAM department. The left side of Figure 21 shows a photograph of the rack just after the main DNC Server computer died which brought down the whole system.



Before



After

Figure 21. DNC Server rack at Nova Drilling Services, Inc.

The right side of Figure 21 shows the DNC System after it was rebuilt using a modern PC running Windows xp and a USB to serial port hub.

The Original DNC Server was composed of the computer and Digi board shown previously in figures 17 and 18. When the old computer failed Mike was unable to find the necessary parts. This forced the entire shop back to running from floppy disks. Both Mike Doherty, vice president of Nova Drilling, and Mike Banks wanted a better solution which ideally would include multiple sources for inexpensive parts, modern computers, and hardware independent software.

Mike Banks contacted Russ Walton at California Software Systems through their web site at [www.californiasoftwaresystems.com](http://www.californiasoftwaresystems.com). For the past two years California Software Systems had been developing new DNC software intended to replace the aging Excellon product. CSSDNC File Server For Windows was written in Visual Basic specifically for Microsoft Windows. This enables up to 16 machines to be connected to a single computer through add-on serial ports. A separate copy of the CSS DNC Server program is loaded into memory for each COM port and runs in it's own "window" on the computer. This means that if you are driving 16 machines there are 16 separate copies of the program running on the computer at the same time.

All 16 DNC windows can be minimized, individually, or as a group, on the screen of the DNC File Server computer.. When they are minimized they are still functioning which means your network is still up and running properly. This is very useful if you are having trouble with one leg of your DNC network. You can bring up just that window on screen while you're trouble shooting the problem.

In addition, all 16 windows can be minimized allowing other tasks to be preformed simultaneously on the computer. These tasks can include graphically displaying the drilling or routing program currently running on any machine connected to the DNC network.

From the graphic display it is easy to select specific groups of holes to drill or individual segments to route. The computer then automatically creates a modified drill/route program to do the required task and sends it to the designated machine over the DNC network. More sophisticated tasks such as scaling or offsetting individual parts on a panel and automatically inserting tool parameters (feeds, speed, max hits, etc.) for various types of laminate can also be done by the computer – while it is still acting as a DNC server.

Mike ordered new computers and two different types of serial port hubs. The computer came with Vista installed which we replaced with Windows Xp. Windows Xp has been around long enough to be tried, true, and relatively stable. Most of the new bells and whistles included in Window Vista we don't need or want in an industrial machine shop environment.

At first we thought we would use the Ethernet to serial hub. However, because we decided to leave all the cables where they were and simply cleanup the mess as much as possible, it turned out to be easier to use the USB hub. This decision was based on the location and quantity of cables and short haul modems, not any technical differences between Ethernet and USB serial port devices.

Here are the machines we initially connected to the new DNC Server:

<u>COM Port</u>	<u>Machine Description</u>	<u>Machine Number</u>
1	Excellon Century 2000 / CNC-7	#1
2	Hitachi	#25
3	Excellon MK-6/CNC-6	#3
4	Excellon MK-6/CNC-6	#4
5	Hitachi	#22
6	Kennard Router + CX 9000	#23
7	Kennard Router + CX 9000	#19
8	Hitachi	#24
9	Excellon Century 2001/CNC-7	#9
10	Kennard Router + CX9000	#17
11	Excellon EX300/CNC-6	#11
12	Excellon MK-6/CNC-6	#12
13	Kennard Router + CNC-6	#13
14	Kennard Router + CX9000	#20
15	Kennard Router + CX9000	#18
16	Hitachi	#26

Table 2. Machines Initially Connected To New DNC Server

One of the first things we should have done but didn't was carefully label all the short haul modems in the rack and their output cables. The output cables contain two twisted pairs of wires which carry the current pulses to the short haul modems in the machines on the production floor. Later, when we were installing the new DNC server and serial hub we did this and – we almost got it right the first time. Had we done it in the very beginning we would have probably saved many hours of trouble shooting time.

The short haul modems plug into their own rack mountable frame (Figure 21). A single, external, 16 VAC supply provided power to all the modems in the frame. The individual modems, without their protective cases, slide into plastic rails in the frame. The frame becomes a stack of bare boards with cables hard wired to terminal strips on each of the exposed short haul modem. This works but frankly it's crude, cumbersome, and prone to failure. It would be much better if the output cables fastened to the modems through a connector rather than being screwed into terminal blocks.

Each modem receives it's 16 VAC power from it's own set of three pins in the frame. This enables individual short haul modems to be unplugged from the frame while the power is On. It can be done but – it's a very bad thing to do. The modems simply do not like to be removed and re-inserted into their slots while the frame is electrically hot. The result is they die for no apparent reason. During the installation of the new DNC Server we lost five of the original 32 short haul modems. This is not unusual. You should expect to lose short haul modems every time you have to work on them. Fortunately,

once you get them all up and running, if left undisturbed, they often work for years – until they burn out just like light bulbs.

### **Trouble Shooting The DNC Network**

Most people seem to naturally pick one of two different approaches to test and trouble shoot a DNC network.

1. Setup each machine, one at a time, and make it work before proceeding to the next
- OR
2. Plug everything together and try it. Then go back and fix the problems.

The first approach may seem logical and methodical but it's generally not the way to go. It seems to break the big picture into small problems which can be individually resolved one at a time. The trouble is when you are dealing with groups of similar machines the problems come in two types.

The first type of DNC network problems I call "system" problems. These are problems which effect all machines of a given type or class. For example, maybe you should be using DNC 1.4 protocol rather than DNC 1.3. Perhaps the machines are set to 4800 baud rather than 9600 which is more common. Maybe the drilling program you are trying to call up is not available to the DNC Server and this causes the machine to display an incorrect error message. When you solve a "system" problem for one machine you generally solve it for all machines of that type.

The second type of typical DNC network problems I refer to as "individual" problems. These can be such things as broken wires, dead modems, and corrupted machine software. Even though they can be caused by either hardware or software failures, they are normally unique to a given machine and do not repeat elsewhere in the shop.

#### *Excellon Machines*

An example of a "System" problem at Nova was all of the Excellon machines. When we first fired up the new DNC System we couldn't talk to any of them. We finally discovered that we had to move the slide switch on each modem in the rack to the opposite position of what it had been with the old DNC Server. This has something to do with the new USB to Serial Hub but we never took the time to figure out exactly what. We moved the switches and all the Excellon started working - so we moved on to the "individual" problems.

An example of an "individual" problem was two Kennard routers setting side by side. Both worked properly before the old DNC Server died.. When we connected the new Server one machine worked and the other didn't. The problem turned out to be the short haul modem inside the controller cabinet of the second machine. We hadn't even opened the back of the controller cabinet, let alone touched the modem. Yet for unknown reason it died at the precise time we were trying to get the shop back up and running.

### *Hitachi Machines*

Another example of a "System" problem was the Hitachi drills. Though they worked on the new DNC Server, they seemed slow when downloading drilling programs. We talked to Jeff Penney who provided field service for Hitachi machines for years. Jeff told us this is not unusual and suggested that we completely disconnect the DNC and instead make direct Ethernet connections.



Small, Windows 95, Computer



Hitachi H.Mark-20D Controller

Figure 22. Hitachi drill showing small computer running Windows 95 which can be connected directly to Microsoft LAN.

The Hitachi H.MARK-20D and H.MARK-30D controllers have a small PC in the controller cabinet below the keyboard. This PC has an Ethernet port built into the motherboard. The operating system is Windows 95. All that has to be done is to load the Realtek RTL8139 LAN Driver and configure the network connection - just like an ordinary computer running Windows 95. The NIC driver can be found on [www.driverguide.com](http://www.driverguide.com).

To test the setup we temporarily put a network hub behind one of the machines in production and ran CAT 5 cables across the floor. Using Windows 95 we enabled TCP/IP protocol on the Hitachi Drills. We then setup a workgroup (NOVA) on the DNC Server which Mike Banks named "NOVASERV". All drill and route programs were moved to the NOVASERV\DRILFILES\DRILL subdirectory. We shared the subdirectory, with full read/write user privileges, as the "DRILL" resource on the computer. This single computer then became (1.) the DNC File Server for the entire shop, and (2.) an ordinary Windows Xp Network File Server. Lastly we setup user accounts for the Hitachi Drills on the new Network File Server.

Latter we discovered a problem with the Hitachi machines automatically logging on the Drill Room File Server when they were first turned “On” in the morning. Once the connection was properly mapped the drills worked fine. However, the network connection was consistently lost when the machines were shut down at the end of the day. This probably had something to do with users account, privileges, and passwords required by Windows xp running TCP/IP. However, instead of fighting xp we simply switched to NetBEUI protocol and the problems went away – most of the time.

There was nothing particularly difficult or unusual about setting up the Hitachi machines on a Microsoft peer-to-peer network. Unlike DNC, anyone who is familiar with modern networks should be able to understand and do it using the standard software tools and wizards built into Windows.

DNC was first developed in the 1960's. It provided a way to connect printed circuit drills and routers to a host computer. At the time it was "state-of-the-art". Today it is completely obsolete and should be avoided any time an Ethernet connection is available.

An Ethernet connection is at least a 1000 times faster than DNC. It is also easier to setup, trouble shoot, and maintain. There is no danger of poor electrical grounds damaging the machines. Therefore, short haul modems are not required. In addition both the network hardware and software are inexpensive and readily available. The bottom line is don't screw around with DNC if you can make an Ethernet connection to a machine.

#### *Kennard Machines*

All but one of the Kennard Routers at Nova Drilling have Lexica CX-9000 controllers. One uses an Excellon CNC-6 which had to continue to be connected to the network file server using DNC with short haul modems.



Figure 23. Kennard Router with CX-9000 Controller

The CX-9000 is built like a standard, IBM AT compatible, computer. It has a 486 CPU, 4 megabytes of RAM, and four ISA expansion slots on the motherboard. It can be removed from the CNC-6 type cabinet by simply unplugging the cables in the back and removing four screws in the front panel.

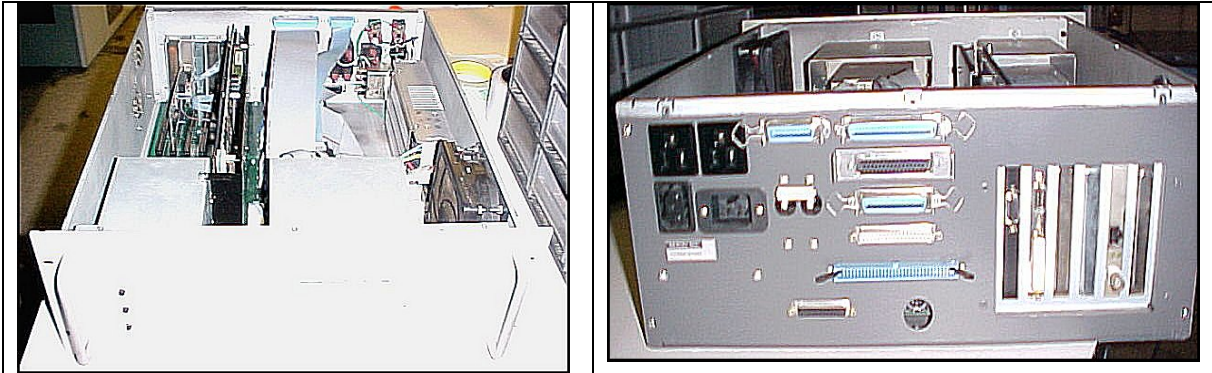
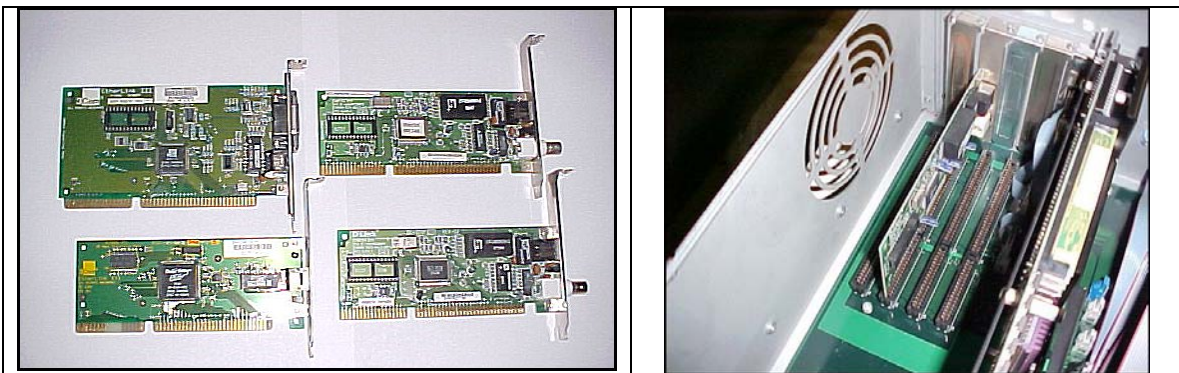


Figure 24. IBM AT Compatible computer removed from CX-9000

The operating system for the CX-9000 is IBM PC DOS version 6.3. This is slightly different from Microsoft MS-DOS. However, you can install a network interface card and Microsoft Workgroups for DOS. The CX-9000 then becomes an ordinary peer-to-peer client for a Microsoft LAN.



Typical 16 bit Network Interface Cards

NIC Installed in CX-9000

Figure 25. Network Interface Cards for ISA Slot in Kennard CX-9000 Controller

Figure 25 shows typical network interface cards from 3COM, D-Link, and LinkSys that can be used in the CX-9000. We chose the D-Link DE-200P which comes with the necessary DOS driver on a floppy disk. The software drivers for the other cards can be found on the internet.

We installed the DE-200P and put the computer back into the controller cabinet. We then installed Microsoft Workgroups for DOS version 3.11 and setup the machine as a client for a Microsoft Network. Rather than using TCP/IP protocol, which we consider to be unnecessarily complicated for this application, we simply used NetBEUI. This required us to enable NetBEUI on the Windows xp file server. A standard Xp installation does not include NetBEUI but it can easily be added. The files are included on the installation CD from Microsoft. They can also be downloaded from California Software Systems.

The Kennard software is installed in the C:\LCX subdirectory on the computers hard disk. In this subdirectory there is a batch file named SI.BAT which originally used DNC 1.3 to download a drill/route program from a DNC File Server.

Original Batch File: `dnc1 recv 2 %1 c:\ncf\%1`

We changed this batch File to read:

New Batch File: `copy g:\%1 c:\ncf`

We defined logical drive G: on the CX-9000 as NOVASERV\DRILFILES\DRILL which corresponds to the subdirectory on the new Network File Server in which all drill and route programs are stored. The batch file now Shells to the DOS COPY command to copy the selected route program from the network file server to the local hard disk drive. It places the file in the C:\NCF subdirectory where it can be used by the Kennard software.

The procedure for calling up a new drill/route program is the same as it was when the machine was using DNC. The operator simply types SI, (File Name). However, instead of using the DNC connection with the short haul modems, the machine now uses its Ethernet connection. This is so much faster that it is almost unbelievable. Yet, from the operators' standpoint, the Kennard machine still operates exactly like it did before.

## Rebuilding The Rack

Manufacturer	Model	Network
Excellon	Century 2000/CNC-7	DNC
	Century 2001/CNC-7	DNC
	Mk-6/CNC-6	DNC
	Mk-6/CNC-6	DNC
	Mk-6/CNC-6	DNC
	EX-300/CNC-6	DNC
	Concept 129/CNC-7 PC	Ethernet
	Cobra Laser Drill/Route	Ethernet
	OPIC Programmer	DNC
	Hitachi	ND-6N210E/H.MARK-30D
ND-6L210E/H.MARK-20D		Ethernet
ND-5L250E/N.MARK-20D		Ethernet
ND-5L250E/H.MARK-20D		Ethernet
Kennard	226-R/CNC-6	DNC
	400/CX-9000	Ethernet
	200/CX-9000	Ethernet
	200/CX-9000	Ethernet
	200/CX-9000	Ethernet
	200/CX-9000	Ethernet
	200/CX-9000	Ethernet
Schmoll	LM6-160S	None

Table 3. Final Network Configuration For Nova Drilling Services

The final configuration ended up with seven Excellon machines using DNC with short haul modems. The one Kennard router with an Excellon CNC-6 controller also uses DNC. The four Hitachi and six Kennard machines have direct Ethernet connections. A newer Excellon Concept 129 and a Cobra Laser Drill also have direct Ethernet connections. The one remaining machine is a Schmoll drill with 160K air bearing spindles. The operating system is an early version of IBM OS/2. We haven't yet taken the time to work out a network connection for this machine but we will - soon.

The right side of Figure 21 is a picture of the new rack with a single black computer which is now both the Drill Room File Server and the DNC File Server for all machines. The second computer to the right of the black one is not part of the drill room network, It is a CAM work station. The rack was simply a handy place to put the computer.

We switched to a rack with wheels so we can easily get behind it. Mike and Ruben re-routed and labeled all the cables so we can now quickly find what we're looking for. Mike also installed an uninterruptible power supply to try and protect the computer, USB hub, and short haul modems from line surges and power outages.

I loaded our Graphic Drill/Route System 7 software on the DNC Server computer. Now, a machine operator can come into the CAM area and see a good, clear picture of the job being run. They can also use all of the features of the graphic display including selecting holes, offset parts, scaling panels, etc. However, frankly this powerful capability is not yet being used. The main reason is that no one wants to walk from one end of the building to the other and then back to setup their machine. In the near future we plan to install two or three freestanding graphic workstations (computers with Ethernet connections) in production next to the machines they work with.

### **Conclusion**

This entire project from start to finish required about eight man-days. That's a lot of labor. However, we were learning as we went. We believe the end result is a combination DNC/Ethernet Drill Room Network which others can use as a starting point for updating their own facilities. We also think we met our original objectives. We now have modern hardware, modern software, and multiple sources for inexpensive spare parts. In addition we believe Nova now has a system which makes sense to anyone familiar with modern local area networks and for which technical support will be available as long as Microsoft chooses to support Windows. If you would like more information or wish to discuss a similar project please feel free to contact us.

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## **About The Author**

Russell W. Walton is founder and owner of California Software Systems. The company has been developing software for manufacturing printed circuit boards since 1986. Over the years he has written more than a dozen technical papers about circuit design, software development, and printed circuit board manufacturing which have been published in the trade press. During his professional carrier he has either owned and operated, or been a principal in, several printed circuit board manufacturing ventures. He received his BSEE and BS-Math from California State Polytechnic College and his MBA from the University of Santa Clara. He now lives with his wife Dianne in San Juan Bautista, California. They have been married for 50 years and have three grown children and two grand children. He can be reached by email ([russw@californiasoftwaresystems.com](mailto:russw@californiasoftwaresystems.com)) or by phone at 831 477-6843.