PRODUCTION COUNTING USING A COMPUTER NETWORK

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Summary. The advent of microprocessors has made possible the development of low cost intelligent terminals for industrial applications. Several of these "smart" terminals can be connected to a communications network which is controlled by a it "master" computer. Such a computer network has been developed at Whirlpool Research for use in production counting for inventory control purposes.

This paper discusses the design, development, installation and debugging of the production counting system. The advantages and limitations of this type of computer network are discussed in the context of the industrial environment.

Introduction. Improved industrial data acquisition is possible with new developments in electronics and computers. In particular, faster and more accurate in-process inventory control has been obtained for a reasonable cost using a network of intelligent terminals on the factory floor with a host minicomputer system.

Historically mechanical and electro-mechanical means were used for maintaining piece counts on production machines such as metal presses. Such counts had to be read and recorded by the operator or some other person with the associated loss of accuracy and timeliness. The counts could be in error if provision were not made for subtracting rework And scrap parts. Estimates of the numbers of parts per container often replaced the use of counters. A centralized counting system replaced the individual machine counters to provide information on a timely basis. This system still had the problem of scrap and rework parts and provided no knowledge of the counts per container. The cost of the system was high due to the large number of graphical output terminals and a separate pair of wires to each machine. If the central system was down all counting was terminated.

What was needed, it was agreed, is a system that has local counting at the presses with a central system to periodically poll the local terminals or "operator boxes" to provide timely information for inventory and other purposes. Solid state logic was initially proposed to be used for the local operator boxes with a star communications system connecting all boxes with a central minicomputer.

Two new electronic developments -- microprocessors and UART's (Universal Asynchronous Receiver Transmitters) -- provided increased flexibility and reliability for a similar or reduced cost. This paper describes this system -- its design and implementation for production counting.

The distributive system concepts presented may have wider application to other industrial needs.

System Design. This distributive system consists of three major elements as shown in Figure 1 -- a minicomputer system, a number of operator boxes (one per press), and a communication system. The operator boxes include switch inputs, a microcomputer, a power supply, and a part of the communications system all packaged in a single NEMA enclosure (shown in Figure 2), installed at the press site. The operator boxes and communication system are discussed in detail below.

The minicomputer system is interfaced to the network and to several remote keyboard printer terminals located it the factory. The minicomputer is programmed to provide several functions including:

Communications Control
Operator Box Polling
Error Detecting
Data Processing
Report Generation

The mini system is supported by a card reader and a magnetic disk, which stores the system monitor and inventory control programs and serves as a backup for the count data in the event of loss of main memory.

Operator Boxes. The operator boxes are the intelligent terminals located at each press. The boxes provide the following functions:

Inputs (press and panel switches)
Count Storage (press, scrap, and rework)
Container Information (counts and tote number)
Sequence Logic
Power Up and Reset
Clock
Communications

All of these functions must be provided with the restrictions of factory environment, low cost, and independent operation for at least a day to prevent information loss during central system downtime.

Two approaches were considered in meeting the above requirements -- IC logic using binary counters and secondly, microcomputers. The latter approach was chosen due to advantages of: smaller number of components, more flexibility for changes, and lower costs.

Hardware. A 4-bit microprocessor was selected on a price/performance basis. A single 256X8 bit PROM (programmable read only memory) was judged adequate for an optimized program and a single RAM (random access memory) was required for count storage. A two phase clock was designed using a TV crystal for reference with count down and phase logic added. A multiplexing scheme was designed to allow input of the large number of switch lines (30). A local power supply, rather than a single central supply, was decided upon to maintain box autonomous operation in the event of central system problems or power distribution line faults. Power fail detection, reset and restart circuitry was also added to the box. Several of the timing and interface circuits have become available as single chip integrated circuits. (The communications hardware is discussed below.)

Software. The use of a stored program allows a more flexible approach to system design. It is relatively easy to change a sequence of instructions as compared to changing wired logic. The program was designed to minimize as much as possible the amount of peripheral IC's needed. Therefore, be, sides doing its intended function of counting and storing, the software also provides such functions as: debouncing the switch inputs, checking for operator input errors, controlling the communications, and providing time delays. A few modifications had to be made during the system development to meet changing system requirements. Minor programming changes sufficed in most cases.

Communication System. The communication system permits a single central minicomputer to communicate with the many operator boxes. The considerations for such a system include:

Number of Lines
Noise Immunity
Distance
Simple Protocol
Error Detection
Baud Rate

A simplified block diagram of the communication system is shown in Figure 3. The basic elements of this system are discussed below.

UART. Serial data transmission was decided upon to reduce the number of communication lines. However, since computers normally have parallel output, a parallel to serial conversion means is required. A shift register could have been used but for a slight additional cost a UART was employed. The UART additionally provides full double buffering, parity checking, and 8-bit character formatting. The UART was clocked using the computer clock. A crystal controlled clock was used to insure that transmitting and receiving ends have sufficiently close frequencies to prevent framing errors. The UART's add parity information to the transmitted characters and check parity, framing, and overrun on the received characters. The minicomputer requests retransmission if any errors are received.

Line Driver/Receiver. Since the UART output is low power TTL, a line driver wis needed to boost the power level into the line to provide high threshold,'long distance communication through a factory. The receivers are differential input for maximum common mode rejection. The use of the driver/ receiver pair provides good switching characteristics, hence baud rate, while retaining fairly low impedances for maximum electromagnetic noise rejection.

Cabling. The intraplant cabling between the operator boxes and the minicomputer could be a separate cable for a single loop, each additional receiver further loads the line resulting in signal loss or very large wire size with high capacitance and reduced bandwidth. In addition, if the single cable is down for any reason, the whole system is down. Separate cables for each box would be cost prohibitive, so a compromise was reached of using several cables with several boxes on each cable. The number of boxes per cable are a function of the required baud rate and the electrical characteristics of the cable and receiver/transmitter pair. For this application, number 22 shielded pair cable was selected. The last box in each line was terminated in its characteristic impedance.

Protocol. Each operator box has a seven bit address. Communication in all cases is initiated by the minicomputer to an individual box by transmitting the box address as a single character over the required cable. All boxes on that cable receive the address and convert it from serial to parallel. If the seven bit address matches the box hardwired code, a data request signal is sent to the microcomputer, which then responds by sending the counts and other information according to a prescribed message format. In this case the message is 9 characters in length. The minicomputer waits for a response from the box which creates an interrupt. If the box fails to respond, it is polled twice more before an error message is printed. If transmission or parity errors are detected by the UART, the minicomputer also repolls and prints an error message. The minicomputer has the ability to reset all the counts (RAM memory) in addressed boxes. This is accomplished by sending out a high eighth bit with the seven box address bits.

The choice of this fairly simple protocol dictates that separate transmit and receive pairs (4 lines total) are required for each loop. If a single pair were used for both transmit and receive, one box ‘ could accidently poll another by sending the right bit pattern in its count message. Methods to overcome this problem appeared to be more expensive and complex than having a four wire system.

Installation and Troubleshooting. The system was tested before-installation to verify that cable lengths somewhat longer than those required in the plant, and the multiple drop scheme, would not degrade transmission. Each of the operator boxes was functionally tested using a custom test box containing a microcomputer which simulated the minicomputer communication. The test box can be used to poll and reset any desired box by setting the box address on thumbwheel switches and using pushbuttons for the control. The message received from the box is displayed on an LED array for checking.

Installation in the plant proceeded with the typical problems such as miswirings, shorted cables, and operator box assembly mistakes. No design changes, however, were required; the system performed just as it was designed to do.

Oscilloscope measurements on the communication lines showed good waveforms despite the adverse factory environment. Grounding and noise problems were resolved by connecting all operator box DC commons, which are also the communication line commons, to earth ground with a capacitor rather than directly. All cable shields were directly connected to earth ground.

The system has been in operation for more than a year. The usual number of component failures occured during the first few months of operation, but in most cases replacement of one of the four PC cards remedied the problem. No microprocessor chips or memory chips have failed to date. One program change was required shortly after installation. This was accomplished by reporgramming the PROM’s on site and reinstalling them. Most problems are handled by factory electricians with minimum additional training.

Conclusions. Microcomputers provide a cost effective means for dedicated local intelligence in the industrial setting. Microcomputers provide advantages of reprogrammability, simplified assembly and maintenance, reliability and cost effectiveness. In this application, i.e., production counting, the microprocessor performed primarily a data acquisition task, but the application to other areas such as machine control and testing is also possible.

A distributive system composed of many microcomputer terminals (operator boxes) and a single central minicomputer with a communications system was used in this production counting application. Local intelligence in each terminal allows independent operation for a period of time without information loss; while the central larger computer serves to periodically gather all the terminal data and process it for centralized timely reporting.

The use of UART's, receiver/drivers, and shielded cable for a communication system was very effective. The system described in this paper allows a fairly high transmission rate at a low cost. A multiloop system with several terminal drops per loop was used to optimize system cost and reliability. The number of drops per line is a tradeoff between message length and line length. A four wire communication cable was used in this application to keep the communication hardware and protocol as simply as possible, although a two wire system is feasible.

In summary it has been shown that:

1) Microcomputers provide a good means for local intelligence in a factory.

2) A distributive system optimizes local autonomy with centralized computing power and immediate data accessability.

3) Multidrop shielded cabling with UART's and line receivers and drivers provides an effective, low cost communications network.

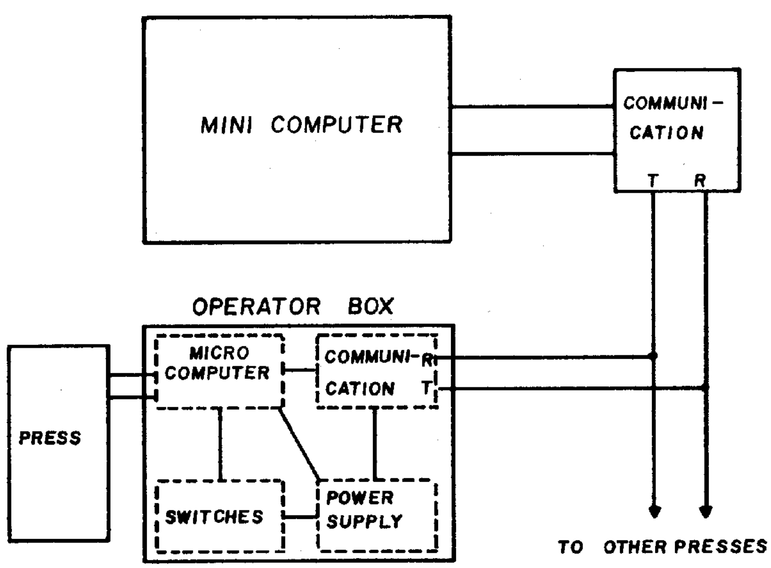

FIGURE 1. - PRODUCTION COUNT SYSTEM

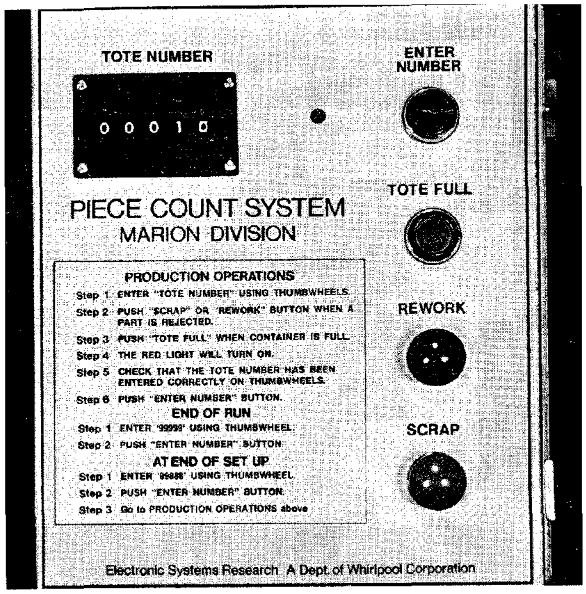

FIGURE 2. - OPERATOR BOX

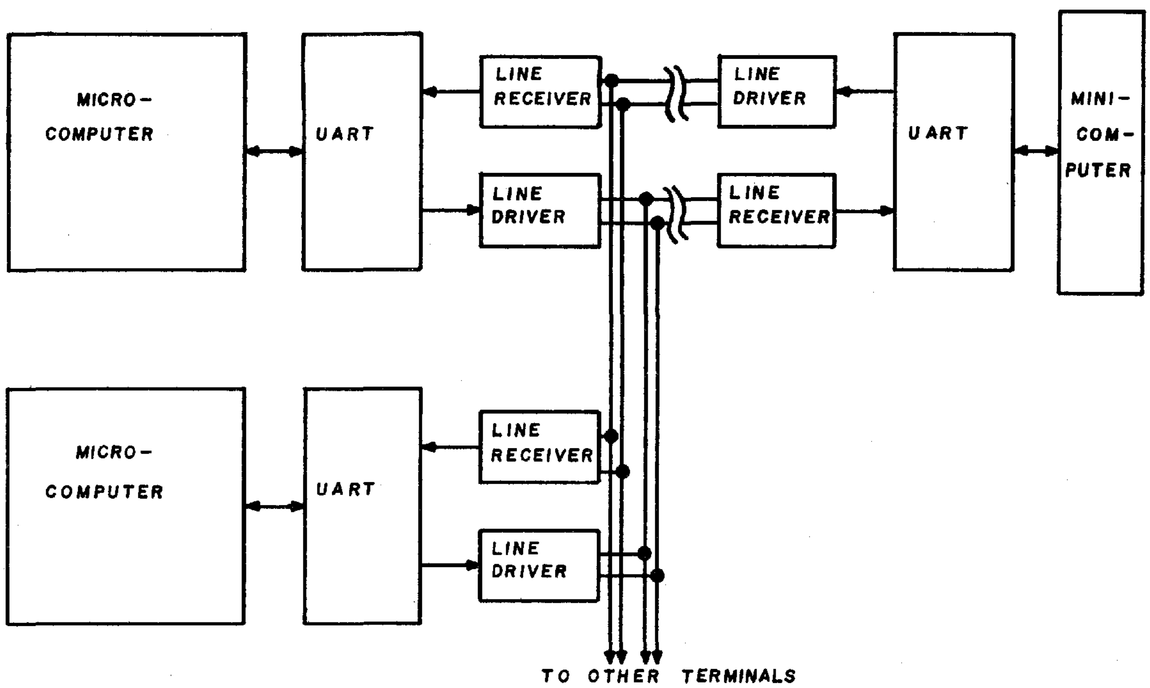

FIGURE 3. - COMMUNICATION SYSTEM