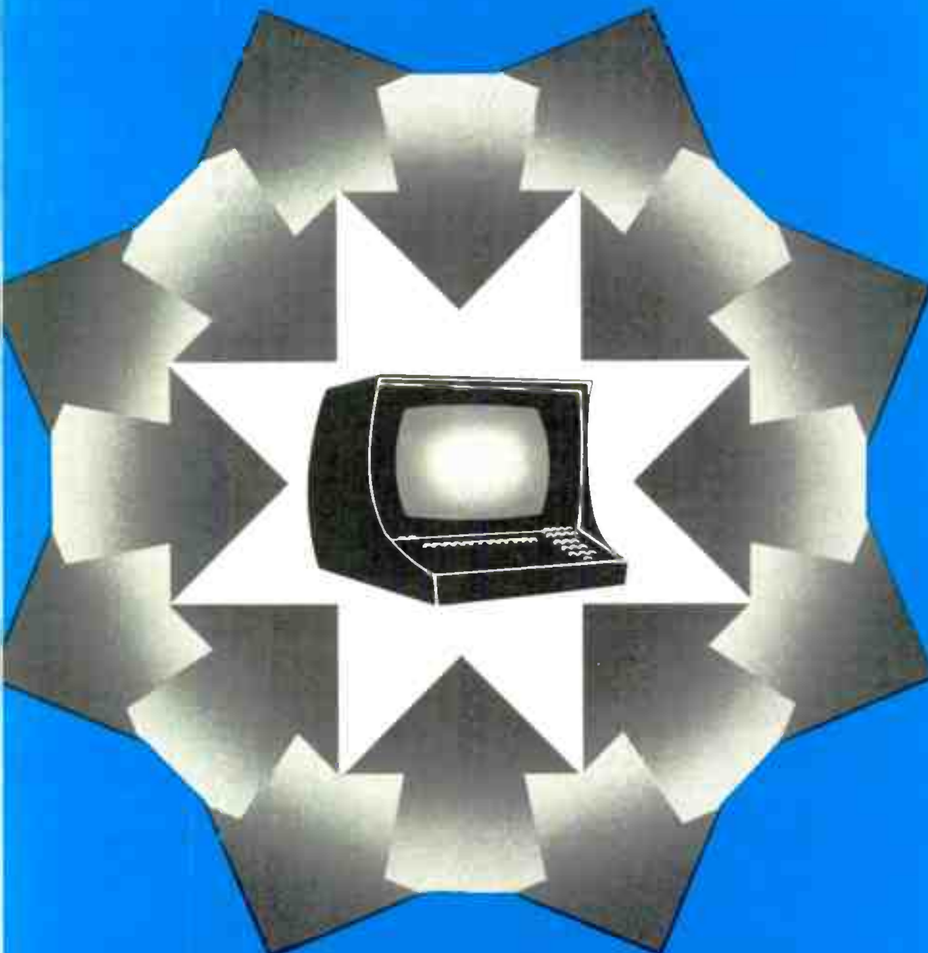
GTE LENKURT

# DEMODULATOR

DECEMBER 1973



# computers and supervisory control

**Supervisory and control systems are used to perform such services as data collecting, monitoring, controlling, and alarm reporting of unattended remote equipment. The incorporation of a minicomputer in an overall system design imparts considerable expediency and reliability to these functions.**

Supervisory and control systems run the gamut from simple status reporting, to remote transmission of complex analog signals. Telecontrol systems transmit control commands to unattended remote stations to activate relays, operate valves, and perform many other forms of control functions. Status reporting systems continuously monitor the status of isolated sites. Alarm reporting systems report the occurrence of any unusual event that may be detrimental to the operation of an unattended site. Telemetery systems relay information such as measurements of pipeline pressures, flow rates, task levels, and electrical quantities. Where a combination of several systems is necessary, the use of a minicomputer to process the information can save time and expense.

## Minicomputers in Supervisory Control

Supervisory control systems deal with many forms of discrete information, including digitized analog, which must be presented to the operator in some understandable format. Traditionally, large numbers of display lamps and pushbuttons have been used for this man/machine interface with digital data, while meters or recorders have been used for the interface with analog data.

As systems grow in size, display lamps become inadequate as the only means of monitoring the status of a system. Not only does the quantity of lamps become unwieldy, but the information conveyed by the lamps may become difficult to comprehend. What is needed is a means of gathering the data, storing and editing it, and providing as an output, an indication or decision based on the useful information contained in the data. Since a minicomputer deals with binary digits, and can store and process data and make logic decisions, it is ideally suited to applications in supervisory control systems.

A minicomputer associated with a supervisory control system is normally arranged to include the following functions:

(a) data requests – requesting data from a remote site
(b) data storage – storage of raw data received
(c) data logging – printout of status changes and periodic or requested lists of current status or value
(d) data processing – manipulations and calculations with raw data to produce useful outputs
(e) decision making – logic processes on raw data to produce a recommended course of action or, in closed loop control, to initiate action via the telecontrol system.

These functions are what distinguish the minicomputer-based supervisory control system from the earlier data-logging systems, and what add a new dimension to the techniques of supervisory control.

Third generation minicomputer systems for supervisory control have incorporated the experience gained in custom designed systems, and have become easier to use, while at the same time providing the exact information desired by the operations personnel.

Some of the important aspects of the new systems include:

(a) ease of operation in normal day-to-day use, with minimum training required

(b) readout of system conditions in clear and unambiguous terms

(c) rapid pinpointing of alarm conditions

(d) telecontrol commands that are simple to initiate, yet secure and free of possible errors that may occur in dialing or pressing of buttons

(e) ability to provide permanent records for future analysis without creating too much paper printout (a "paper mill" effect)

(f) reliable, low maintenance operation

(g) security against false operation

(h) reasonable initial cost and low expansion cost.

In a computerized system, these objectives are brought about through proper arrangement of computer hardware, choice of peripheral equipment, and application of new technologies in supervisory hardware. In addition, software plays a key role in accomplishing all of the above objectives. Figure 1 shows a diagram of a GTE Lenkurt 51H central processor designed to operate with a combination of supervisory and control systems.

## Computer Software

The software portion of a computerized supervisory control system is often thought of as an "add-on" item which is added last to make the system go. Software is actually a very important part of the system, and could even be considered as the essence of the system with the hardware portion being only a means of executing the functions contained in the software.

The software for a supervisory control system is often provided as one or both of two separate programs. One is the real-time operating program which is always needed for the functioning of the system. It is responsible for all aspects of data acquisition, storage, processing, calculations, outputs, and internal hardware monitoring. It may also include tasks for encoding, decoding, bit checking, and other data transmission functions which would otherwise be done in hardware. The other program, which is optional, is the system configurator that allows the user to add station and point names, logic equations, and mathematical routines to the software package.

## ATS Executive Program

A major advantage of a computerized system is its flexibility in allowing expansion or changes with a minimum of disruption and expense. To achieve maximum flexibility, the real-time operating program used by GTE Lenkurt is structured on a modular basis. It is based on an asynchronous tasking supervisor (ATS) executive program which consists of an interrupt supervisor and a master scheduler to allocate the computer's resources among several tasks. The interrupt supervisor diverts the computer from the main program because of a particular event or set of circumstances, to a specific address which is directly related to the type of inter-

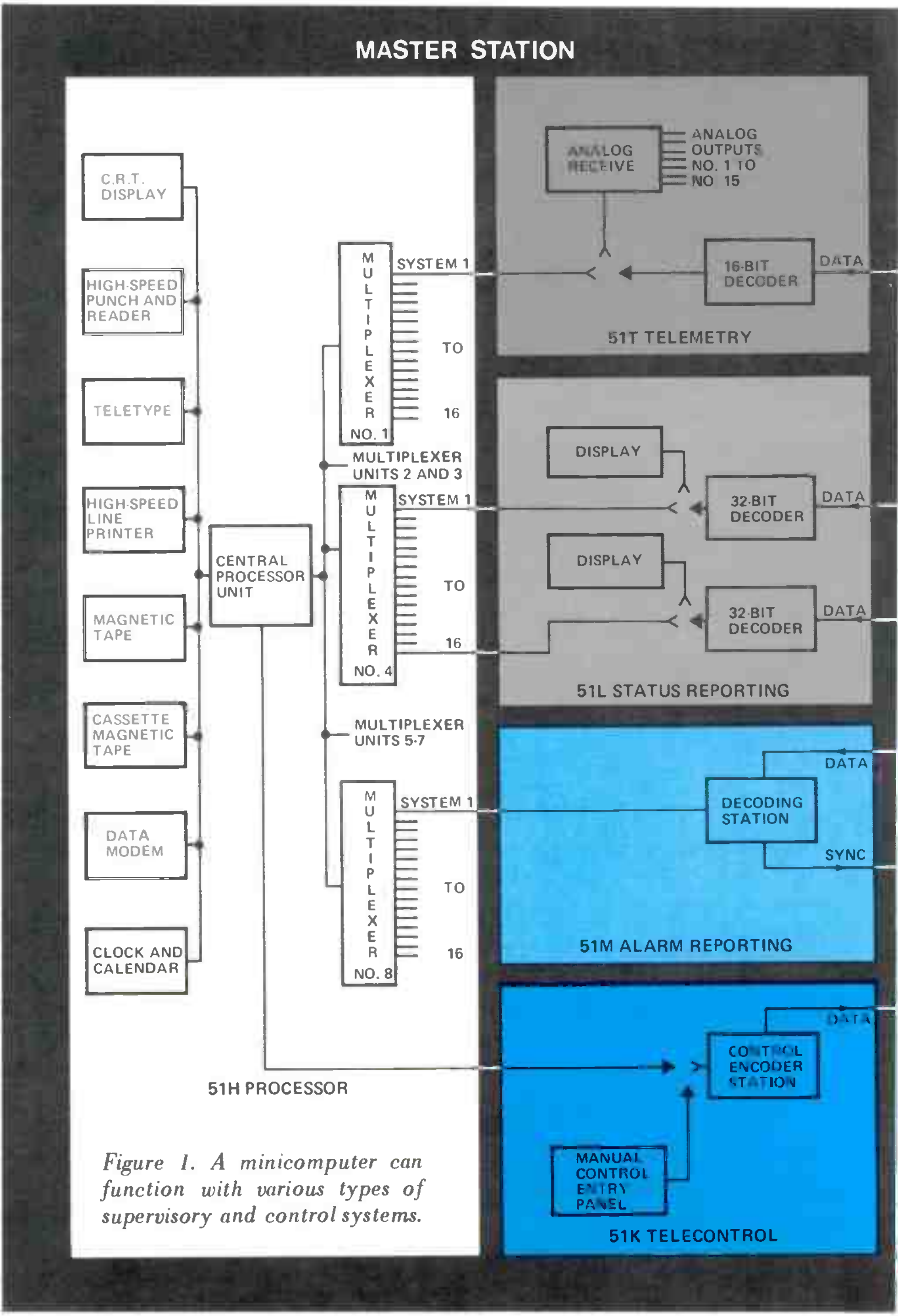
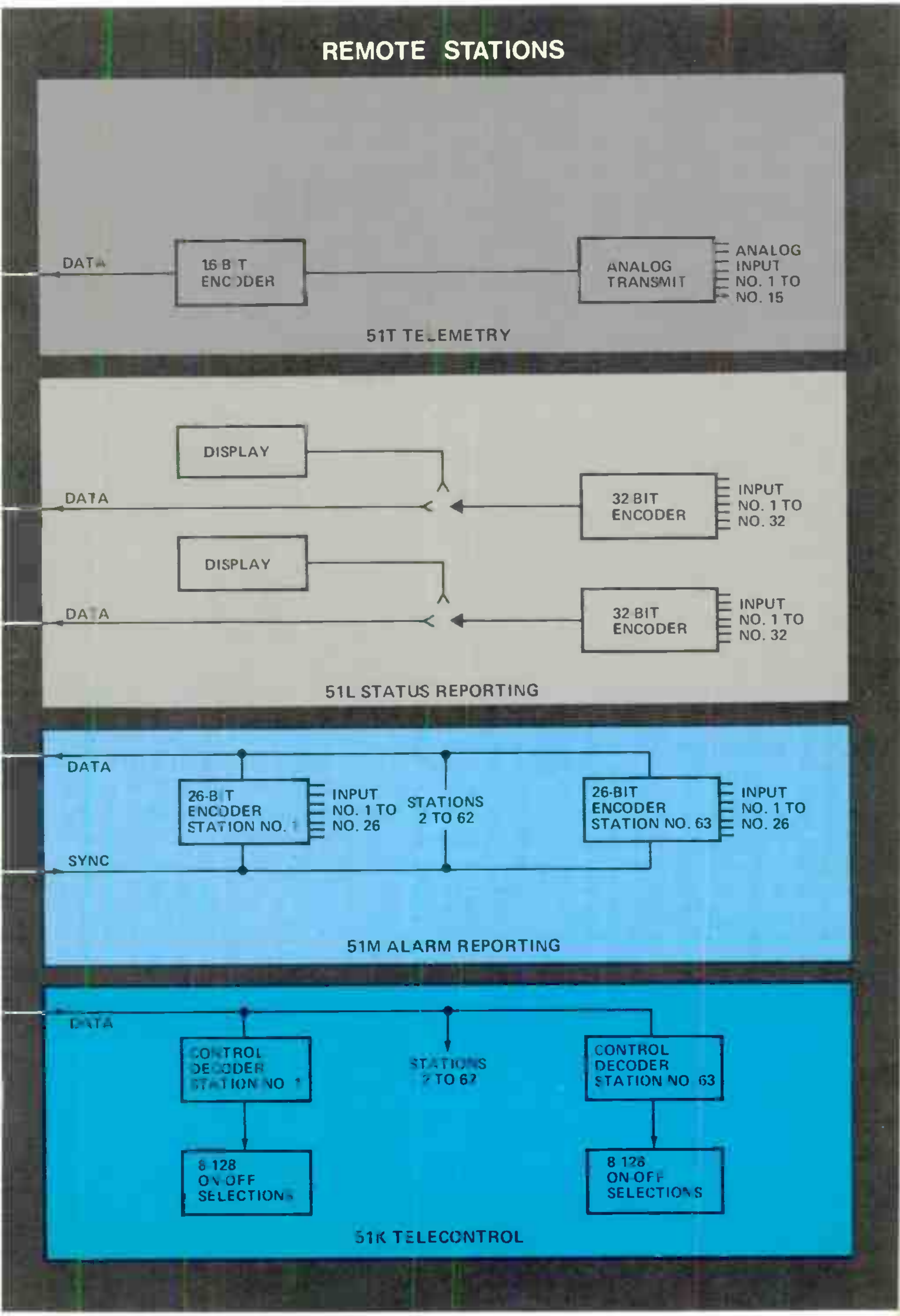



*Figure 1. A minicomputer can function with various types of supervisory and control systems.*


REMOTE STATIONS
DATA
16 BIT ENCODER
ANALOG TRANSMIT
ANALOG INPUT NO. 1 TO NO. 15
51T TELEMETRY
DISPLAY
DATA
32 BIT ENCODER
INPUT NO. 1 TO NO. 32
DISPLAY
DATA
32 BIT ENCODER
INPUT NO. 1 TO NO. 32
51L STATUS REPORTING
DATA
26-BIT ENCODER STATION NO. 1
INPUT NO. 1 TO NO. 26
STATIONS 2 TO 62
26-BIT ENCODER STATION NO. 63
INPUT NO. 1 TO NO. 26
SYNC
51M ALARM REPORTING
DATA
CONTROL DECODER STATION NO. 1
STATIONS 2 TO 62
CONTROL DECODER STATION NO. 63
8 128 ON OFF SELECTIONS
8 128 ON OFF SELECTIONS
51K TELECONTROL

rupt that has occurred. The master scheduler is called at periodic intervals to determine which program in memory is to be run. The tasks are programs, each of which is responsible for executing a certain function in the system. Typical tasks are timing, scanning, responding to keyboard requests, calculations, control and printout. The real-time operating program is comprised of all the tasks required by a particular system configuration, plus the ATS executive which supervises these tasks. To expand or modify the program, individual tasks are simply added or deleted.

The real-time operating program, due to timing and memory space considerations, generally accesses information in a coded format, and identifies station and point locations by a numerical address. For example, stations may be identified as station #00 to station #63, points from #000 to #127, and the point status as either a "1" or a "0". These numerical identifications can be translated to English language names and point conditions by using files produced by the user via the optional system configurator program.

## System Configurator Program

The system configurator program is a compiler that permits the user to create a system definition file containing names of stations and points, phrases which appear in the printout, alarm limits for analog values, logic and mathematic statements, and other items which may be required in a specific system. The value of the system configurator lies in that the user can tailor the supervisory control system to his exact requirements and, because the program allows relatively simple inputs from the user, he does not have to be a computer expert to do this. Allowing the user to retain mastery over the computer in this way is extremely valuable, as he is the person most familiar with the operation of the supervised system and the requirements for supervision and control.

The logic and mathematical statements that can be put into the system by the user are really what distinguishes the computerized system from previous forms of supervisory control. In alarm reporting, statements can be added such that logic decisions must be made by the computer when certain combinations of alarms are received, and the output becomes a summary or recommended course of action rather than multiple alarm reports. Eventual closed loop control may follow from this system configuration.

In telecontrol, similar logic statements can inhibit undesirable commands and notify the operator of the reasons, such as attempts to shut down a main system when the standby system is out of service, or attempting to start machinery when a door alarm has been received (indicating a visitor on site). Usually an override command is available for use at the discretion of the operator. Mathematical statements can be added for telemetry measurements for scaling, setting alarm limits, or making calculations with the received values.

A very useful feature to have in the program is the ability to disable certain alarms via requests through the keyboard. This applies to cases where an intermittent alarm has been acknowledged or maintenance is being done at a site and the series of alarms received would be distracting to the operator.

## Memory Space Requirements

The computers used in supervisory control are normally of the minicom-

| | | | |
|---|---|---|---|
| OPERATING PROGRAM | ATS EXECUTIVE PROGRAM | 0.5k WORDS |
| | TASK PROGRAMS | 5.5k |
| | SYSTEM DEFINITION FILE | 2.0k |
| | STATUS TABLE (POINTS X STATIONS) | 4.0k |
| | QUEUE SPACE | 4.0k |
| | TOTAL | 16.0k WORDS |

*Figure 2. Typical storage capacity for a computerized supervisory and control system.*

puter type, with core memory storage capacity of up to 32k words, expandable in about 4k or 8k word increments. The minimum storage required for a particular system is the sum of that required for the operating program, the system definition file, status tables, and output queue space. In a large supervisory system of 250 stations, each with 200 points, the required storage capacity would typically be as shown in Figure 2, based on the computer using 16 bits per word.

The queue space provides temporary storage for internal routines and allows outputs to be stored ready for printing, while the teleprinter is in the process of printing previously received messages. The amount of queue space determines how far the printer may fall behind the actual status of the system (without losing any of the data) when a greater-than-normal number of changes is received. Usually, any additional core memory which may remain is allotted to queue space.

## Man/Machine Interfaces

Peripheral equipment is a subject much closer to the user than is the actual computer equipment, and also is more loosely defined in terms of actual devices and their arrangements. Since these devices perform the man/machine interface to the whole supervisory control system, considerable thought should be given to this equipment group by both application engineers and users.

Smaller systems can use teletype machines for hard copy printout and keyboard access to the minicomputer. These machines provide economical and reasonably reliable service, and have been available for a number of years. The use of high-speed line printers with larger systems increased the printing rate from 10 characters per second to about 350 characters per second, so the printout normally could keep up with status changes in the system. The "paper mill" problem, however, is even greater with line printers, since 350 characters per second represents about 250 lines or 10 pages per minute, and while much of the printout may be unnecessary in hard copy form for permanent record, it may be required for temporary indication, if no other means of output is available.

Today, the man/machine interface is often made through the combined use of CRT terminals, keyboards, hard-copy printers, and recording devices. The type of man/machine communications handled by these devices include such functions as:

(a) alarm indications from a remote station
(b) status change indications from a remote station
(c) status of a group of points requested by the operator
(d) telecontrol command entry and check-back
(e) indication of selection and execution of telecontrol functions
(f) alarm lockout by operator for recurrent alarms or during maintenance
(g) indication of failures in supervisory control system
(h) data and time indication with each output
(i) results of logic evaluation of alarms status changes, or requests
(j) readout of telemetry values
(k) request for telemetry readout.

Depending upon the type of system to be supervised, whether it is a telecommunications network, power distribution system, oil pipeline, or transportation system, many of the above man/machine communications need not be printed out in hard copy. Others may require periodic printout, while a few require a permanent record of every occurrence.

Computerization should be considered today for any system whose total points exceed four or five hundred. Such a system might be a supervisory control system monitoring an electrical distribution network consisting of 15 substations, each with about 50 indications and 20 control functions. System totals of 750 indications and 300 control functions are more than sufficient to justify a computerized system. A full system status printout for 750 points would take at least 25 pages in hard copy, and would be largely useless, after once informing the operator of the system status. On the other hand, a CRT terminal can provide the same service without the paper, in less time, and with less effort from the operator. While the operator may not be able to read the CRT display any faster than he can a printed page, it *is* visible directly in front of the operator (no paper rolls or typing mechanisms in the way), and is associated with the keyboard from where the request came. Therefore, the reaction time is decreased, since the operator can begin to read immediately after requesting the information display, and can quickly erase the information and ask for a new display as soon as he has verified the status conditions.

When hard copy or other permanent record is required, either periodically or for selected points, it can be made by manual request through the keyboard or by a scheduling task in the computer software. In many cases, records are required for all alarm conditions, changes of status, exceeded preset limits, or control command inputs, and this can be scheduled by the software also.

Minicomputers may be used to activate lamps in display panels or mimic boards (single-line diagrams, displayed on the face of a control panel, representing the main connections of a system), and read control switches, where this remains the best means of operator interface, from a human engineering standpoint.

## Backup Arrangements

In the interests of system reliability, all equipment on which the system is 100% dependent should be protected by duplicate on-line equipment or off-line standby equipment. System reaction times govern whether it is most practical to have a full time on-line standby or to allow a cold off-line minicomputer to update itself when switched into service or to have no standby at all. Experience has shown that for some computerized supervisory control systems, duplicate on-line equipment provides many advantages in hardware economy, reliability, and operational features over standby off-line equipment. In the duplicate on-line arrangement, both minicomputers are hardwired to the channel multiplexing equipment and are normally continuously on-line and capable of performing identical functions. In the standby arrangement, one minicomputer is on-line, being connected to the channel multiplexing equipment through a switch, and carries out all functions required of the computer equipment, while the standby minicomputer is idle and can perform system operations only when it is switched on-line.

To provide back-up protection to each other, each minicomputer must be capable of wholly carrying the system. Therefore, computer hardware and software will probably be identical in both. In the duplicate on-line arrangement, the need for switching hardware is eliminated, and a source of possible unreliability is avoided. Switching between the two minicomputers for output is done internally in software, and adds another degree of flexibility to system usage, since software can usually be modified to suit new system requirements, while hardware is much more difficult and expensive to change.

## Trouble Shooting Programs

One of the problems in maintaining a computerized supervisory control system is determining what has gone wrong when the system malfunctions. The trouble may be in the supervisory hardware, the computer hardware, or the software. To add to the problem, the maintenance man may only be familiar with the supervisory hardware. To assist in trouble shooting (and debugging), programs are available for hardware simulation and diagnosis.

Hardware simulation programs allow the operator to simulate the action of a hardware item from his keyboard, so that the minicomputer can respond to the inputs in the same manner that it would to the hardware item. These programs provide substitutions for hardware suspected of malfunction, as well as providing a check on correct software operation.

Diagnostic programs perform a series of tests on hardware items suspected of malfunction, and provide printouts whenever incorrect responses are received from the hardware. Together with the simulator programs, these programs enable the operator to pinpoint a trouble spot and restore service by substitution of equipment.

## Supervisory Computer Systems

Typical systems consist of a central processor unit (CPU) and a number of interface units and peripheral devices needed for the particular application, along with a software package tailored to the application. In systems such as the GTE Lenkurt 5111 supervisory computer system, a wide range of input and output services is available, including standard teletypes, medium and high speed printers, CRT displays, magnetic or paper tape devices, standard keyboards and touch-tone type entry panels (see Figure 3).

The programming, or software, portion of the system is structured on a modular basis, consisting of small individual programs for various tasks and an ATS program to supervise these tasks. This approach allows a software package to be tailored to a particular application in minimum time and at low cost, and has the added advantage

*Figure 3. Operator area of a computer supervisory system.*

of allowing changes to be made later for system expansion, change in operating procedures, or any other reason, without rewriting the complete program.

Flexibility in system arrangements is desirable. A computerized supervisory system may, for example, be arranged to operate unprotected, or it may be a fully protected system, having lamp displays, standby equipment, or duplicate on-line equipment as protection. More than one computer center may supervise the same operating system, where this arrangement is found advantageous.

## Conclusions

Ten years ago a simple major/minor alarm from one unattended site was considered adequate – but not so today. Maintenance personnel and management alike, when receiving a call in the middle of the night, want to know exactly what is wrong before deciding to call out a repair crew. As a result, the demand for additional information from each location is increasing, with now an average of 24 to 32 separate alarm indications per site being required. High security remote control of such sites is also becoming a must, and often telemetering of certain operating measurements is desirable to further evaluate a problem.

Many alarm systems are initially being installed on a manually operated basis, utilizing visual status displays, with the knowledge that as the number of systems grows, a centralized minicomputer display system can be added economically.

As has been pioneered by oil and gas companies and power utilities, the operators of large communication systems, for example, are beginning to centralize alarm status reporting into one location, where immediate decisions can be made on utilization of alternative facilities and routes, as well as decisions on dispatching of repair crews.

Centralization of all information at one location, however, produces another problem: so much information may arrive at one time that the maintenance staff does not know what to attend to first. There is also the task of reading the alarm lamps or printouts to see what the trouble is and to determine its seriousness. All this takes valuable time.

The solution to many of the above problems may be a minicomputer to coordinate the system. The minicomputer is programmed to recognize faults, to evaluate their seriousness, to print this information out, and to recommend specific instructions on what to do.

The economical provision of such minicomputer systems, which can be readily maintained and added to by local maintenance forces, is a keystone of the new third generation supervisory and control systems. Such systems are now in service in many countries, and are being used for reporting and controlling of unattended microwave repeaters, for pipeline monitoring and control, as well as for remotely controlling and monitoring generating stations and substations by the power utilities.

Many users of supervisory and control systems will find the use of a minicomputer beneficial to their overall operation, whether it is included in initial system design or installed during system expansion.

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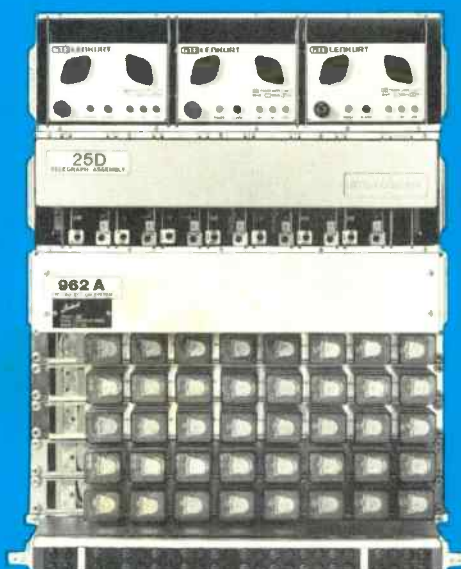


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