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MODULAR ECONOMICAL PC-BASED ALARM DISPLAY SYSTEM

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ABSTRACT

Historically, large scale safeguards alarm and communication systems have required the expensive computational power of a mainframe or midsize computer. Due to the widespread availability and reduced cost of PC-based technology, this class of machine is a much preferred solution. This paper will discuss a development program integrating this technology with inexpensive local area network (LAN) hardware to support 1) many touch panel based operator graphics consoles, 2) redundant LAN communications, 3) fault-tolerant LAN communication, 4) redundancy in subsystem failure, 5) modularity in design, 6) fault-tolerant video communication, 7) inexpensive PC-based video annotation and switcher design, 8) inexpensive video replay capability, 9) use of fiber optic communication media, 10) distributed parallel processing, and 11) minimized overall system cost. The Intel BitBus architecture was selected for network communications between PC CPUs. The network supports both fiber optic and copper media and insures message integrity/receival. Custom boards have been developed to transform PCs into modular expandable routing switchers with video presence detection and annotation.

INTRODUCTION

The Modular Adaptable Network for Alarm Reporting (MANAR) system is directed toward using PC technology to provide a versatile system with applicability to many types of facilities. The network example, shown in Figure 1, illustrates the capability and configurability of the system. Each network node may be multiple or single PCs each having a specific function. The network architecture is based on the Intel BitBus and provides the ability to survive physical attacks at any line or node network location without loss of information from the rest of the network. Special hardware was developed to provide this capability since such a network is not commercially available. The BitBus operates in a polled mode with one CPU on the network assuming the responsibility of master. Each CPU is dedicated to its specific function thus providing true modularity of both hardware and software. The CCTV node is a PC with Sandia-developed routing switcher and character annotation boards. An alternate master provides for redundancy to ensure uninterrupted operation. Other nodes within the system may be duplicated as well to achieve the desired level of redundancy required. The network structure and use of PC technology is expected to provide the functionality needed for a broad variety of applications in a cost-effective but reliable manner.

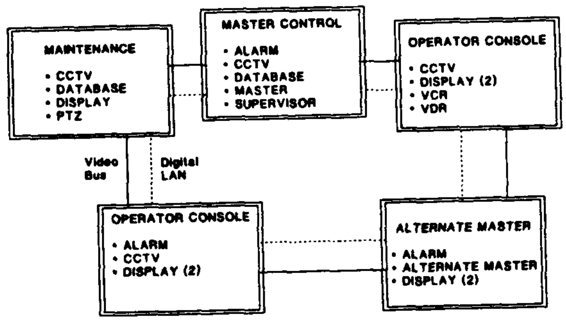

Figure 1 MANAR-Possible Large Site Application

The purpose of the MANAR is to collect alarm data and present information to security operators in a manner which promotes rapid assessment of alarms. Operators should be able to interact with the system in a straightforward manner. The system must remain reliable and rapid in its preparation of information and in its response to operator commands. It will 1) collect sensor and system component status; 2) process new status information and operator commands; 3) provide a human-engineered operator interface; 4) provide a means to record and archive alarms, operator actions, and other system events; and 5) coordinate operations from multiple manned consoles.

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This paper will address both hardware and software design features of the inexpensive modular alarm communication and control system.

OVERALL SYSTEM DESIGN

The MANAR design capitalizes on the world-wide availability, proven reliability, and low cost of today's personal computer (PC). The design utilizes only multiple source, standard PC- based technology with the exception of five custom boards. The custom boards, all designed for the standard PC bus, enable significant cost reduction for CCTV switching/character annotation and provide a fault-tolerant network capability.

A distributed network of PCs offers many advantages over the more conventional dual processor systems. These advantages include 1) rapid throughput - all CPUs function in parallel, 2) modularity and logic separation - each CPU has a dedicated function, 3) virtually unlimited system expansion, and 4) a cost-effective solution to satisfy the requirements of both small and large sites. Figure 1 illustrates a possible application of the system to a large site. The number of PCs required depends on the site requirements, such as the number of sensors and cameras, number of control consoles, degree of redundancy required, etc.

Due to the volume of standard bus PC systems being used currently, the technology "life" of the MANAR system should exceed that of system stied to a specific vendor's device. This is especially apparent with respect to rapidly changing graphics display technology. Often before a conventional system has been fielded, the vendor has discontinued manufacture, replacing the device with a newer model which may not be compatible with the previous one. Designing around long-term, established standards, such as standard PC bus using EGA/VGA, has many long-term advantages.

Video Bus

A video bus loop must be used whenever camera control is partitioned between multiple CCTV PCs. The video bus loop insures that two isolated independent video paths exist between the CCTV PC switcher and any output device. Examples of output devices include an operator's black/white assessment monitor or the Video Recording PC. The advantages of using the video bus include: 1) redundancy to single point of physical attack. In the event of a video bus cut, video is still available to all output devices; 2) the bus permits multiple video switchers to be attached to the network, reducing cable cost in routing all video lines to a single point, and 3) simplification in system expansion. Addition of new video may be accomplished by routing new cameras into a CCTV PC and tapping into the bus.

The video bus loop consists of multiple video lines, routed in a loop fashion around the site. Certain lines from the video bus will be connected to the CCTV, Video Recording, and Display PCs. Each line on the video bus will provide one of three functions: 1) general purpose live video, 2) live video destined for recording at the Video Recording PC, or 3) playback output from the Video Recording PC.

When video is not switched to a particular video bus channel, the video bus controller card residing within the CCTV PC insures the bus channel is directly connected. This permits a video signal emanating from either direction to pass through uneffected. When the Master requests that video be assigned to a channel on the bus, the CCTV PC will perform the operation. The video bus controller will detect the presence of the signal locally assigned to the bus, and will split, amplify, and transmit the signal in both directions around the bus loop. Total isolation is maintained between signal transmission on either side of the loop. Any cut will not cause reflection or in any way effect the signal reception in the opposite direction.

Network

The Intel BitBus architecture was selected for network communications between PCs. It has been proven reliable for many years in process control and robotics applications. Its cost- effective design transmits short command/response messages between PCs rapidly. With relatively minor modification to the fiber optic repeater hardware, the network has been made fault-tolerant to single point failures. It supports both fiber optic and copper media and insures message integrity/receival.

A MANAR system configuration may incorporate as few as three PCs (Master, Alarm, and Display functions) or as many as 254 PCs having a variety of different functions. Use of fiber optic communication media is recommended whenever communication between controlled access regions becomes necessary. A maximum of 25 PCs may be assigned to each fiber optic repeater before any reduction in communication rate is required. The minimum network communication rate of 62.5K Baud must be used if physical separation between fiber optic repeaters exceeds 1000 feet (or if more than 25 PCs are tied to one repeater), otherwise a maximum data rate of 375K Baud may be used. A maximum separation distance of 5000 feet between fiber optic repeaters may exist while operating reliably at the minimum communication rate.

Due to transmission overhead and time used in waiting for responses, the worst case network throughput is approximately 40K Baud. The MANAR network protocol has been designed to minimize message length requiring an average of ten bytes per PC poll. For a large site application comprising 25 PCs, each PC would be polled approximately 16 times per second.

Network commands which effect groups of sensors are understood at both Display and Alarm PC levels. This significantly reduces network traffic when an operator accesses or secures entire buildings.

The BitBus operates in a polled mode. One PC on the network has the responsibility of being the master. Remote Access Commands (RAC) are used to transfer information between master and slaves. RAC commands are efficient because they do not place any real time processing requirements on the PC processor. An 8K RAM buffer on the BitBus interface card contained within each slave holds information received as well as information not yet transmitted. All network communication is handled by the 12Mhz 8044 Bitbus processor. The PC processor can, at its convenience, determine the amount of data received and queue additional responses. Should additional performance be required of the Bitbus controller, a 16Mhz crystal and CPU may be easily substituted.

Custom firmware has been developed to insure all message traffic on the LAN is captured. This capability is used by both the Alternate Master and Database PCs to monitor all system activity. This significantly reduces the message transmission overhead required of the master by eliminating the requirement to inform these PCs directly whenever system status has changed. This firmware logic could also be expanded to provide DES encryption/decryption should this capability be required.

System Synchronization

The software operating on both the master and alternate master will be identical. The logic will listen for any existing network communication. Should none exist, one of the PCs begins serving as the master. Initially, all system status is considered un-initialized. As communication develops with other PCs attached to the network, the master becomes more knowledgeable of system status. When the alternate master is powered up, the master ceases communication with all other CPUs until the master has completed download of entire status to the alternate master. Once complete, synchronization with master is insured; the alternate master then monitors all network traffic, insuring continuous synchronization as long as traffic may be monitored.

The PC serving as the master will continuously poll all operational slave PCs attached to the network. Logic within the master will process the command from a slave, then delete the command from the slave's network buffer before proceeding to poll the next PC. When the master fails during the processing of a command, the command will remain queued for the alternate master to process. The system has been designed such that duplication in processing a command will have no effect. Thus, a fully synchronized alternate master can immediately assume master control when network communication from the prior master ceases.

The system will also insure all operator displays remain in synchronization when multiple operators may be simultaneously attempting contradictory operations. Messages which effect changes in sensor state are passed as requests to the appropriate alarm PC. The alarm PC will process the requests on a first in, first out (FIFO) basis. Responses generated from the requests will be queued to the master also on a FIFO basis. The master will receive the responses in FIFO order and will inform all displays of the actual alarm status as reported by the alarm CPU.

COMPUTER FUNCTION CLASSES

Any computer may be used which incorporates the original IBM bus design. All hardware and software is designed to operate on the minimum PC/XT eight bit address bus. Where additional processing power is desirable for system performance, an 80286 or 80386 processor may be used. One slot within each computer is required to interface to the network copper bus. An additional slot is needed for those PCs interfaced to the fiber optic loop.

For reliability reasons all PCs, with exception of the Database and Supervisor Interface, will initially boot from floppy disk then immediately load all necessary files to virtual disk. After initial boot, the executable image controlling the PCs functionality will be invoked. The fan in the power supply will be the only moving part within the PC after boot up.

Each computer within each function class runs identical software and performs a unique function which will now be discussed. MANAR is designed to support additional function classes with minimal impact due to logic isolation within each PC.

Master/Alternate Master

The master is responsible for maintaining current system status by polling all PCs attached to the network as rapidly as possible. The master will also detect system failures and report any failure to the operator. In the event of a network fault, the master will dynamically disconnect and reroute network communication as necessary. The master will also handle all autoscan operations and translation of group sensor and camera operations.

The alternate master will continually maintain current system status through observation of all network traffic. Should traffic cease, the alternate must instantly assume master responsibility.

Supervisor Interface

All system software, database files, and site maps will reside on the supervisor interface PC. This PC will permit a supervisor to make any logic changes or site configuration changes from this terminal through user-friendly pop-up windows. Changes made may be tested and dynamically downloaded to the necessary PCs while the system is operating. Any PC may be remotely rebooted to introduce the modifications into the operational system. When informed by maintenance that network faults have been repaired, the supervisor may direct the system to reconfigure the network to include repaired hardware. Some hardware repair may be automatically detected, and the system will reconfigure to use the repaired equipment immediately.

Database

This PC will serve two functions. First, it will archive all system history by monitoring all network traffic. History can be archived to either/or both hard disk and printed listing. Second, it will serve as a maintenance terminal, where maintenance personnel may come to obtain a current list of non-operational hardware requiring service within the MANAR system.

CCTV

The CCTV PC will switch and annotate video as requested from the Master. Quality of each video signal controlled by the PC will be monitored and reported to the Master. Both live and recorded video channels will be controlled. Time and date annotation will be placed on all recorded video. As many CCTV PCs may be attached to the network as necessary to provide localized routing switcher control. Localized control will reduce routing cost of bringing all video lines to a single point. Distributed switching control does not permit a single-point attack to the video subsystem. Cameras which support dual outputs may be connected to both a primary and backup CCTV PC. The backup will serve as a hot standby which can instantly assume primary responsibility.

Video Recording

MANAR is presently being designed to use an inexpensive winchester disk based video image file to archive assessment video. The Video Recording PC will control up to eight image file devices in parallel. Thus, as many as eight simultaneous alarms may occur and video can be captured for each. The number of fields captured per alarm and capture rate are adjustable. Assuming ten fields are captured per alarm occurrence, the eight units may retain assessment video for more than 1900 queued alarms. Whenever a particular alarm assessment is complete, the storage used may be reused to record a new alarm. Use of optical storage devices is under investigation to provide a permanent means of video archival.

Display

Operators interact with the MANAR system through touch panel controlled graphics displays. A mouse is provided as an alternate control device. Each operator display is controlled by its own Display PC. Displays may be coupled together and operate as a pair - one used to specify detail, the other to provide a global site view. The mode (display detail only, site only or either) in which a particular display operates is selectable from the touch panel. All detail views will contain a miniaturized global site view which continuously reflects the overall site status. This enables the site situation to be continuously observed even while operating from a single display.

As many operator displays may be attached to the network as needed.

Each Display PC database will contain information pertinent to a particular operator's function. For example, assume it was desirable to partition the workload between operators. One operator had primary responsibility to assess perimeter alarms and alarms within buildings 1 through 3. Another operator will service Buildings 4 through 10. The supervisor could prevent either operator from assisting another by preventing an operator from changing state or ending assessment on the other's sensors. In this case, both operators may still observe what the other is doing since the status of all sensors is provided to each operator.

The supervisor may choose to permit operators to work together; however, should any alarms occur within an operator's area of concern, they would be brought to the operator's attention as higher priority than other alarms in the system. Either operator could manually address any alarm or change the state of any sensor in the system.

Instead of dividing the workload between local areas of interest, the supervisor could have both operators address all alarms equally on a first come, first served basis. The ability to effect changes in sensor state and order in which alarms are recommended to an operator for assessment is defined within the display database at the sensor level. Thus, any combination may be defined to limit or highlight sensor control for a specific operator workload.

Ability to use particular cameras and maps are also controlled through the database in a similar manner. View of a particular camera at an operator's console may be granted or denied on an individual camera basis. Certain areas of the site may be denied view to an operator by disallowing the view of system maps showing the restricted site region.

A primary concern to any security system is the collusion scenario in which an authorized operator places key areas in access in an attempt to defeat the system's function. MANAR permits operators to monitor each other's activity. Whenever suspicious behavior is recognized, an operator may remotely disable another operator's console. This action results in an alarm indication to be registered at all consoles except the one being disabled. This operator may not disable another operator's console until a specific time window has elapsed, preventing control of more than two consoles at once from an adversarial operator.

CUSTOM BOARDS

Video Routing Switcher Controller

In the past, security systems which required video crosspoint switching for closed-circuit television had no other option than to use expensive equipment designed primarily for the broadcasting industry. Although this equipment performed as required, it was bulky and relatively expensive. In order to reduce cost and minimize space, a PC-based video switching system was developed.

A 16x16 video routing switcher has been developed to occupy a single slot within a standard PC. Several identical boards may be daisy-chained together to construct variable capacity routing switchers. PC expansion cabinets may be used to further expand switching capacity. Because the boards are directly PC-bus driven, switching is accomplished more rapidly than using traditional RS-232 communication. Options are available to switch the video signal immediately, perform the switch on the next vertical interval, or switch video based on an externally-supplied master sync signal. The board may be used to switch black and white as well as color signals.

In addition to performing video switching, each board has the ability to detect video signal presence. All 16 input channels are tested in continuous succession for signal presence. Since each board can process signal presence detection in parallel, loss of video may be detected much more rapidly than previously possible.

The PC performing the video switching may also serve as a manual-switching controller. Input from the PC keyboard is used to control the switching functions while the PC monitor will display routing switcher and presence detection status.

Fabrication and parts cost of one 16x16 video switching board is less than $400. A standalone 64x16 video switcher with four of these boards, output channel annotation, and the PC is estimated to cost less than $2500. Typical cost of an equivalent conventional switching system would exceed $20K.

Independent software libraries have been developed to rapidly permit any application program to use the video-switching board and the character annotation board described in the next section. Documentation on installation and use of the software library to interface with the video switcher board is being written.

A single PC may be configured to perform all video routing switching required, or multiple smaller capacity PC switchers may be attached to the network to control cameras at several locations. Use of multiple switchers may reduce the cost and vulnerability of bringing all video lines back to a single point. The MANAR system will support either application of the PC-based routing switcher controller.

The MANAR system uses the same video routing switcher board in the CCTV, Display, and Video Recording nodes. Within CCTV nodes, the board permits the master to route video to operator displays and to the video recording system for archival. The board is used within the display CPU to sample the video signals from both directions on the video bus. Should video only be present from one direction, this video signal is routed to the operator's monitor. The Video Recording node uses the board to route video to the appropriate recording device and route the recording device replay to the appropriate operator monitor.

Video Character Annotation

An inexpensive PC bus based character annotation capability has been developed for use within the MANAR system. The card occupies a single slot within a standard personal computer and provides independent annotation of 16 video channels. Annotation text can be blinking or solid white and can be generated in a variety of font sizes. The cost, less than $300 per board, is less than one-fourth the cost of a typical single channel commercial RS-232 based character annotation controller. Because the board interfaces directly to the PC bus, time in annotation modification is reduced considerably from that required by a serial interface. Documentation on installation and use of a software library used to interface with the board is being developed.

Video Bus Controller

The Video Bus Controller will permit redundant video communication paths to exist between the video-switching controller and operator's monitor. The board will physically reside within each CCTV node. It will have independent control of all 16 channels of switched output. Should a particular channel not be switched through this controller, the board will permit the channel video to pass through, physically connecting opposite directions of the video bus together. If video is placed on the bus through this CCTV PC, the board will insure that the video signal is transmitted around opposite directions on the video bus and that any cut on one side will not effect video signal quality transmitted in the other direction. Only one of these boards is required within each CCTV PC. The video bus controller card will cost less than $400 for parts and fabrication.

Fiber Optic Network Repeater

Development of this board was critical to obtaining a truly fault-tolerant LAN. The board permits physical disconnection of both transmit and receive channels from either direction on the fiber optic loop under software control. Whenever a failure in communication is detected by the master, the network is analyzed; and should a break in a fiber optic link be discovered, the master will issue software commands to physically disconnect from either side of the cut section.

Should power failure occur within the PC containing the fiber optic repeater, the board will continue to function from power supplied on the local copper LAN provided any PC attached to the LAN is powered up. Should power be lost to all PCs, the board has a 12-hour rechargable battery backup.

Horn Controller

A PC bus based horn controller card will be installed in each Display PC. The horn controller is a microprocessor-based board used to control volume, rate, pitch and tone of various sounds necessary to audibly alert an operator to changes in site security. The cost of this board is under $200 and is directly coupled to a speaker located at the operator's console.

SOFTWARE

All MANAR software is written in Microsoft C running under MS DOS. All software is well documented and modular in design, following established style standards. All source code is available with exception of that contained within the commercial database management package. Software residing on each PC consists of an executable image and database file. Display PCs also contain system map files. All PCs providing a similar function will operate from an identical executable image.

COST

The cost of the hardware/software to handle a small to medium size facility (80 alarms, 32 cameras) is less than $53K. This cost excludes cable cost, trenching, fencing, lighting, grading, installation, cameras, and sensors. The cost includes a fully redundant AMCS alarm system, redundant alarm interface, redundant network master, dual operator console with rack/furniture/display, 20 minute UPS on all equipment, video switcher, character annotation with redundant video communication, and VDR capacity to store 500 alarm scenes (ten fields/scene) and record two simultaneous alarms.

To better appreciate the cost reduction provided by the MANAR design, it is appropriate to compare the system costs using MANAR versus other current technology approaches used for a large site application. The hardware/software cost of a specific current system fabricated using conventional technology is roughly $775K. The same system design implemented using MANAR hardware/software would cost about $300K.

Additional long-term cost savings will be recognized from elimination of vendor-specific CPU maintenance contracts. Because all CPUs used require identical, commonly available parts, cost and size of spare parts inventory will also be reduced from that typically required.

DEVELOPMENT SCHEDULE/STATUS

A demonstration MANAR system is scheduled for September 1989. The demonstration system will illustrate the functionality of the following PCs networked together with a master:

Alarm - interfaced to AMCS with 64 sensor inputs
CCTV - configured to control 32 cameras
Video Recording - configured to control two video image files
Display - dual display, single operator console
Alternate Master - cold standby operation only

Integration of database archival and hot standby alternate master capability will be added to the demonstration system in fiscal year 1990. Development of an integrated access control capability will be initiated during this period.

CONCLUSION

PC and LAN technology may be successfully applied to large scale safeguards alarm display and control systems. The technology will considerably reduce costs of future system implementations while providing sufficient performance, reliability, modularity, and flexibility. Many improvements in new areas including insider protection, distributed video switching, and redundancy in video communication have been addressed. Inexpensive PC-based video switching and character annotation capability may be readily adapted and used for many applications other than fixed-site security.

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