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In recent years, the new integrated circuit technology has spawned the development of many low cost high performance microcontrollers. With the improvement in the processor speed, instruction sets, and memory capacities, these microcontrollers are ideal for the implementation of Control-Oriented Local Area Networks (COLAN) for real-time distributed control systems. The design of COLAN V has evolved from a series of predecessor networks developed at Oregon State University. COLAN V is a low cost, real-time, distributed local control network. The network provides complex control and monitoring of activities remotely from a centralized master scheduler. With a single master scheduler, bus contention and the need for complex protocols are eliminated. Since twisted-pair wire is used as the communication medium, cost is kept at a minimum.

As a practical control application, a microcontroller-based local network task node for controlling slide projectors was implemented. The use of a task node to concurrently control several slide projectors enhances the overall effectiveness of a presentation without the high cost associated with the commercially available composer systems. In addition, COLAN V can control and monitor different presentations in different locations through the use of different task nodes from the centralized master scheduler. Since the commercially available composer systems are non-networkable, this is not possible. When monitoring is not required, COLAN V provides the capability of storing a presentation onto a tape along with the corresponding sound. This offers a convenient and economical method for storing an entire audio/visual presentation that can be played back at a later time.

A Multi-Media Presentation System For Control Oriented Local Area Networks (COLAN)

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1. INTRODUCTION

1.1. Background

The term local area network (LAN) is generally used to refer to a general-purpose communication network that provides interconnection of a wide variety of data communicating devices within a limited geographic area. In recent years, the rapidly evolving field of local area network technology has produced a steady steam of commercially available products. The reasons behind this rapid development can be found in some fundamental trends in the development of integrated circuits.

The advent of today's start-of-the-art microprocessors and microcontrollers offers a dramatic reduction in the cost and the improvement in the processing speed. In comparison, today's processors have speeds, instruction sets, and memory capacities comparable to the medium-scale mainframes of a decade ago. This trend has spawned a number of changes in the way information is collected, processed, and used. There is an increasing use of small, dispersed, single-function systems that are more efficient and cost effective than the large central time-sharing systems. This leads to the reduction in the complexity for the implementation of distributed real-time control system.

Complex control and monitoring systems often require multiple microcontrollers, each optimized and located for the best performance [HERZ

87]. In order to achieve overall control and synchronization, a single system scheduler may be used to manage a group of microcontroller-based systems or simply called task nodes.

1.2. Overview of COLAN V

The design of COLAN V (Control Oriented Local Area Network) evolves from a series of predecessor networks developed at Oregon State University. Utilizing Intel's 8051 family microcontroller, the implementation of COLAN V provides a fully functional network for distributed real-time control systems. COLAN V can provide both remote data acquisition and control applications in real-time. It consists of a host scheduler and one or more task nodes.

1.3. Objective for Thesis

One of the most effective means of presenting new ideas and concepts is the use of visual aids. One exceptionally popular and economical method has been the use of slide projectors to formulate a slide show or a presentation. A single projector or several projectors can be used. The use of several projectors enhances and adds variety to the presentation. With several projectors, the presentation is then composed of sequences of alternating images shown through the different projectors. The simplest arrangement is the use of two projectors. Each will take a turn showing a slide. While one projector is showing a slide the other will advance to the next slide in its tray. By showing the images with no other means of control to the projector, the viewers will simply see a sequence of images being flashed onto the screen. This abrupt flashing of images may not be very pleasant to the viewers. A better solution is to provide a smooth transition between every image. In addition to being more pleasant to the viewers, this adds variety and enhances the overall effectiveness of the presentation. Effects such as superimpose, and variable fade-in and fade-out rates add interest and variety to the presentation. This is especially useful when a presentation needs to be repeated many times for different groups of audiences. The ability to store or record the presentation will be of great importance. This requires a system that can store and play back the audio portion of the presentation and the ability to synchronize it with the slide images or the visual portion of the presentation.

Composer systems that are currently available in the market place with the above capabilities are quite costly and non-networkable. In addition, these systems do not provide the capability of controlling and monitoring several presentations located in different locations simultaneously from a single centralized controller. They generally require an operator at every viewing location.

The high cost and the limitations of the commercially available composer systems are the prime motivation for the design and implementation of COLAN V for the specific application of multi-media presentation. COLAN V is a low cost, high performance, distributed local-control network. It's design is based on a series of experimental networks developed at Oregon State University. The implementation of COLAN V requires the following:

1) Modification of the task node operating system developed for previous COLANs to enhance memory management and to provide user selectable baud rates.

2) Design and implementation of a task node to provide concurrent control of the slide projectors and the different modes of operations.

3) Implementation of a tape recorder as the system scheduler when network monitoring is not required.

Figure 1-1 depicts the configuration for COLAN V. Shown in the figure are the major components in the network: the task nodes, the network interface units (NIUs), and the system scheduler which is composed of a modem, a host computer, and a tape recoder. The remaining discussion will describe the functionalities of all the components in the network. As a practical control application, the discussion will focus primarily on the design and implementation of the multi-media presentation portion of COLAN V.

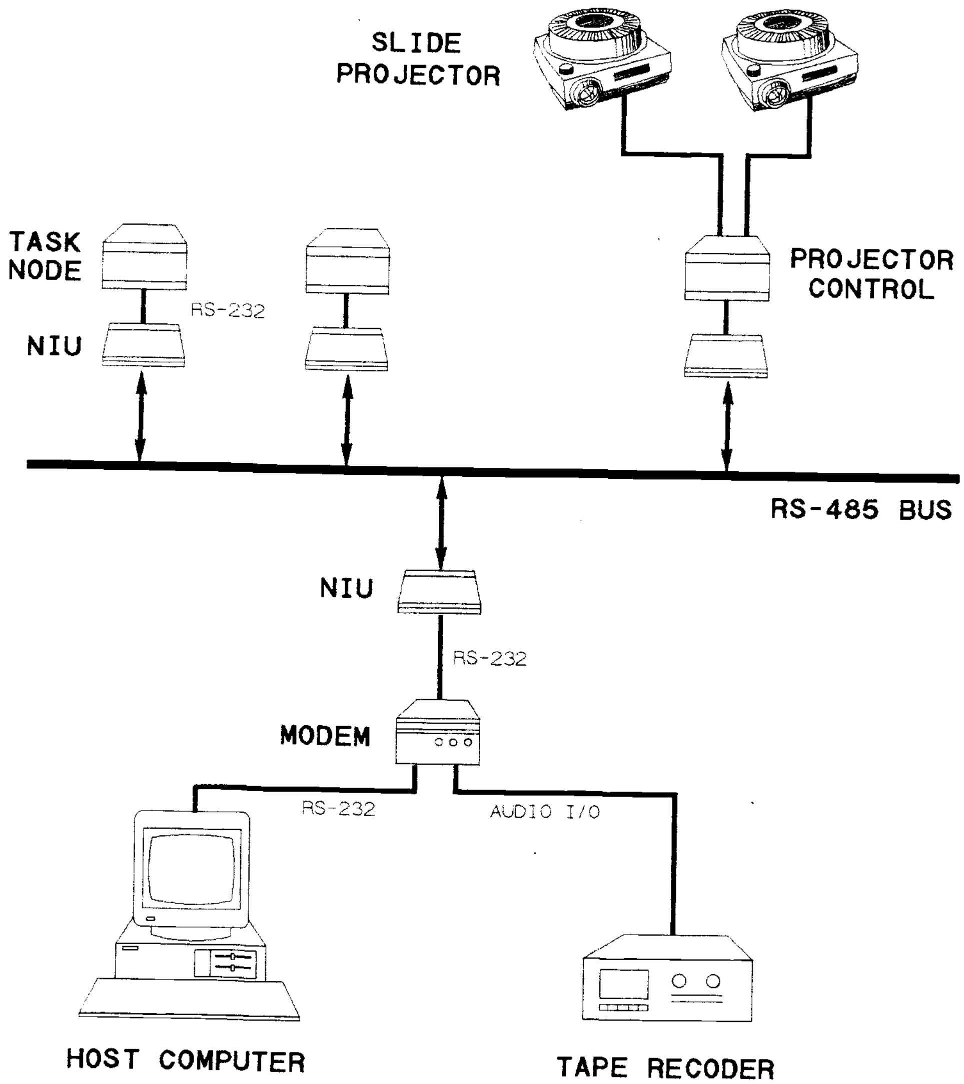

Figure 1-1. COLAN V - Multi-Media Network Configuration.

2. LOCAL AREA NETWORK TECHNOLOGY

2.1. Overview

The principle technological alternatives that determine the nature of a local area network are its topology and transmission medium. These determine the type of data that may be transmitted, the speed and efficiency of communications, and even the kinds of applications that a network may support [ROSE 82]. The following sections examine the topologies and transmission media that are currently available for local area networks.

2.2. Network Topologies

Local area networks are often characterized in terms of their topology. The topology of a network is the way in which the nodes are connected. Topologies for local area networks are of three main types: star, ring, and bus or tree. The bus is a special case of the tree with only one trunk and no branches. These three types of topologies are depicted in Figure 2-1.

In the star topology, a central switching element is used to connect all the nodes in the network. A station wishing to transmit data sends a request to the central switch for a connection to some destination station. The central element uses a technique called circuit switching to establish communication. Circuit switching is a method of communicating in which a dedicated communication path is established between two stations. Once the circuit is set up, data are exchanged between the two stations as if they were connected by a dedicated point-to-point link. Digital data are sent as a continuous stream of bits.

The ring topology consists of a closed loop, with each node attached to a repeating element. Data circulate around the ring on a series of point-to-point data links between repeaters. A station wishing to transmit waits for its next turn and then sends the data out onto the ring in the form of a packet, which contains both the source and destination address fields as well as data.

The bus topology is characterized by the use of a multiple-access, broadcast medium. Because all devices share a common communications medium, only one device can transmit at a time, and as with the ring, transmission employs a packet containing source and destination address fields and data.

For the ring and bus topologies, two types of digital switching techniques are generally employed: packing switching and message switching. Packet switching is a method of transmitting messages through a network, in which long messages are subdivided into short packets. Unlike circuit switching, packet switching does not require a dedicated communication path. Rather, each packet contains a destination address and is passed from source to destination through intermediate nodes. At each node, the packet is received, stored briefly, and then passed on to the next node. Message switching is similar to packet switching except that the entire message is contained in one packet. Usually, packet switching is more efficient and rapid than message switching.

2.3. Transmission Media

The transmission media most commonly used for local area networks have been the twisted pair and the coaxial cable. Twisted pair is typically used for low-speed transmission. It is relatively low in cost and is readily available. Coaxial cable provides higher throughput and supports a larger number of devices. It can span greater distances than twisted pair wire. Two transmission methods, baseband and broadband, can be employed on a coaxial cable. Baseband supports a single digital data channel, whereas broadband can support multiple simultaneous analog data channels. Associated with the higher performance of using coaxial cable is the higher cost.

2.4. Medium Access Control

All local area networks consist of a collection of devices that must share the network's transmission medium. Some means of controlling access to the transmission medium is needed so that any two particular devices can exchange data when required. A network's access method is the technique by which the network distributes the right to transmit among its participating stations. How access is controlled is constrained by the topology and is a trade-off among competing factors: cost, performance, and complexity. In general, access control can be centralized or distributed. Most LANs use distributed access methods in which each station participates equally in controlling the network.

There are two general classes of distributed access: random, or "contention," and deterministic. With a random access method, any station has the ability to initiate a transmission at any time. With a deterministic access method, each station must wait for its turn to transmit. The two most common medium access control protocols are the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) for the bus topology and the Token Ring for the ring topology. The CSMA/CD method uses the random access method and the Token Ring method uses the deterministic access. These two medium access methods are discussed in detail in section 2.6.

2.5. OSI Reference Model

The design of most LANs is based on the reference model for Open System Interconnection (OSI) proposed by the International Organization for Standards (ISO). The OSI reference model is intended to:

- Provide a common basis for coordination of standards developments for the purpose of system interconnection.
- Allow existing standards to be placed into perspective within the overall reference model.
- Identify areas for developing or improving standards.
- Provide a common reference for maintaining consistency of all related standards.

The OSI reference model has seven layers. The principles that were applied to arrive at the seven layer are as follows [TANE 88]:

- A layer should be created where a different level of abstraction is needed.
- Each layer should perform a well defined function.
- The function of each layer should be chosen with an eye toward defining internationally standardized protocols.

- o The layer boundaries should be chosen to minimize the information flow across the interfaces.

- o The number of layers should be large enough that distinct functions need not be thrown together in the same layer out of necessity, and small enough that the architecture does not become unwieldy.

As depicted in Figure 2-2, the OSI reference model consists of seven layers which are relatively independent of each other. A message originating in an upper layer of a sending station passes down through the layers and over the medium to the receiving station, where it passes up to the layer corresponding to its originating layer. From the protocol stand-point, the message may be thought of as passing directly from one layer to a corresponding layer. Table 2-1 provides a brief description of the functionality of each layer.

2.6. IEEE 802 Standards for LAN

From the OSI model, the IEEE Standards Committee adopted several standards for LANs. These standards, collectively know as IEEE 802. The purpose for adopting these standards is to standardize the means of connecting digital equipment within a local area, as opposed to the longer distances served by telecommunications common carriers. The standards define the specifications for the first two layers, physical and data link, of the ISO Open Systems Interconnection Reference Model. As depicted in Figure 2-3, the two lower layers of the ISO Open Systems Interconnection reference model map onto three layers of the local area network reference model. Levels 3 through 7 of the OSI model are outside the scope of the local network model except to the degree that the logical link control layer has to interface to the network layer.

Classification of the IEEE 802 standards for LANs is based on the topologies and media access methods of the networks. The standards are divided into 5 parts: 802.1, 802.2, 802.3, 802.4, and 802.5. Figure 2-4 depicts how each part of the standards fits into the OSI Reference Model. The IEEE 802.1 standard provides the overview to the set of standards and defines the interface of each part of the 802 standards. The IEEE 802.2 standard describes the functionality of the upper portion of the data link layer and the Logic Link Control protocol. The remaining three parts describe the three LAN standards: CSMA/CD, token bus, and token ring. The following table shows the media access method and the network topology that is associated with each standard.

STANDARDS	ACCESS METHODS	TOPOLOGIES
802.3	*CSMA/CD*	*Bus*
802.4	*Token Bus*	*Bus*
802.5	*Token Ring*	*Ring*

With CSMA/CD access method, two or more stations share a common transmission medium. When a station wants to transmit data, it first listens to the medium to determine whether another transmission is in progress. If the medium is idle, the station may transmit. Otherwise, the station waits for some period of time and tries again, using one of the "persistence algorithms." This is the Carrier Sense Multiple Access (CSMA) portion of the protocol. While the station is transmitting data, it continues to listen to the medium. If a collision is detected during transmission, it immediately terminates the remaining transmission and waits a random amount of time before attempting to transmit again. This is the Collision Detection (CD) portion of the protocol.

The three "persistence algorithms" are:

1) Nonpersistent - The station waits for a random amount of time and then senses the medium again.

2) 1-Persistent - The station continues to sense the medium until it is idle, then transmits.

3) p-Persistent - The station continues to sense the medium until it is idle, then transmits with some preassigned probability p.

The token bus access method is a technique in which the stations on the bus forms a logical ring. Stations are assigned positions in an ordered sequence, with the last member of the sequence followed by the first. Each station knows the identity of the stations preceding and following it. A control packet known as the token regulates the right of access: When a station receives the token, it is granted control of the medium for a specified time, during which it may transmit one or more packets and may poll stations and receive responses. When the station is done, or time has expired, it passes the token on to the next station in logical sequence. During steady-state operation, each station gets access to the medium sequentially according to its position in the logical ring.

In the Token Ring access method, stations are arranged on a transmission medium which physically forms a ring. To gain access to the bus, a station must first acquire the token which circulates around the network. A token is a special bit pattern that provides a technique to control when a station can get access to the bus. There is only one token within a given network. When all stations are idle, the token packet is labeled as a "free" token. A station wishing to transmit waits unit it detects the token passing by, alters the bit pattern of the token from "free token" to "busy token," and transmits a packet immediately following the busy token. There is now no free token on the ring, and so other stations wishing to transmit must wait. The packet on the ring will make a round trip and be purged by the transmitting station. The transmitting station will insert a new free token on the ring when it has completed transmission of its packets and the busy token has returned to the station [STAL 84].

2.7. Selection Criteria for a LAN

There are a number of factors that must be considered when selecting or designing a LAN. Each of the LAN configurations and control schemes described earlier has both strong and weak points, requiring the designer to make trade-offs in selecting the appropriate system design. A primary criterion in selecting a LAN is to minimize the cost of installing, operating, and maintaining the system without sacrificing network performance and reliability. Other costs include: media (twisted pair wire or coaxial cable), media access units (transceivers), and interface unit. The cabling and installation costs of a LAN are not the dominant costs.

The major costs are the media access and interface components which must be obtained for each device attaching to the network. Another design criterion is the functionality of the network. Functionality deals with the services the network will perform. This generally defines the characteristics of the network and what services are available. Data-throughput is another criterion that must be examined. The required data-throughput will usually dictate what medium and topology to use. This affects the maximum transmission rate and allowable cable length. The above LAN design criteria and others are incorporated into the COLAN V architecture which is discussed in the following sections.

2.8. COLAN V and OSI Model Relationship

With respect to the OSI reference model, COLAN V employs the bus topology with network nodes sharing a common communications medium. The design of COLAN V follows the first two layers of the OSI reference model. The physical layer of COLAN V is composed of twisted-pair wires and uses the RS-485 standard as the interface between the communication medium and the network nodes. Medium access is controlled by the network master scheduler. Any access to the medium by the nodes must be first initiated by the master scheduler. For the data link layer, command packets are used to provide interchange of data between the nodes and the master scheduler. Each command packet contains information on the destination of the packet, the task to be performed by the addressed node, and any other necessary paramenters. Specific details for each of the above network components are discussed in later sections.

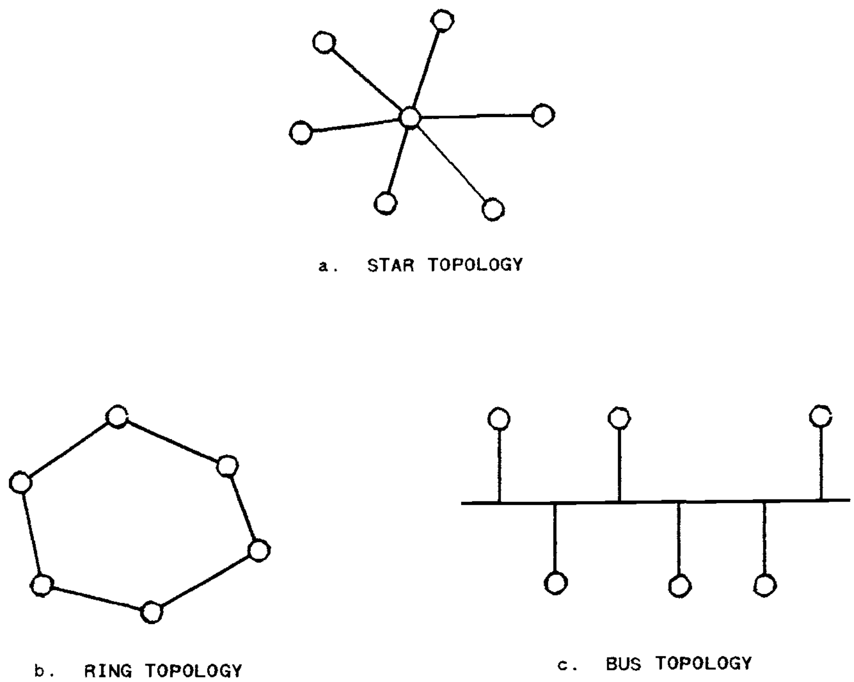

Figure 2-1. Local Area Network Topologies.

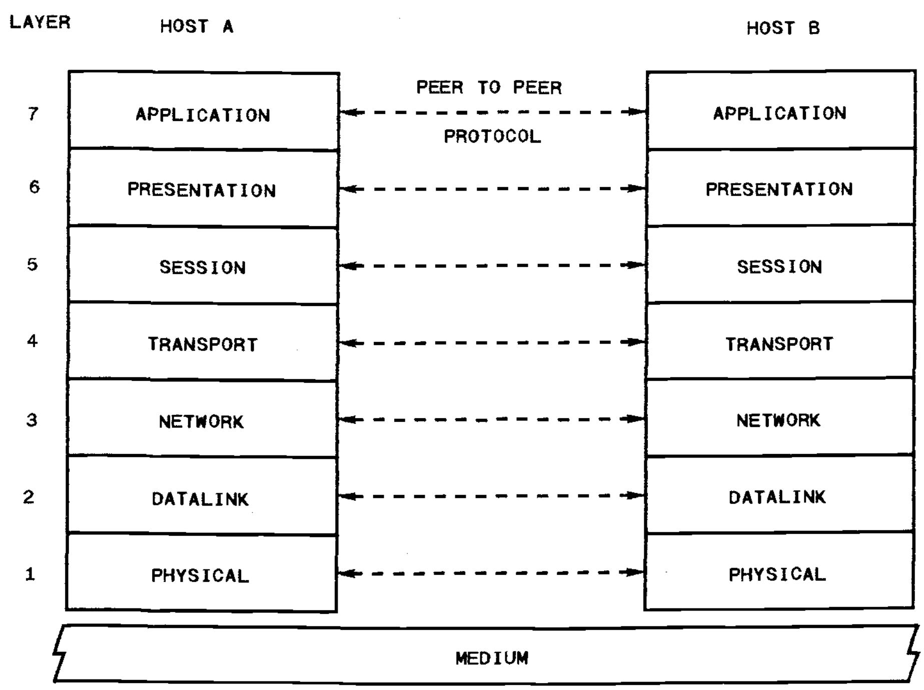

Figure 2-2. ISO Open System Interconnect Model [MYER 82].

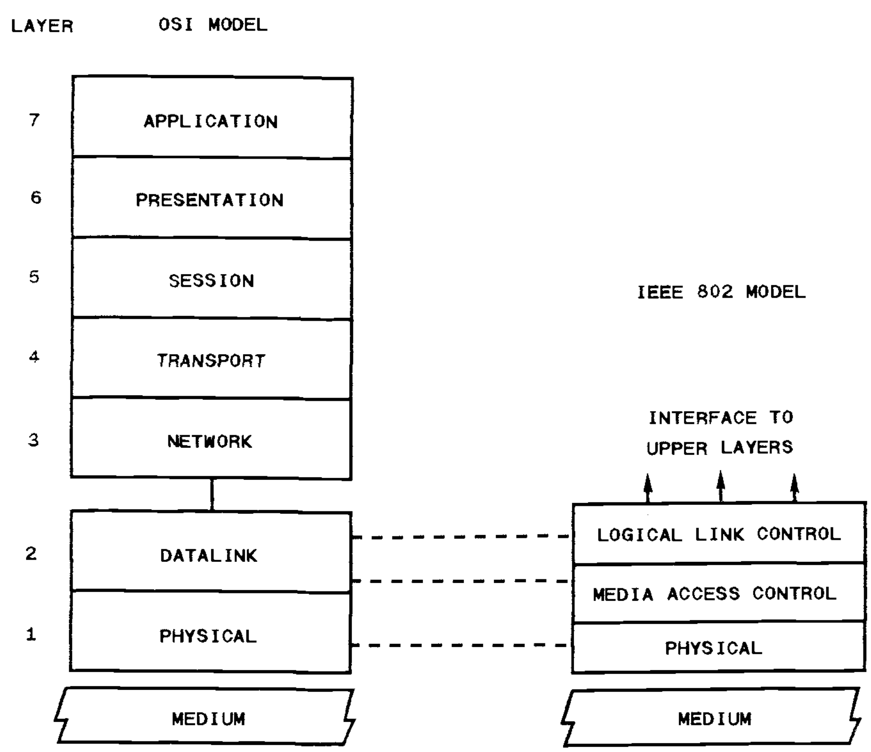

Figure 2-3. IEEE 802 Model Relationship to OSI Model [STAL 84].

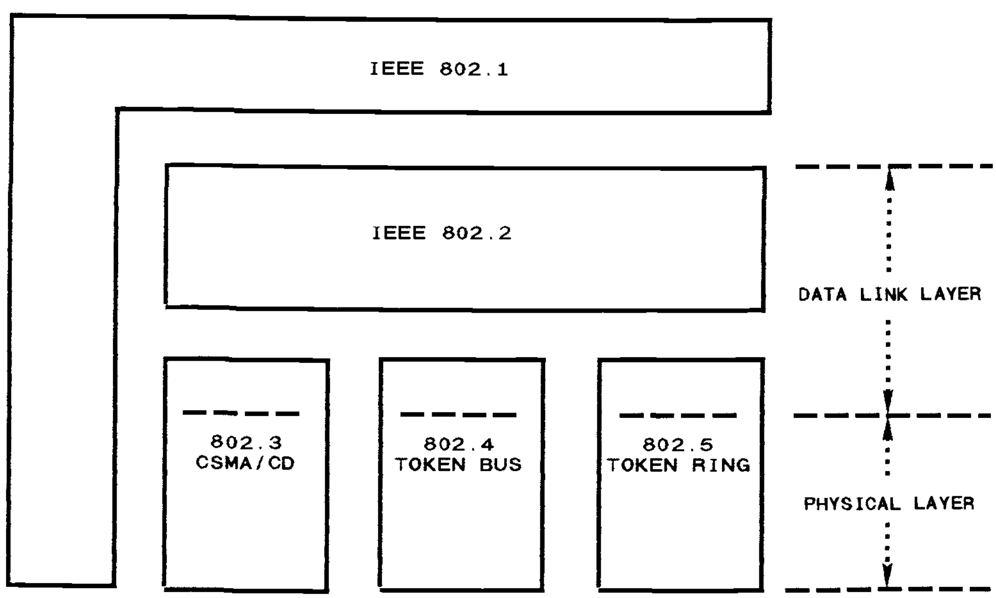

Figure 2-4. IEEE 802 Local Area Network Standard.

Table 2-1. Definitions of OSI Layers.

LAYER	EXAMPLE	FUNCTION
1 Physical	V.21, X.21, RS-232, RS-422,	*The physical, electrical, functional and procedural characteristics needed to connect, maintain and disconnect the physical circuits between places of equipment.*
2 Data Link	ANSI X3.28, HDLC, BSC	*Provides for the reliable interchange of data between pieces of equipment connected by layer 1 facilities.*
3 Network	X.25	*Provides for the exchange of data and control between users and the network and for the request of network services.*
4 Transport	TCP	*Provides a network independent interface to transport services, assuring reliable and sequential data and control flow.*
5 Session	Log-on protocol	*Supports a dialog (structured exchange) between processors.*
6 Presentation	X.28, X.29	*Provides required transformations of information being processed.*
7 Application	Application protocol	*Performs application/system activities to provide/support the information processing function of the enterprise.*

3. FUNCTIONAL ARCHITECTURE OF COLAN V

3.1. Overview

COLAN V is a low cost, high performance, real-time, distributed local control network. The goal of this network is to provide complex control and monitoring of activities on the network. These may include: 1) coordinating and synchronizing multiple equipment, 2) collecting data from remote sensors and transducers, 3) controlling and monitoring specialized instruments, and 4) automating routine tasks.

The objectives for the COLAN V design are: 1) low cost, 2) simple to operate and install, 3) high performance, 4) ease of maintenance, and 5) expandable. Using the criteria described in the previous sections, a bus topology was adopted for the network using a master system scheduler to control and monitor activities on the network. With a single master scheduler, bus contention and the need for complex protocols are eliminated. In addition, this scheme provides centralized control and data collection by using remote task nodes. Since twisted-pair wires are used as the communication medium, cost is kept at a minimum. Task nodes can easily be added or deleted without affecting the performance of the network. Each task node contains specialized hardware and software to perform the required tasks. Collectively, the task nodes provide the distributed resources that are available on the network.

3.2. The Concept of Task Oriented Structure

The distributed real-time control system set up by COLAN V requires a system scheduler to function as the master which manages all the activities of the task nodes on the network. The system scheduler initiates activity by formulating control or data packets and sending the packets on the system bus. By the proper sequencing of tasks, complex control and monitoring activities in the network can be performed.

The operation of this distributed control system is composed of individual tasks executed by the appropriate task nodes. Each command packet describes a particular task to be performed by the addressed task node. By the nature of the bus, all the nodes receive the packets simultaneously. Only the task node with the matching address will perform the appropriate task described by the packet.

A task node can be viewed as the slave which carries out the commands or tasks issued by the master. In this network, a common operating system resides on every task node. This operating system has two main functions. First, it receives properly addressed task command packets from the scheduler and stores them in memory. Second, it initiates tasks, terminates tasks, and manages the tasks.

3.3. Command Packet Format

A command packet describing a task is composed of five data fields enclosed in a set of flags. The left and right braces are used to denote the beginning and the ending of a packet, respectively. The meaning of each field is inferred by its position in the packet. Blanks are used only to separate the fields and for clarity.

A typical packet has the following format:

{ AA P NN S DD }

The individual fields in the packet shown above have the following definitions:

{ Packet begin flag. This character denotes the start of the packet.

AA Destination node address. This field consist of two ASCII characters indicating the destination of the packet. The special address "00" is reserved as the universal address that directs the packet to all nodes on the network.

P Pre-Execution control character. This single character describes the method to process the task. There are three permissible characters:

- : Queued Task. The task is to be placed at the end of the Task Queue and only to be executed at the completion of all the preceding tasks on the queue.

- ? Synchronized Task. Same as Queue Task except the task will not start executing until the host issues the special synchronize task.

- ! Immediate Task. The task is to be executed immediately. If a queued task is currently running the queued task is temporarily suspended and will resume upon the completion of the immediate task.

NN Task number. The two ASCII characters specify the task to be performed.

S Post-Execution control character. This single character describes the operation to be performed on the packet after it has been executed.

. Execute Once Task. The task is to be executed only once and is discarded after completion of execution.

\+ Re-Queued Task. Place the task at the end of the Task Queue at the completion of execution.

DD Data field. This field may have up to 5 pairs of hexadecimal characters. The use of this field allows passing of arguments from the host.

} Packet end flag.

4. HARDWARE IMPLEMENTATION

4.1. Overview

The implementation of COLAN V consists of a number of microcontroller-based systems or task nodes linked together via the RS-485 bus. Each node is composed of a stand-alone single-board computer using Intel's 8051 family microcontroller and application specific hardware components. The functionality of each node depends on the need of each specific application. Each task node has a built-in RS-232 interface. An RS-232 to RS-485 network interface unit is used to link each node with the RS-485 bus. Every task node on the network requires a NIU to communicate to the bus. Figure 4-1 depicts a typical interface from the task node to the RS-485 network bus via the NIU.

A system scheduler is used to control and monitor the activities on the network in real-time. It is responsible for scheduling and controlling the activities on every task node. Each node is responsible for carrying out all the specific actions requested by the system scheduler. In essence, this network can be viewed as a master/slave type of network, where the master is the personal computer or the system scheduler and the slave is the task node. The slave will only listen to the master and will perform according to what is specified by the master. With this type of configuration, bus contention and the need for complex protocols are eliminated.

If only unidirectional communication is required from the master to the slave, then the personal computer can be replaced by a tape recorder unit acting as the master. The tape recorder will then be responsible for scheduling all activities in the network by simulating how the host computer would send out commands. The following sections describe the main components that are associated with the microcontroller-based system common to all nodes and the specific circuitry for implementing the multi-visual presentation portion of the network.

4.2. Microcontroller-based System

The key component of COLAN V is the microcontroller system that is used to serve as the main processor of each task node. The microcontroller system is based on a single-board computer design originated by Binary Technology, SIBIC II, which utilizes one of the Intel's MCS-51 family microcontrollers as the main processor operating at the system clock rate of 11.0592 MHz. In addition to the microcontroller, several other essential components are used to form the core system in the task node. These components provide program storage, data memory, and peripheral interface. These components are:

1. One 8K program memory EPROM (2764)
2. Four 8K data memory RAMs (6264)
3. One programmable peripheral I/O interface (8255)

Figure 4-2 depicts the architecture of the microcontroller based system with the above components and the control points to the slide projector control circuitry.

4.2.1. Architecture of the 8051 Family

The Intel MCS-51 family of microcontrollers includes the 8031, 8032, 8051, 8052, and other CMOS versions. Common features of all the microcontrollers in the MCS-51 family are:

1. 8-bit CPU optimized for control applications
2. Extensive Boolean processing capabilities
3. 64K Program Memory address space
4. 64K Data Memory address space
5. 4K bytes of on-chip Program Memory
6. 128 bytes of on-chip Data RAM
7. 32 bidirectional and individually addressable I/O lines
8. Two 16-bit timer/counters
9. Full duplex UART
10. 6-source/5-vector interrupt structure with two priority levels

4.2.2. Memory Organization of the Board

As described in the previous section, the microcontroller-based system has one 8K EPROM and four 8K RAMs. The EPROM is for storing the operating system common to all nodes and the specialized library of tasks for each task node. It is the library of tasks that makes each node unique and defines the functionality of each microcontroller-based system. Data memory resides on the four 8K RAMs. This provides a total of 32K of system and user memory.

4.2.3. Communication and I/O Interface

Communication between a task node and the system scheduler or the master is through the microcontroller's on-board serial port via the network interface unit. For the node, the serial port is programmed to support half-duplex, asynchronous, serial transmission up to a maximum data rate of 9600 baud.

The Intel 8255 is a programmable peripheral I/O interface component providing high output drive capability. Three ports are available to provide a total of 24 programmable I/O's. The microcontroller-based system for the slide projector control application uses the 8255 component to drive the solid state relays. The relays are used to control the intensity of the lamp and the different modes of operations within the slide projector. A single 8255 component has enough I/O pins to accommodate up to four slide projectors.

4.2.4. Node Address and Baud Rate Select

The network address of each task node and the associated communication baud rate are specified by an 8-bit DIP switch bank depicted in Figure 4-9. The least significant 5 bits, SW.4 through SW.0, are used to defined the task node address and the most significant 3 bits, SW.7 through SW.5, are used for selecting the baud rate. With 5 bits, 32 unique node addresses, from 0 to 31 can be selected. This allows the network to have a maximum of 32 task nodes. Each task node can operate at one of the five baud rates specified by the 3 most significant bits on the DIP switch. Although each node has an option of selecting one of the baud rates, in order for the network to function as a whole, all task nodes must have the same baud rate settings. The following table shows the DIP switch setting, where SW.7 is the most significant bit, for the desire baud rate selection.

BAUD RATE	SW.7	SW.6	SW.7
300	*OFF*	*OFF*	*OFF*
1200	*OFF*	*OFF*	*ON*
2400	*OFF*	*ON*	*OFF*
4800	*OFF*	*ON*	*ON*
9600	*ON*	*OFF*	*OFF*

4.3. Application Specific Component

In addition to the components composed in the microcontroller-based system, other components were used to implement the specialized node for the multi-visual presentation application. Figure 4-3 depicts the block diagram of the components that form the slide projector control circuitry.

4.3.1. Relays Random/Zero Voltage Turn-on

To provide a totally independent, optically isolated interface, solid state relays are used to provide the interface between the 8255 programmable parallel interface with the circuitry in the slide projectors. Potter & Brumfield's SSR and SSRQ series solid state relays are ideal for interfacing between the logic output of TTL and AC loads such as the lamp in the slide projector.

Two types of the relays are used in the implementation, random voltage turn-on and zero voltage turn-on. Random voltage turn-on relays provide full phase control and the zero voltage turn-on provides reduction in EMI and RFI. Phase control is a method of applying the ac supply to the load for a controlled fraction of each cycle. In this operation, the relay is an off or open condition for a portion of each positive and negative cycle, and then is triggered into an on condition at the half cycle determined by the control logic. The phase control capability of the relay allows the amount of power to the lamp in the slide projector to be fully controllable; thus, provides full control of the intensity.

Although the phase controllable relay is quite useful in this application, it has one main disadvantage, generation of EMI. Each time the relay is turned on the current rises from zero to the load-limited current value in a very short time. This generates a wide spectrum of noise which may interfere with the operation of nearby electronic equipment unless proper filtering is used. For the lamp control application, any EMI introduced will not be crucial since the electronics are well isolated from the relay.

In addition to filtering, EMI can be minimized by zero-point switching. A zero-point switch controls sine wave power in such a way that either complete cycles or half cycles of the power supply voltage are applied to the load. This reduces, or eliminates, turn-on transients and the EMI. This type of relay is excellent for ON/OFF ac load control. It is used to interface with the circuitry in the slide projector for controlling the advancing of the slides in both the forward and reverse direction.

4.3.2. Zero-Crossing Circuit

The key element for controlling the intensity of the slide projector lamp is the ability to have full control over the supplied power. In addition to the use of the random voltage turn-on relay, a zero-crossing detection circuitry is used to establish a reference for determining when in the cycle to turn on the phase control relay. The main component in the zero-crossing circuitry is the RCA zero-voltage switch component. The RCA's CA3059 zero-voltage switch is a monolithic silicon integrated circuit design. It is used in a variety of AC power switching applications. For the zero-crossing detector, this component synchronizes the output pulses of the circuit at the time when the AC cycle is at zero voltage point. Figure 4-4 depicts the zero-crossing circuitry using the CA3059 and other components. The HCPL2630 Opto-Isolator is used primarily to isolate the signal grounds.

4.3.3. Projector Interface

The control link from the projector task node to the slide projector is through the projector's accessory receptacle. Figure 4-5 depicts a simplified view of the slide projector's internal control circuitry. Operations such as controlling the power to the lamp, and advancing the slides forward and backward are controlled through the slide projector's accessory receptacle shown in Figure 4-5. Figure 4-6 shows the control interface between the microcontroller to the relays and the relays to the receptacle. For speed, one of the I/O ports, P1, on the microcontroller is used to trigger the SSR random voltage turn-on relay which controls the power to the lamp. The Potter & Brumfield's SSR relay is an optically isolated, phase controllable solid state relay in one standard package. The advancing of slides is controlled through the 8255 programmable parallel interface via the SSRQ relays. Each SSRQ relay package contains four totally independent and optically isolated solid state relays. This provides four ON/OFF switches with maximum current loads of 20 amperes each. With the I/O's available, four projectors can be controlled by a single task node.

4.4. System Scheduler

The function of the scheduler is to control, schedule, synchronize, coordinate, and monitor the activities in the network. In particular, for the master/slave type of network, it is the system scheduler that initiates all the activities in the network. The primary function of the slaves are to carry out the orders specified by the scheduler.

4.4.1. Personal Computer

To provide total real time control of the network, a personal computer is used as the system scheduler. The use of the personal computer as the system scheduler provides full control and monitoring of the network. In this configuration, control to the nodes is through the use of the network interface software which resides in the host computer. Depending on the level of sophistication and the ease of use, different interface softwares are currently available. One such interface package is the Task Master Controller (TMC), developed at Oregon State University [LIM 89]. This is a programmable task scheduling software which offers network users a friendly environment to perform the task programming process and as a development tool.

4.4.2. Tape Recorder

Another way of controlling the activities in the network is the use of a tape recorder. In this operation the tape recorder serves as the system scheduler, providing only instructions to the task nodes. There is no communication from the task nodes to the scheduler, only from the scheduler to the task nodes. One advantage of this is that once the sequence of commands has been stored onto a tape the personal computer can be utilized for other functions. There is no waste of resources. This is possible only if the communication required is from the scheduler to the task nodes. If communication is required from the task nodes to the scheduler then a personal computer must be used. The ability to store the series of command packets or tasks onto the tape provides a mechanism for synchronizing the images with the audio portion of the presentation. This provides a low cost and a convenient method for storing an entire audio/visual presentation that can be viewed at a later time.

A typical stereo tape recorder system uses two audio channels, one for the left and the other for the right, to create the three-dimensional auditory perspective effect. If the stereo effect is not important then one of the channels can be used to store the command packets and the other for sound. The command packets are the tasks that describe the instructions for the task nodes to perform. To transfer the digital information from the computer to the analog form for storage onto the tape, a modem is used. Likewise, to convert the analog information back to the digital form that is useful to the network, the same modem is used.

4.4.3. Modem

A modem (modulator/demodulator) is a device for transmitting and receiving serial data over a narrow bandwidth communication channel. It fills the need in a data communication network to provide an interface between the system that carries analog information, and a computer system that operates on digital information. The tremendous growth in data communication has spurred the development of many diverse modems for use on normal dial-up telephone networks, remote data collection, tone signalling systems, and remote process control.

Among the diverse modems, the 300 baud low-speed modem is perhaps the most common type of modem encountered in data communications. Its advantages are many: low cost and complexity, full-duplex operation, and high reliability. The TMS 99532A low-speed modem chip, manufactured by Texas Instruments, is such a modem. It employs a modulation scheme called

Frequency Shift Keying (FSK). This technique uses different frequencies to encode digital data for analog transmission. A logic one causes the modem to transmit one frequency while a logic zero causes another frequency to be transmitted. Figure 4-7 shows the circuit which utilizes the TMS 99532A in the implementation of the modem.

4.5. Communication Medium

In data communication system todays there are two basic means of communicating between components. One method is single-ended, which uses one signal line and a signal ground for data transmission. The other is differential which uses two signal lines. The Electronics Industry Association (EIA) has developed several standards to simplify the interface in data communication systems.

4.5.1. Single-Ended Data Transmission

The first single ended transmission, RS-232, was introduced in 1962 and has been widely used throughout the industry. It was developed for single-ended transmission over short distances at relatively slow data rates. With the need to transmit data faster and over longer distances, RS-423, a newer standard for single-ended applications, was established. Today's higher-performance systems, demanding data transmission at faster rates over longer distances, are rapidly making RS-232 and RS-423 inadequate.

4.5.2. Differential Data Transmission

When transmitting at very high data rates, over long distances and through noisy environments, single-ended transmission is often inadequate. In these applications, differential transmission nullifies the effects of ground shifts and noise signals which appear as common-mode voltages on the transmission line. EIA standard RS-485 defines such a differential interface that allows multipoint interface. It is intended to allow for as many as 32 driver-receiver pairs on a data bus.

4.5.3. Twisted-pair cable

One of the most commonly used inexpensive and readily available communication mediums is the twisted-pair cable. Telephone communication is one area which uses this medium extensively. The fact that the wires are twisted provides shielding against interference. If differential transmission techniques are used, twisted-pair cable can transmit up to 10 Mbps on 50 feet cable length. The following table shows the comparison between the RS-232C and the RS-485 standards.

SPECIFICATION	RS-232C	RS-485
Mode of Operation	*Single-Ended*	*Differential*
Number of drivers and receivers allowed on one line	*1 Driver, 1 Receiver*	*32 Drivers, 32 Receiver*
Maximum cable length	*50 Feet*	*4000 Feet*
Maximum data rate	*20 Kbps*	*10Mbps*

4.6. Network Interface Unit

The purpose of the network interface unit is to provide the necessary signal level conversion between RS-232 of the task nodes and the host system to the RS485 network bus. Typically, RS-232 logic signals operate at the levels of +/- 12 volts and RS-485 operate at the signal levels of +/- 5 volts. Figure 4-8 depicts the internal circuitry for the Network Interface Unit. Four major components are used to implement the interface unit. The RS-485 high speed differential line driver (75174) and receiver (75175) set. These components have tri-state outputs that are optimized for balanced multipoint data bus transmission. The driver has a wide positive and negative common mode range for multipoint applications in noisy environments. The receiver features high input impedance, input hysteresis for increased noise immunity, and input sensitivity.

Logic level conversion is accomplished by using the MAX232 component manufactured by Maxim. This component includes both the RS-232 receiver and driver in a single package. One attractive feature of this component is that it operates on a single power supply voltage of +5 volts. It has an on-board charge pump voltage converter which converts the +5 volts input power to the appropriate voltage level needed to generate the RS-232 output levels.

The tri-state control of the differential line driver is driven by the host or by the task node. The line driver is turned-on only when the host or the task node wants to transmit data onto the RS-485 bus. Otherwise, it is at high impedance or tri-stated to prevent unnecessary loading of the bus. An inverter is used to provide a complementary control of the line receiver. When the line driver is enabled for transmission, the line receiver is disabled, and vice-verse. Normally, the line receiver is enabled until data transmissions are required. A one shot composed of the 74LS123 is used to ensure that no other task nodes are transmitting before a task node transmits any data onto the bus.

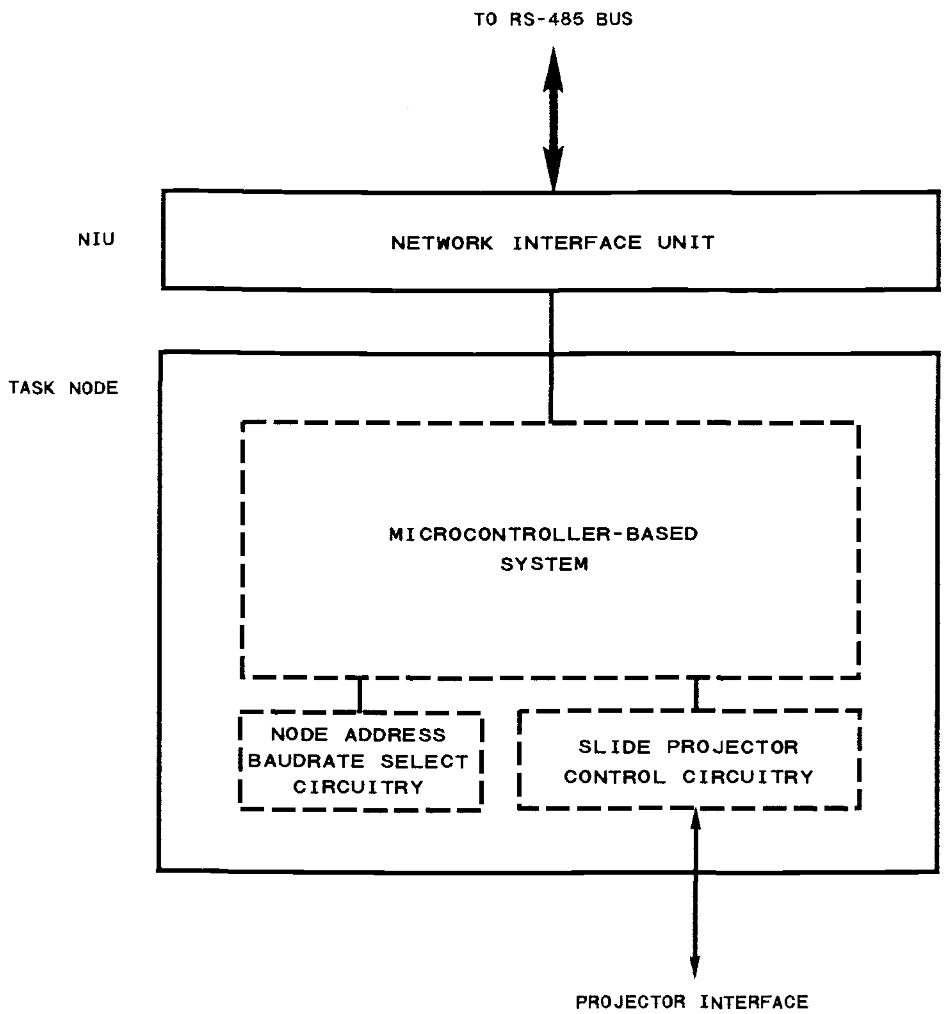

Figure 4-1. Task Node to Network Bus Interface.

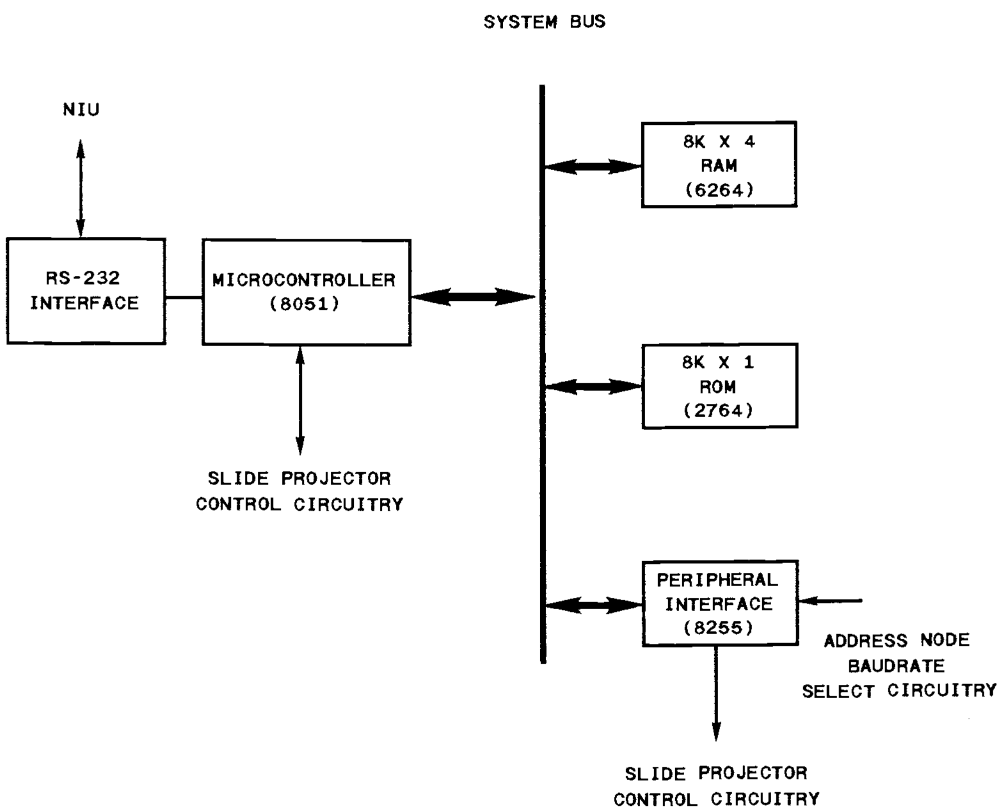

Figure 4-2. Microcontroller-Based System.

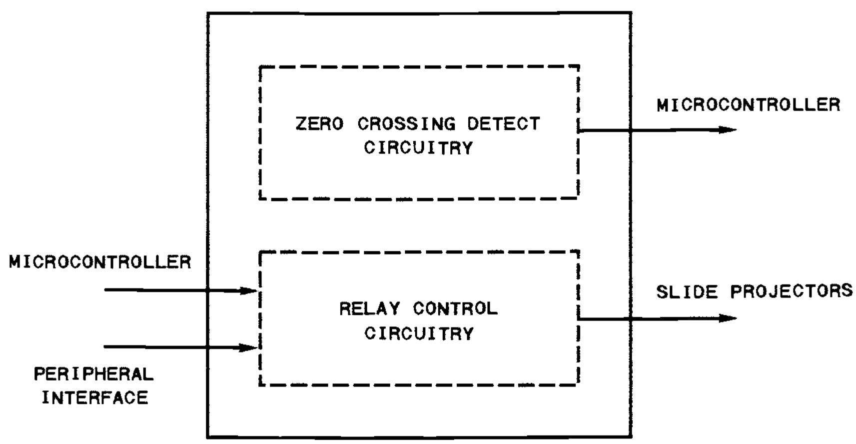

Figure 4-3. Slide Projector Control Circuitry.

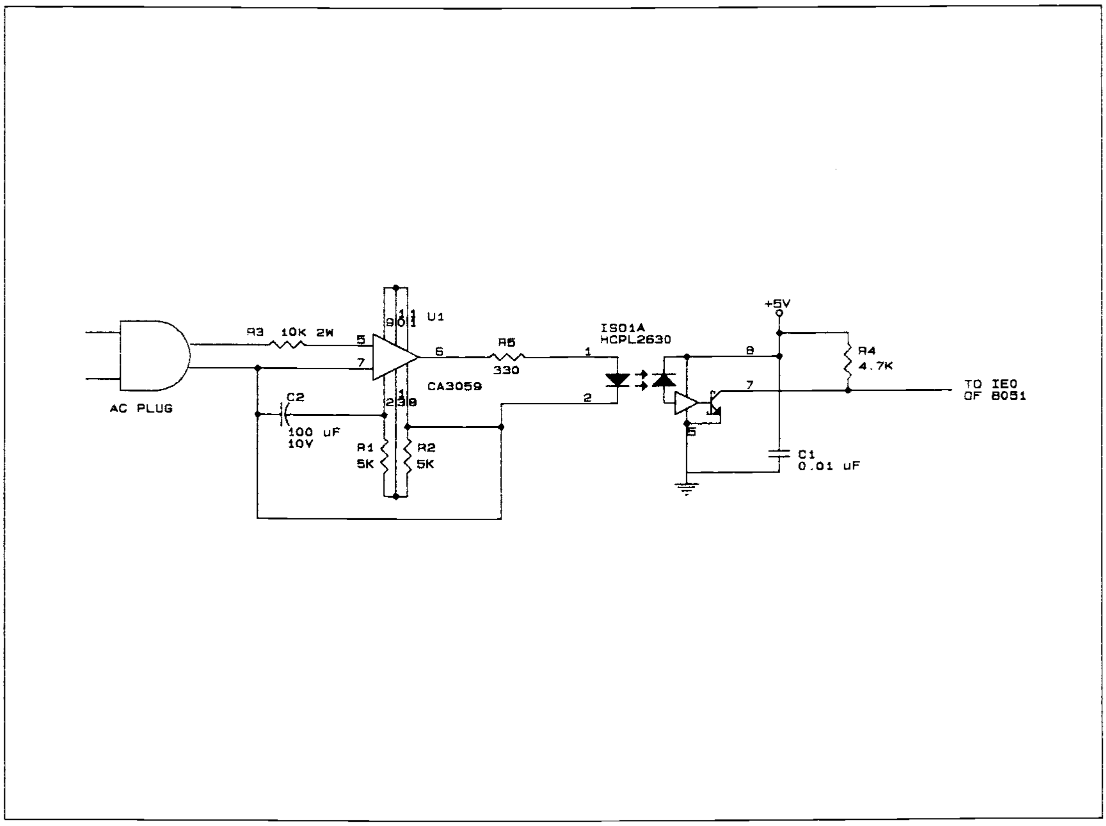

Figure 4-4. Zero-Crossing Detect Circuitry.

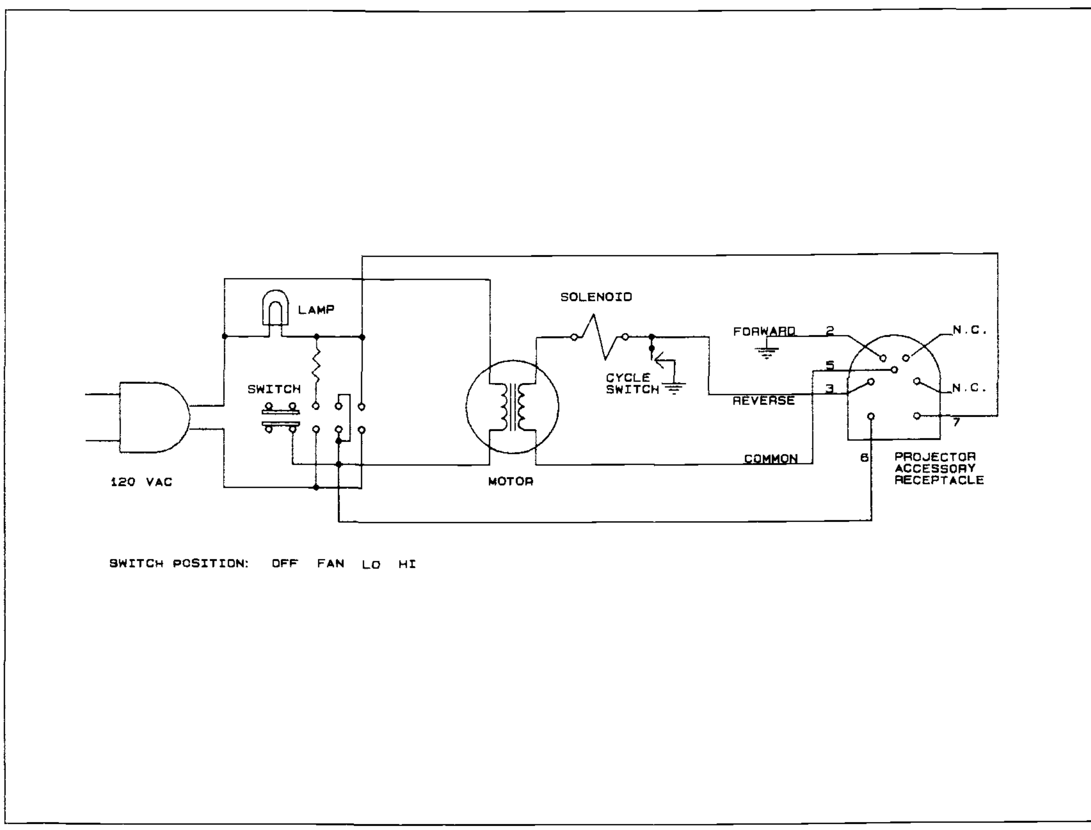

Figure 4-5. Slide Projector Internal Control Circuitry.

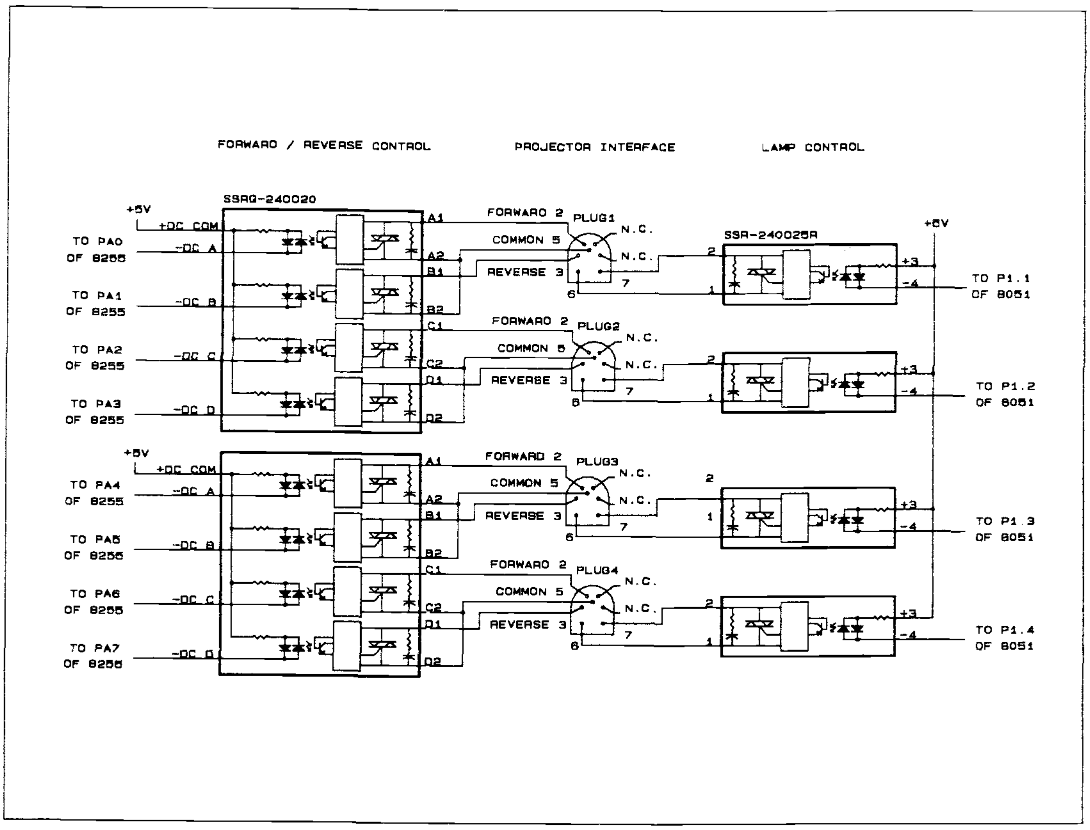

Figure 4-6. Control Relays to Slide Projectors Interface.

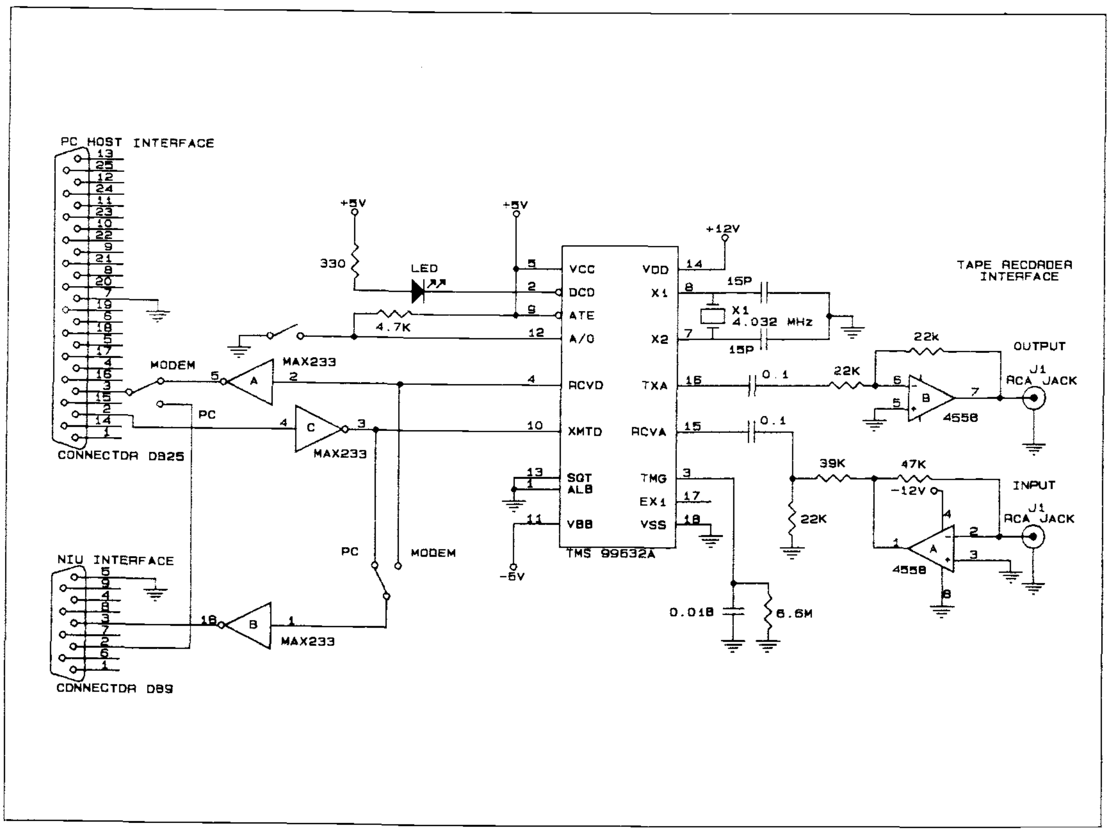

Figure 4-7. Modem Utilizing the TMS 99532A.

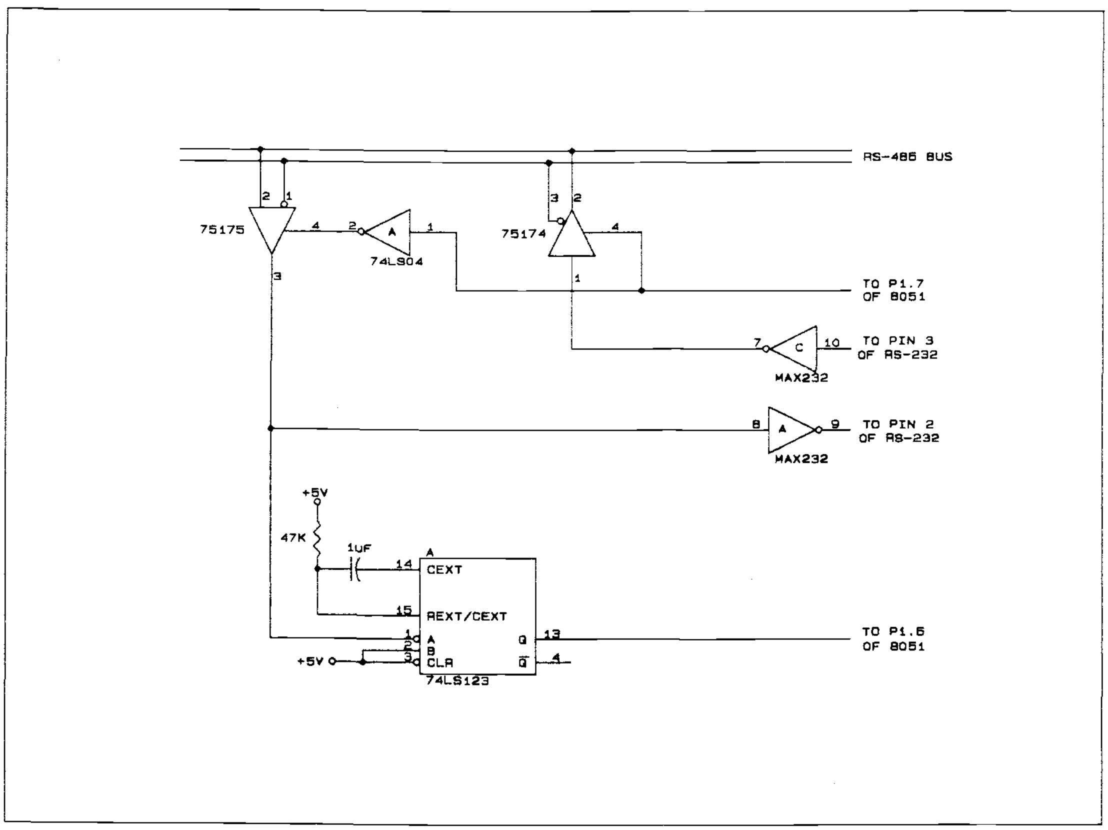

Figure 4-8. Network Interface Unit.

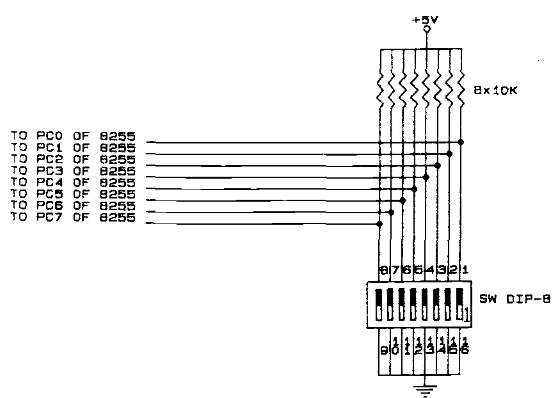

Figure 4-9. Node Address and Baud Rate Select Circuitry.

5. SOFTWARE IMPLEMENTATION

5.1. Overview

The software of COLAN V mainly consists of two types: high level software which resides at the host computer and low level software which resides in the task nodes. The two communicate through the RS-485 network bus via the NIU. The system interface software in the host computer can be written in any high level languages. One such control software package is the Task Master Controller (TMC) programmable task scheduling software package written in Turbo Pascal [LIM 89]. The software in the microcontroller-based system is written in the low level assembly language of the Intel 8051 family of microcontrollers. The following sections will focus primarily on the software that resides in the task nodes.

5.2. Memory Allocation

There are two types of memory on the microcontroller-based system: the internal data memory which resides within the microcontroller and off-chip external memory. External memory can also be divided into two types: read only for the operating system and read/write for the task queue. All of the internal memory is used exclusively by the operating system.

5.2.1. Internal Memory

In terms of access time, the internal data memory is the fastest. It is used exclusively for time critical functions, such as those performed by the operating system. The 128 bytes of internal data memory are assigned as follows:

00H to 07H -- Queued task (Register Bank 0)
08H to 0FH -- Immediate task (Register Bank 1)
10H to 17H -- Frame counters (Register Bank 2)
18H to 1FH -- Operating system (Register Bank 3)
20H to 2FH -- Special status registers and pointers
30H to 47H -- System stack
48H to 57H -- Task command packet buffer
58H to 7FH -- Reserved for future expansion

5.2.2. External Memory

All I/O operations are mapped onto the same address space as the external memory. The external address includes both the actual external memory space and the I/O addresses. For COLAN V, the entire external memory space is dedicated for the task queue and is allocated as follows:

0000 to 1FFF -- PROM, Program memory (2764 EPROM)
2000 to 5FFF -- RAM, Task queue (6264 RAMs)
6000 to 7FFF -- RAM, Scratch pad for tasks (6264 RAM)
8000 to 9FFF -- RAM, Future expansion (6264 RAM)
A000 to EFFF -- Reserved, Future I/O expansion
F000 to F003 -- Programmable peripheral interface (8255)

5.3. Operating System

A common operating system resides on every task node. To obtain optimal performance and speed, the operating system has been written in assembly code for the Intel 8051 family of microcontrollers. It has two main functions. First, it receives the properly addressed task command packets from the system scheduler and places them on the First-In-First-Out (FIFO) task queue. Second, it initiates tasks, terminates tasks, and manages the task queue. When it is not receiving the task command packets from the system scheduler, the operating system will simply execute the next task on the task queue. It will continue to do so one at a time sequentially until the queue is empty. When this condition occurs, the operating system goes into an idle loop waiting for a task packet to come in through the serial port.

The operating system is always interrupted whenever there is information available at the serial port. This will hold true even if the operating system is executing a task from the task queue. Since serial data rates are relatively slow in comparison with the processing speed of the microcontroller, the time spent servicing the serial port is insignificant in comparison with the time to service an active task. In effect, the short period of time required to service the serial port is virtually transparent and in most cases does not degrade the performance of the system.

5.4. Application Specific Software

In addition to the operating system software, specialized software are written for the slide projector task node. This node provides full control of the slide projectors for creating the different visual effects. The different modes of operation available for the slide projectors are written as routines. Collectively, these routines form the Application Specific Task Library. It is this Specific Task Library that provides the task node the capabilities to create the visual effects such as superimpose, and variable fade-in and fade-out rates. The most important mode of operation for the task node is the ability to vary the intensity of the lamp within the slide projector. It is this ability that forms the foundation for creating the other visual effects. With respect to the slide projector, dimming the lamp corresponds to fading out an image off the screen and bringing the lamp to full intensity corresponds to fading in an image onto the screen.

5.4.1. Background

The basic operation of the lamp in the projector can be modeled by a pure resistive electrical circuit energized by a sinusoidal source. The ultimate output of the lamp is light energy, which is achieved by heating the filament in the lamp to a temperature high enough to cause radiation in the visible range. The filament can be modeled by an ideal resistor. Although the resistor will account for the amount of electrical energy converted to thermal energy, it will not predict how much of the thermal energy is converted to light energy. Assuming the energy delivered to the lamp is represented by the amount of energy dissipated through the resistor and corresponds to the intensity of the lamp, then this energy can be described by the following:

$$p = vi \qquad \text{where, } v = V_m\cos(wt) \text{ and } i = I_m\cos(wt) \qquad (5\text{-}1)$$

For a pure passive or resistive electrical circuit, there is no phase shift between the current and voltage. Both signals are in phase; therefore the power at any instant of time is given by the above equation. Since the resistance in the circuit is assumed to be constant, and

$$i = v / R \qquad (5\text{-}2)$$

the above equation can be re-written as

$$p = v^2 / R \qquad \text{where, } p = \text{instantaneous power} \qquad (5\text{-}3)$$

The average power associated with a sinusoidal signal is the average of the instantaneous power over one period. In equation form, this is written as

$$P = \frac{1}{T} \int_{t}^{T} p \, dt \qquad (5\text{-}4)$$

where, T is the period of the sinusoidal function and P is the average power when t = 0. Substituting the relationship for the instantaneous power, p, the average power equation becomes

$$P = \frac{1}{TR} \int_{t}^{T} v^2 \, dt \qquad (5\text{-}5)$$

Graphically, this is simply the area under the v^2 waveform divided by the product of the period and the resistance.

5.4.2. Sectioning of the Sinusoidal Waveform

The above relationship describes the average power for a complete sinusoidal signal when the integration is over one period or when t = 0. Assuming that t = 0 is at the zero crossing of the waveform, instead of integrating over a complete period, the average power can be varied by controlling the starting time or the lower limit integration value, t. For example, with t = T / 2 , the average power would be half of that when t = 0, since the integration time is half of a period. Graphically, changing the lower limit integration value, t, changes the integrated area under the v^2 waveform; hence, the average power.

This is precisely the method that was used to provide a way to control and vary the intensity of the lamp. Since the v^2 waveform is similar to a sinusoidal waveform except that the magnitudes are squared and positive, the remaining discussion on the power calculation will simply refer to the area of a half sinusoidal waveform. Because integration is simply the summing of the area under a curve, the average power from a sinusoidal source is indicated by the size of the area. Figure 5-1 depicts the Voltage Time Areas (VTA) under both the positive and negative cycle of the sinusoidal waveform for different values of t. As shown in the figures, as t increases, the VTA gets smaller and thus, decreases the average power. By increasing t from 0 to T/2, the average power is reduced from full to zero. Conversely, decreasing t from T/2 to 0 increases the average power from zero to full. Since the brightness of the lamp is determined by the average power, varying t varies the brightness of the lamp.

The rate at which t increases from 0 to T/2 or decreases from T/2 to 0 determines the rate at which the lamp is dimmed or brought to full brightness, respectively. In the case of dimming the lamp, the rate is specified by the number of half cycles between every increment of t. The smaller the number of half cycles between every increment of t the faster the lamp gets dimmed. The larger the number of half cycles, the longer it takes the lamp to dim. Likewise, for bringing the lamp to full brightness, instead of incrementing t, t is decremented.

5.4.3. Selecting the Number of Sections

To provide the lamp with the smoothest transition from full off to full brightness or vice-versa, it is desirable to vary t with a smallest increment (delta t) as possible. Graphically, since the horizontal scale of the sinusoidal waveform is time, dividing the time span for the half waveform into small increments of t can be viewed as partitioning the area of the half sinusoidal waveform into small sections. Each section represents the incremental step size of t or delta t. Although having more sections is desirable, it also increases the required processing time of the microcontroller. Since the microcontroller has a finite processing speed, the maximum number of sections to partition the waveform is not without bound.

Having more sections is desirable, but it might not be necessary. Even though the human eyes are very acute, like the ears, they are not without limits. The human ears can only hear sound within a narrow band of frequency. They can not detect sounds that are below or above this band of frequency. Likewise, the human eyes can only detect visual changes below a certain frequency. This is demonstrated when viewing a motion picture. When viewing a film at 30 frames per second, the human eyes do not notice the changing of the image frame from one to another. But below this rate or frequency, the changing of the frames becomes noticeable. At the other end, increasing the frequency will probably not show any noticeable improvement. Therefore, there is an optimal frequency or rate that when exceeded will not have a significant enhancement on the way the human eyes perceive change in images.

Since the intensity of the lamp is not directly proportional to the supplied power, it was found experimentally that no noticeable changes in the intensity of the lamp until t has reached beyond the 30 degree portion of the waveform from the zero crossing. It was also found that if t is beyond the 150 degree portion of the waveform, no light was found to be emitted from the lamp. To minimize the processing time and to at least reach the optimal frequency level, the number of sections to divide the half waveform was experimentally determined to be 40.

Excluding the first and last 30 degrees portions of the waveform, each section corresponds to 3 degrees of the half sinusoidal waveform. For a 60 Hz sinusoidal signal, where each half cycle has a period of 8.333 ms, each 3 degrees section of the sinusoidal waveform corresponds to a period of approximately 0.139 ms and the 30 degrees portions correspond to a period of 1.389 ms.

5.4.4. Zero Crossing Interrupt

A zero-crossing circuit is used for synchronizing the microcontroller with the 60 Hz, 120 Volts sinusoidal signal. The circuit generates a pulse at every zero-crossing of the sinusoidal signal. With a 60 Hz sinusoidal signal, a pulse will be generated approximately every 8.333 ms. Knowing the zero-crossings of the signal provides a mean for the microcontroller to determine the necessary delay time that will provide the desired power level to the lamp. The delay time is used to determine when in the half cycle or how long to wait before turning on the relay that controls and drives the lamp circuitry once the zero-crossing has been detected. Since the response time in detecting the zero-crossings is crucial for determining the delay time, one of the external input interrupts, IE0, is used to sense the zero-crossing circuitry signal.

5.4.5. Algorithm for Fading

Controlling the rate to dim and to bring a lamp to full brightness involves the use of three counters and one of the system timers on the microcontroller. One counter serves as an index stepping through each of the 40 sections within the half sinusoidal waveform. The second counter is used to indicate the section when the relay was last triggered. The last counter is the half cycle counter. It is used to control the fade rate. To keep track of the elapsed time while performing calculation within a section, one of the system timers on the microcontroller is used.

The flowchart shown in Figure 5-2 describes the general algorithm for dimming a lamp. The basic algorithm consists of two loops. One for controlling the fade rate and the other controls when to trigger the relay within the half cycle for supplying the power to the lamp. The variable *RATE* is for specifying the fade-out rate or the time required to reduce the intensity of the lamp to zero. The value contained in *RATE* specifies how many half cycles to wait before incrementing *PSECTION*. The counter *PSECTION* is used to indicate the number of sections to wait, after the detection of a zero crossing, before triggering the relay. Since the half cycle sinusoidal waveform is divided into 40 sections and a sinusoidal signal with a frequency of 60 Hz has 120 half cycles, the value for *RATE* for a particular fade rate (in seconds) is determine by

$$RATE = (120 / 40) * (\text{fade rate})$$

For a fade rate of 5 seconds, the value for *RATE* is equal to 15. This means that *PSECTION* is incremented after every 15 half cycles. The value for *RATE* does not get changed during the fade operation. Instead, a counter is used to keep track of the number of half cycles remaining before *PSECTION* is incremented. The counter, *WKRATE*, is first loaded with the value stored in *RATE*. It is decremented at the beginning of each half cycle or at the zero crossings until it reaches the count of 0. The fade operation is completed if the intensity of the lamp has been reduced to zero. Otherwise, the value of *RATE* is reloaded into *WKRATE* and the cycle repeats starting at the zero crossing.

When the intensity of the lamp has been reduced to zero, *PSECTION* will have a value equal to the number of sections in the half cycle waveform, which is 40. At the start of the fade operation, *PSECTION* is initialized with the value 0. Each time the number of half cycles specified by *RATE* has elapsed, *PSECTION* is incremented. This continues until *PSECTION* reaches 40, which indicates the intensity of the lamp has been reduced to zero.

Within each half cycle, an index counter, *SINDEX*, is used to step through each section from 0 to 40. It provides a mean to determine when to trigger the relay as *PSECTION* is incremented. Whenever *SINDEX* equals to *PSECTION*, the relay is triggered. The *SINDEX* counter is initialized to 0 at the start of every new half cycle. It is incremented at the end of every section until it reaches 40. The lag period shown in the flowchart is the first 30 degrees portion of the half cycle waveform and it is not used in the fade operation.

The algorithm used to bring the lamp to full brightness is shown in Figure 5-3. It is very similar to the previous algorithm. Instead of initializing *PSECTION* to 0, it is initialized with the value 40. Also, at the bottom of the loop, *PSECTION* is decremented instead of incremented. The method of determining *RATE* is the same as before.

The above discussion is for controlling the fade-in and fade-out rate for a single lamp in a slide projector. By concurrently controlling more then one lamp, special effects such as superimposing several images on the screen and variable fade rates for different images can be created. The specialized software written for the projector task node has the capability to control up to four lamps concurrently to create these special effects.

5.5. 8051 Family Cross-Assembler

There are many assemblers that are currently available that can generate the 8051 family of microcontroller code for the task nodes, some generate more efficient code than others and even provide better development tools. One such development system is the *AVMAC*, developed by AVOCET. This package lets the user develop microcontroller code on any MS-DOS computer system. The *AVMAC* development system includes the following [AVOC 87]:

* The assembler (AVLINK51) translates instruction mnemonics, pseudoops, and symbolic addresses into machine-level opcodes and numeric addresses, as well as handling macros, preprocessor directives, and conditional assembly.

* The linker (AVLINK) provides relocatable segments for code, data, etc., along with modularization of source files.

* The librarian (AVLIB) collects multiple object modules for simplified linking.

* The cross-reference report generator (AVREF) aids in coordinating large development projects.

5.6. Library of Tasks

The key concept in the implementation of COLAN V is to divide the activities in the network into small tasks to be executed by the appropriate task node. From the view of the node, a task is simply a subroutine which reside within the system ROM. It is different from the normal subroutines from the way it is called, the way it receives data, and the way it is terminated. There are two types of tasks, global tasks and application specific tasks. Global tasks are common to all nodes. They provide the basic operation to the system. Application specific tasks provide specialized operations based on the hardware of the individual task node.

5.6.1. Global Task

The purpose of the Global Task Library is to provide a set of basic utilities for input/output operations and for system development purposes. These tasks provide ways for transporting data from the host computer to any task node interface port, and vise-versa. In addition, system flags and internal memory contents can be examined by using the these tasks. The following is the list of tasks in the global library.

TASK0 -- Reset the task node
TASK1 -- Clear the task queue
TASK2 -- Abort the current task
TASK3 -- Start a synchronized task on the queue
TASK4 -- Pause the system
TASK5 -- Resume system operation
TASK6 -- Set time out register
TASK7 -- Null task
TASK8 -- Task with infinite loop
TASK9 -- Display task queue to the host
TASKA -- Send task node address to the host
TASKB -- Send to task data memory transfer
TASKC -- Data memory to host transfer
TASKD -- Host to external memory transfer
TASKE -- External memory to host transfer
TASKF -- Sensitize local asynchronous port
TASK10 -- De-Sensitize the asynchronous port

TASK11 -- Sensitize the parallel port
TASK12 -- De-Sensitize the parallel port
TASK13 -- Set time delay
TASK14 -- Audio signal
TASK15 -- Friendly blink of LED

5.6.2. Application Specific Task

The application specific task library for the slide projector control task node is a collection of tasks that provide the system scheduler the capability to control one or more slide projectors remotely. Special effects such as superimpose, and variable fade-in and fade-out rates are accomplished by using this task library. Besides tasks for creating the special effects, the library also includes other utility tasks for setting up and monitoring the operation of the projectors. The following is a list of tasks available in this library.

TASK40 -- Initialize projector connections
TASK41 -- Fade lamp(s) in / out
TASK42 -- Display lamp status (on / off)
TASK43 -- Set lamp / frame display option
TASK44 -- Set tray size
TASK45 -- Home tray
TASK46 -- Advance slide(s)
TASK47 -- Initialize frame counter(s)
TASK48 -- Display frame counter(s)
TASK49 -- Delay time

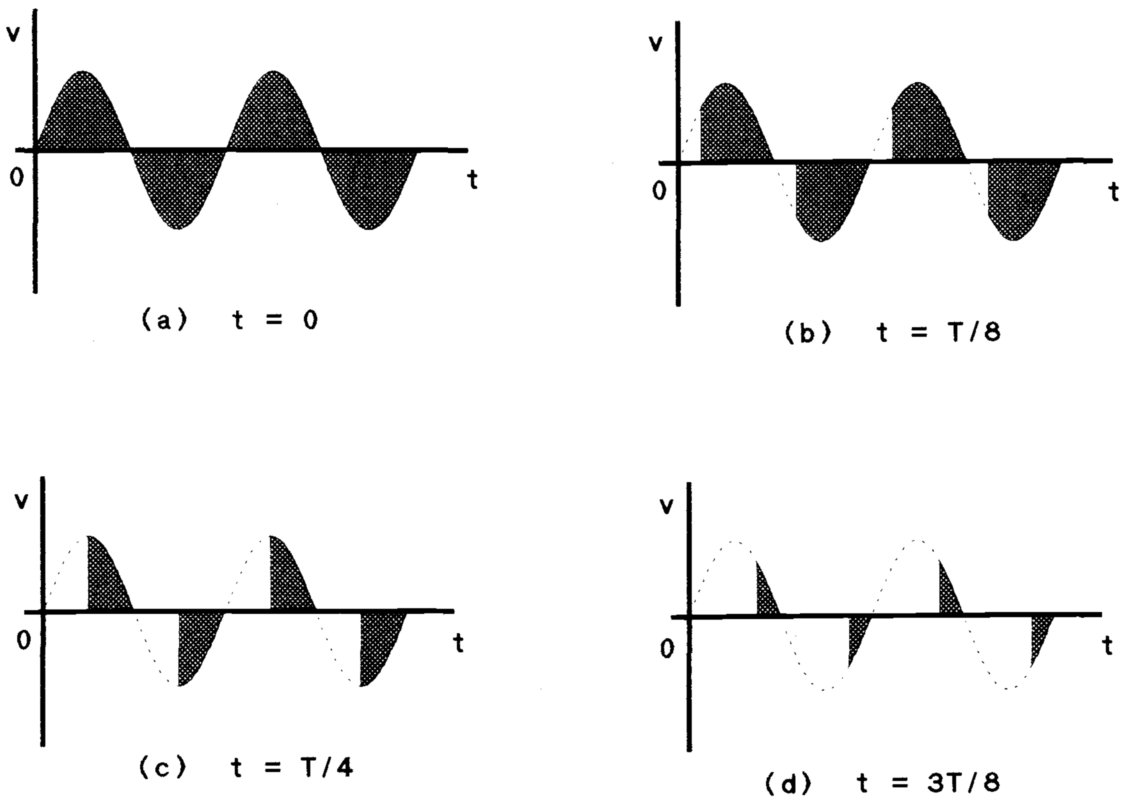

Figure 5-1. Sinusoidal Waveforms Using Different t Values.

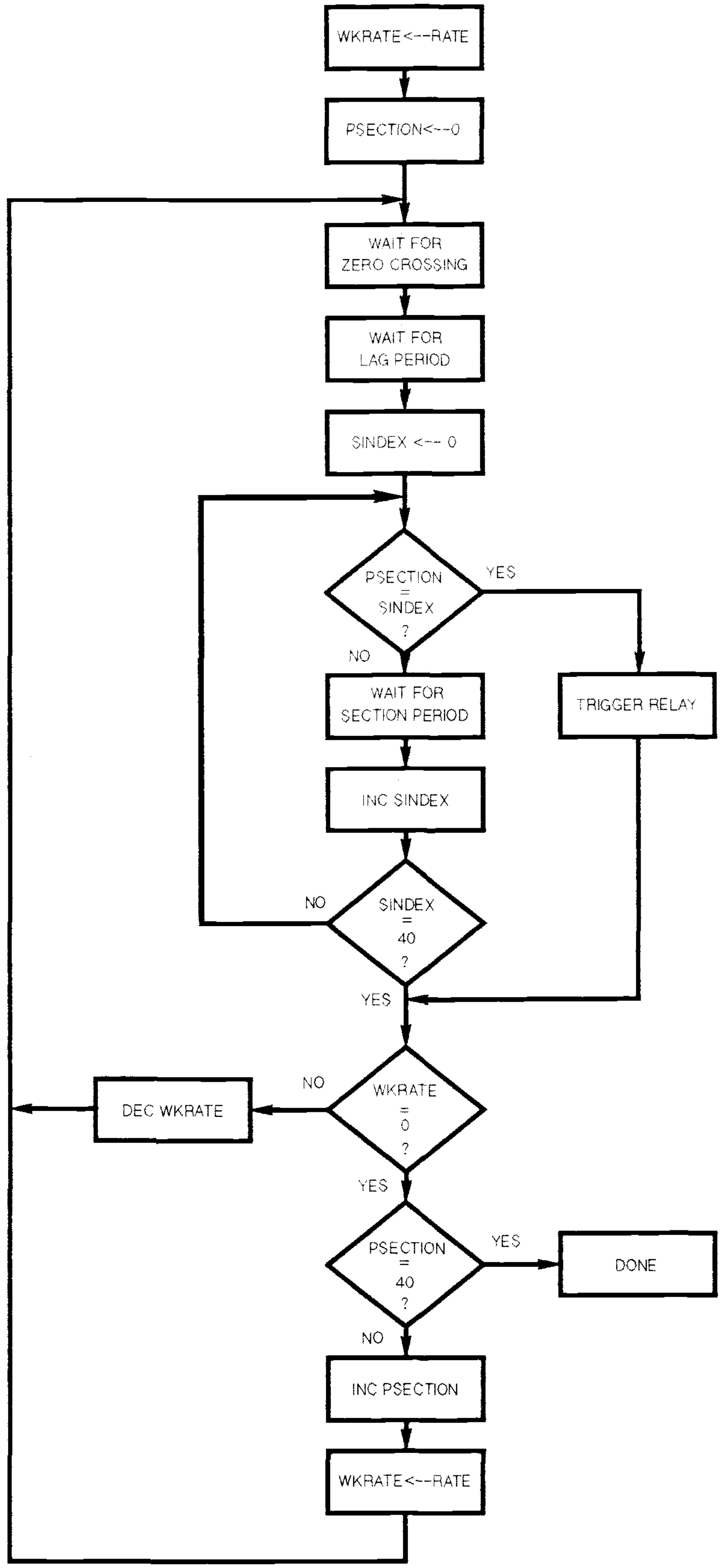

Figure 5-2. Flowchart for Dimming a Lamp.

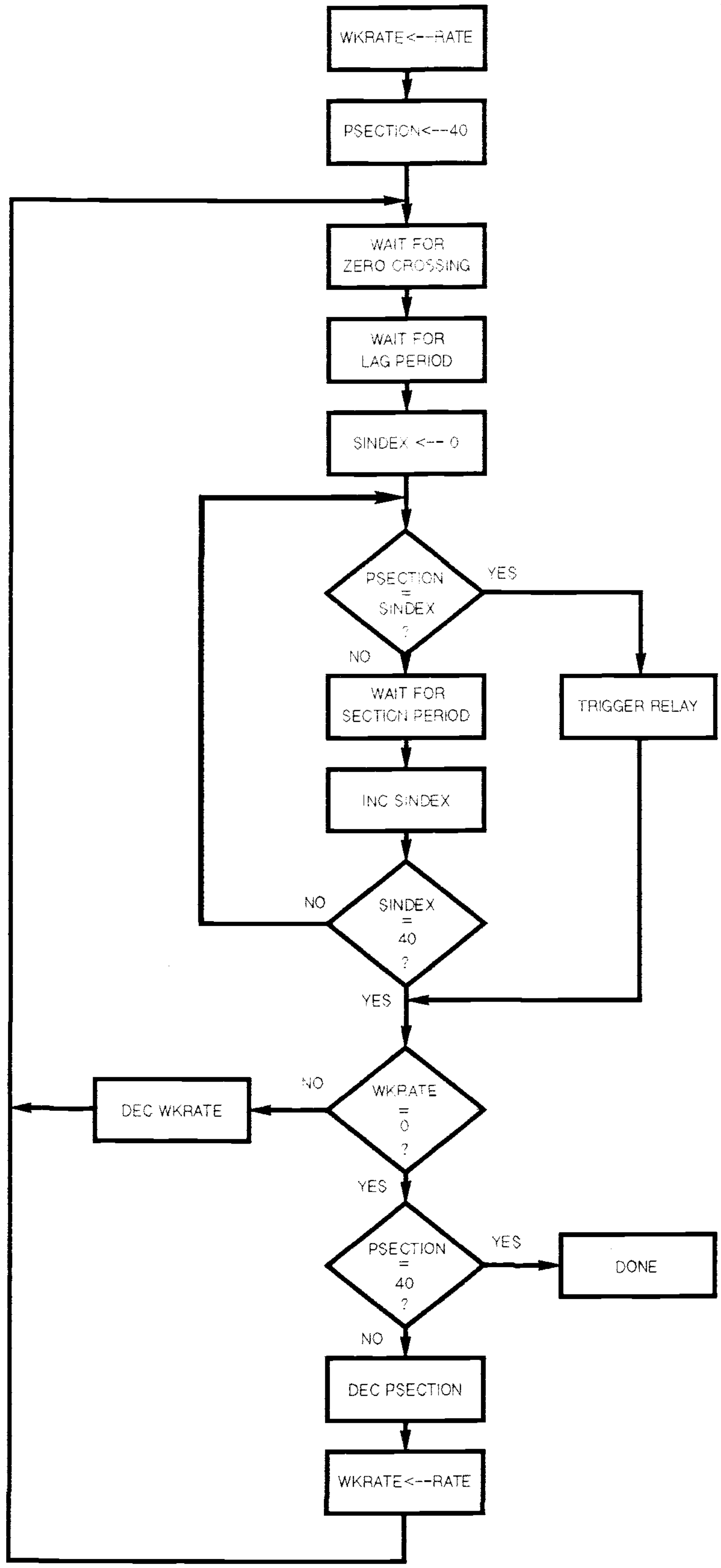

Figure 5-3. Flowchart for Bring a Lamp to Full Brightness.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The primary objectives for the implementation of the multi-media visual presentation system for control oriented local area networks were to provide a low cost, reliable, real-time distributed control system. The following indicates the results and the accomplishments made from the implementation of COLAN V.

1) The task node operating system from the predecessor networks was modified to enhance memory management and to provide user selectable baud rates.

2) A task node was designed and implemented to provide concurrent control of the slide projectors and the different modes of operations.

3) A tape recorder along with a modem was implemented as the system scheduler when network monitoring is not required.

The functionalities of COLAN V have been successfully verified with three microcontroller-based task nodes. In particular, an experimental network was setup at Oregon State University. The network provided capabilities to control and monitor stage lights, an audio system, and multi-media presentation through the use of slide projectors. The use of both a personal computer and a tape recorder as the master scheduler was shown to be successful. Task node status was monitored through the personal computer.

Two slide projectors were used to verify the operation of the slide projector task node. Effects such as superimpose, and variable fade-in and fade-out rates were demonstrated. Synchronization between the audio portion of the presentation with the slide images was also achieved through the use of the tape recorder. The use of the modem to provide the interface between the personal computer and the tape recorder, and from the tape recorder to the network was shown to be reliable at 300 baud rate.

6.2. Recommendations for Future Research

Even though the current implementation of COLAN V has successfully satisfied the original goals and objectives, improvements can still be made in different areas to enhance the overall performance of the network. The following is a list of recommendations that can be used as a guide for future research and development of COLAN V.

* When using the tape recorder as the master scheduler, throughput is limited by the baud rate of the modem. This limits the number of command packets per second that can be sent to the network. By using a modem with a higher baud rate, the throughput can be increased.

* To ensure reliable interchange of data when operating in a noisy environment, some sort of error checking technique should be employed.

* Although the current projector task node can control the intensity of the lamp and the advancing of the slides, it still requires an operator intervention to turn on and to turn off the projectors before and after each presentation, respectively. To eliminate any operator intervention, additional relays should be added to the

task node for controlling the power to the projectors while leaving the switches in the on position.

* The current software in the projector task node only provides options to fade the lamp in the projector to either full on or off. To be more flexible, the software should be modified to allow options for the lamp to fade to any desired intensity level.

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APPENDIX

APPENDIX A

Task Node Application Library and Example Program

A.1. Application Specific Library

The following is a list of the tasks in the Application Specific Library for the slide projector control task node. The notations that are used in the task definitions are:

Task Command Packet Format -- {AA P NN S DD}

AA	:	Destination Node Address	
P	:	Pre-Execution Control Character	
		:	Queued Task
		?	Synchronized Task
		!	Immediate Task
NN	:	Task Number	
S	:	Post-Execution Control Character	
		.	Execute Once
		+	Re-Queued Task
DD	:	Data Field	
		AB	Argument #1
		CD	Argument #2
		EF	Argument #3
		GH	Argument #4

Task Number: 40

Function: Initialize projector connections

Format: {07:40.0B}

Description: This task must always be executed at the start-up of the system. It provides information to the task node specifying how many projectors and which projector interface ports are used. In addition, it initializes all the counters.

Arguments: The hexadecimal value of argument B indicates which projector port on the task node is connected.

Examples:

Data Field	Connection Ports			
B	4	3	2	1
1				X
2			X	
3			X	X
4		X		X
5		X	X	
6	X		X	
B	X		X	X
C	X	X		
F	X	X	X	X

Task Number: 41

Function: Control fade rates of the lamps

Format: {07:41.ABCDEFGH}

Description: This task is used to specify the fade rate of each lamp and the final intensity level. The fade rate is the time it takes to reach the final intensity level.

Arguments: The argument numbers correspond directly to the projector numbers. Data fields A, C, E, and G specify the fade rates and data fields B, D, F, and H specify the final intensity levels. The following list the possible fade rates and intensity values:

Fade Value	Fade Rate (Sec)
0	Instantly
1	1
2	2
3	3
4	4
5	5
6	6

7	7
8	8
9	9
A	10
B	12
C	15
D	20
E	25
F	30

Intensity Value	Intensity Level
0	No Change
1	ON
7	OFF

Examples:

Data Field	Proj #1		Proj #2		Proj #3		Proj #4	
ABCDEFGH	Rate	Lamp	Rate	Lamp	Rate	Lamp	Rate	Lamp
31470021	3	ON	4	OFF	X	X	2	ON
5721E747	5	OFF	2	ON	25	OFF	4	OFF
210041D1	2	ON	X	X	4	ON	20	ON
00373100	X	X	3	OFF	3	ON	X	X
41410000	4	ON	1	ON	X	X	X	X

In the examples, all rates are specified in seconds and X indicates no change.

Task Number: 42
Function: Display lamp status
Format: {07:42.}
Description: This task returns the lamp status packet containing the ON / OFF status of the lamps in the projectors to the host computer.
Arguments: None.
Examples: Typical return status message packets:

Lamp Status [ON:OFF:OFF:ON]

The projector numbers corresponding to the lamp status are inferred by the positions in packet, [Projector 1:Projector 2:Projector 3:Projector 4].

Task Number: 43

Function: Sets lamp status / frame counter display options.

Format: {07:43.AB}

Description: This task sets and clears the flags for determining whether to return the lamp status packet and the frame counter packet after the execution of each task.

Arguments: Argument A sets the frame counter flag and argument B sets the lamp status flag. Either or both flags can be set at one time. The arguments have two options: the value of 1 sets the flag and the value of 0 clears the flag. Once the flag is set, the corresponding return packet will be return upon the completion of each task. The format of the return packets is the same as those from executing task 42 and task 48.

Examples:

Data Field (AB)	Packet(s) Returned
00	None
01	Lamp status packet
10	Frame counter packet
11	Both lamp and frame counter packets

Task Number: 44

Function: Sets the slide projector tray size

Format: {07:44.ABCD}

Description: This task sets the tray size on each of the slide projectors connected to the task node. Two possible tray sizes are: 80 frames and 140 frames per tray.

Arguments: The arguments are used to set the size of the tray on each projector: the value 0 is for 80 frames per tray and the value 1 is for 140 frames per tray.

Examples:

Data Field	Tray Size			
ABCD	Proj #1	Proj #2	Proj #3	Proj #4
0000	80	80	80	80
1010	140	80	140	80
1111	140	140	140	140

Task Number: 45

Function: Home Tray

Format: {07:45.0B}

Description: This task rotates the tray back to its original starting position. The tray will be automatically rotated in the shortest direction, either clock-wise or counter clock-wise.

Arguments: Argument B is used to specify which tray to home. The tray number corresponds to the projector number.

Examples:

Data Field (B)	Tray #
0	1
1	2
2	3
3	4

Task Number: 46

Function: Advance tray forward or reverse

Format: {07:46.ABCDEFGH}

Description: This task is used to specify the direction the slide advances or the direction the tray rotates.

Arguments: The argument numbers correspond to the projector numbers. Data fields A, C, E, and G specify the forward direction and fields B, D, F, and H specify the reverse direction.

Examples:

Data Field	Advance Direction			
ABCDEFGH	Proj #1	Proj #2	Proj #3	Proj #4
01000000	F			
00010000		F		
00000100			F	
00000001				F
10000000	R			
00001000			R	
00100000		R		
01100110	F	R	F	R
10011001	R	F	R	F

Task Number: 47
Function: Initialize frame counter
Format: {07:47.ABCD}
Description: This task is used to initialize a frame counter with a new value.
Arguments: Argument A specifies which counter and BCD specifies the new counter value.
Examples:

Data Field	New Counter Value			
ABCD	Proj #1	Proj #2	Proj #3	Proj #4
1078	78			
2105		105		
3027			27	
4112				112

Task Number: 48
Function: Display frame counter values
Format: {07:48.}
Description: This task returns the frame counter packet to the host computer when it is executed.
Arguments: None.
Examples: Typical return status packet:

[045:101:004:086]

The projector numbers corresponding to the frame counter values are inferred by the positions in the packet. [Projector 1:Projector 2:Projector 3:Projector 4].

Task Number: 49
Function: Delay loop
Format: {07:47.AB}
Description: This task specifies the number of second to wait before executing next task.
Arguments: The arguments are used to specify the number of seconds, up to 99 seconds, to wait before the next task is executed.
Examples:

Data Field (AB)	Time (sec)
06	6
27	27
79	79

A.2. An Example of a Presentation

The following is a simple slide presentation program demonstrating the use of the tasks in the Application Specific Library. Two slide projectors will be used in this example.

TASK	*DESCRIPTION*
{07:40.03}	Indicate projectors are connected to port 1 and 2.
{07:41.3137}	Fade projector #1 ON and projector #2 OFF in 3 seconds.
{07:41.4751}	Fade projector #1 OFF in 4 seconds and projector #2 ON in 5 seconds.
{07:46.0100}	Advance tray in projector #1 forward.
{07:41.4147}	Fade projector #1 ON and projector #2 OFF in 4 seconds.
{07:46.0001}	Advance tray in projector #2 forward.
{07:41.4731}	Fade projector #1 OFF in 4 seconds and projector #2 ON in 3 seconds.
{07:46.0100}	Advance tray in projector #1 forward.
{07:41.3147}	Fade projector #1 ON in 3 seconds and projector #2 OFF in 4 seconds.
{07:46.0001}	Advance tray in projector #2 forward.
{07:41.4741}	Fade projector #1 OFF and projector #2 ON in 4 seconds.
{07:46.0100}	Advance tray in projector #1 forward.
{07:41.3100}	Superimpose both images by fading projector #1 ON.
{07:41.0047}	Fade projector #2 OFF while leaving projector #1 ON.
{07:46.0010}	Advance tray in projector #2 backward.
{07:41.4731}	Fade projector #1 OFF in 4 seconds and projector #2 ON in 3 seconds.
{07:45.00}	Home tray in projector #1.
{07:41.0047}	Fade projector #2 OFF.
{07:45.01}	Home tray in projector #2.