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PRACTICAL PROBLEMS WITH MULTIPLE INTERFACE STANDARDS

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1. INTRODUCTION

It must have been a manufacturer who said that the most convenient aspect of adopting standard is that there are so many to choose from. Contractors, on the other hand have to interpret clients or consultants specifications and work with whatever interfaces the various manufacturers deem appropriate.

This paper introduces the concept of Show Control for entertainment systems and surveys some of the more popular interface standards from a Contractor's point of view.

2. SHOW CONTROL SYSTEMS

The origins of Show Control Systems date back to the early multimedia presentations where 1kHz audio pulses from a multitrack tape player initiated a dissolve between two 35mm slide projector in synchronism with the soundtrack. A similar technique was used for Son-et-Lumiere shows where the similar 1kHz tone sequenced a rudimentary lighting control system.

The ever increasing complicity of technical effects in the Performing Arts require sophisticated control methods. Control surfaces are designed for specific disciplines, be it lighting, sound, video or rigging to allow the operator to assemble the programmes to achieve the desired effects, test them during rehearsals and modify the programmes as necessary. The effects may then be replayed in a consistent manner but subject to amendment by the operator according to the vagaries of a live performance.

Effects may be self-contained, such as a clap of thunder, or a transition from one steady state to another, such as a lighting scene change. Each control surface forms part of a stand alone system requiring an operator to initiate the effects (or cues).

Synchronisation of cues with the action on-stage is generally controlled by a stage manager. Communication systems are required between the Stage Manager and the operators and the operators and may employ audible or visual signalling. For audible signalling a ring intercom system is frequently used allowing the Stage Manager to communicate with all operators. A specific operator is addressed and instructed with a "Sound Cue 17 Go" command.

In certain instances audible communications are not appropriate, (for example, a technician operating a counterweight flying system) and a visual signalling system may be employed. Red (standby) and green (go) lights provide limited information to the operator to initiate the next cue in sequence.

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Show Control Systems enable a Stage Manager to send commands to the various control systems to initiate cues without intervening operators; the command structures closely resemble the above audible signalling.

Show Control Systems are particularly suited to fully automated systems such as those used for theme park attractions, rides and museums. With 100 or more performances each day the repeatability of Show Control Systems coupled with reduced labour costs is of major importance. There is a trend in light entertainment shows for segments to be performed using a pre-recorded soundtrack. This is a middle case between the fully automated systems and the requirements of live show control.

Show Control Systems in live entertainment should augment human capabilities rather than replace them. In particular, control of sound is complex. Humidity, temperature, audience size and other factors influence sound for more than other media. Humans must assume the responsibility of monitoring and overriding control.

3. DATA COMMUNICATION

Two basic types of interfaces exist: analogue and digital. Analogue remote control is rarely used for complex interfaces but does have application in controlling individual peripheral devices for example thyristor dimmers, servo controlled mechanical devices such as animatronic figures and voltage controlled amplifiers.

Digital interfaces may be sub-divided into parallel and serial. Parallel interfaces such as Centronics are familiar to most computer users as the protocol by which their computer communicates with their printer. Although fast, this protocol is limited to very short cable runs and is not used within the field of show control except for communicating with printers. The most frequently used parallel interfaces are simple closing contacts providing the most basic control of peripheral equipment particularly motion control of sound replay machines and stage mechanical equipment such as curtains.

Serial data communication has a long history dating from the last century. To meet the demands of computerised communications the Electronic Industries Association formulated, in 1969, a Recommended Standard to interface computer terminals and modems. This standard, RS232, has been adopted and adapted for many applications including control systems and peripheral equipment used in the entertainment industry.

Data may be sent at a rate of 38kBaud usually in 8-bit packets corresponding to the ASCII keyboard character set. Communication is bidirectional between two points and the signals are unbalanced. The EIA standard imposes a capacitance limit restricting cable runs to around 15m. In practise developments in cable technology and especially in the integrated circuits used for line drivers and receivers allow up to 200m cable runs to be used without problems.

More recent standards have been adopted. RS422 provides a 10MBaud data rate, has balanced signals and allows a cable to be daisy chained from the source to a maximum of 10 receivers along a 1,200m cable. RS485 is similar but allows up to 32 receivers and 32 senders on a single data cable.

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4. LIGHTING SYSTEM INTERFACE - DMX512

Over the last 100 years stage lighting control has progressed from mechanical valves controlling gas fittings, through rheostat control of electric lights, to computer control of thyristor dimmers.

The early manual control consoles provided individual analogue outputs to control thyristor dimmers. There was no agreement between manufacturers as to the magnitude of the voltage (or even the sign) representing 100% conduction at the dimmer. Other dimmer manufacturers employed a current drive rather than voltage source.

With the development of memory lighting control consoles, the internal processing included time division multiplexing of the analogue signals. The control system demultiplexed the signal and individual analogue control lines were employed to connect the control system to the dimmer racks.

The analogue, one wire per dimmer, interface was expensive to cable between compatible systems. Interfacing between systems with different control voltages incurred considerably more costs with inverting amplifiers and/or level convertors for each dimmer channel.

Eventually manufacturers moved the demultiplexer to the dimmer racks and an analogue multiplex signal formed the interface between control system and dimmer racks.

Several digital interfaces were also developed but all different and incompatible. Manufacturers restricted information on their proprietary interface for fear of piracy and the contractor was obliged to source both the control system and dimmers from the same supplier.

At a US Institute of Theatre Technology conference in 1986, representatives from all the major manufacturers discussed the possibility of creating an open, digital multiplexed lighting control standard. The DMX512 standard was born. The original 1986 standard had some ambiguities which were resolved in the 1990 revision.

DMX512 may not be the perfect solution for lighting control but was deliberately kept simple to ensure its wide adoption throughout the world. It is based on the electrical characteristics of RS485 including line driver and receiver selection, line loading and multidrop configurations. Data is transmitted with a rate of 250KBaud in a continuous but a synchronous serial format. Data packets start with a RESET and NULL START code. After that dimmer level data is transmitted sequentially starting with dimmer 1 and ending with the last implemented dimmer up to a maximum of 512. Valid dimmer levels are 0 to 255 representing OFF to FULL in a linear relationship.

Although originally intended for the control of lighting levels, DMX512 has been used by manufacturers of lighting equipment for the remote selection of colour fuller media and positional control of moving lights. Effects equipment manufacturers have also adopted this standard to allow, for example, a smoke machine to be controlled via DMX512 from the lighting control desk.

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5. MIDI INTERFACES AND DERIVATIVES

In the late 1970s a number of major electronic music instrument manufacturers agreed a standard for the connection and synchronised performance of their products such as synthesizers, drum machines and sequencers. This Musical Instrument Digital Interface (MIDI) sends serial data from a 5 volt source via a 5mA current loop which is opto-isolated at the receiver. This opto-isolation is particularly useful in avoiding ground loop problems between audio equipment. Cable loss restricts the maximum cable runs to around 15m although this can be extended to 200m by increasing the source voltage in the sending end. Data rate is 31.25 kBaud and the data is transmitted in 8-bit packets generally represented by 2 Hexadecimal digits.

MIDI is essentially a point to point unidirectional protocol with a MIDI OUT signal on one piece of equipment being connected to the MIDI IN on a second. The MIDI output usually provides data generated from within that equipment and does not repeat data appearing on the MIDI input. A MIDI THROUGH output on most equipment allows control commands to be daisy chained from one unit to the next. A variety of 'black boxes' have been developed to distribute a MIDI signal to several destinations and to merge several MIDI outputs onto a single data line. By looping the MIDI signal back to the MIDI input of the controlling console bidirectional communication can be established.

The MIDI command protocol while suited to its original purpose as a musical instrument interface has restrictive commands for show control. MIDI Show Control (MSC) was introduced in 1991 to allow MIDI systems to communicate with and to control dedicated intelligent consoles in theatrical, live performance, multimedia, audiovisual and similar environments. Applications may range from a simple interface through which a single lighting control console can be instructed to GO, STOP or RESUME to complex communications with large, timed and synchronised systems utilising many controllers of all types of performance technology. The set of commands was modelled on the command structure of existing lighting, sound and show control systems with the intent that translation between the MSC specification and the dedicated control consoles would be relatively straightforward being based on the same operating principles.

MIDI machine control (MMC) was introduced to allow MIDI systems to communicate with and to control some of the more traditional audio recording and production systems. Applications may range from a simple interface through which a single tape recorder can be instructed to PLAY, STOP, FAST FORWARD or REWIND, to complex communications with large, time code based and synchronised systems of audio and video recorders, digital recording systems and sequencers.

While not strictly a command protocol, mention should be made of the time code developed under the auspices of the Society of Motion Picture and Television Engineers (SMPTE). Time is expressed, using two binary-coded-decimal digits per byte, as hours, minutes, seconds and frames. Using frequency shift keying (FSK) the time code may be recorded as an audio signal. A total of 80 bits is recorded per frame, 32 to express time, the remainder for synchronism, direction sense and user application. While originally developed for film and television the SMPTE time code has become the de facto timing reference in the professional audio world. It is therefore the obvious choice for synchronising show control systems with audio and video replay devices.

Timing within MIDI systems is based upon musical concepts such as tempo, bars and beats per bar. MIDI Time Code (MTC) is an encoding of the SMPTE time code providing an absolute timing reference independent of tempo for use within MIDI systems.

The first version of MIDI Show Control specification expressly cautions users against use in safety-critical conditions since this version has not been designed for fail-safe control. MSC is not yet intended to serve as a critical link between intelligent controllers and relatively unintelligent peripheral devices that may have uncontrolled responses to corrupt data. Manual controls such as emergency stops, deadman switches and confirmation enable controls together with automatic devices such as limit switches, proximity detectors and motion detectors shall be used for maximum safety. MSC is not intended to command potentially dangerous equipment when it is safe to go; it is only intended to signal the desire to go if conditions are correct for safe operation.

The MSC working party have proposed an extension of the MSC protocol to incorporate 'two-phase commit' capability thereby adding data checking and error detection. Suggested uses include situations where a show is being completely monitored and controlled from a central remote location, or performance conditions where safety requires additional checking and redundancy in the control system. A standby cue message is sent from the controller to the controlled device. If the controlled device is in a suitable state to execute the cue it responds with a standing-by message. If the controlled device is unable to execute the cue it responds with an abort message. If the controller does not receive any message within 2 seconds it proceeds as if an abort message had been sent from the controlled device. Once the standing-by message has been received by the controller it sends the go cue message to the controlled device. When the controlled device has carried out the cue, it responds with a cue-complete message. The messages, or assumed messages, returned to the controller allows logical branching of the cue lists and subsequent action by the controller.

6. SHOW CONTROL HARDWARE

The simplest form of control hardware is event based. The inputs and outputs would be closing contacts and the output states would be determined by combinational logic applied to the input states. Internal timers could be utilised to provide a sequence of output signals initiated by a combination of input stimuli. Programmable Logic Controllers (PLC) are typical of this type of controller. They are relatively safe and particularly suited as dedicated controllers of stage machinery and working light systems. Programming is slow and timed sequences cumbersome to implement. Although not appropriate as a show control system controller, they may include an RS232 interface and could be a controlled device within a show control system.

A second form of control hardware may be considered time based. These controllers would receive time code and output commands to other devices as determined by its internal programming. Modern lighting control consoles frequently include facilities for accepting SMPTE time code. At predetermined time codes these consoles could carry out cues and output state information as DMX512 data. Simple show control applications synchronised with time code could thus be implemented provided that all the required peripheral devices could respond to DMX512 protocol. A number of different control systems each responding to time code could be combined to provide a multi-discipline show control system. Each system would require individual programming and thereby hold independent cue lists. Interaction between these control systems would not be available.

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A computer based system with purpose written software provides the most powerful solution for show control applications. STAGE MANAGER software from Richmond Sound Design of Vancouver,Canada provides a powerful MSC sequencer. In addition to MIDI Show Control and regular MIDI commands the STAGE MANAGER software handles MIDI Machine Control and MIDI Time Code. Cue lists are created by clicking through plain language menus. Cues are implemented manually at the keyboard or from external signals, timed sequences controlled from external time code, internal timer or real time clock. Because STAGE MANAGER was designed initially for live performances manual override of cue execution is always available with the ability to skip cues and advance or retard timing. Single discipline cue lists can be assembled to allow, for example, a complex sound effect sequence to be tested and amended in isolation and then linked back with the cue lists for other disciplines.

A recent development is the ability of STAGE MANAGER software to send commands via the computer's operating system to SCSI ports allowing the direct control of CD ROM drives playing conventional audio CDs. Several CD ROM drives may be controlled synchronously providing multi-track replay. When controlled individually the CD ROM drives provide low cost, high quality replay sources for spot effects.

7. NETWORK SYSTEMS

Standards such as DMX512 and MIDI have specific purposes. However, as systems become more complex considerations might be given to connecting devices in a network; but which one?

The problem with virtually all commercially available networks is their inability to run in real-time. It matters little if it takes a few seconds for a spreadsheet to arrive at a printer. Within a Show Control System such delays would be totally unacceptable. Two proprietary systems are available to meet the real-time networking needs of the entertainment industry.

Lone Wolf's MediaLink does not replace any protocol but acts as a transmission medium able to carry, for example, MIDI, DMX512, and SMPTE. The network hardware and control software is established and has been adopted by other manufacturers including Carver, Rane, Yamaha and JBL.

Intelix Mind-Net can also carry data such as MIDI. It does not have enough band width to accommodate SMPTE and similar high band rate data thereby restricting it to peripheral control applications.

Both Media-link and Mind-Net are available under licence and this may restrict its adoption. Ideally an open network system is needed to become universally available in the same way as DMX512 and MIDI.

Several manufacturers are using Ethernet to implement custom network systems. By keeping the topology simple, package length short and traffic under 2 Mbps the delays due to collisions are minimal and "near-enough" real-time performance can be achieved. The major restriction is the simple topology and combining equipment from different manufacturers to achieve a comprehensive Show Control Network System seems improbable.

It also seems unlikely that smaller manufacturers would have the necessary resources to implement their own network solutions.

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8. CASE STUDY

The Theatre Royal is the premier performance venue aboard the M.V.Oriana, a new-build for P&O Cruises due to sail in April 1995. The consultant's requirement is for sophisticated lighting, sound, video, projection, stage rigging and effects systems. The client's requirement is that all technical aspects of the performances are coordinated by two technicians -- and one of them would be located on-stage! The project seemed an obvious candidate for a show control system.

The primary sound replay source is a Tascam DA-88 digital 8-track tape machine controlled by MIDI Machine Control and providing a MIDI Time Code output from the tape.

The main lighting control system is an Arri Imagine 3 controlling 144 thyristor dimmers via DMX512 protocol and interfacing with the show control system using MIDI Show Control. To provide complex effects lighting an Axon Showcad system under MIDI Show Control is used to control the same thyristor dimmers, colour changers, automated lighting fittings and strobe units via DMX512 protocol. In addition the DMX512 protocol is converted to analogue, 0 to +10 volt, to control smoke machines and gobo rotators.

Both lighting consoles also accept SMPTE time code. Provision is made to use a SMPTE output from the 8-track tape machine to directly control the lighting consoles if required.

One of the applications of the venue will be for conference and educational events. A simple operator interface is required to control two Sony S-VHS players, a Pioneer Laserdisc Player, two Navitar Slide-to-Video Convertors and a Hedco Audio/Video Matrix Switcher routing video signals to any of three video projectors. All the video equipment incorporates RS232 interfaces and an AMX touch screen and control system is provided. The AMX control system accepts and returns MIDI commands from the show control system for total system integration.

Stage rigging system comprises 12 variable speed Triple-E tracks controlled from a Programmable Logic Controller with touch screen operator interface. The PLC also includes an RS232 interfaced to the MIDI show control system for convenience via the AMX control system.

The show control system uses Richmond Sound Design STAGE MANAGER 3000 software.

P&O tradition requires that the Musical Director is able to initiate certain show segments and a local control push button panel is provided to interface directly with the show control system.

It can, therefore, be seen that within this single facility the following protocols are used: MIDI; MSC; MTC; MMC; RS232; DMX512: SMPTE time code as well as closing contacts and analogue. In addition to the MSC sequencer, there is the capability of direct time based control of lighting and moving lights and event based control using a PLC for the stage rigging systems.

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9. CONCLUSIONS

The avid reader having reached this point may have noted the ommission of Crown's IQ, Crest's Nexsys and similar proprietory protocals.

Whilst flexible enough to provide control for complex sound systems they may only be used to control their proprietor's products and a handful of licenced manufacturers.

The most successful protocols are those which have been developed through consensus of major manufacturers. Work is currently underway at the AES Standards Committee on an object oriented protocol fully complient with the OSI model known as AES-24.

Criteria for the network have been established although which system would be endorsed by the AES is yet to be determined.

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