Proceedings of the Institute of Acoustics

REMOTE AND NETWORK CONTROL FOR AV SYSTEMS BASED ON THE IEC 1030 CONTROL MODEL

A J Stirling

Communication & Control Electronics Ltd., Redhill, Surrey, RH1 1DL, UK.

1 INTRODUCTION

This paper describes a control model for a system comprised of devices which process or are connected with the processing of audio and video signals. This control model is based upon IEC 1030 (Domestic Digital Bus (D2B))[1].

2 BACKGROUND

D2B was developed as a control bus for integrating a variety of audio and video devices into a system. It was designed to simplify the control of such a system for the consumer, allowing the addition of devices of various brands to expand the capabilities of the system. It was specified to be reliable and sufficiently simple to implement in consumer products. Its development was also co-ordinated with that of home-buses (in Europe (IHS) and Japan (HBS)) to simplify the design of interfaces (gateways) between them.

D2B as defined by IEC 1030, consists of an application (control) model and a message communications system. In this paper the application model derived from IEC 1030 is described separately to the message communications, since the application model can be used with a variety of communications systems. So far the model has been applied with two types of message communications:

- IEC 1030 communications (electrical)
- D2B Optical communications

3 CURRENT APPLICATIONS

The main current application for this control model is in the integration of entertainment and information devices into systems within cars. These systems might include: CD changers, video tuners, navigation systems, traffic message decoders and mobile communication equipment (telephone, facsimile, electronic mail). The D2B control model has been applied to provide integrated system control for this diversity of functions.

Other applications include a satellite reception system linked by D2B (IEC 1030). The system comprises a satellite TV tuner (with an internal descrambler) linked to a separate decryptor device (with a smart card reader) and also linked to a satellite antenna positioner. The use of a separate decryptor device allows the decryption facility to be shared simultaneously with multiple satellite TV tuners (e.g. in a television and in a video-cassette recorder). Alternatively, multiple decryptors (each with a different smart card) can be linked into the system to allow any satellite tuner to select whichever decryptor is appropriate.

4 AV SYSTEM MODEL

A D2B system consists of a set of devices which are interconnected by a communications medium for exchanging control messages. The communication medium is:

- a cable (electrical) in the case of IEC 1030

- an optical fibre in the case of D2B Optical

4.1 Device Model

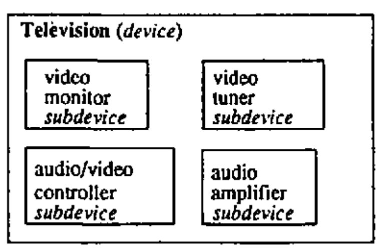
A *device* is a physical entity: a node on the network. Each device on the network has a set of functions which may be controlled using control messages from any other device on the network.

In order to simplify the control of these functions, they are divided into logical groups and each logical group is represented by a subdevice. In the control model, a device can be viewed as a container for the various subdevices that represent its functions. If another device wishes to control one of these functions, it must send a control message to the appropriate device and the control message must specify the subdevice which has the required function.

For example, suppose that there is an amplifier on the network. The amplifier functions of that device can be manipulated by sending control messages to its amplifier subdevice. Thus a control message for the amplifier carries both the address of the device containing the amplifier and the address of the subdevice to be controlled. This subdevice address is used to route the control message internally to the amplifier subdevice.

A television is an example of a device, containing the following subdevices:

- a video monitor
- an audio amplifier
- a video tuner
- an audio/video controller (representing the device's 'intelligence')



4.2 Device & Subdevice States (Properties)

Each device and subdevice has its own associated properties. Some of these are static (e.g. the version number of the protocols), whilst others are dynamic. If a property is dynamic then its value can change either due to a control message from another device on the network or else due to a local event. For example, the *mute* state of an audio amplifier subdevice is a dynamic property which can be changed either by a control message from the network or else by a local control button.

4.2.1 Device States. The device states are general states which are applicable to any type of device and are independent of any particular subdevice function. For example:

- power state (on/off)
- device type (amplifier, tuner etc.)

4.2.2 Subdevice States. These states are unique for each type of subdevice. For example, amplifier subdevice states include:

- volume level (e.g. 0 to 64)
- mute (on/off)

5 CONTROL MESSAGES

System control is based on the exchange of control messages between devices within the system. Within the system, any device (or subdevice) can send a control message to any other device (or subdevice). Thus the system may be controlled either centrally (e.g. using a device with a system control panel) or it may be controlled from any of the devices in the system.

Each control message carries the address of the device which sent it (the master address) and of the device which should receive it (the slave address).

5.1 Device Addresses

Each device on the network has a unique 12 bit address, consisting of:

- *service type* (4 bits), e.g.:
  - Audio Video & Control (AV/C)
  - Communication Telephony (CT)
- *device type* (5 bits), indicates the main function of the device, (that of its principal subdevice) e.g.:
  - amplifier
  - audio disc player
- *device number* (3 bits), to allow up to and including 8 devices of the same type within a system

The initialisation of each device includes a check that the device address to be used by that device is unique within the system. There are two device addresses reserved for special purposes:

- for a device which does not wish to participate in the network (e.g. the device has detected a fault)
- for broadcasting a message to all devices in the system

5.2 Subdevice Addresses

Whilst device addresses are used to deliver a message on the network, subdevice addresses are used to route messages to/from particular subdevices within a device.

For example a video cassette recorder device typically has a *video tape-deck subdevice* and a *video tuner subdevice*. If another device needs to send a command to the *video tape-deck subdevice* to start playing a tape, it must specify a destination subdevice address (*video tape-deck subdevice* (number 1)) as part of the control message.

Subdevice addresses are 10 bit numbers consisting of: service area (2 bits, e.g. Audio Video/Control); subdevice type (e.g. video tape deck) and subdevice number (e.g. 1). The subdevice number enables several subdevices (up to 8) of the same type to be present in the same device.

5.3 Control Message Contents.

The following diagram shows the contents of a control message as it would be passed for communication, together with the address of the device to which it must be sent.

Destination Device Address	Message Length	Subdevice Addressing	Command Identifier	Operand 1	------	Operand n

The function to be controlled is specified by the combination of a command identifier (an operation code) and one or more operands. The command identifier specifies the basic function e.g. *play* (for a tape deck subdevice) and the operand(s) are used as qualifiers e.g. *play forward* or *play reverse*.

6 TYPES OF CONTROL MESSAGE

The following types of control message are used:

- *commands*, normally used to change the state of a specified function e.g. amplifier mute *on* or *off*.
- *status reports*, indicating the current state of a particular function, e.g. muted
- *data messages*, to carry information from one device to another

6.1 Commands
Commands are used to set the state of particular device and subdevice functions. See the later section for more details of command messages and their use.

6.2 Status Reports
Status reports can be returned by a subdevice (or device) in response to a command message and also when a local event causes a state change. Any device can request a subdevice to deliver subdevice status reports which will then be provided as:

- an initial complete set of status
- updates of any item of status whenever a change in that item occurs
  - when a command is received
  - when a local event occurs (e.g. the user ejects a disc using a local control button)

For example, a system controller (device) could arrange to monitor the status of a CD player so that the system controller could update a track number display whenever the CD player starts to play a new track.

6.3 Data Messages
Data messages are used to carry information from one device to another within the system. For example, a Digital Compact Cassette player could provide text to a display device whilst a tape is being played.

7 COMMANDS

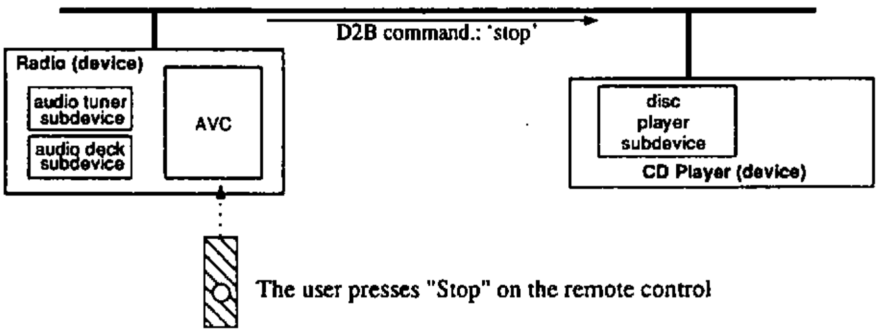
7.1 Command Types
There are two types of command within the system:

- native commands: these are the fundamental components of system control
- user commands: these are user triggers for system functions

7.2 Native Commands
These are the basic means by which one device can control the functions of another device (and its subdevices). The result of executing these commands is predictable and is normally a single state change. The behaviour of the device (or subdevice) which executes the command is defined by application protocols. For example, when the *stop* command is sent to an audio tape-deck subdevice, only a single state change will occur (unless the tape-deck was already stopped). More complex control can be achieved by sending a sequence of commands to one or more subdevices.

Command messages are normally generated as a direct response to a user stimulus (instruction). For example, the user may press a button on a control panel. This instruction requires interpretation by an

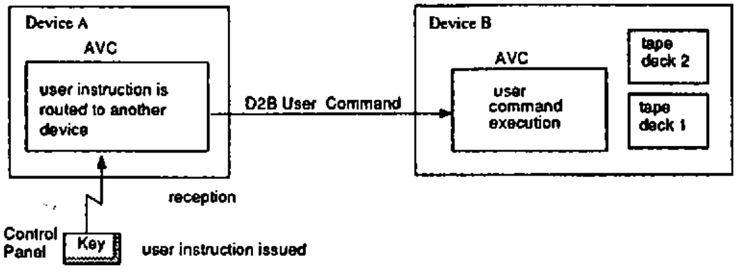
Audio Video Controller (AVC) subdevice. In the simplest case the interpretation occurs within the device which received the instruction (via a local control panel or infra-red remote control receiver).



7.3 User Commands
If an AVC subdevice finds that it cannot interpret or execute a particular user instruction, the AVC can use a reserved command message (a *user command*) to forward that user instruction to another AVC subdevice elsewhere in the system. In this way a single control panel or infra-red remote control receiver in one device can be shared with the other devices in the system.

Since user commands may be regarded as an extension of the user interface of a particular device, the precise effects of a user command are determined by the manufacturer of the executing device. A user command can cause local state changes in the executing device and may result in control messages being sent to other devices in the system. This contrasts with the effects of native D2B commands, which are defined by the control model and which typically affect only one device or subdevice state within the device to which they are sent.

Consider the example shown in the following diagram. This device (Device A in the diagram) sends a user command (e.g. copy tape 1 to tape 2) to a device (B) which is capable of interpreting and executing that command e.g. a tape recorder with two tape decks.



8 AV SIGNAL CONNECTIONS

There are two methods of co-ordinating the construction of audio and video signal connections within the devices in the system:

- centralised
- distributed

8.1 Centralised Connection Control

With this approach, a single device in the system (the *resource manager*) keeps all the knowledge of audio and video signal cable connections for the system. If another device wishes to build an AV signal connection then it must send a control message to the resource manager, specifying the details required to build the connection (source, destination, signal type).

This centralised approach avoids the difficulty of setting up and maintaining distributed maps of cable connections within the system. The resource manager bears most of the software burden for this method, but reduces the burden for all the other devices in the system. The disadvantages of this approach are:

- the need for arbitration to select which device will be the resource manager, if more than one device is capable of this function
- the expansion of the system is limited by the capacity of the resource manager to hold the cable connection maps.

8.2 Distributed Connection Control

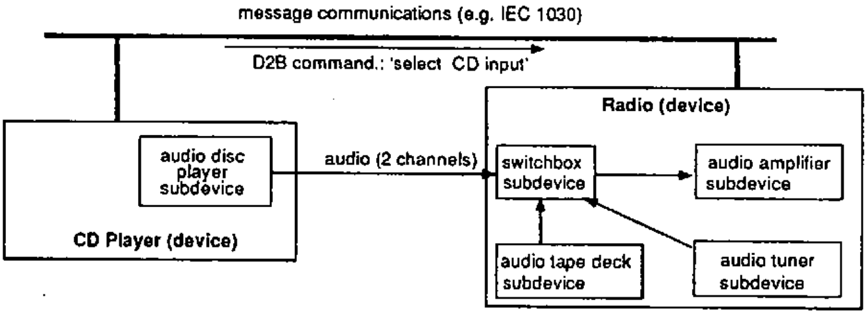
Distributed control means that the co-ordination for building a signal connection is split amongst the devices which will be involved in the connection. Each device needs to know its own local cable connections and its own signal switching abilities. With this approach, connections are built in a chain from a source device (e.g. an audio tuner) to a destination device (an audio tape deck) by a process of trial and error. The sequence is as follows:

- a command is sent first to the source device, specifying signal type and destination
- that device knows its own cable connections, its own switching abilities, and knows the addresses of its neighbouring devices
  - it passes a connection-building command to one of its neighbouring devices
  - waits for a confirmation message to check the success of the path building
- in this way the signal path propagates either to the required destination or until it is clear that the wrong path is being built
  - if the wrong signal path has been built (the destination does not match the requested destination), then the path will be unravelled and a new path will be tried
  - if the path is correct, then a confirmation message is passed back along the chain of devices which form the new signal path

This algorithm is more complex than for centralised connection control. Each AV device needs to set-up and maintain the details of its local cable connections. However, the size of the system is not limited by the capabilities of any particular device, since no device needs to keep more than its own local connection details.

8.3 Physical Means of Building Connections

8.3.1 Systems based on IEC 1030. In systems based on IEC 1030 communications, control messages are sent between devices to set the audio/video signal switches (called switchbox subdevices in the model) as required to build a particular signal path.



8.3.2 Systems based on D2B Optical. In D2B Optical systems, control messages are carried together with digital audio and (compressed) digital video signals over the same medium (optical fibre). Control messages are sent to set the signal routing within each device as required to build a particular signal path. In the case of D2B Optical, the AV signal switching consists of allocating or releasing slots in the multiplex.

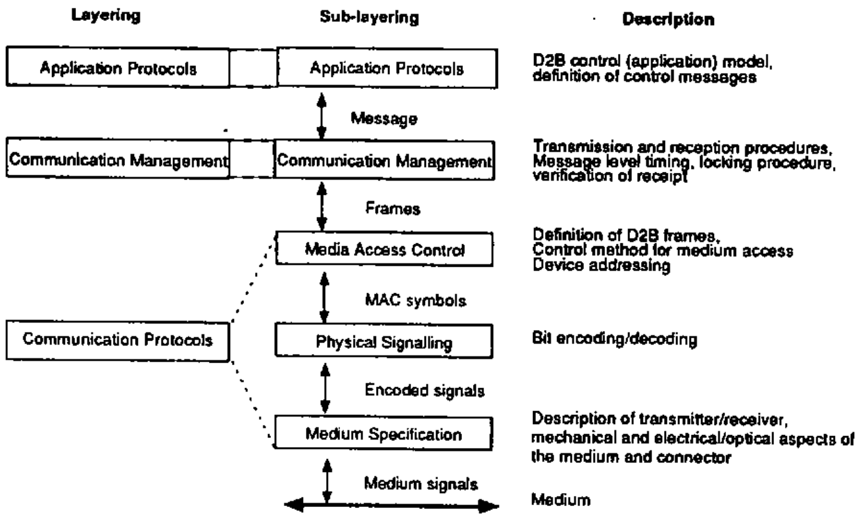
In addition to audio and video signals, D2B Optical is also intended to carry data from devices such as CD-ROM drives (for navigation equipment) and broadcast data decoders (e.g. for the Traffic Message Channel of the Radio Data System (RDS)).

9 MESSAGE COMMUNICATIONS

Message communications may be viewed as two basic layers:

- communication management
- communication protocols

The diagram below shows the message communications layers and their components:



9.1 Communication Management

9.1.1 Transmitting a Message. When a device is sending a message, the controlling application passes the message to the communication management, which in turn passes the message frame to the communication protocol layer for transmission. The communication management is then responsible for:

- checking that the message has been received correctly
- re-transmission if the message has not been correctly received
- reporting the eventual result back to the application

Rules for the maximum number of re-transmissions and the interval between retries have been defined such that message transmission has a very high probability of success and also that all devices in the system have a fair chance to send messages.

9.1.2 Receiving a Message. When a device has correctly received a message, the communication management is responsible for collecting the received message from the communication protocol layer and passing it to the application.

9.2 Communications Protocols

This layer is responsible for:

- transmitting each message frame and reporting back to the communication management on the success or failure of the transmission
- receiving frames addressed to this device from other devices on the network
  - acknowledging correctly received frames
  - rejecting erroneous frames

9.3 Communications Implementation
The message communications are normally implemented using a single dedicated communications controller integrated circuit within each device. This relieves the device's main microcontroller from the most time critical aspects of message communication.

10 IEC 1030 COMMUNICATIONS

The IEC 1030 standard (Audio, video and audio-visual systems, Digital Domestic Bus), defines a complete communication structure:

10.1 Message Frame Structure
The frame transmitted on the IEC 1030 medium (electrical) is shown below. Note that each field following the master address field has a parity bit and an acknowledgement flag. The acknowledgement flag is used for signalling the successful reception of that field to the sender of the message. Each byte in the message (data) field also has its own parity, acknowledgement flag and a flag to indicate whether or not this is the last byte of the message.

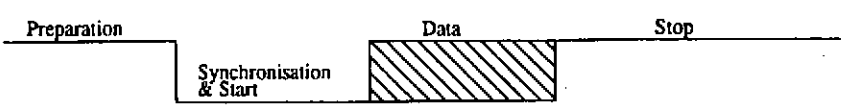
IEC 1030 Message Frame

Start Field	Mode Field	Master Address Field	Slave Address Field	Control Field	Message (Data) Field
1 bit	≥ 1 bit	13 bits	14 bits	6 bits	≤ 32 x 11 bits

The type of control message being carried is indicated in the control field (e.g. *command* or *data*) .

10.2 Medium Access Control:
- uses Carrier Sense Multiple Access with Collision Detection (CSMA/CD)
- carrier sense using a start bit
- one device always succeeds when a collision occurs

10.3 Bit Encoding
- 3 'speeds' (modes) have been defined, giving the following maximum net data rates
  - mode 0: 209 bytes/second
  - mode 1: 2457 bytes/second
  - mode 2: 7760 bytes/second
  - each bit comprises 4 periods for protection of the data, in addition to the parity check at field level, (both receiver and transmitter monitor the timing of these periods and use this to detect errors)



10.4 Transmission Characteristics
- balanced cable pair and return
- bi-directional
- the electrical driver and receiver characteristics are defined

10.5 Network Topology
- daisy chained with a termination at each end

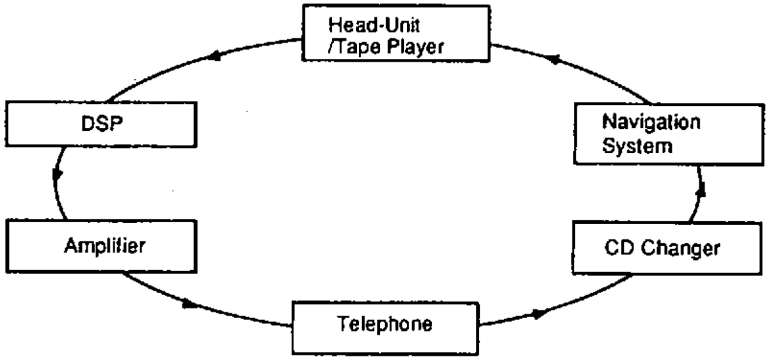
10.6 Cable Characteristics
- impedance 120Ω
- maximum length 150 metres

11 D2B OPTICAL COMMUNICATIONS

D2B Optical communications have been developed from a system known as A-LAN [2], which itself was derived from the AES/EBU serial digital audio interface (consumer), also known as IEC 958 [3]. Briefly the differences are:

- the subframe size is doubled
- a ring topology is used
- optical fibre is the normal transmission medium
- each subframe carries a multiplex of source data channels

11.1 Example: A Car Entertainment & Information System

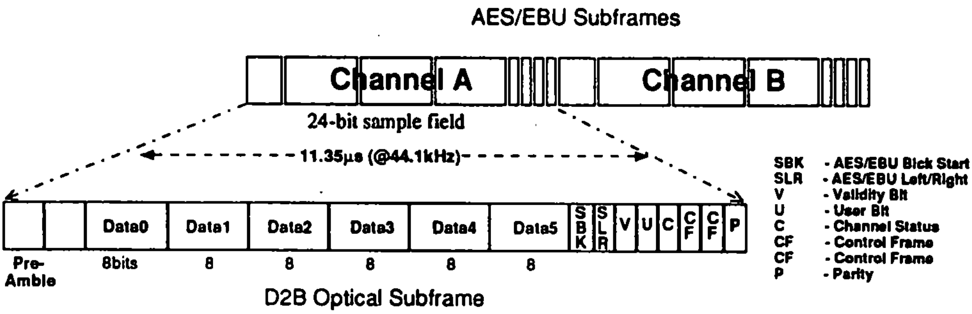


11.2 D2B Optical Frame
The D2B Optical frame size is 128 bits (compared with 64 bits in the AES/EBU frame) with the additional capacity used for carrying:

- multiple source data channels for audio, compressed video and general data (approx. 4.2 Mbits/second at a frame rate of 44.1kHz)
- a dedicated control message channel (separate from the user data)
  - each control message frame consists of 192 control bits
  - with a message capacity of approximately 14.7 kbytes/second (or approximately 1 message per millisecond, at a frame rate of 44.1kHz).

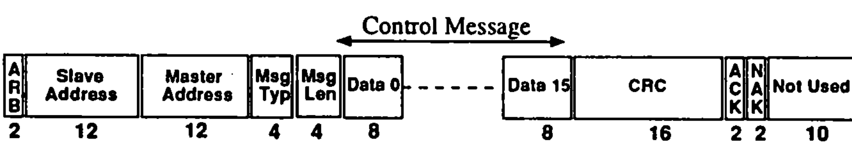
The D2B Optical frame carries bits for identifying the start of an AES/EBU block when the frame is carrying either audio or data derived from an AES/EBU input.

Note that multiple channels can be carried within the same D2B Optical subframe.



11.3 Control Message Frame

The *control message frame* is assembled from the CF bits in the D2B Optical frame (source data frame).



Key

ARB - Arbitration ensures that the frame is used by one device only
Slave Address - Selects one of 4095 destination addresses or All devices
Master Address - Identifies the device which sent the message
Msg Typ (Message Type) - Clearly identifies the function of the message (i.e. command, data, etc.)
Msg Len (Message Length) - the number of bytes occupied by the message
Data - the message
CRC - Cyclic redundancy check
ACK - Acknowledgement for signalling successful reception back to the device which sent the message
NAK- Negative acknowledgement for broadcast error reporting

12 REFERENCES

[1] IEC 1030 : Audio,video and audiovisual systems, Digital Domestic Bus (D2B), 1991.
[2] D J KNAPP & H HETZEI, "Audio Local Area Network Chip for Cars," 92nd AES Convention, Vienna, Preprint 3318, March 1992.
[3] IEC 958 : Serial Digital Audio Interface, 1989.