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AV/C Command Set for Rate Control of Isochronous Data Flow 1.0

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Abstract:
This specification defines an AV/C command set to control data rates on AV subunit plugs. The command set enables rate control of isochronous data flows between AV devices with the connections described in IEC-61883 and the AV/C Digital Interface Command Set General Specification.

Keywords:
Audio, Video, 1394, Digital, Interface, Asynchronous, Isochronous, Connection, Synchronization.

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Editor, 1394 Trade Association
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1. Overview

1.1 Purpose

The purpose of this document is to provide a mechanism that enables a device to control the rate of isochronous data flows between AV devices and gives a variety of options for synchronization between the devices.

1.2 Scope

This document defines an AV/C command set to control data rates on AV subunit plugs. The command set enables rate control of isochronous data flows between AV devices with the connections described in IEC-61883 [R2] and the AV/C Digital Interface Command Set General Specification [R3]. The rate control contains two models, the command-based rate control and the clock-based rate control. They can be performed with command functions, namely *clock-source selection*, *base-rate configuration* and *flow-rate control*.

2. References

The following standards contain provisions, which through reference in this document, constitute provisions of this standard. All the standards listed are normative references. Informative references are given in annex A. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

[R1] IEEE Std 1394-1995, Standard for a High Performance Serial Bus.

[R2] IEC-61883-1, Consumer audio/video equipment – Digital interface – Part 1: General.

[R3] AV/C Digital Interface Command Set General Specification, Version 3.0. TA document number 1998003.

3. Definitions

3.1 Conformance Levels

3.1.1 expected: A key word used to describe the behavior of the hardware or software in the design models *assumed* by this Specification. Other hardware and software design models may also be implemented.

3.1.2 may: A key word that indicates flexibility of choice with *no implied preference*.

3.1.3 shall: A key word indicating a mandatory requirement. Designers are *required* to implement all such mandatory requirements.

3.1.4 should: A key word indicating flexibility of choice with a strongly preferred alternative. Equivalent to the phrase *is recommended*.

NOTE — The IEEE is investigating whether the “may, shall, should” and possibly “expected” terms will be formally defined by IEEE. If and when this occurs, draft editors should obtain their conformance definitions from the latest IEEE style document.

3.2 Glossary of Terms

3.2.1 AV unit: The physical instantiation of a consumer electronic device within a Serial Bus node.

3.2.2 AV subunit: An instantiation of a virtual entity that can be identified uniquely within an AV unit and offers a set of coherent functions.

3.2.3 isochronous: A term that indicates the essential characteristic of a time-scale or signal, such that the time intervals between consecutive instances either have the same duration or durations that are integral multiples of the shortest duration. In the context of Serial Bus, “isochronous” is taken to mean a bounded worst-case latency for the transmission of data; physical and logical constraints that introduce jitter preclude the exact definition of “isochronous."

3.2.4 node: An addressable device attached to Serial Bus with at least the minimum set of control registers defined by IEEE Std 1394–1995.

3.2.5 node ID: A 16-bit number, unique within the context of an interconnected group of Serial Buses. The node ID is used to identify both the source and destination of Serial Bus asynchronous data packets. It can identify one single device within the addressable group of Serial Buses (unicast), or it can identify all devices (broadcast).

3.2.6 plug: A physical or virtual end-point of connection implemented by an AV unit or subunit that may receive or transmit isochronous or other data. Plugs may be Serial Bus plugs, accessible through the PCR’s; they may be external, physical plugs on the AV unit; or they may be internal plug group implemented by the AV subunits.

3.2.7 source plug: A subunit source plug is a source of output data.

3.2.8 destination plug: A subunit destination plug receives incoming data.

3.2.9 stream: A time-ordered set of digital data originating from one source and terminating at zero or more sinks. A stream is characterized by bounded bandwidth requirements and by synchronization points, or time stamps, within the stream data.

3.3 Acronyms and Abbreviations

AV/C Audio Video Control

4. Command-based Rate Control

4.1 Command-based Rate Control of Isochronous Data Flow

By controlling the rate of an isochronous data flow between a source device and a destination device, the destination device can prevent its buffer from overflow and underflow despite a phase error between the applications on the devices. The command-based rate control of an isochronous data flow is performed between a single source device and a single destination device with an asynchronous AV/C command set. An example of a typical procedure for the command-based rate control is described in annex B.

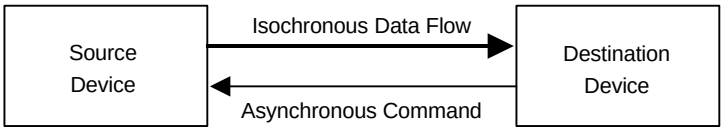


Figure 4.1 – Command-based rate control of isochronous data flow

4.2 Connections

Figure 4.2 illustrates a source device, which is a target of the command-based rate control, and a destination device, which issues the command-based rate control. The source device is represented by the source unit that has a subunit outputting a stream, and the destination device is represented by the destination unit that has a subunit inputting and processing the stream.

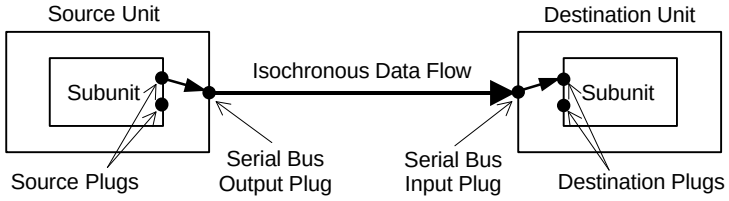


Figure 4.2 – Connections between source and destination

To realize the command-based rate control of an isochronous data flow, the following connections shall be established.

1) A connection between the Serial Bus output plug of the source unit and the Serial Bus input plug of the destination unit.
2) A connection between the source plug of the subunit and the Serial Bus output plug of the source unit.
3) A connection between the destination plug of the subunit and the Serial Bus input plug of the destination unit.

The unit-to-unit connection shall be established with the procedures described in IEC-61883-1 [R2]. It may be a point-to-point connection or consist of broadcast-in/out connections.

If the unit-internal connections are not hard-wired, they can be established with the CONNECT command defined in the AV/C Digital Interface Command Set General Specification [R3].

The target does NOT care whether the controller that issues the rate control commands is the destination of the isochronous stream or not. The command may also be accepted with or without any connections described above. If one or more of these connections are broken, however, the rate control of the isochronous data flow will fail even if control of the data rate on the subunit source plug succeeds.

4.3 Exclusive Rate Control in a Broadcast Scenario

Though the command-based rate control is performed between a single source device and a single destination device, the source device may broadcast to multiple destination devices. In this case, only one of the destination devices shall control the data rate, and the other devices should discard the data. To acquire or release exclusive control of the data rate, a controller can use the SYNC SELECT subfunction of the RATE control command on the source device (see clause 6.1.1). While the command-based rate control is being performed, the selection state of the sync source on the subunit source plug shall be the FLOW CONTROL state. For information about the other states available, see Table 6.4.

4.4 Base-rate Configuration

A subunit source plug has a base rate that may be configured before data streams through the plug. To configure the base rate on the subunit source plug, a controller can use the BASE CONFIGURE subfunction of the RATE control command on the source device (see clause 6.1.3). The base rate depends on the configuration state, the clock source and the stream format, which does not include packet headers for isochronous transfer. While the selection state is the FLOW CONTROL state, the base rate can be configured only by the controller that selected the FLOW CONTROL state.

4.5 Flow-rate Control

A subunit source plug has a flow rate that may be controlled dynamically while streaming data. The dynamic control would occur in response to the level of data in the destination device's buffer. To control the flow rate on the subunit source plug, a controller can use the FLOW CONTROL subfunction of the RATE control command on the source device (see clause 6.1.5). The flow rate depends on the variables control state and base rate, and would speed up and slow down based on the destination buffer's needs. While the selection state is the FLOW CONTROL state, the flow rate can be controlled only by the controller that selected the FLOW CONTROL state.

4.6 Voluntary Release of Exclusive Control (Informative)

As described in clause 4.3, only one destination device can flow-control an isochronous stream exclusively by selecting the FLOW CONTROL state on a subunit source plug. This flow-control mechanism is possible to cause the situation that the other devices cannot input and process the stream even though they want to. Therefore it is desirable that a controller that has exclusive control examines periodically whether or not another device is listening to the stream, and voluntarily releases the exclusive control if the stream is being listened and the flow control is interruptible. On the other hand, it is also desirable that devices examine whether or not a stream is flow-controlled, and overlay a point-to-point connection only when they want to interrupt the flow control.

The examination of the connection can be performed typically by reading the Plug Control Register on the source device, which is defined in IEC-61883-1 [R2].

5. Clock-based Rate Control

5.1 Clock-based Rate Control of Isochronous Data Flow

The clock-based rate control means that an application's data stream is synchronized with a given clock. This rate control mechanism is an alternative to the command-based rate control system, and is possible only when a synchronizable clock exists on the network. The application's data stream is time-stamped and delivered in isochronous packets. To describe the usage of this model, four entities are introduced.

1) Clock source
2) Clock sink
3) Data source
4) Data sink

Clock information is generated by the clock source and delivered to the clock sink, and a data stream is generated by the data source and delivered to the data sink. If the clock sink and the data source are in one device, the device can synchronize the data stream with the clock information. The control method such as PLL (Phase Locked Loop) or SRC (Sampling Rate Converter) is implementation dependent.

NOTE — The data sink and the clock source are not necessarily in one device.

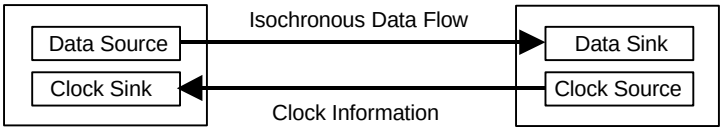


Figure 5.1 – Clock-based rate control of isochronous data flow

5.2 Connections

Figure 5.2 illustrates a source device, which is a target of the clock-based rate control. The source device is represented by the source unit that has a subunit outputting a stream synchronous with the clock information.

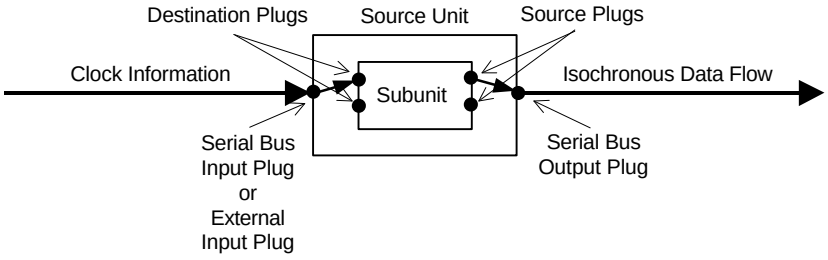


Figure 5.2 – Connections for clock and data

To realize the clock and data deliveries needed for the clock-based rate control, the following connections shall be established.

1) A connection between the destination plug of the subunit and the Serial Bus or External input plug of the source unit.

2) A connection between the source plug of the subunit and the Serial Bus output plug of the source unit.

If the unit-internal connections are not hard-wired, they can be established with the CONNECT command defined in the AV/C Digital Interface Command Set General Specification [R3].

5.3 Clock-source Selection

While the clock-based rate control is being performed, the source device that has a data source synchronizes the data stream with a clock source. To select the clock source, a controller can use the SYNC SELECT subfunction of the RATE control command on the source device (see clause 6.1.1).

5.4 Base-rate Configuration

A subunit source plug has a base rate that may be configured before data streams through the plug. To configure the base rate on the subunit source plug, a controller can use the BASE CONFIGURE subfunction of the RATE control command on the source device (see clause 6.1.3). The base rate depends on the configuration state, the clock source and the stream format, which does not include packet headers for isochronous transfer.

6. Command Set for Rate Control

This section defines the command set for rate control as summarized in Table 6.1. The RATE command shall be addressed to a subunit. Any RATE command addressed to a unit shall be returned with a NOT IMPLEMENTED response.

Table 6.1 – Command set for rate control

Opcode	Value	Support level (by *ctype*)			Comment
		C	S	N	
RATE	$B3_{16}$	O	O	–	Control a data rate on a subunit plug.

In the preceding table, an "O" means "Optional" and a "–" means "Not defined" for the *ctype* value, CONTROL, STATUS or NOTIFY. The specific command format is described in the following clause.

6.1 RATE Command

The RATE command is used to control a data rate on a subunit plug and to determine the control status. The format of the RATE command is shown in Figure 6.1.

	msb							lsb
opcode	RATE ($B3_{16}$)							
operand[0]	subfunction							
operand[1]	result							
operand[2]	plug_type							
operand[3]	plug_id							
operand[4] :	subfunction_dependent							

Figure 6.1 – RATE command

subfunction: The *subfunction* field definitions are shown in Table 6.2. If the RATE control command is implemented, the CAPABILITY INQUIRY subfunction shall be supported. The other subfunctions are supported optionally, depending on applications.

Table 6.2 – *subfunction* field definitions

Subfunction	Value	Meaning
SYNC SELECT	00_{16}	Select a clock source to synchronize with a stream on a subunit source plug.
BASE CONFIGURE	01_{16}	Configure a base rate on a subunit source plug.
FLOW CONTROL	02_{16}	Control a flow rate on a subunit source plug.
CAPABILITY INQUIRY	80_{16}	Inquire about subunit plug capabilities associated with the RATE command.
–	all others	Reserved for future specification.

result: The *result* field shall be set to FF_{16} by the controller in the command frame. In the response frame, the subunit shall update the field with a result code. Result codes and their interpretations are defined for each subfunction.

plug_type: The *plug_type* field specifies either a source (= 00_{16}) or destination (= 01_{16}). All other values for this field are reserved for future specification.

plug_id: The *plug_id* field specifies the ID of the subunit plug.

subfunction_dependent: The *subfunction_dependent* field is defined for each subfunction.

The response frame returned for the RATE command has the same format as shown in Figure 6.1. Some operands such as the *result* field are updated by the target in the response frame and they are described for each subfunction.

6.1.1 SYNC SELECT Subfunction for Control Command

The SYNC SELECT subfunction is used to select a clock source with which a stream on a subunit source plug is synchronized. The format of the RATE control command with the SYNC SELECT subfunction is shown in Figure 6.2.

	msb							lsb
opcode	RATE ($B3_{16}$)							
operand[0]	SYNC SELECT (00_{16})							
operand[1]	result							
operand[2]	plug_type (00_{16})							
operand[3]	plug_id							
operand[4]	sync_select_state							
operand[5]	destination_plug							

Figure 6.2 – RATE control command with SYNC SELECT subfunction

Table 6.3 – *result* field in the control response

Response frame type	Result	Result code name	Meaning
ACCEPTED	00_{16}	success	Successful completion.
	all others	–	Reserved for future specification.
REJECTED	80_{16}	invalid	The requested selection is invalid in the current base rate and/or flow rate (see clause 6.1.7).
	81_{16}	unavailable	The requested selection is valid, but the controller has no permission to select the clock source on the subunit source plug because another controller is flow-controlling it.
	FF_{16}	unknown	An unknown error occurred.
	all others	–	Reserved for future specification.
NOT IMPLEMENTED INTERIM	FF_{16}	–	No result.

result: The *result* field in the response may have one of the values shown in Table 6.3.

plug_type: The *plug_type* field shall have a value of 00_{16} (source plug).

plug_id: The *plug_id* field specifies the ID of the source plug.

sync_select_state: The *sync_select_state* field specifies the selection state of the sync source on the subunit source plug as shown in Table 6.4. If the SYNC SELECT subfunction is implemented, the INTERNAL state shall be supported. The other states are supported optionally.

If the FLOW CONTROL state is supported, the FLOW CONTROL subfunction described in clause 6.1.5 shall be implemented. If the FLOW CONTROL subfunction is implemented, the FLOW CONTROL state shall be supported.

Table 6.4 – *sync_select_state* field

sync_select_state	Value	Meaning
INTERNAL	00_{16}	The stream on the subunit source plug is synchronized with the internal clock.
EXTERNAL	01_{16}	The stream on the subunit source plug is synchronized with an external clock.
FLOW CONTROL	$0F_{16}$	The data rate on the subunit source plug is dynamically controlled with the FLOW CONTROL subfunction. The internal clock is expected to be controlled by an external device.
–	all others	Reserved for future specification.

destination_plug: The *destination_plug* field specifies the ID of the subunit destination plug that is connected to the Serial Bus or External input plug and inputs an external clock to synchronize with a stream on the subunit source plug. When the *sync_select_state* field specifies the INTERNAL or FLOW CONTROL state, the *destination_plug* field shall have a value of FE_{16}.

A subunit, which has one or more source plugs, accepts a valid RATE control command with the SYNC SELECT subfunction for each of the source plugs, according to the following rules. If the requested selection is invalid in the current base rate and/or flow rate (see clause 6.1.7), the subunit shall reject the request. The *result* field of the REJECTED response has a value of 80_{16} (*invalid*).

1) If the selection state of the sync source on the source plug is the INTERNAL or EXTERNAL state, it may be changed to another selection state by any controller that issues a RATE control command with the SYNC SELECT subfunction.

2) When the selection state of the sync source on the source plug is changed to the FLOW CONTROL state, the subunit shall internally record the node ID of the controller that changed the selection state on the source plug.

3) While the source plug is in the FLOW CONTROL state, the subunit shall reject any RATE control command with the SYNC SELECT subfunction unless the received command includes a node ID value that is the same as the recorded node ID for the source plug. The *result* field of the REJECTED response has a value of 81_{16} (*unavailable*).

4) If a RATE control command with the SYNC SELECT subfunction is received from the controller that has the same node ID that is recorded for the source plug, it shall be accepted. This permits the original controller to change the selection state of the sync source to the INTERNAL or EXTERNAL state.

5) When the subunit detects a Serial Bus reset, it shall set the recorded node ID to a value of $FFFF_{16}$. Then, the subunit assumes that a RATE control command with the SYNC SELECT subfunction received from a controller within 10 seconds after the bus reset is legitimate, and it shall accept the command and record the reassigned node ID of the controller for the source plug. If the subunit does not receive a RATE control command with the SYNC SELECT subfunction within a period of 10 seconds after the bus reset, it shall reset the selection state to the state before the FLOW CONTROL state was selected or to the initial state.

If the selection state of the sync source on the subunit source plug is the FLOW CONTROL state before a bus reset, controllers shall not issue RATE control commands with the SYNC SELECT subfunction within 10 seconds after the bus reset unless they were the last one to change the selection state prior to the bus reset.

If the SYNC SELECT subfunction is implemented, the initial selection state of the sync source shall be the INTERNAL or EXTERNAL state.

6.1.2 SYNC SELECT Subfunction for Status Command

If the RATE control command with the SYNC SELECT subfunction is implemented, the RATE status command with the SYNC SELECT subfunction shall also be implemented. The RATE status command with the SYNC SELECT subfunction is used to determine the current selection state of the sync source on the subunit source plug. In this case, *operand[4]* and *operand[5]* are set to $FFFF_{16}$ when the command is issued, and are updated to the current selection state and the associated destination plug when the STABLE response is returned. The *result* field in the status response may have one of the values shown in Table 6.5.

	msb							lsb
opcode	RATE ($B3_{16}$)							
operand[0]	SYNC SELECT (00_{16})							
operand[1]	result							
operand[2]	plug_type (00_{16})							
operand[3]	plug_id							
operand[4]	FF_{16}							
operand[5]	FF_{16}							

Figure 6.3 – RATE status command with SYNC SELECT subfunction

Table 6.5 – *result* field in the status response

Response frame type	Result	Result code name	Meaning
STABLE	00_{16}	in_sync	The stream on the subunit source plug is in sync with the clock source.
	01_{16}	out_of_sync	The stream on the subunit source plug is out of sync with the clock source.
	08_{16}	stopped	The stream on the subunit source plug was stopped normally.
	09_{16}	suspended	The stream on the subunit source plug was suspended because of some error.
	all others	–	Reserved for future specification.
NOT IMPLEMENTED REJECTED IN TRANSITION	FF_{16}	–	No result.

6.1.3 BASE CONFIGURE Subfunction for Control Command

The BASE CONFIGURE subfunction is used to configure a base rate on a subunit source plug. The format of the RATE control command with the BASE CONFIGURE subfunction is shown in Figure 6.4.

	msb							lsb
opcode	RATE ($B3_{16}$)							
operand[0]	BASE CONFIGURE (01_{16})							
operand[1]	result							
operand[2]	plug_type (00_{16})							
operand[3]	plug_id							
operand[4]	base_config_state							

Figure 6.4 – RATE control command with BASE CONFIGURE subfunction

result: The *result* field in the response may have one of the values shown in Table 6.6.

Table 6.6 – *result* field in the control response

Response frame type	Result	Result code name	Meaning
ACCEPTED	00_{16}	success	Successful completion.
	all others	–	Reserved for future specification.
REJECTED	80_{16}	invalid	The requested configuration is invalid in the current sync selection and/or flow rate (see clause 6.1.7).
	81_{16}	unavailable	The requested configuration is valid, but the controller has no permission to configure the base rate on the subunit source plug in the FLOW CONTROL state.
	82_{16}	not_configured	The requested configuration is valid and the subunit source plug is available, but the base rate on the subunit source plug cannot be configured to any speed other than the current base rate, because the subunit is outputting a stream on the source plug.
	FF_{16}	unknown	An unknown error occurred.
	all others	–	Reserved for future specification.
NOT IMPLEMENTED INTERIM	FF_{16}	–	No result.

plug_type: The *plug_type* field shall have a value of 00_{16} (source plug).

plug_id: The *plug_id* field specifies the ID of the source plug.

base_config_state: The *base_config_state* field specifies the configuration state of the base rate as shown in Table 6.7. The data rate at the x*N* (*N* = 1, 2 ... 16) speed depends on the stream format and the clock source. If the BASE CONFIGURE subfunction is implemented, the X1 SPEED state shall be supported and in combination with each of supported sync-selection states. The other states are supported optionally.

NOTE — In the case of audio and music isochronous transmission, the stream format for high speed transfer is defined in the Enhancement to Audio and Music Data Transmission Protocol [B3].

A base rate on a source plug shall be configured while a subunit is NOT outputting a stream on the source plug. If the subunit is outputting a stream on the source plug, it shall reject any RATE control command with a different base-rate configuration from the current base rate. The *result* field of the REJECTED response has a value of 82_{16} (*not_configured*).

Note that outputting a stream on a subunit source plug does not mean transmitting a stream on a 1394 bus. To transmit a stream on a 1394 bus, appropriate connections need to be established (see clause 4.2 and clause 5.2). When a subunit is not outputting a stream on a source plug, a Serial Bus output plug connected to the source plug may output isochronous data indicating no stream.

When the subunit that accepted a RATE control command with the BASE CONFIGURE subfunction outputs a stream, it shall output the stream at the rate configured as the base rate. The rate may be controlled by using the FLOW CONTROL subfunction described in clause 6.1.5.

When the selection state of the sync source on the subunit source plug is the FLOW CONTROL state, the subunit shall reject the RATE control command with the BASE CONFIGURE subfunction from any controller other than that which changed the selection state to the FLOW CONTROL state. The *result* field of the REJECTED response has a value of 81_{16} (*unavailable*).

When a subunit that has a source plug in the FLOW CONTROL state detects a Serial Bus reset, it shall reject the RATE control command with the BASE CONFIGURE subfunction on the source plug until the FLOW CONTROL state on the source plug has been reselected, or until a period of 10 seconds has elapsed. If the FLOW CONTROL state on the source plug is not reselected within a period of 10 seconds, the selection state is reset to the state before the FLOW CONTROL state was selected or to the initial state (see clause 6.1.1). If a subunit resets the selection state, it shall also reset the configuration state of the base rate on the source plug to the state before the FLOW CONTROL state was selected or to the initial state.

Table 6.7 – *base_config_state* field

base_config_state	Value	Meaning
X1 SPEED	00_{16}	The base rate is set to x1 speed.
X2 SPEED	01_{16}	The base rate is set to x2 speed.
X3 SPEED	02_{16}	The base rate is set to x3 speed.
X4 SPEED	03_{16}	The base rate is set to x4 speed.
X5 SPEED	04_{16}	The base rate is set to x5 speed.
X6 SPEED	05_{16}	The base rate is set to x6 speed.
X7 SPEED	06_{16}	The base rate is set to x7 speed.
X8 SPEED	07_{16}	The base rate is set to x8 speed.
X9 SPEED	08_{16}	The base rate is set to x9 speed.
X10 SPEED	09_{16}	The base rate is set to x10 speed.
X11 SPEED	$0A_{16}$	The base rate is set to x11 speed.
X12 SPEED	$0B_{16}$	The base rate is set to x12 speed.
X13 SPEED	$0C_{16}$	The base rate is set to x13 speed.
X14 SPEED	$0D_{16}$	The base rate is set to x14 speed.
X15 SPEED	$0E_{16}$	The base rate is set to x15 speed.
X16 SPEED	$0F_{16}$	The base rate is set to x16 speed.
–	10_{16} -FF_{16}	Reserved for future specification.

6.1.4 BASE CONFIGURE Subfunction for Status Command

If the RATE control command with the BASE CONFIGURE subfunction is implemented, the RATE status command with the BASE CONFIGURE subfunction shall also be implemented. The RATE status command with the BASE CONFIGURE subfunction is used to determine the current configuration state of the base rate on the subunit source plug. In this case, *operand[4]* is set to FF_{16} when the command is issued, and is updated to the current configuration state when the STABLE response is returned. The *result* field in the status response may have one of the values shown in Table 6.8.

	msb							lsb
opcode	RATE ($B3_{16}$)							
operand[0]	BASE CONFIGURE (01_{16})							
operand[1]	result							
operand[2]	plug_type (00_{16})							
operand[3]	plug_id							
operand[4]	FF_{16}							

Figure 6.5 – RATE status command with BASE CONFIGURE subfunction

Table 6.8 – *result* field in the status response

Response frame type	Result	Result code name	Meaning
STABLE	00_{16}	configurable	The base rate on the source plug may be configured because the subunit is NOT outputting a stream on the source plug. (This result does not guarantee the success of the configuration.)
	01_{16}	not_configurable	The base rate on the source plug cannot be configured because the subunit is outputting a stream on the source plug.
	all others	–	Reserved for future specification.
NOT IMPLEMENTED REJECTED IN TRANSITION	FF_{16}	–	No result.

6.1.5 FLOW CONTROL Subfunction for Control Command

The FLOW CONTROL subfunction is used to control a flow rate while a subunit is outputting a stream on the source plug. The format of the RATE control command with the FLOW CONTROL subfunction is shown in Figure 6.6.

	msb							lsb
opcode	RATE ($B3_{16}$)							
operand[0]	FLOW CONTROL (02_{16})							
operand[1]	result							
operand[2]	plug_type (00_{16})							
operand[3]	plug_id							
operand[4]	flow_control_state							

Figure 6.6 – RATE control command with FLOW CONTROL subfunction

result: The *result* field in the response may have one of the values shown in Table 6.9.

Table 6.9 – *result* field in the control response

Response frame type	Result	Result code name	Meaning
ACCEPTED	00_{16}	success	Successful completion.
	all others	–	Reserved for future specification.
REJECTED	80_{16}	invalid	The requested control is invalid in the current sync selection and/or base rate (see clause 6.1.7).
	81_{16}	unavailable	The requested control is valid, but the controller has no permission to control the flow rate on the subunit source plug in the FLOW CONTROL state.
	82_{16}	not_controlled	The requested control is valid and the subunit source plug is available, but the flow rate on the source plug cannot be controlled with any operation other than STANDARD, because the subunit is NOT outputting a stream on the source plug.
	FF_{16}	unknown	An unknown error occurred.
	all others	–	Reserved for future specification.
NOT IMPLEMENTED INTERIM	FF_{16}	–	No result.

When the selection state of the sync source on the subunit source plug is the FLOW CONTROL state, the subunit shall reject the RATE control command with the FLOW CONTROL subfunction from any controller other than that which changed the selection state to the FLOW CONTROL state. The *result* field of the REJECTED response has a value of 81_{16} (*unavailable*).

plug_type: The *plug_type* field shall have a value of 00_{16} (source plug).

plug_id: The *plug_id* field specifies the ID of the source plug.

flow_control_state: The *flow_control_state* field specifies the control state of the flow rate as shown in Table 6.10. If the FLOW CONTROL subfunction is implemented, the STANDARD state shall be supported and in combination with each of supported sync-selection and base-configuration states. The other states are supported optionally. If the STANDARD state is supported for a subunit source plug, the subunit shall keep the control state at STANDARD while the source plug is in the sync-selection state other than the FLOW CONTROL state.

NOTE — In the case of audio and music isochronous transmission, the stream format for flow-controlled transfer is defined in the Enhancement to Audio and Music Data Transmission Protocol [B3].

If the FAST state is supported, the SLOW state shall also be supported. Conversely, if the SLOW state is supported, the FAST state shall also be supported. The STANDARD state indicates the base rate of the output and may be configured with the BASE CONFIGURE subfunction. The FAST or SLOW state indicates the output at the base rate ± 1% on the source plug. Their accuracy is ± 0.1%.

Table 6.10 – *flow_control_state* field

flow_control_state	Value	Meaning
STANDARD	00_{16}	The source plug outputs a stream at the base rate.
FAST	01_{16}	The source plug outputs a stream at the base rate + 1%.
SLOW	81_{16}	The source plug outputs a stream at the base rate - 1%.
–	all others	Reserved for future specification.

The FAST and SLOW states may be supported by a subunit capable of outputting a stream at a constant bit rate. If they are supported, the subunit source plug has three rates for controlling the flow rate corresponding to the STANDARD, FAST and SLOW, and switch them in response to a RATE control command with the FLOW CONTROL subfunction.

The phase error rate between the base rate on a subunit source plug that supports the FAST and SLOW and the processing rate of the destination subunit is expected to be less than 0.9% (1% - 0.1%) of the base rate. The FAST and SLOW states can cover this phase error rate. Buffer management on the destination side using the FAST, SLOW and STANDARD rates is described in annex C.

The delay from when the subunit accepts a RATE control command with STANDARD, FAST or SLOW to when the flow rate on the source plug actually changes into the requested rate shall be less than 1000 milliseconds.

When the subunit is NOT outputting a stream on the source plug, it shall reset the control state to STANDARD and reject any RATE control command with FAST or SLOW. The *result* field of the REJECTED response has a value of 82_{16} (*not_controlled*). The way to start and stop outputting a stream on the source plug is beyond the scope of this specification.

Note that outputting a stream on a subunit source plug does not mean transmitting a stream on a 1394 bus. To transmit a stream on a 1394 bus, appropriate connections need to be established (see clause 4.2 and clause 5.2).

When a subunit that has a source plug in the FLOW CONTROL state detects a Serial Bus reset, it shall reject the RATE control command with the FLOW CONTROL subfunction on the source plug until the FLOW CONTROL state on the source plug has been reselected, or until a period of 10 seconds has elapsed. If the FLOW CONTROL state on the source plug is not reselected within a period of 10 seconds, the selection state is reset to the state before the FLOW CONTROL state was selected or to the initial state (see clause 6.1.1). If a subunit resets the selection state, it shall also reset the control state on the source plug to the STANDARD state.

A controller that selected the FLOW CONTROL state on a subunit source plug shall send a RATE control command with the FLOW CONTROL subfunction for the source plug within 5 seconds and periodically thereafter in order to indicate the presence of the controller. The interval between successive RATE control commands with the FLOW CONTROL subfunction shall also be less than 5 seconds and should be minimally 1 second. A subunit that does not receive a RATE control command with the FLOW CONTROL subfunction for 5 seconds shall reset the sync-selection and base-configuration states on the source plug to the states before the FLOW CONTROL state was selected or to the initial states and reset the flow-control state on the source plug to the STANDARD state.

NOTE — While the subunit is NOT outputting a stream, the controller that selected the FLOW CONTROL state on the source plug is expected to send a RATE control command with STANDARD for the source plug repeatedly.

If the FLOW CONTROL subfunction is implemented, the initial control state of the flow rate shall be the STANDARD state.

6.1.6 FLOW CONTROL Subfunction for Status Command

If the RATE control command with the FLOW CONTROL subfunction is implemented, the RATE status command with the FLOW CONTROL subfunction shall also be implemented. The RATE status command with the FLOW CONTROL subfunction is used to determine the current control state of the flow rate on the subunit source plug. In this case, *operand[4]* is set to FF_{16} when the command is issued, and is updated to the current control state when the STABLE response is returned. The *result* field in the status response may have one of the values shown in Table 6.11.

	msb							lsb
opcode	RATE ($B3_{16}$)							
operand[0]	FLOW CONTROL (02_{16})							
operand[1]	result							
operand[2]	plug_type (00_{16})							
operand[3]	plug_id							
operand[4]	FF_{16}							

Figure 6.7 – RATE status command with BASE CONFIGURE subfunction

Table 6.11 – *result* field in the status response

Response frame type	Result	Result code name	Meaning
STABLE	00_{16}	controllable	The flow rate on the source plug may be controlled because the subunit is outputting a stream on the source plug. (This result does not guarantee the success of the control.)
	01_{16}	not_controllable	The flow rate on the source plug cannot be controlled because the subunit is NOT outputting a stream on the source plug.
	all others	–	Reserved for future specification.
NOT IMPLEMENTED REJECTED IN TRANSITION	FF_{16}	–	No result.

6.1.7 CAPABILITY INQUIRY Subfunction for Control Command

The CAPABILITY INQUIRY subfunction is used to inquire about subunit plug capabilities associated with the RATE control command. The format of the RATE control command with the CAPABILITY INQUIRY subfunction is shown in Figure 6.8.

result: The *result* field in the response indicates whether or not the specified capabilities (the combinations of the states) are supported, as shown in Table 6.12. Supporting a combination of states means that the subunit plug can be in each of the states at the same time.

	msb							lsb
opcode	RATE ($B3_{16}$)							
operand[0]	CAPABILITY INQUIRY (80_{16})							
operand[1]	result							
operand[2]	plug_type (00_{16})							
operand[3]	plug_id							
operand[4]	number_of_combinations (n)							
operand[5]	combination_of_states[0]							
operand[6]								
operand[7]								
:	:							
:	combination_of_states[n-1]							
:								
:								

Figure 6.8 – RATE control command with CAPABILITY INQUIRY subfunction

Table 6.12 – *result* field in the control response

Response frame type	Result	Meaning
ACCEPTED	xxxx $xxx1_2$	combination_of_states[0] is supported.
	xxxx $xx1x_2$	combination_of_states[1] is supported.
	xxxx $x1xx_2$	combination_of_states[2] is supported.
	xxxx $1xxx_2$	combination_of_states[3] is supported.
	xxx1 $xxxx_2$	combination_of_states[4] is supported.
	xx1x $xxxx_2$	combination_of_states[5] is supported.
	x1xx $xxxx_2$	combination_of_states[6] is supported.
	1xxx $xxxx_2$	combination_of_states[7] is supported.
REJECTED NOT IMPLEMENTED INTERIM	FF_{16}	No result.

plug_type: The *plug_type* field shall have a value of 00_{16} (source plug).

plug_ID: The *plug_id* field specifies the ID of the source plug.

number_of_combinations: The *number_of_combinations* field specifies the number of combinations to inquire. The number shall be eight or less. This means that a controller can inquire up to eight combinations at a time.

combination_of_states[]: If a subunit source plug implements a subfunction for the RATE control or status command, it has the state corresponding to the subfunction such as *sync_select_state*, *base_config_state* and *flow_control_state*. The *combination_of_states[]* field specifies a combination of the three states, as shown in Table 6.13. Each state (*sync_select_state*, *base_config_state* and *flow_control_state*) may have one of the values shown in Table 6.4, Table 6.7 and Table 6.10 respectively,

or may have a value of FF_{16}. These values are set by a controller. The state set to a value of FF_{16} is ignored by the target.

NOTE — A value of FF_{16} can be used as a wild card value for the state.

Table 6.13 – *combination_of_states[]* field

Address offset	combination_of_states[]
00_{16}	sync_select_state (see Table 6.4)
01_{16}	base_config_state (see Table 6.7)
02_{16}	flow_control_state (see Table 6.10)

If a controller issues a RATE control command with the SYNC SELECT, BASE CONFIGURE or FLOW CONTROL subfunction that requests an unsupported combination of the states even though each of the states is supported, the command shall be rejected with a result code indicating the request is invalid (see Table 6.3, Table 6.6 and Table 6.9).

6.1.8 CAPABILITY INQUIRY Subfunction for Status Command

The RATE status command with the CAPABILITY INQUIRY subfunction shall not be implemented. The *result* field in the status response shall have a value of FF_{16}.

Table 6.14 – *result* field in the status response

Response frame type	Result	Result code name	Meaning
NOT IMPLEMENTED	FF_{16}	–	No result.

6.2 Relation Between SYNC SELECT Subfunction and RESERVE Command

The RESERVE command is defined in the AV/C Digital Interface Command Set General Specification [R3]. The relation between the SYNC SELECT subfunction of the RATE command and the RESERVE command is described below:

1) When the subunit that has one or more source plugs in the FLOW CONTROL state accepts a RESERVE control command, it shall reset each selection state to the state before the FLOW CONTROL state was selected or to the initial state unless the selection state was changed by the same controller that issues the RESERVE control command.

2) When the unit including the subunit that has one or more source plugs in the FLOW CONTROL state accepts a RESERVE control command, it shall reset each selection state to the state before the FLOW CONTROL state was selected or to the initial state unless the selection state was changed by the same controller that issues the RESERVE control command.

NOTE — Without these rules, the selection state of the sync source on a source plug is possible to be unchangeable by any controller.

Annex A: Bibliography (Informative)

[B1] AV/C Disc Subunit General Specification, Version 1.0. TA document number 1998013.

[B2] Audio and Music Data Transmission Protocol, Version 1.0. TA document number 1997001.

[B3] Enhancement to Audio and Music Data Transmission Protocol. TA document number 1999014.

Annex B: Procedure for Command-based Rate Control (Informative)

This annex provides an example of a typical procedure for the command-based rate control between a source device which has a subunit source plug and a destination device which has a subunit destination plug. The controller described here is usually the same as the destination device.

1) Configure the base rate

A controller configures the base rate on the subunit source plug by using the RATE control command with the BASE CONFIGURE subfunction.

2) (Re)establish connections

a) If a connection between the source plug of the subunit and the Serial Bus output plug of the source device is not hard-wired, a controller establishes the connection by using the CONNECT control command.

b) If a connection between the destination plug of the subunit and the Serial Bus input plug of the destination device is not hard-wired, a controller establishes the connection by using the CONNECT control command.

c) A controller establishes a connection between the Serial Bus output plug of the source device and the Serial Bus input plug of the destination device by using the procedures described in IEC-61883-1 [R2].

NOTE — If the configured base rate requires higher bandwidth than the previous rate does, a controller breaks the connection between the source and destination devices before the base-rate configuration and reestablishes it thereafter.

3) Select the FLOW CONTROL state

a) A controller checks the selection state of the sync source on the subunit source plug by using the RATE status command with the SYNC SELECT subfunction.

b) If the selection state is the INTERNAL state, the controller selects the FLOW CONTROL state by using the RATE control command with the SYNC SELECT subfunction. The selection state is changed to the FLOW CONTROL state.

4) Start streaming data

A controller makes the source device start streaming data by using a control command, for example, the PLAY control command defined in the AV/C Disc Subunit General Specification [B1]. The output rate is the base rate configured by using the RATE control command with the BASE CONFIGURE subfunction.

5) Control the flow rate

The controller that selected the FLOW CONTROL state controls the flow rate on the subunit source plug by using the RATE control command with the FLOW CONTROL subfunction. The subunit rejects the request for the flow-rate control on the source plug from any other controllers.

6) Reselect the FLOW CONTROL state for the identification

When the controller that selected the FLOW CONTROL state detects a Serial Bus reset, it reselects the FLOW CONTROL state with its reassigned node ID. If the controller is the same as the destination device, it can identify the node ID of the source device by using the SID field of the received CIP header. The CIP header and SID field are defined in IEC-61883-1 [R2].

7) Detect the connection is broken

If the unit-to-unit or unit-internal connection on which the data rate is controlled is broken and cannot be restored, the destination device detects the situation and quits processing the stream. The controller that selected the FLOW CONTROL state also detects the situation and resets the selection state to the INTERNAL state.

8) Stop streaming data

A controller makes the source device stop streaming data by using a control command, for example, the STOP control command defined in the AV/C Disc Subunit General Specification [B1]. The control state is reset to the STANDARD state.

9) Select the INTERNAL state

The controller that selected the FLOW CONTROL state resets the state to the INTERNAL state by using the RATE control command with the SYNC SELECT subfunction.

10) Break the connections (if necessary)

a) A controller breaks the connection between the Serial Bus output plug of the source device and the Serial Bus input plug of the destination device.

b) A controller breaks the connection between the source plug of the subunit and the Serial Bus output plug of the source device by using the DISCONNECT control command.

c) A controller breaks the connection between the destination plug of the subunit and the Serial Bus input plug of the destination device by using the DISCONNECT control command.

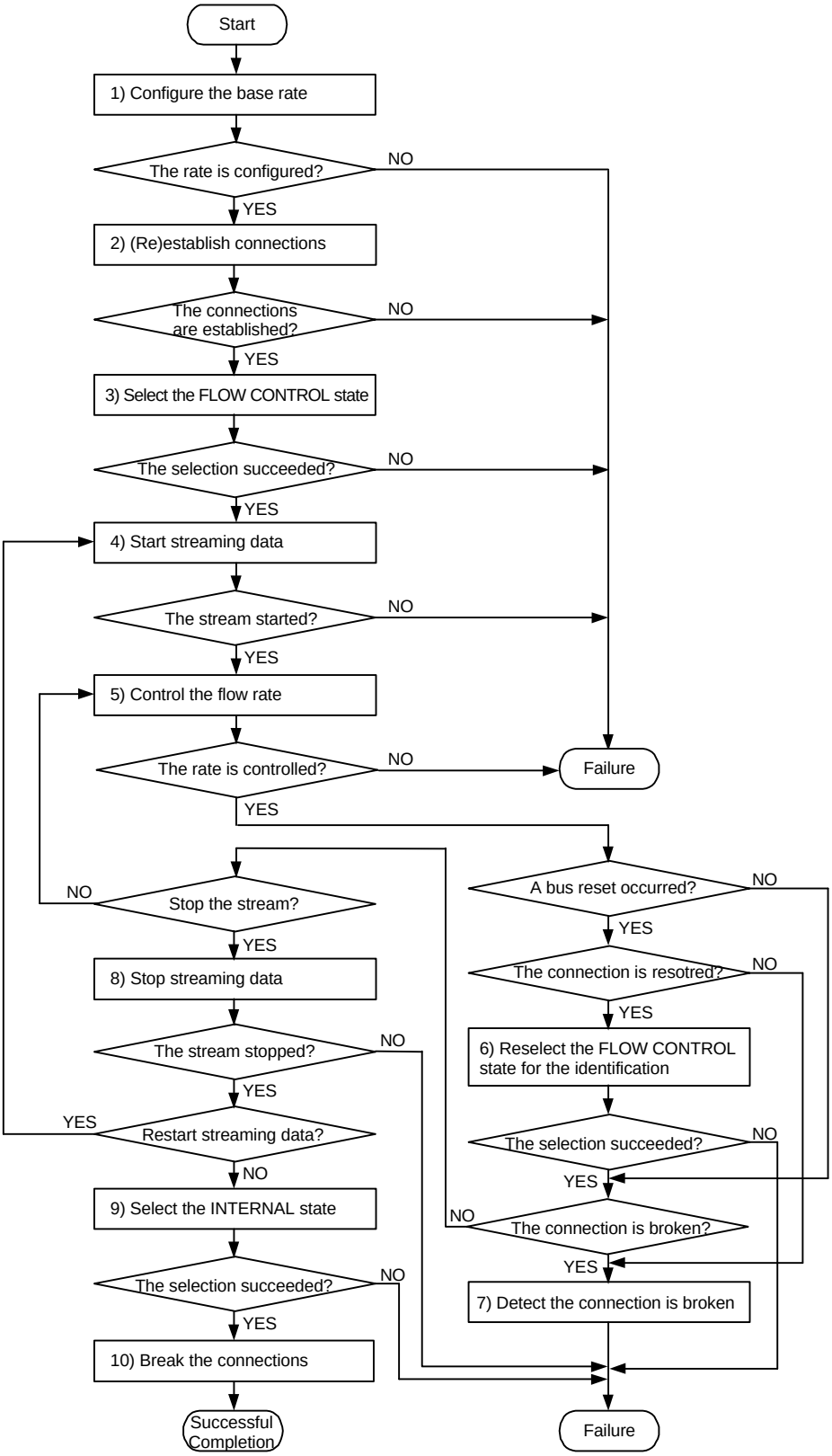
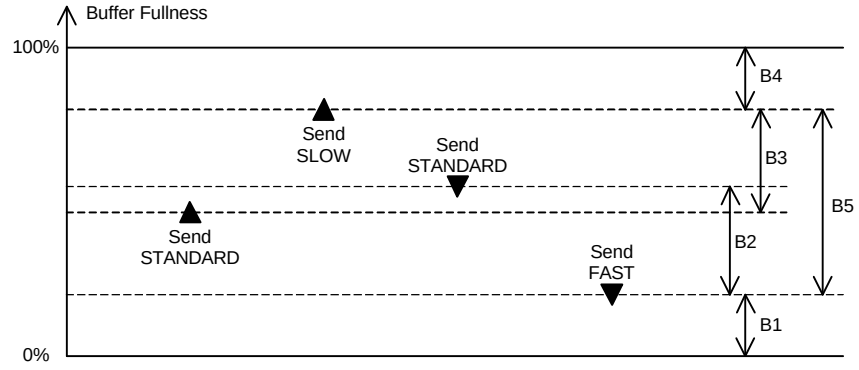


Figure B.1 – Procedure for command-based rate control

Annex C: Buffer Management for Command-based Rate Control (Normative)

If a destination device processes a stream with a different phase from that with which a source device outputs the stream, the destination device needs a buffer management mechanism to prevent the buffer from overflow and underflow. The rate control between a subunit source plug in the source device and a subunit destination plug in the destination device using the STANDARD, FAST and SLOW of the FLOW CONTROL subfunction shall be performed with the following buffer management.

Figure C.1 shows the relation between the action the destination device takes and the fullness of the buffer it holds. While receiving an application's data stream, the destination device shall keep sending the same flow-control state to the source device between these actions. The interval between successive commands shall be less than 5 seconds (see clause 6.1.5).



Send STANDARD/FAST/SLOW : Send a RATE control command with the FLOW CONTROL subfunction that takes the STANDARD, FAST or SLOW in the *flow_control_state* field.

▲ : Indicate the buffer fullness to trigger the action when the buffer data is increasing.

▼ : Indicate the buffer fullness to trigger the action when the buffer data is decreasing.

Figure C.1 – Action and buffer fullness of the destination device

B1, B2, B3, B4 and B5 in Figure C.1 shall meet the following conditions:

$$B1 > PHASE\_ERROR\_RATE * CONTROL\_DELAY + B0 \quad (C.1)$$

$$B5 > B2 > (PHASE\_ERROR\_RATE + SLOW\_RATE) * CONTROL\_DELAY \quad (C.2)$$

$$B5 > B3 > (PHASE\_ERROR\_RATE + FAST\_RATE) * CONTROL\_DELAY \quad (C.3)$$

$$B4 > PHASE\_ERROR\_RATE * CONTROL\_DELAY \quad (C.4)$$

The buffer requirement is the minimum of (B1 + B4 + B5).

If the initial buffer fullness is in the range of B1, B5 or B4, the destination device shall send FAST, STANDARD or SLOW respectively.

The PHASE_ERROR_RATE is the maximum phase error rate between the base rate on the subunit source plug and the processing rate of the destination subunit (see clause 6.1.5).

$$PHASE\_ERROR\_RATE = 0.009 * BASE\_RATE \quad (C.5)$$

The BASE_RATE is the nominal base rate on the subunit source plug and depends on the configuration state, the clock source and the stream format, which does not include packet headers for isochronous transfer.

B0 is the size of the buffer to absorb network delay and jitter.

$$B0 = ISOCH\_TRANSFER\_DELAY * BASE\_RATE \quad (C.6)$$

The ISOCH_TRANSFER_DELAY is the maximum delay from when a non-empty isochronous packet is ready to be transmitted by the source device to when the packet is received by the destination device. In the case of audio and music isochronous transmission, the delay is described as TRANSFER_DELAY in the Audio and Music Data Transmission Protocol [B2].

The SLOW_RATE is the maximum slowing down rate when the source subunit accepts a RATE control command with the FLOW CONTROL subfunction that takes the SLOW in the *flow_control_state* field (see clause 6.1.5).

$$SLOW\_RATE = 0.011 * BASE\_RATE \quad (C.7)$$

The FAST_RATE is the maximum speeding up rate when the source subunit accepts a RATE control command with the FLOW CONTROL subfunction that takes the FAST in the *flow_control_state* field (see clause 6.1.5).

$$FAST\_RATE = 0.011 * BASE\_RATE \quad (C.8)$$

The CONTROL_DELAY is the maximum delay from when the buffer fullness reaches a level to trigger an action to when the input rate to the buffer actually changes to the rate that the action requested.

$$CONTROL\_DELAY = SELECTION\_DELAY + DESTINATION\_DELAY + ASYNC\_TRANSFER\_DELAY + SOURCE\_DELAY + ISOCH\_TRANSFER\_DELAY \quad (C.9)$$

The SELECTION_DELAY is the maximum period that the destination device does not send a RATE control command with the FLOW CONTROL subfunction because of the sync selection for the controller identification after a bus reset (see clause 6.1.1). The SELECTION_DELAY is implementation dependent within the following condition.

$$SELECTION\_DELAY < 10+5 = 15 \text{ seconds} \quad (C.10)$$

The DESTINATION_DELAY is the maximum delay from when the buffer fullness reaches a level to trigger an action to when the destination device actually completes the action (assuming that no bus reset occurs). This delay is implementation dependent.

The ASYNC_TRANSFER_DELAY is a delay from when a RATE control command is ready to be sent by the destination device to when the command is received by the source device.

$$ASYNC\_TRANSFER\_DELAY = 125 \text{ microseconds} * 63 = 7875 \text{ microseconds} \quad (C.11)$$

The SOURCE_DELAY is the maximum delay from when the source subunit accepts a RATE control command with the FLOW CONTROL subfunction to when the flow rate on the source plug actually changes to the requested rate, the STANDARD, FAST or SLOW rate (see clause 6.1.5).

$$SOURCE\_DELAY = 1000 \text{ milliseconds} \quad (C.12)$$

It is possible to employ a buffer management mechanism compliant to this model. A compliant mechanism shall guarantee to prevent the buffer from overflow and underflow under the PHASE_ERROR_RATE, FAST_RATE, SLOW_RATE, ISOCH_TRANSFER_DELAY and CONTROL_DELAY described here.