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COMMISSION OF THE EUROPEAN COMMUNITIES

CAMAC
ORGANISATION OF MULTI-CRATE SYSTEMS

Specification of the Branch Highway and CAMAC Crate Controller Type A

1972

Joint Nuclear Research Centre
Ispra Establishment - Italy

ESONE Committee

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ABSTRACT

The CAMAC Specification (EUR 4100 e), drawn up by European laboratories under the auspices of the ESONE Committee, defined the means of communication, within a CAMAC crate, between modules and a crate controller. This extension to the specification defines a CAMAC Branch Highway for communication between the crate controllers in seven crates and a system controller or computer. The connections from units to the Highway are specified in sufficient detail to ensure compatibility between units from different sources of design and production. A standard CAMAC Crate Controller Type A is specified, and there are general recommendations for all crate controllers used with the Branch Highway.

This specification does not invalidate other methods of interconnection, including those using crate controllers dedicated to specific computers. The USAEC NIM Committee has endorsed this specification and will publish an identical document (TID-25876).

KEYWORDS

DATA TRANSMISSION
TECHNICAL SPECIFICATIONS
COMPUTERS
EUROPE

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Designers of Crate Controllers Type A–1 should note that a revision of the CAMAC Specification EUR 4100e will be published as EUR 4100e (1972). Advance information relevant to the design of this crate controller is available on request.

1. Introduction

The Dataway, defined in EURATOM Report EUR 4100e, is the basis of all CAMAC systems. It provides the means of inter-connection between modules and a crate controller within one crate. Multi-crate CAMAC systems can be organised as one or more larger structural units, called branches, in which a branch highway provides the means of inter-connection between crate controllers in seven crates and a branch driver.

This specification defines the signals, timing, and logical organisation of the connections from crate controllers and branch drivers to the branch highway through a standard 132-way connector. The internal structures of crate controllers and branch drivers, and the physical construction of the branch highway, are only defined where they affect compatibility between parts of the system.

An appendix defines in more detail those features of the crate controller that affect hardware and software compatibility. This appendix can be used either as the formal specification of a standard crate controller (CAMAC Crate Controller Type A)* or as general recommendations intended to promote uniformity between crate controllers.

2. Interpretation of this Document

This document is a reference text describing and specifying the CAMAC Branch Highway. Authorised translations are available in French, German and Italian. It should be read in conjunction with, and is supplementary to, the latest revision of CAMAC Specification EUR 4100e. No part of this document is intended to supersede or modify EUR 4100e.

Mandatory clauses of the specification are written in bold type, as here, and are usually accompanied by the word 'must'.

The word 'should' indicates a recommended or preferred practice which is to be followed unless there are sound reasons to the contrary.

The word 'may' indicates good practice but leaves freedom of choice to the designer.

The word 'reserved' indicates that a feature must not be used until it has been more fully defined by the ESONE Committee.

In order to claim compatibility with the CAMAC Branch Highway specification any equipment or system must comply with the mandatory statements in *both* EUR 4100e and this specification, excluding Appendix 1. Compatibility with the specification of the CAMAC Crate Controller Type A requires, in addition, conformity with the mandatory sections of Appendix 1.

No licence or other permission is needed in order to use this specification.

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*The designation Crate Controller Type A–1 (CCA–1) has been allocated for more specific identification of crate controllers conforming to this final specification, in contrast to the Preliminary Specification issued in November 1970 (available from the Secretary of the ESONE Committee).

3. The Branch

A multi-crate CAMAC system consists of one or more *branches*, each having a *branch highway* which is the means of inter-connection between a *branch driver* and *crate controllers*. During each *branch operation* the branch driver can communicate with a maximum of seven crate controllers. All branch drivers and crate controllers have standard *branch highway ports** by which they are connected to the highway. Each port consists of a 132-way connector (for 65 signals and their individual return lines, plus cable screen) with defined contact allocations and signal conventions. Each crate controller has two identical internally-linked ports in order to allow the branch to have the chain configuration shown in Figure 1. Other configurations are possible, such as that shown in Figure 2, where the branch driver is not at the end of the branch and some crates are connected by only one port.

In addition to their normal *on-line* state, crate controllers have an *off-line* state which allows them to remain physically connected to the branch while ignoring (and not impeding) all branch operations. If required, the branch driver can recognise which crate addresses are associated with on-line crate controllers.

The basic mode of operation of the branch is the *command mode*. The branch driver, which is typically associated with a system controller or computer, issues a command during each branch operation. This command includes crate address information to select one or more crate controllers. Each addressed crate controller accepts the command from the branch highway and generates the corresponding Dataway command (station number, sub-address and function). During *read* operations data signals are generated by a module on the Dataway Read lines, transferred to the data lines of the branch highway by the crate controller, and accepted by the branch driver. During *write* operations the branch driver generates data signals on the branch highway and these are transferred to the Dataway Write lines by the crate controller, and accepted by a module. During other command operations there is no transfer of read or write data via the branch highway.

The branch has two *demand handling* features which allow the branch driver to respond to Look-at-Me signals from modules. For single-level demand handling, which merely indicates the presence of demands without identifying them, the crate controllers combine the Look-at-Me signals to form a common *Branch Demand* signal. For multi-level demand handling, which allows the branch driver to identify 24 different demands, there is the *Graded-L mode* of branch operation. The branch driver issues a Graded-L Request (typically as the result of receiving the Branch Demand signal) and each on-line crate controller responds by selecting or rearranging its Look-at-Me signals to form a 24-bit Graded-L word. The Graded-L words from all crates are combined on the branch highway and presented to the branch driver.

At a branch highway port the *Data* lines are used in the command mode for information transfers in either direction between crate controllers and the branch driver. These lines are also used to convey the pattern of demands in the Graded-L mode.

Transfers in either mode through a branch highway port are controlled by inter-locking *timing signals*, which automatically adjust the timing of each branch operation to suit the actual transmission delays and controller performance that are encountered.

Initialise is the only *common control* signal that is transmitted through the branch highway port to the Dataway.

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*In the sense that a *port* is 'an entrance or exit of a network, etc.'

4. Use of Lines at a Branch Highway Port

Each line at a branch highway port must be used in accordance with the mandatory requirements detailed in the following sections. Table I (overleaf) shows the titles, the standard designations, and the sources of the signals. Lines at a port are distinguished from corresponding lines in the Dataway by the prefix B, e.g., the function code is carried by F lines in the Dataway and BF lines at a branch highway port.

4.1 Command

The command signals are used to control operations in the command mode, at which time the signal on the BG line (see 4.4.2) must be in the '0' state. They are transmitted by the branch driver on the BCR, BN, BA and BF lines at the branch highway port (see below).

4.1.1 Crate Address (BCR1 – BCR7)

The seven crate controllers that can be addressed during any branch operation must each be associated with a different BCR line (although all branch highway ports have provision for all seven BCR lines).

Each crate controller must therefore include means, such as a switch or patch connection, for selecting the appropriate BCR line (referred to as BCR_i). The assignment of BCR lines to crates is not necessarily related to the physical arrangement of crates within the branch. The branch driver is permitted to generate signals simultaneously on more than one BCR line in order to select several crates for the same operation.

It is recommended that the crate controller should include a means of protection against spurious signals on the selected BCR line. For example, the incoming BCR signal or an internal signal derived from it may be conditioned by integration.

It will be seen later, in Section 4.3, that each crate controller is associated with not only one of the BCR lines but also the corresponding one of seven BTB lines.

The branch is not in a valid operating condition if more than one on-line crate controller is connected to the same BCR line. A means of reducing the risk of this occurring is suggested in Section 5.4.

4.1.2 Station Number (BN1, 2, 4, 8, 16)

Signals on these five lines indicate the binary coded station number to be used within the selected crate or crates, and are decoded in the crate controller. In a crate controller the 32 codes are allocated as shown in Table II.

At least one normal station is occupied by the crate controller, and there are station number codes to address the remaining 23 normal stations individually. In addition there are codes to multi-address all normal stations or those stations indicated by the contents of a *Station Number Register* (SNR). Two further station number codes address the controller and its extensions irrespective of their location in the crate.

4.1.3 Sub-Address (BA1, 2, 4, 8)

Signals on these four lines must be re-transmitted on the Dataway Sub-address lines (A1, 2, 4, 8) by an addressed crate controller whenever it is on-line during a command mode operation.

TABLE I Signal Lines at Branch Highway Ports

Title		Designation	Generated by	Signal Lines	Use
Command	Crate Address	BCR1 – BCR7	Branch Driver	7	Each line addresses one crate in the branch
	Station Number	BN1, 2, 4, 8, 16.	" "	5	Binary coded station number
	Sub-address	BA1, 2, 4, 8.	" "	4	As on Dataway A lines
	Function	BF1, 2, 4, 8, 16.	" "	5	As on Dataway F lines
Data	Read/Write	BRW1 – BRW24	Branch Driver (W) or Crate Controller (R,GL)	24	For Read data, Write data, and Graded-L
Status	Response	BQ	Crate Controller	1	As on Dataway Q line
	Command Accepted	BX	Crate Controller	1	As on Dataway X line
Timing	Timing A	BTA	Branch Driver	1	Indicates presence of Command, etc.
	Timing B	BTB1 – BTB7	Crate Controller	7	Each line indicates presence of data, etc., from one crate controller
Demand Handling	Branch Demand	BD	Crate Controller	1	Indicates presence of demand
	Graded-L Request	BG	Branch Driver	1	Requests 'Graded-L' Operation
Common Control	Initialise	BZ	Branch Driver	1	As on Dataway Z line
Reserved		BV1 – BV7		7	For future requirements

An individual return line is provided for each signal line. Two lines are provided for a connection to the screen, if any, of the branch highway cable.

TABLE II Station Number Codes used in Crate Controllers

N Code	Use	B, S1, and S2	Remarks
N(0)	Reserved		
N(1) – (23)	Address the corresponding normal station	Yes	Normal stations occupied by the controller need not be addressed
N(24)	Address preselected normal stations	Yes	
N(26)	Address all normal stations	Yes	
N(28)	Address crate controller only	Yes	
N(30)	Address crate controller only	No	No Dataway operation
N(25, 27, 29, 31)	Reserved		

4.1.4 Function (BF1, 2, 4, 8, 16)

Signals on these five lines must be re-transmitted on the Dataway Function lines (F1, 2, 4, 8, 16) by an addressed crate controller whenever it is on-line during a command mode operation.

4.2 Data and Status

4.2.1 Read and Write (BRW1 – BRW24)

These 24 lines are used in command mode read operations to transmit data from the addressed crate controllers to the branch driver, with BRW1 corresponding to the Dataway R1, etc. They are also used in command mode write operations to transmit data from the branch driver to the crate controllers, with BRW1 corresponding to the Dataway W1, etc.
In the Graded-L mode they are used to transmit the pattern of demands from all on-line crate controllers in the branch to the branch driver. The generation of '1' state outputs to these lines is restricted to branch drivers during command mode write operations and to addressed on-line crate controllers during Graded-L operations and command mode read operations.

4.2.2 Response (BQ)

During a command mode operation with an associated Dataway operation each crate controller that is on-line and addressed must generate BQ corresponding to Dataway Q (BQ = Q). During a command mode operation that tests the status of a feature of the crate controller, without a Dataway operation, the crate controller must generate the appropriate BQ response. At all other times crate controllers must generate BQ = 0. The signal on the BQ line at the branch driver is the OR combination of the signals from all crate controllers.

4.2.3 Command Accepted (BX)

During a command mode operation with an associated Dataway operation each crate controller that is on-line and addressed must generate BX corresponding to Dataway X (BX = X). During all other command operations the crate controller must generate BX = 1 if it accepts the command and BX = 0 if it does not accept the command. The signal on the BX line at the branch driver is the OR combination of the signals from all crate controllers.

4.3 Timing (BTA, BTB1 – BTB7)

The timing of all command mode and Graded-L branch operations is controlled by branch timing signals. The branch driver initiates operations by signals on the common BTA line, and each addressed crate controller responds with a signal on its individual BTB line. All seven BTB lines are provided at each branch highway port, but each crate controller uses the line BTB_i corresponding to the line BCR_i by which it is addressed.

Each on-line crate controller must generate $BTB_i = 1$ when it is not addressed. The branch driver (and other crate controllers) can thus distinguish between BTB lines associated with on-line crates ($BTB_i = 1$) and off-line or absent crates ($BTB_i = 0$). (See Section 5.4).

The branch driver generates BTA = 1 to indicate that it is presenting a command or Graded-L request at its port, and maintains the signal until it has accepted the resulting BRW or BQ information. Each crate controller generates $BTB_i = 0$ when it has established data or BQ information during branch operations.

The timing signals must be generated through intrinsic OR outputs and must have 10-90% signal transition times in the range 100 ± 50 ns.

It is recommended that the crate controller should include a means of protection against spurious signals on the BTA line. For example, the incoming BTA signal or an internal signal derived from it may be conditioned by integration.

The full timing sequence is described in Section 5.

4.4 Demand Handling

Look-at-Me (L) signals from units in any part of the branch typically demand that an appropriate command or sequence of commands be generated. The branch therefore has two demand handling features, one associated with the Branch Demand signal and the other with the Graded-L Request signal.

4.4.1 Branch Demand (BD)

Each crate controller can generate a demand signal, as any logical function of the L signals on the Dataway, through an intrinsic OR connection to the common Branch Demand line (BD). No restriction is placed on the time at which the BD signal may change, and therefore its 10-90% transition time must be in the range 100 ± 50 ns. The delay between the time when an L signal at the control station of the crate controller reaches a maintained '1' or '0' state and the time when the BD signal at the branch highway port of the same crate controller reaches a corresponding maintained '1' or '0' state must not exceed 400 ns.

This maximum delay may be due partly to the crate controller and partly to some other unit involved in processing the L signals (for example, the LAM Grader associated with Crate Controller Type A). The maximum delay due to Crate Controller Type A is defined in Appendix A1.9.2.

4.4.2 Graded-L Request (BG)

The branch driver initiates Graded-L mode operations by generating the Graded-L Request signal (BG), accompanied by BCR signals to all on-line crates. Each addressed crate controller generates a 24-bit Graded-L word on the BRW lines, and the branch driver reads the OR-combination of these words. The Dataway L signals in each crate are graded, to select the relevant signals and assign them to the appropriate bits of the Graded-L word.

The grading process may, for example, be organised so that the branch driver reads a word indicating which crates require attention, or which actions (such as program interrupts or autonomous transfers) are required. If the Graded-L requests from the branch are arranged in priority order in the word it is recommended, for uniformity, that a request on line BRW(n + 1) should have priority over a request on BRW(n).

Crate Controller Type A provides an additional means of access to the Look-at-Me information. (See Section A1.9.4 and Table IX).

4.5 Common Controls

4.5.1 Branch Initialise (BZ)

The Branch Initialise signal (BZ) is generated by the branch driver and has absolute priority over all other signals in the branch. The normal branch timing signals are not used with BZ. In order to allow crate controllers to discriminate against spurious signals of short duration the branch driver must maintain BZ = 1 for a minimum of 10 μs. It must not generate a Graded-L or command mode operation during the following 5 μs period.

4.5.2 Dataway Initialise (Z), Clear (C) and Inhibit (I)

A crate controller receiving a Branch Initialise signal whose duration exceeds a minimum value (specified as 3 ± 1 μs) must initiate the generation of Dataway Initialise (Z) together with Busy (B) and Strobe S2 as required by EUR 4100e. The generation of S1, in addition to the mandatory B and S2, is optional and cannot be relied upon by other units connected to the Dataway.

All crate controllers must include some means of generating Dataway Clear (C) and Inhibit (I) signals.

There are no branch highway lines for the Dataway common control signals Clear and Inhibit. A crate controller should generate Dataway Z and C signals, and generate and remove Dataway I, in response to command mode operations as defined in Table IX.

A crate controller may also generate Dataway common control signals in response to front panel signals, unless this is specifically prohibited (as in the case of Crate Controller Type A).

4.6 Reserved Lines (BV1 – BV7)

Signal and return lines, reserved for future requirements, are provided at all branch highway ports. Where more than one port is provided, as in crate controllers, these reserved lines must be linked across between corresponding contacts.

Any future allocation of the reserved lines by the ESONE Committee will be in the order BV7, BV6 and so on.

5. Branch Operations

All transfers of information (read-data and write-data, Q, X and Graded-L) through branch highway ports are organised as branch operations. The timing of each operation is controlled by the branch timing signals BTA and BTB1 – BTB7, and can be divided into four phases as defined in Tables III and IV and Figures 3 and 4.

During *Phase 1* the branch driver presents at its port one or more crate addresses either included in a command (together with write-data if required by the command), or accompanying a Graded-L Request. After a delay which compensates for signal skew it generates BTA = 1 to start the next phase.

During *Phase 2* each addressed crate controller responds to BTA = 1 either by initiating the Dataway operation required by the command and presenting Q, X and any read-data at its port, or by presenting Graded-L information. It then generates $BTB_i = 0$ on its individual BTB line. The branch driver starts the next phase when it has received $BTB_i = 0$ from all addressed crate controllers.

During *Phase 3* the branch driver introduces a delay to compensate for signal skew and then accepts Q, X and read-data, or the Graded-L information. It generates BTA = 0 to start the next phase.

During *Phase 4* each addressed crate controller responds to BTA = 0 either by completing the Dataway operation and removing Q, X and read-data presented at its port, or by removing the Graded-L information. It then generates $BTB_i = 1$ on its individual BTB line.

The branch driver ends Phase 4 when it has received $BTB_i = 1$ from all addressed crate controllers, and is then free to begin another branch operation, either immediately (in which case new command, write-data, or Graded-L Request signals are set up) or later (in which case the existing signals are removed).

The BTB lines corresponding to off-line or absent crate controllers remain in the '0' state throughout the operation, and those corresponding to unaddressed on-line crates remain in the '1' state.

The timing of the four phases is automatically adjusted by the sequence of timing signals to suit the actual signal delays occurring in the highway and the response times of crate controllers, etc.

The timing sequence for command mode operations is described in detail in Section 5.1. Graded-L operations are described in Section 5.2.

In practice the various branch, command and data signals are unlikely to have precisely the same transmission delay, and this problem of signal skew is discussed in Section 5.3.

Branch operations will not be completed if the branch driver or addressed crate controllers fail to respond to the timing signals in the correct sequence. Branch drivers should therefore include some form of time-out feature to detect when an operation has not been completed within a reasonable time, so that appropriate action can be taken. Precautions against operations that would otherwise fail due to addressing absent or off-line crate controllers may be based on the means of recognising these crates described in Section 5.4.

The relationship between the branch highway operation and the Dataway operation in addressed crates must satisfy the requirements of Table III and EUR 4100e.

The relative timing of the Dataway strobes (S1 and S2) and the branch timing signals (BTA and BTB) is specified in detail for Crate Controller Type A (see Section A1.7). In other crate controllers the relative timing will depend, for example, on whether or not there are registers for data and command.

5.1 Command Mode Operations

The sequence during a command mode operation is shown in Table III (see overleaf).

The following sections detail the four phases of a read operation and then outline the minor respects in which other operations differ. One or more crates may be addressed in any operation.

5.1.1 Read Operations: Phase 1

The sequence during a read operation (Function codes 0 – 7) is illustrated in Figure 3.

Phase 1 involves actions in the branch driver, which presents the complete command [BCR, BN, BA, BF(0 to 7)] at its port and then, after a delay to compensate for skew (see Section 5.3), generates BTA = 1 to initiate Phase 2.

5.1.2 Read Operations: Phase 2

After the transmission delay and signal transition time of the branch highway each crate controller receives the command signals and then, when they are stable, the timing signal BTA = 1. Phase 2 involves actions in all addressed crate controllers.

Each addressed crate controller ($BCR_i = 1$) responds to BTA = 1 by beginning the timing sequence for a Dataway operation. In Figure 3 the Dataway operation is initiated by BTA after conditioning by integration, as recommended in Section 4.3. At time t_o of this operation (see Figure 9 of EUR 4100e) the Dataway Busy (B) and command signals must be generated. It is recommended that B and the N signals (derived by decoding the BN signals) should be generated when the crate controller has received BTA = 1, although the A and F signals (reproduced from the corresponding BA and BF signals) may be generated earlier (see Figures 3 and 4).

The addressed module responds to the command by transmitting Q, X and read-data which are established on the Dataway at time t_3 (see Figure 9 of EUR 4100e). These signals are reproduced by the crate controller on the BRW, BQ and BX lines at its branch highway port, and are maintained during Phase 3. (If the command addresses a register in the crate controller, the read-data and Q information need not be transferred via the Dataway). When the controller has presented these BRW, BQ and BX signals it generates $BTB_i = 0$.

The branch driver initiates Phase 3 at some later time when it has received BTB = 0 from all addressed crates. Figure 3 shows $BTB_i = 0$ from a particular crate, and also earlier and later BTB signals from other addressed crates. The branch driver waits for the last BTB signal. For example, it may detect the condition:

$$(\overline{BCR1} + \overline{BTB1}).(\overline{BCR2} + \overline{BTB2})...........(\overline{BCR7} + \overline{BTB7}) = 1$$

For each unaddressed crate $\overline{BCR}_i = 1$, and therefore the state of $\overline{BTB}_i$ is ignored. For each addressed crate $\overline{BCR}_i = 0$, and therefore the condition is satisfied only when $\overline{BTB}_i = 1$.

5.1.3 Read Operations: Phase 3

During Phase 3 the branch driver introduces a delay to allow for signal skew and then takes whatever action is necessary to accept the information from the BRW, BQ and BX lines. When it has accepted this information it generates BTA = 0 to initiate Phase 4.

TABLE III Sequence of Command Mode Operation

PHASE		ACTION in branch driver	TIMING SIGNAL change and direction	ACTION in crate controller 'i'	
BRANCH OPERATION	1	1. Establishes branch command (and write-data) 2. Compensates for skew			
	2		BTA ↓ 0 1 →		
				1. Initiates Dataway Operation 2. Establishes BQ and BX (and read-data on branch highway or write-data on Dataway)	DATAWAY OPERATION
			← ↑ 0 1 BTB_i		
		1. Waits for $BTB_i = 0$ from all addressed crate controllers			
	3	2. Compensates for skew 3. Accepts BQ and BX (and read-data)			
	4		BTA ↑ 0 1 →		
				1. Completes Dataway Operation	
				2. Removes BQ and BX (and read-data) from branch highway	
			← ↓ 0 1 BTB_i		
		1. Waits for $BTB_i = 1$ from all addressed crate controllers			
		2. Removes command (and write-data) or Begins Phase 1 of next operation.			

Throughout the operation BG = 0

Actions shown in brackets apply when required by the command

5.1.4 Read Operations: Phase 4

Each addressed crate controller receives BTA = 0 at some later time and is then free to change its signal outputs to the BRW, BQ and BX lines. During Phase 4 the crate controller takes any further action necessary to complete its Dataway operation.

This may result in the read-data and Q signals changing (shown by broken lines in Figure 3), due to actions in addressed modules in response to Strobe S2.

At the end of the Dataway operation (t_9) the crate controller removes the Dataway B and N signals. It also removes any "1" state outputs to the BRW, BQ and BX lines. It may do this immediately after the end of the Dataway operation at t_9 (as shown in Figure 3) if it has gates between the Dataway and branch highway lines. This is mandatory for Crate Controller Type A. Alternatively, it may remove the BRW and BQ signals within 400 ns of the end of the Dataway operation at t_{12} by relying on the addressed modules removing their outputs to the R and Q lines when they receive N = 0.

In either case the crate controller generates $BTB_i = 1$ when it has removed all "1" state outputs to the branch BRW, BQ and BX lines, and the Dataway B and N lines.

The branch driver ends Phase 4 at some later time when it has received $BTB_i = 1$ from all addressed crates. For example it may detect the condition:

$$(\overline{BCR1} + BTB1).(\overline{BCR2} + BTB2). \ldots\ldots\ldots (\overline{BCR7} + BTB7) = 1$$

For each unaddressed crate $\overline{BCR_i} = 1$, and therefore the state of BTB_i is ignored. For each addressed crate $\overline{BCR_i} = 0$, and therefore the condition is satisfied only when $BTB_i = 1$. The branch driver is then free to remove the command signals and to begin another command mode or Graded-L operation. The extreme case, shown in Figure 3, is when Phase 1 of the next operation follows immediately, so that the branch driver removes the command signals of one operation whilst setting up the command or Graded-L Request signals for the next.

5.1.5 Write Operations

The sequence during a write operation (Function codes 16 – 23) is shown in Figure 4. The sequence is similar to that for a read operation (described above), except that write-data signals are generated by the branch driver for the same period as command signals. The signal $BTB_i = 1$ from the crate controller during Phase 4 has the additional significance that the write-data has been accepted.

5.1.6 Other Command Operations

Operations with Function codes 8 – 15 and 24 – 31, which do not use the Read or Write lines of the Dataway, nevertheless use the Dataway Q and Branch BQ lines. Their timing is therefore similar to that of read operations as described above. The Dataway Q signal is allowed to change during these operations (see EUR 4100e, Section 5.4.3), hence the BQ signal may also change at any time.

5.2 Graded-L Operations

The Graded-L operation is equivalent to a multi-crate read operation in which the normal command is replaced by the Graded-L Request signal (BG = 1) and crate address signals to all on-line crate controllers. The station number, sub-address, and function signals are not used, and are ignored by crate controllers during this operation. It is typical, but not essential, that Graded-L operations are initiated by the Branch Demand signal, BD = 1.

TABLE IV Sequence of Graded-L Operation

PHASE		ACTION in branch driver	TIMING SIGNAL change and direction	ACTION in crate controller 'i'
BRANCH OPERATION	1	1. Establishes BG and BCR for on-line crates 2. Compensates for skew		
	2		BTA $0 \downarrow 1$ $\longrightarrow$	
				Establishes GL information on branch highway
			$\longleftarrow$ $0 \uparrow 1$ BTB_i	
		1. Waits for $BTB_i = 0$ from all addressed crate controllers		
	3	2. Compensates for skew 3. Accepts GL information		
	4		BTA $0 \uparrow 1$ $\longrightarrow$	
				Removes GL information
			$\longleftarrow$ $0 \downarrow 1$ BTB_i	
		1. Waits for $BTB_i = 1$ from all addressed crate controllers		
		2. Removes BG and BCR or Begins Phase 1 of next operation		

Throughout the operation BG = 1

Command signals BN, BA and BF are ignored

During the Graded-L operation the branch driver generates a set of BCR signals which must have $BCR_i = 0$ on all lines corresponding to absent or off-line crate controllers and $BCR_i = 1$ on all lines corresponding to on-line crates. The BCR signals are accompanied by BG = 1.

It is recommended that the branch driver should derive the necessary information about the state of the crate controllers from the BTB lines (see Section 5.4).

When the branch driver has presented the BCR signals and the Graded-L Request Signal it generates BTA = 1. In response to BG, BCR_i, and BTA each on-line crate controller generates its Graded-L word through intrinsic OR outputs to the BRW lines at its branch highway port, without generating Dataway signals B, S1 or S2.

The grading process which forms the Graded-L word need not take place in the crate controller, but may involve another unit, such as the LAM-Grader associated with Crate Controller Type A (see Section A1.9). The Dataway L signals are free to change at any time, and hence the BRW signals may also change.

Each addressed crate controller generates $BTB_i = 0$ when it has presented its Graded-L information to the BRW lines. The process of establishing the Graded-L information involves two special causes of delay. Firstly, if the L signal from a module has been gated off the Dataway by a preceding command mode operation there will be a delay of up to 400ns before L is re-established at the crate controller. Secondly, the Crate Controller Type A which is specified in Appendix 1 requires a separate *LAM-Grader* unit for processing L signals. This can involve additional delays in establishing L signals at the LAM-Grader unit, and in establishing the Graded-L signals at the crate controller.

When the branch driver has received $BTB_i = 0$ from all addressed crates it introduces a delay to allow for signal skew and then accepts the Graded-L word from the BRW lines. Having done this it generates BTA = 0.

When the crate controller receives BTA = 0 it removes the Graded-L information from the BRW lines and generates $BTB_i = 1$. The operation is completed when the branch driver receives $BTB_i = 1$ from all addressed crate controllers and is free to remove the Graded-L Request and crate address signals.

5.3 Differential Delays (Skew)

The delays encountered by the BTA and BTB signals are used to adjust the timing of the branch operation. However, there may be 'skew', or differential delays, between BTA and the individual bits of the command and write data signals received at the crate controller, and between BTB and the individual bits of the BRW, BQ and BX signals received at the branch driver. The branch driver must introduce an appropriate delay before generating BTA = 1, in order to ensure that all command signals are established at crate controllers before they receive BTA. It must also delay its internal action in response to BTB = 0, in order to ensure that all data, BQ and BX signals have become established.

This correction for skew may be either fixed, to cover a stated maximum skew, or adjustable to suit the specific application. Additional compensation for skew is permitted elsewhere in the branch.

5.4 Identification of On-line Crate Controllers

During the period between the end of Phase 4 of one branch operation and the beginning of Phase 2 of the next operation, the branch driver receives $BTB_i = 1$ from on-line crate controllers and $BTB_i = 0$ from off-line or absent crate controllers. The state of the BTB lines may therefore be sampled by the branch driver immediately before any operation in order to identify the on-line crate controllers.

It is strongly recommended that the branch driver should identify the on-line crate controllers in this way immediately before each Graded-L operation in order to fulfil the mandatory requirement of Section 5.2 that all on-line crate controllers are addressed. Hence, the branch driver should generate $BCR_i = 1$ if $BTB_i = 1$.

The branch driver may also identify the on-line crate controllers before all command mode operations, and compare them with the crate addresses specified in the command. This allows prompt detection of operations that would otherwise fail through addressing off-line or absent crate controllers, and avoids the much slower process of relying on a time-out feature which operates after the operation has failed (see Section 5).

A further application of this method of identifying on-line crate controllers would be to ensure that a crate controller cannot come on-line if there is already an on-line controller with the same address (see Section 4.1.1). Each crate controller could check that the condition $(BTB_i + BCR_i) = 0$ is satisfied before switching to the on-line state. It would remain off-line if there is already an on-line controller with the same address, either in the unaddressed state ($BTB_i = 1$) or in the addressed state ($BCR_i = 1$).

6. Connectors

The branch highway ports use the Hughes 132-way connectors defined in Table V, or equivalent types approved by the ESONE Committee. The fixed member used on the branch driver, crate controller and termination unit has 132 sockets. The free member used on cables has 132 pins.

The contact layout and outline dimensions of the fixed and free members are given (for information only) in Figures 5 and 6.

TABLE V Standard Connector for Branch Highway Ports

Original Manufacturer:	Hughes Aircraft Company
Connector Type:	WSS Sub-miniature Rectangular Connector
Number of Contacts:	132
Polarising Code:	BN
Catalogue Code Numbers:	
Fixed member (socket moulding):	WSS 0132 SOO BN 000
Free member (pin moulding):	WSS 0132 Pxx BN yyy where Pxx yyy denotes type of jackscrew
Hood for free member:	WAC 0132 H005 (for example)

The assignment of the signal and return lines is defined in Table VI, arranged by signals, and in Table VII, arranged by contact numbers.

At least two fixed connectors must be mounted at the front of each crate controller, with all corresponding contacts joined to provide a continuous path through the controller. The correct orientation of these connectors is important. Contact 1 must be uppermost on the top connector and lowermost on the bottom connector (see figure 5).

TABLE VI Contact Assignments at Branch Highway Ports: By Signals

Signal Contact	Return Contact	Signal	
32	13	BCR1	Crate Address
33	14	BCR2	
34	15	BCR3	
35	16	BCR4	
67	50	BCR5	
68	51	BCR6	
69	52	BCR7	
36	17	BN1	Station Address
37	18	BN2	
38	19	BN4	
39	20	BN8	
40	21	BN16	
41	1	BA1	Sub-Address
23	2	BA2	
24	3	BA4	
25	4	BA8	
70	53	BF1	Function Code
71	54	BF2	
72	55	BF4	
73	56	BF8	
74	57	BF16	
61	44	BQ	Response
63	46	BTA	Timing
31	10	BTB1	
11	12	BTB2	
58	22	BTB3	
132	92	BTB4	
123	102	BTB5	
120	101	BTB6	
121	122	BTB7	
60	43	BD	Demand
59	42	BG	Graded-L Request
62	45	BZ	Initialise

Signal Contact	Return Contact	Signal	
93	76	BRW1	Read/Write Lines
94	77	BRW2	
95	78	BRW3	
96	79	BRW4	
97	80	BRW5	
98	81	BRW6	
99	82	BRW7	
100	83	BRW8	
103	84	BRW9	
104	85	BRW10	
105	86	BRW11	
106	87	BRW12	
107	88	BRW13	
108	89	BRW14	
109	90	BRW15	
110	91	BRW16	
112	113	BRW17	
114	115	BRW18	
116	117	BRW19	
118	119	BRW20	
124	125	BRW21	
126	127	BRW22	
128	129	BRW23	
130	131	BRW24	
26	5	BV1	Reserved Lines
27	6	BV2	
28	7	BV3	
29	8	BV4	
30	9	BV5	
64	47	BV6	
65	48	BV7	
66	49	BX	Command Accepted
111	75	BSC	Cable Screen

TABLE VII Contact Assignments at Branch Highway Ports: By Contact Numbers

Contact	Signal	Contact	Signal	Contact	Signal	Contact	Signal	Contact	Signal	Contact	Signal	Contact	Signal	Contact	Signal
1	BA1(R)	18	BN2(R)	35	BCR4	52	BCR7(R)	69	BCR7	86	BRW11(R)	103	BRW9	120	BTB6
2	BA2(R)	19	BN4(R)	36	BN1	53	BF1(R)	70	BF1	87	BRW12(R)	104	BRW10	121	BTB7
3	BA4(R)	20	BN8(R)	37	BN2	54	BF2(R)	71	BF2	88	BRW13(R)	105	BRW11	122	BTB7(R)
4	BA8(R)	21	BN16(R)	38	BN4	55	BF4(R)	72	BF4	89	BRW14(R)	106	BRW12	123	BTB5
5	BV1(R)	22	BTB3(R)	39	BN8	56	BF8(R)	73	BF8	90	BRW15(R)	107	BRW13	124	BRW21
6	BV2(R)	23	BA2	40	BN16	57	BF16(R)	74	BF16	91	BRW16(R)	108	BRW14	125	BRW21(R)
7	BV3(R)	24	BA4	41	BA1	58	BTB3	75	BSC(R)	92	BTB4(R)	109	BRW15	126	BRW22
8	BV4(R)	25	BA8	42	BG(R)	59	BG	76	BRW1(R)	93	BRW1	110	BRW16	127	BRW22(R)
9	BV5(R)	26	BV1	43	BD(R)	60	BD	77	BRW2(R)	94	BRW2	111	BSC	128	BRW23
10	BTB1(R)	27	BV2	44	BQ(R)	61	BQ	78	BRW3(R)	95	BRW3	112	BRW17	129	BRW23(R)
11	BTB2	28	BV3	45	BZ(R)	62	BZ	79	BRW4(R)	96	BRW4	113	BRW17(R)	130	BRW24
12	BTB2(R)	29	BV4	46	BTA(R)	63	BTA	80	BRW5(R)	97	BRW5	114	BRW18	131	BRW24(R)
13	BCR1(R)	30	BV5	47	BV6(R)	64	BV6	81	BRW6(R)	98	BRW6	115	BRW18(R)	132	BTB4
14	BCR2(R)	31	BTB1	48	BV7(R)	65	BV7	82	BRW7(R)	99	BRW7	116	BRW19		
15	BCR3(R)	32	BCR1	49	BX (R)	66	BX	83	BRW8(R)	100	BRW8	117	BRW19(R)		
16	BCR4(R)	33	BCR2	50	BCR5(R)	67	BCR5	84	BRW9(R)	101	BTB6(R)	118	BRW20		
17	BN1(R)	34	BCR3	51	BCR6(R)	68	BCR6	85	BRW10(R)	102	BTB5(R)	119	BRW20(R)		

N.B. BRW1(R) is the return line corresponding to BRW1.

Branch drivers must have at least one fixed connector. If they do not contain the terminations of the signal lines (see Section 7.3) they must have at least two fixed connectors.

Extra connectors may be provided on branch drivers and crate controllers, unless this is specifically prohibited (as in the case of Crate Controller Type A).

6.1 Connection to Screen of Branch Highway Cable

The contacts designated BSC and BSC(R) are available for making a connection through the branch highway port to the screen, if any, of the branch highway cable. These two contacts are normally used in parallel, and do not carry branch highway signals.

Units that terminate the branch highway signal lines (see Section 7.3) must connect BSC and BSC(R) to ground. All other units must provide the option of connecting these contacts to ground.

7. Signal Standards at Branch Highway Ports

All units connected to the branch highway must conform to the absolute limits of the signal standards at the branch highway ports, as specified in Table VIII.

In addition, Table VIII gives recommended values for certain characteristics. The recommended value for input current, to closer limits than the absolute value, leads to a set of design values for a preferred terminating circuit.

The signal standards assume that the branch highway presents, at all ports, conditions equivalent to a twisted-pair cable with a characteristic impedance of at least 70 ohms (see Table VIII at (h)).

A unit behaves with respect to a particular line as either an input (accepting signals from the highway) or an output (generating signals on the highway) or a termination (biassing the signal lines to the '0' state and terminating them with approximately the characteristic impedance). In some cases a unit may perform several of these rôles. For example, the BRW lines have inputs and outputs at crate controllers and branch drivers, and may also have terminations in branch drivers. Such units must satisfy the parts of Table VIII that are appropriate to each particular rôle.

Any capacitative load imposed on the signal lines by shaped outputs and integrated inputs (see Sections 4.3, 4.4.1 and A1.7) must be small compared with the characteristic impedance of the highway, taking into account the transition time of the signals.

7.1 Inputs

All inputs that receive signals from the branch highway ports must accept the voltage ranges specified in Table VIII at (a) and must not impose current loadings greater than those specified in Table VIII at (b). The specified input current loading refers to the total current supplied to any signal line at a branch highway port by a unit that is receiving signals from the line, including the effect of any output circuits connected to the same line. A maximum of eight units is allowed on each signal line.

The absolute value for current loading corresponds to typical TTL devices, but a lower value is recommended for all units, and is mandatory for Crate Controller Type A (see Section A1.3).

TABLE VIII Signal Standards at Branch Highway Ports

CONDITION at branch highway ports	LOGIC STATE	ABSOLUTE LIMITS	RECOMMENDED VALUES
INPUTS			
a) Voltage range accepted by unit	0 1	+2.4V to +5.5V 0V to +1.2V (1)	
b) Maximum current supplied by unit (see Section 7.1)	0 1	±0.3mA +1.6mA (± 0.3mA for Crate Controller Type A)	± 0.3mA* (2)
OUTPUTS			
c) Voltage range generated by unit	1	0V to +0.5V	0V to +0.3V
d) Minimum current sinking capability (3)	1	127mA	133mA
TERMINATION			
e) Open circuit voltage	0	+4.5V max	+4.1V preferred*
f) Short circuit current	1	50mA max	
g) Terminating impedance			100Ω preferred*
BRANCH HIGHWAY			
h) Characteristic impedance		70Ω min	100Ω max*

(1) Higher than TTL voltage levels provide an increased noise margin taking into account cable losses and reflections due to mismatches.

(2) Low input currents result in smaller reflections. Receivers with high input impedance may feed current into the line or draw current from the line.

(3) The current sinking capability is given by

$$\frac{V_o - V_{out\ low}}{Z/2} + 8.I_{in\ low} = \begin{cases} 127\text{mA absolute minimum} \\ 133\text{mA recommended minimum} \end{cases}$$

where V_o = 4.5V maximum open circuit voltage

$$V_{out\ low} = \left.\begin{cases} 0.5\text{V absolute} \\ 0.3\text{V recommended} \end{cases}\right\} \text{maximum low state output voltage.}$$

Z = 70 Ohm minimum characteristic impedance

$I_{in\ low}$ = 1.6mA maximum low state input current.

(4) Recommended values marked thus*, refer to a set of design values for a preferred terminating circuit.

7.2 Outputs

All outputs that transmit signals through branch highway ports must be sources that allow wired-OR connections. In the '1' state the sources must produce signals within the voltage range specified in Table VIII at (c) and have the current sinking capability specified in Table VIII at (d), in order to drive eight inputs (see Section 7.1) and two terminations (see Section 7.3) under dynamic conditions. The BD, BTA and BTB signals must be generated from sources that define the transition times (see Sections 4.3 and 4.4.1). The generation of other signals with defined transition times is permitted.

If the branch driver includes one termination for the highway, its current sinking capability at the appropriate lines of the port may be reduced accordingly.

7.3 Terminations

All 65 signal lines must be terminated at one end of the branch highway with a circuit providing the appropriate 'pull-up' current to bias the line to the '0' state, and the appropriate terminating impedance to limit signal reflections. All return lines and the connections to the cable screen must be connected to ground at this point. The current from each termination circuit into the branch highway line in the logic '1' state must not exceed the short circuit current specified in Table VIII at (f).

It is strongly recommended that all 65 signal lines should be terminated at both ends of the branch highway. It is suggested that there should be a termination unit that can be used at either end of the highway by connecting it to the second branch highway port of the last crate controller or to the second port of the branch driver if this does not have internal terminations and is at the end of the branch.

If such a termination unit is provided it must terminate all 65 signal lines, and ground the return lines and connections to the cable screen.

If all inputs connected to the branch highway impose the lower current loading recommended in Table VIII at (b), and the highway has a characteristic impedance between 70 and 100 ohms, the terminating circuits should be designed to have the target values for impedance and open circuit voltage given in Table VIII at (g) and (e) in order to achieve optimum speed and noise margin. If inputs have the higher absolute value for current loading it will be necessary to design the terminating circuits for the appropriate compromise between speed and noise margin to suit the particular application.

7.4 Off-line and Power-off Conditions

A crate controller must not generate '1' state outputs at its branch highway ports when in the off-line state and receiving normal power supplies.

It is recommended that a crate controller should not interfere with the operation of the branch when in the off-line state without power supplies. This, which applies to all inputs and outputs through the ports, is in order to allow power to be switched off (e.g., for maintenance and changing modules) without disturbing the remainder of a system.

Appendix 1

Specification of CAMAC Crate Controller Type A *

A1.1 CAMAC Crate Controller Type A

In order to conform with the specification for CAMAC Crate Controller Type A, a crate controller must have all the mandatory features defined in this appendix. It must have no other features that would affect its interchangeability with any other Crate Controller Type A, taking into account the effect of such interchange on both hardware and software. It must be fully interchangeable with one conforming to Figure 7, although it need not have identical structure, internal signals (shown without the prefix 'B' in Figure 7) or logical expressions.

A1.2 Other Crate Controllers

It is recommended that other crate controllers should be interchangeable with Crate Controller Type A in respect of those features that they have in common, although they need not have all the mandatory features of Crate Controller Type A and may have additional features.

A1.3 General Features

The crate controller must conform fully with the mandatory requirements of the CAMAC Specification, EUR 4100e, and the CAMAC Branch Highway Specification (Sections 1 – 7 of this document). It is mandatory that all signal inputs at the branch highway ports of Crate Controller Type A must satisfy the lower input current standard (± 0.3mA) shown in Table VIII.

Crate Controller Type A must not occupy more than three stations. It should preferably be a double-width unit which engages with the Dataway at the control station and the adjacent normal station.

In addition to the two front panel connectors for branch highway ports (see Section A1.4) the crate controller must have a rear-mounted connector for a link to an optional separate LAM-Grader unit (see Section A1.9).

A1.4 Front Panel

The crate controller must have all the following front panel features, and no other that would affect interchangeability (for example, the addition of indicators for test purposes is permitted).

a) There must be two connectors for branch highway ports, as defined in Section 6 of the branch highway specification, mounted with the correct orientation and with all corresponding contacts joined.

b) There must be a means of indicating the selected crate address (1 – 7). There must not be easy access at or through the front panel to the means of changing the crate address.

c) There must be a means of selecting off-line status of the crate controller (see Section A1.10).

d) There must be a coaxial connector for the Inhibit signal input. The type of connector and the signal standard are specified in EUR 4100e, Sections 4.3.3 and 7.2.1, respectively.

e) There must be two push-buttons, or equivalent manual controls, for Initialise and Clear. These are only effective in the off-line state, and the front panel layout or markings should indicate this.

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*The designation Crate Controller Type A–1 (CCA–1) has been allocated for more specific identification of crate controllers conforming to this final specification, in contrast to the Preliminary Specification issued in November 1970 (available from the Secretary of the ESONE Committee).

A1.5 Dataway Signals

A1.5.1 Data Signals

When the crate controller is on-line and addressed during a read command operation with a station number other than N(30) it must retransmit the signals from the 24 Dataway Read lines through intrinsic OR outputs to the BRW lines. Crate Controller Type A must have gates between the R and BRW lines so that this transfer of read data occurs only when the crate controller is addressed and on-line, for example when $BCR_i.(BTA + \overline{BTB_i}) = 1$. During write operations with station number other than (N30) it must retransmit the signals from the 24 BRW lines to the Dataway Write lines.

It is recommended that all crate controllers should include gates between the R and BRW lines, and between the BRW and W lines, so that these transfers of data are only effective when the crate controller is addressed and on-line. These gates may further limit the transfers to read operations ($\overline{BF16}.\overline{BF8} = 1$) and write operations ($BF16.\overline{BF8} = 1$), respectively. However, the crate controller is permitted to generate signals on the Dataway Write lines during any operation, but other units connected to the Dataway can only rely on the presence of such signals during Dataway write operations.

A1.5.2 Command Signals

The branch highway command signals BN, BA and BF should be conditioned in the crate controller, for example, by integration or by staticising at a time related to BTA $0 \rightarrow 1$, in order to protect the Dataway command lines from the effects of cross-talk into branch highway command lines.

The sub-address and function signals from the BA and BF lines must be re-transmitted by the crate controller on the Dataway A and F lines during all command mode operations when the controller is on-line and addressed.

In a double-width crate controller each of the Station Number codes N(1) through to N(23) must be decoded in the crate controller to produce a signal on the corresponding Dataway line N1 to N23.

Command operations with N(26) must generate Dataway signals on all the lines N1 through to N23. Command operations with N(24) generate Dataway signals on N1 through to N23 as determined by the contents of a 23-bit Station Number Register (SNR). This register is loaded from BRW1-BRW23 by the command N(30).A(8).F(16). The bit of the Station Number Register that is loaded from BRW1 controls the state of N1, etc. The register is not reset by the Dataway Initialise signal (Z).

A triple-width controller may alternatively have a 22-bit SNR, decode N(1) through to N(22), and generate signals on Dataway lines N1 to N22.

A1.5.3 Common Control Signals

The Dataway Initialise signal (Z) must be generated in response to the command N(28).A(8).F(26) and to the Branch Initialise signal (see Section 4.5.1). It must also be generated in response to the manual Initialise control, but only when the crate controller is in the off-line state.

The Dataway Clear signal (C) must be generated in response to the command N(28).A(9).F(26). It must also be generated in response to the manual Clear control, but only when the crate controller is in the off-line state.

The Dataway Initialise (Z) and Clear (C) signals must be generated with the timing specified for command signals in EUR 4100e, figure 9 They must be associated with a sequence including B and S2 signals, also with the timing specified in EUR 4100e, figure 9. The sequence is permitted to include S1, but this is not mandatory and other units connected to the Dataway must not rely on the generation of S1 with Z and C.

The Dataway Inhibit signal (I) must be initiated when an on-line crate controller generates Dataway Initialise (Z), and must reach a maintained '1' state not later than time t_3 (See EUR 4100e, figure 9). When some other unit generates Initialise (accompanied by Inhibit) an on-line crate controller must generate Inhibit in response to Dataway Z gated by S2. The Inhibit signal must also be generated in response to the command N(30).A(9).F(26). In all these cases the Inhibit signal must be maintained by the crate controller until reset by the command (N30).A(9).F(24). It must also be generated while the front panel Inhibit signal is present.

The command N(30).A(9).F(27) must produce a Q = 1 response if there is a '1' state signal on the Dataway Inhibit line.

A1.5.4 Patch Connections

Crate Controller Type A must not use the patch pins of the Dataway stations that it occupies.

A1.6 Demand Handling

A1.6.1 Branch Demand

The Branch Demand signal (BD) must be derived, subject to the following conditions, from the OR combination of an external demand signal from contact 48 of the LAM-Grader connector and an internal demand signal which is the OR of the 24 GL signals received via the LAM-Grader connector.

The output of the branch demand signal to the BD line must be disabled by the command N(30).A(10).F(24) or by the Dataway Initialise signal (Z) with S2. It must be enabled by the command N(30).A(10).F(26). The command N(30).A(10).F(27) must give a BQ = 1 response if the output of BD is enabled. The command N(30).A(11).F(27) must give a BQ = 1 response if the OR of the internal and external demands is in the '1' state, even if the output of BD is disabled.

The internal demand signal must be inhibited by the '1' state of the Inhibit Internal D signal from contact 51 of the LAM-Grader connector.

A1.6.2 Graded-L

In response to a Graded-L Request signal (BG = 1), accompanied by $BCR_i = 1$, the crate controller must generate the Graded-L Operation signal on contact 1 of the LAM-Grader connector. It must accept the Graded-L signals GL1–GL24 from the LAM-Grader connector and transmit them to the BRW lines (GL1 to BRW1, etc.).

The crate controller must also accept the Graded-L signals from the LAM-Grader connector and transmit them to the BRW lines in response to command mode operations with N(30).A(0–7).F(0). (See Section A1.9.4).

In both cases the GL information must be transferred from the LAM-Grader connector to the BRW lines with minimum delay, and the signals must not appear on the Dataway Read lines.

A1.6.3 Pull-up for GL and L lines

Pull-up current sources in accordance with EUR 4100e, Table VI must be provided on all GL lines in the crate controller, and must not be provided on the L lines, thus allowing a simple LAM-Grader to form wired-OR combinations of L signals.

A.1.7 Timing Requirements

In command mode operations with station number codes other than N(30), the crate controller generates Dataway Strobe signals S1 and S2, with timing related to that of the branch timing signals BTA and BTB as defined in the next Section, A1.7.1.

Command operations with station number code N(30) do not generate S1, S2, or B signals on the Dataway lines. (See Section A1.7.3).

In Graded-L operations there are no Dataway strobe or B signals and the timing must take into account the signal delays in any non-Dataway connections to a LAM-Grader unit. These timing requirements defined in Sections A1.7.2 and A1.9.3.

The internal timing generator of the crate controller must be protected against spurious signals on the BTA and BCR lines.

One method of protection, shown in Figure 7, is to condition the incoming signals from the BTA line and the selected BCR line by integration with a time constant of 100 ± 50ns. Another method is to condition the internal signal (TA) which controls the timing generator. Transitions of the BTA and BCR signals are detected by the crate controller after a delay (shown in Figures 3 and 4) due to this protection.

A1.7.1 Command Mode Operations with Dataway S1, S2 and B

The following timing conditions must be satisfied when the crate controller responds to a command mode branch operation which requires a Dataway operation with signals S1, S2 and B. In this section the time t_0, t_3, t_5 etc. refer to the corresponding key points on Figure 9 of EUR 4100e.

In Phase 2 of the operation, after actions by the branch driver during Phase 1, the crate controller detects BTA = 1, accompanied by BG = 0, BCR_i = 1, and the appropriate command signals. It must then initiate the required Dataway N signals and B, thus starting the Dataway operation at t_o.

At t_3, which is 400^{+200}_{-0}ns after t_0, the crate controller must initiate the $0 \rightarrow 1$ transition of Dataway Strobe S1, and the branch timing signal transition BTB_i $1 \rightarrow 0$. At t_5, which is 200^{+100}_{-0}ns after t_3, the $1 \rightarrow 0$ transition of Strobe S1 must be initiated.

In Phase 4, the crate controller initiates the $0 \rightarrow 1$ transition of Strobe S2 at t_6, which is either when it detects BTA = 0 or when the interval t_5 - t_6 is 100^{+100}_{-0}ns, if this later.

At t_8, which is 200^{+100}_{-0}ns after t_6, the $1 \rightarrow 0$ transition of S2 must be initiated.

At t_9, which is 100^{+100}_{-0}ns after t_8, the crate controller must initiate the $1 \rightarrow 0$ transitions of Dataway signals N and B, and must isolate the Dataway Q and R lines from the branch highway BQ and BRW lines. It must then initiate the branch timing signal transition BTB_i $0 \rightarrow 1$.

A1.7.2 Graded-L Operations

The crate controller must satisfy the following timing conditions during Graded-L operations with BG = 1 and BCR_i = 1. In Phase 2 it must initiate branch timing signal transition BTB_i $1 \rightarrow 0$ within 400^{+200}_{-0} ns after detecting BTA = 1. At the same time it must be presenting to its BRW outputs the GL information received via the LAM-Grader connector (see Section A1.9.3). In Phase 4 it must remove the GL information from its BRW outputs with minimum delay after detecting BTA = 0, and initiate the signal transition BTB_i $0 \rightarrow 1$.

A1.7.3 Command Mode Operations without Dataway S1, S2 or B

Command mode operations addressed to N(30) are concerned with internal features of the crate controller and with reading Graded-L information via the LAM-Grader connector. The crate controller must not generate signals on the Dataway S1, S2, B or R lines.

The timing of these operations must follow the requirements for command mode operations (see Section A1.7.1) with the exception that the S1, S2 and B signals are not generated on the Dataway lines, although there may be equivalent internal signals.

A1.8 Commands Implemented by Crate Controller Type A

Crate Controller Type A must recognise and implement the commands summarised in Table IX, and must not use any other commands. When addressed with any of these commands it must generate BX = 1. The five function codes F(0, 16, 24, 26, 27) must be fully decoded in the crate controller.

The crate controller must generate BQ = 1 in response to all commands that read from or write to its registers, or the LAM-Grader connector. In Crate Controller Type A the two commands to which this applies are N(30).A(0 – 7).F(0) and N(30).A(8).F(16).

TABLE IX Commands Implemented by CAMAC Crate Controller Type A

ACTION	COMMAND			RESPONSE
	N	A	F	
Generate Dataway Z	28	8	26	BQ = 0
Generate Dataway C	28	9	26	BQ = 0
Read GL	30	0 – 7	0	BQ = 1
Load SNR	30	8	16	BQ = 1
Remove Dataway I	30	9	24	BQ = 0
Set Dataway I	30	9	26	BQ = 0
Test Dataway I	30	9	27	BQ = 1 if I = 1
Disable BD Output	30	10	24	BQ = 0
Enable BD Output	30	10	26	BQ = 0
Test BD Output Enabled	30	10	27	BQ = 1 if BD enabled
Test Demands Present	30	11	27	BQ = 1 if demands present

A1.9 LAM-Grader Connector

The rear-mounted connector for a link to an optional separate LAM-Grader unit must be a 52-way Cannon Double-Density fixed member with pins (Type 2DB52P), or equivalent type approved by the ESONE Committee. It must be mounted at the rear of the crate controller above the Dataway connectors within the area for free access (see EUR 4100e, Figure 3), with contact 1 lowermost. The 52 contacts are assigned as shown in Table X.

TABLE X Contact Assignments for Rear Connector of Crate Controller Type A

Contact	Usage	Contact	Usage
1	Graded-L Operation	2	L1
3	GL1	4	L2
5	GL2	6	L3
7	GL3	8	L4
9	GL4	10	L5
11	GL5	12	L6
13	GL6	14	L7
15	GL7	16	L8
17	GL8	18	L9
19	GL9	20	L10
21	GL10	22	L11
23	GL11	24	L12
25	GL12	26	L13
27	GL13	28	L14
29	GL14	30	L15
31	GL15	32	L16
33	GL16	34	L17
35	GL17	36	L18
37	GL18	38	L19
39	GL19	40	L20
41	GL20	42	L21
43	GL21	44	L22
45	GL22	46	L23
47	GL23	48	External D
49	GL24	50	Controller Addressed
51	Inhibit Internal D	52	0V

The LAM-Grader accepts L signals from the crate controller via the LAM-Grader connector. It generates Graded-L (GL) signals and, optionally, the External Demand signal. It may include gates, mask registers, etc., for processing the L signals, or may merely consist of passive inter-connections between the contacts of the LAM-Grader connector. It may interact with the crate controller in the following ways:

(a) *Branch Demand.* Crate Controller Type A derives the Branch demand (BD) signal from the Graded-L signals (and, optionally, the External D signal) which it receives via the LAM-Grader connector.

(b) *Graded-L Operations.* The crate controller generates the *Graded-L Operation* signal on contact 1 to indicate that it requires Graded-L signals.

If the LAM-Grader responds to this signal it must satisfy the timing requirements of Section A1.9.3.

(c) *Command Mode Operations.* In response to commands with N(28) or N(30) the crate controller generates the Controller Addressed signal on contact 50. This allows the LAM-Grader to be treated as a detached part of the crate controller that can be addressed independently of its location in the crate. The presence of Dataway Busy (B) distinguishes operations with N(28) from those with N(30). The Controller Addressed signal with Dataway A(0-7), but without B, indicates that the crate controller requires Graded-L signals. In conjunction with a Dataway operation and B the Controller Addressed signal may be used, for example, to access registers in the LAM-Grader.

If the LAM-Grader responds to the Controller Addressed signal it must satisfy the timing requirements of Section A1.9.4.

The *Graded-L Operation* signal on contact 1 must be in the logic '1' state when the crate controller is on-line and $(BTA + BTB_i).BG.BCR_i = 1$.

The *Controller Addressed* signal on contact 50 must be in the '1' state during command mode operations to N(28) or N(30) when the crate controller is on-line and $[N(28) + N(30)]\ (BTA + BTB_i).BG.BCR_i = 1$.

Equivalent conditions for the generation of these two signals, Controller Addressed and Graded-L Operation, are shown in Figure 7 in terms of the internal (non-mandatory) signals of a particular implementation of Crate Controller Type A.

All mandatory timing requirements refer to signal conditions at the LAM-Grader connector on the crate controller. The interval between the initiation of a signal by the crate controller and the receipt of an established response from the external unit thus includes delays due to both the external unit and its linking cable.

A1.9.1 Signal Standards

All signals via the LAM-Grader connector must satisfy Section 7.1 of EUR 4100e. The signal standard for N signals applies to the 'Graded-L Operation' signal on contact 1, and also to the 'Controller Addressed' signal on contact 50. All other signals including 'External D' on contact 48 and 'Inhibit Internal D' on contact 51, follow the standard for L signals.

A1.9.2 Timing – Branch Demand

The maximum overall delay between the time when an L signal at the control station of the crate controller reaches a maintained '1' or '0' state and the time when the BD signal at the branch highway port of the same crate controller reaches a corresponding maintained '1' or '0' state is defined in Section 4.4.1. When the Crate controller is used in conjunction with an external LAM-Grader the component of this delay due to the crate controller must not exceed 250ns.

A1.9.3 Timing – Graded-L Operations

The interval between the generation of the Graded-L Operation signal, accompanied by L signals, and the establishment of corresponding Graded-L signals must not exceed 350ns.

A1.9.4 Timing – Command Mode Operations

The interval between the generation of the Controller Addressed signal (accompanied by L signals, and in conjunction with Dataway signals F(0), A(0 - 7), B=0) and the establishment of corresponding Graded-L signals must not exceed 350ns.

The external unit must present identical GL information in response to the Graded-L Operation signal and to the Controller Addressed signal with A(0), F(0) and B=0. Sub-Addresses A(1-7) may be used to access different selections of GL information.

If the external unit responds to command mode operations with N(28).A(0 – 15), B= 1, and an F code, it must satisfy the normal timing requirements for a CAMAC module and is permitted to make data transfers via the Dataway R and W lines.

A1.10 Off-line State

The Off-line state is selected by means of the 'Off-line' manual control on the front panel of the crate controller. In this state the controller does not respond to command or Graded-L Request signals on the branch highway, and does not generate branch timing or demand signals on the highway.

The following minimum conditions must be observed in the off-line state:

a) The front panel manual controls for Initialise and Clear must be effective. (They must be ineffective in the on-line state).

b) The front panel Inhibit signal input must continue to be effective. Dataway Inhibit must only be generated in response to the front panel Inhibit input.

c) The crate controller must not respond to BTA = 1. It must not generate Dataway B, N, S1 or S2 signals in response to BTA = 1 with BG = 0, or access the Graded-L information in response to BTA = 1 with BG = 1.

d) The crate controller must not generate '1' state outputs to the BTB, BD, BRW, BQ or BX lines. An off-line crate is thus prevented from interfering with branch operations.

e) The crate controller must not respond to BZ = 1.

The following additional conditions are recommended in the off-line state:

f) If there are gates between the branch highway and Dataway lines W, N, A and F, these should be used to isolate the crate controller. Branch operations are thus prevented from interfering with an off-line crate.

h) In the absence of power supplies to the crate controller, all inputs and outputs via the branch highway ports should be free to assume either the '0' state or the '1' state, as required by other units connected to the branch, and should not impose abnormal current loadings.

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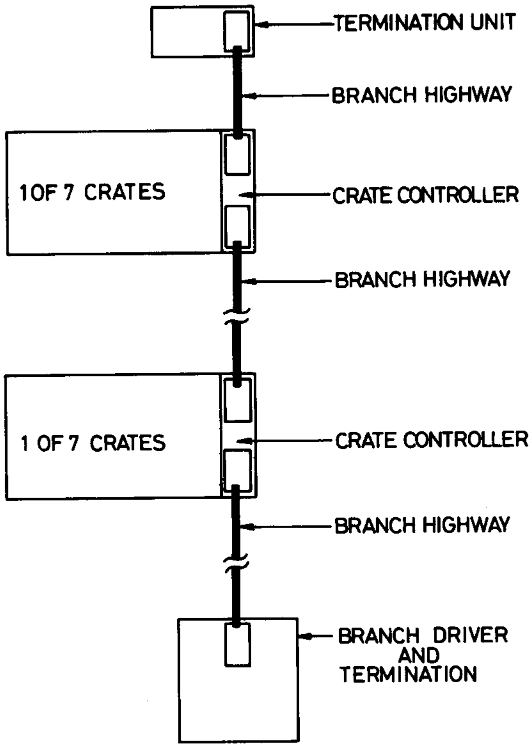


Fig. 1. CAMAC BRANCH: CHAIN CONFIGURATION

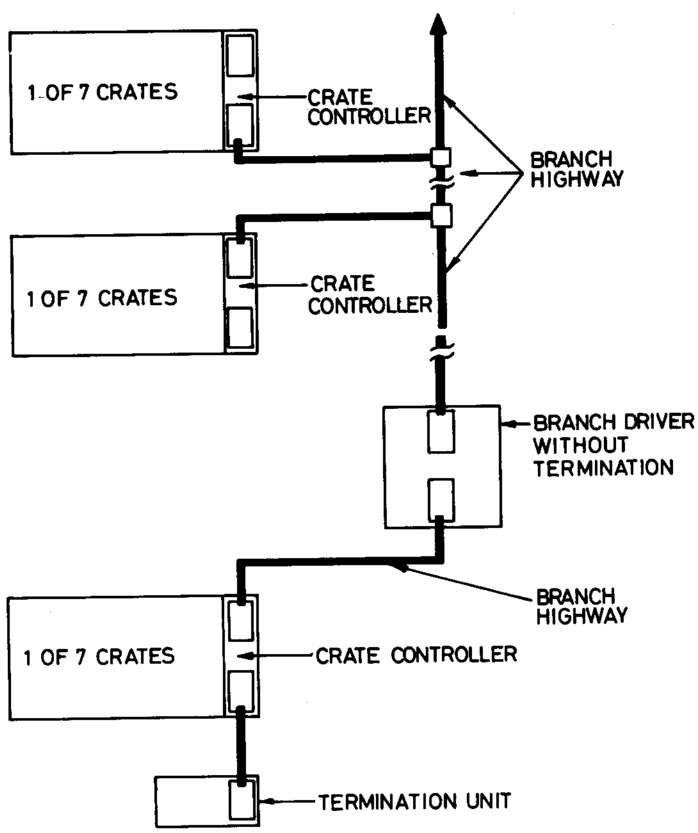


Fig. 2. CAMAC BRANCH: EXAMPLE OF AN ALTERNATIVE CONFIGURATION

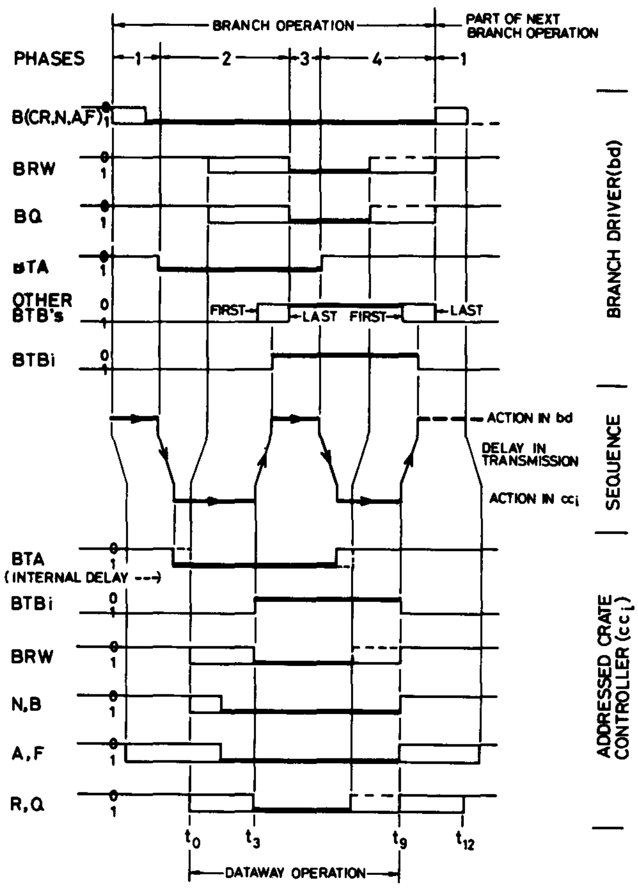


Fig.3. TIMING OF BRANCH READ OPERATION

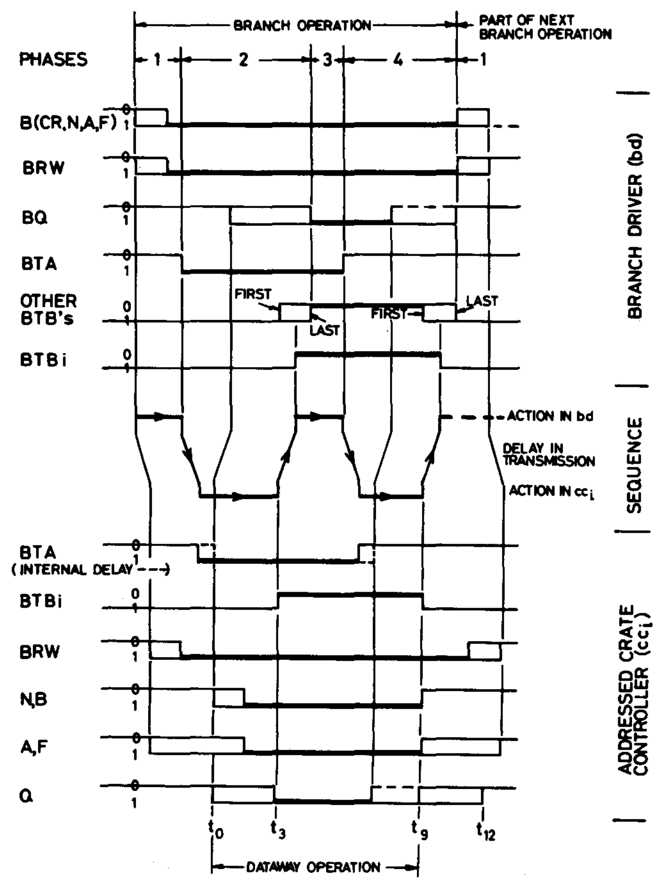


Fig. 4. TIMING OF BRANCH WRITE OPERATION

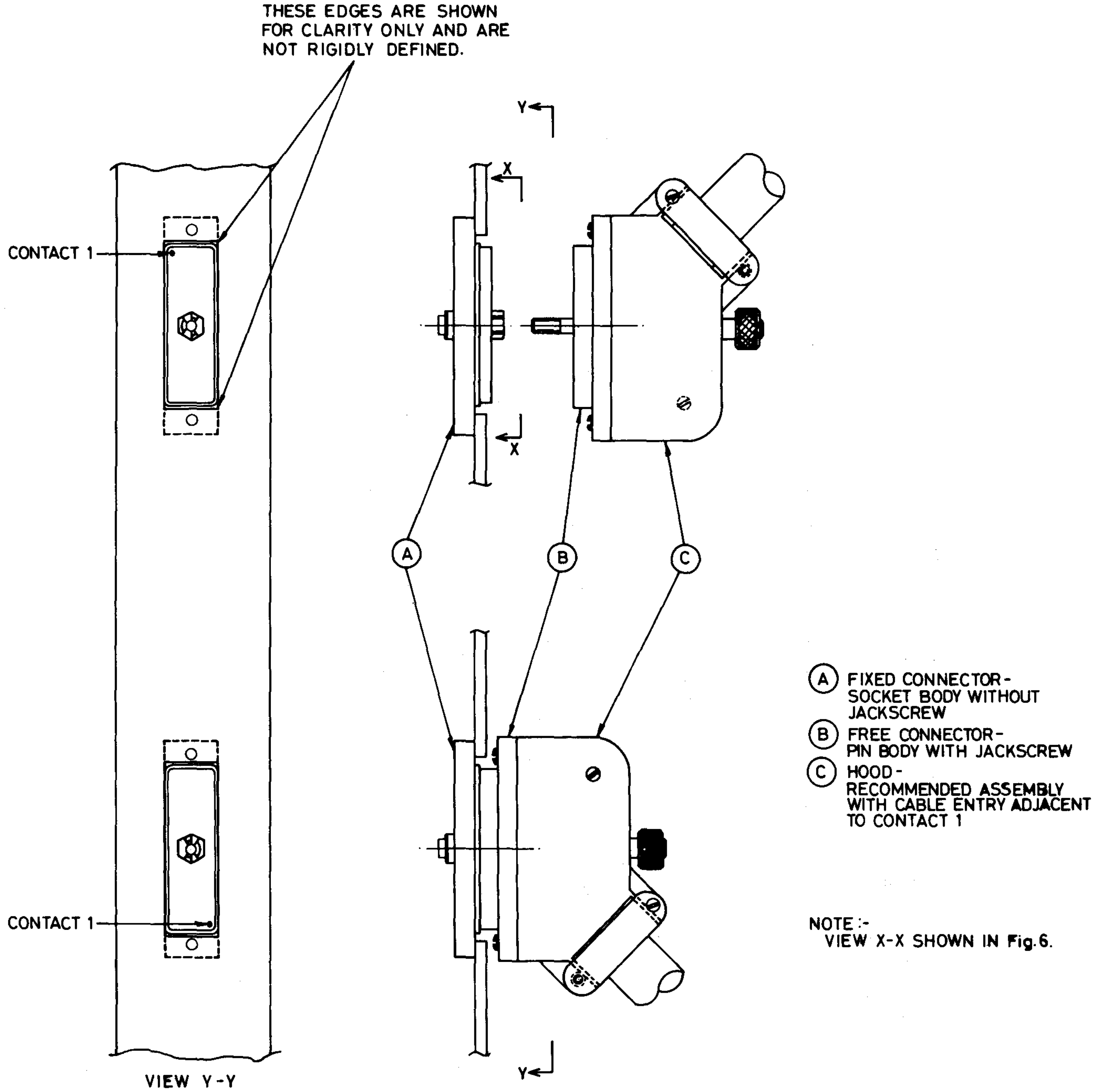
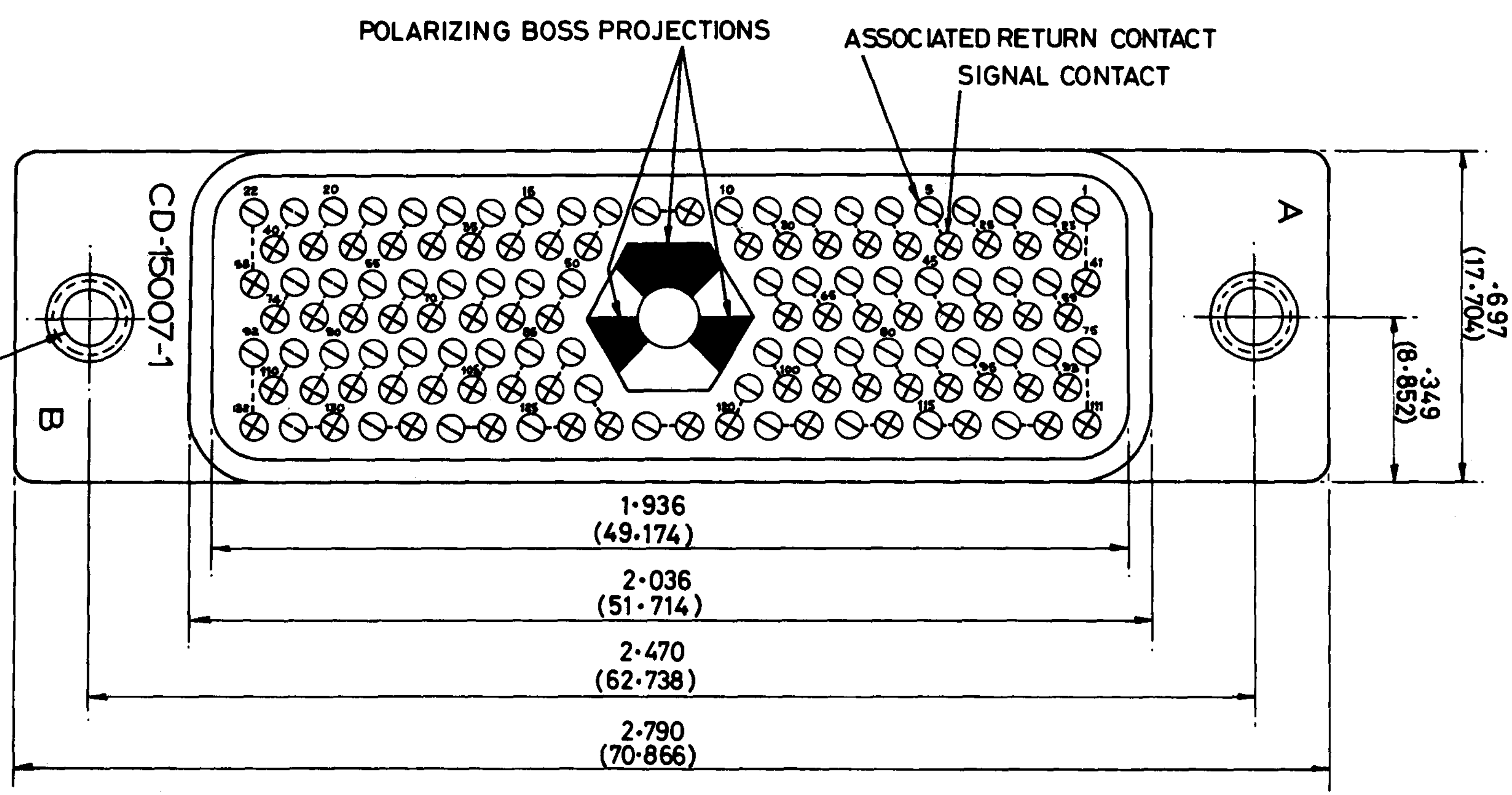


Fig.5. BRANCH HIGHWAY PORTS: ARRANGEMENT OF CONNECTORS ON CRATE CONTROLLERS

NOTE:-
MANUFACTURERS DIMENSIONS SHOWN IN INCHES.
DIMENSIONS IN BRACKETS ARE APPROXIMATE
METRIC EQUIVALENTS.



ENLARGED VIEW X-X IN FIG. 5

Fig. 6. BRANCH HIGHWAY PORTS: CONTACT LAYOUT.
(FRONT VIEW OF FIXED CONNECTOR)

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INDEX

The principal references are given first. Any subsidiary references follow, after a semi-colon (;). Information specific to Crate Controller Type A is indicated by references to Appendix 1, for example A1.9.2.

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