



**The AES - 81/10  
Remote Terminal Unit**

**RTU  
APPLICATION  
BULLETIN**

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## 1.0 INTRODUCTION

### 1.0.1 GENERAL

Automatic Electronic Systems Inc. is pleased to submit details of our remote terminal unit for supervisory control and data acquisition applications.

### 1.0.2 AES CREDENTIALS

Automatic Electronic Systems Inc. specializes in supervisory control and data acquisition equipment. Since inception, AES has developed a comprehensive systems capability in this field. The success that has been achieved is due, in great measure, to furnishing well-proven "of the-shelf" components interconnected in the system configuration. In order to maintain this success, AES has an extensive research and development program to develop new products and to update existing product lines.

AES maintains a full support staff of Sales Engineers and Field Support Engineers for customer liaison. The Field Support Engineers, trained on each system during the production and final test phases, provide on-site assistance during installation and commissioning and serve as a continuous back-up to the users' maintenance staff.

### 1.0.3 EXPERIENCE

AES' experience includes design, manufacture, test, installation, documentation, computer software, and field support on a wide variety of related equipments, some of which are described in the following paragraphs.

#### 1.0.3.1 Data Acquisition Equipment

AES has provide several Data Acquisition Systems ranging from simple "one-to-one" configurations to multiple remote-single master configurations with conventional displays and/or computer controlled data-logging. A typical system, comprising 32 remote stations and a single master with computer, has been installed with the Manitoba Telephone System for several years and is in current usage.

#### 1.0.3.2 Supervisory Control Equipment

Numerous Supervisory Control Systems are in use with Major Utilities for substation control. A typical configuration, such as the Berri Substation for Hydro Quebec, involves the control of approximately 60 breakers (with auto-reclose)

and the reporting of approximately 200 status points complete with telemetering. Currently in production at the AES facility, is a Supervisory Control and Data Acquisition System for the control of a generating station. This system utilizes CRT display systems and microprocessors of AES manufacture.

Also in production are several supervisory control and data acquisition systems, utilizing microprocessors and complex security techniques, for usage by Telesat Canada in television network control applications via synchronous satellite

#### 1.0.3.3. Protective Relaying Equipment

AES manufactures a line of sophisticated tone equipment for protective relaying applications. The "S-300 Tele-Protection System", is a current model and several hundred terminals are in use throughout North America at large power utilities. This equipment, incorporating several new techniques to provide security, is recognized as being the best available for this demanding application.

#### 1.0.3.4. Telex Multiplex Equipment

AES has produced Telex Multiplex Equipment for the Canadian Overseas Telecommunications Corporation. This equipment multiplexes approximately 900 telex channels and provides a high speed data stream into a Univac computer system for the control of overseas telex data originating in Canada for transmission to the United Kingdom. In addition, standard systems have been developed for use by the common carriers in their various applications.

#### 1.0.4. PROPOSED EQUIPMENT

The proposed equipment provides a means for data acquisition and control at all levels ranging from simple applications requiring only alarm reporting and annunciation to those applications requiring full control capability with the acquisition of alarms, status and analog values. The architecture is modular, to permit a building block approach for specialized system applications, and to allow for expansion in the field at a later date if necessary.

1.1 SCOPE

1.1.1 This specification describes the performance characteristics of the AES 81/10 programmable REMOTE TERMINAL UNIT (RTU).

1.2 PURPOSE

1.2.1 The purpose of this specification is to describe the operating and technical characteristics of a RTU which is functionally and communications compatible with commonly used Remote Terminal Control systems.

1.3 INTENT

1.3.1 The intent of this specification is to provide sufficient information to permit an effective technical evaluation of the RTU.

1.4 APPLICABLE DOCUMENTS

The following documents are listed for reference purposes only:

1. AES 80 MICROPROCESSOR REFERENCE MANUAL
2. AES 80 MICROPROCESSOR ASSEMBLER REFERENCE MANUAL

2.0 GENERAL

2.1 PURPOSE OF EQUIPMENT

2.2 GENERAL DESCRIPTION

## 2.0 GENERAL

### 2.1 PURPOSE OF EQUIPMENT

2.1.1 In general, REMOTE TERMINAL units provide the primary interface with the instrumentation and control signals of an electric power network. As such, the RTU must have the capability to perform both systems and local functions.

2.1.2 System functions include:

- a) Communicating with a MASTER site via a suitable communications link,
- b) Operating within the constraint of master station computer controlled operating procedures,
- c) Performing message security operations to minimize the effects of transmission errors.

2.1.3 LOCAL functions include the following:

- a) Provide timed contact closure outputs for operation of two-position devices such as circuit breakers and disconnect switches,
- b) Provide timed contact closure outputs for incremental operation of multi-position devices such as tap changers, gates, governor motors and motor operated rheostats,
- c) Monitor and store status of contact inputs for reporting of alarms and device positions. This also includes momentary change detection.
- d) Provide digital contact outputs, with or without digital-to-analog conversion, for set point control,
- e) Count and store impulses representing quantities such as KWH or positive displacement of liquids,
- f) Provide multiplexing, analog-to-digital conversion and digital storage for quantities such as watts, vars, voltage and current,
- g) Transmit status and data in digital form to the master station upon request.



## 2.2

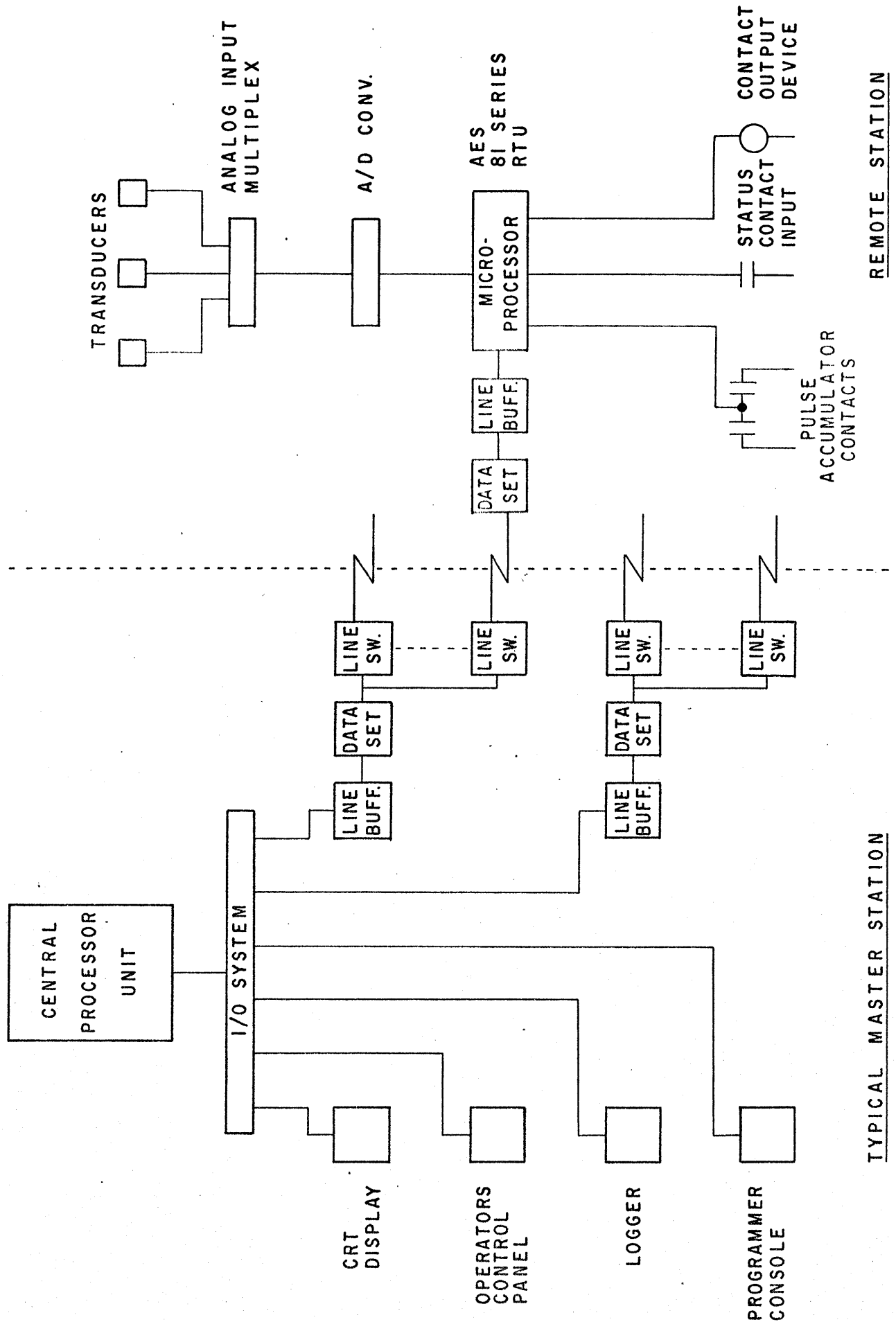
### GENERAL DESCRIPTION

A block diagram of a typical data acquisition and control network integrating an AES 81 RTU System is shown on Fig. 2-1.

The AES 81 system operates in what is commonly known as a continuous scanning mode with the master station in command at all times. System direction and programming are provided by the master station, and the RTU responds and replies only when specifically commanded or interrogated by the master station. Transmissions between the master and remote stations are carried on repetitively under control of a master station program determined by the system requirements. In general, this continuous scanning mode of operation will be interrupted only when it is necessary for the master station operator to perform a control function.

This mode of operation provides a high degree of flexibility in that the master station can request and receive, at different intervals, data of varying degrees of importance. For example, some data must be updated as often as every two seconds, while other data will be required only every fifteen minutes or longer. Programs in the master station central processor unit, coupled with the extremely flexible method of addressing data at the RTU can automatically provide the different data retrieval cycles required. Another advantage of the continuous scanning mode of operation is that frequent checks are made on the satisfactory functioning of the channels and remote terminal units. Any failure of the master station to receive a reply to its request from the remote station can instantly be brought to the attention of the operator.

When not communicating with the master station or performing a control function commanded by the master station, the RTU continuously performs an internal routine for the purpose of gathering and storing status and data. The organization and operating mode of the remote terminal unit are such that current status, unreported indications of status change, and data in digital form are all stored in memory and ready for transmission to the master.



TYPICAL MASTER STATION

REMOTE STATION

FIGURE 2-1 BLOCK DIAGRAM

- 3.0 OPERATIONAL DESCRIPTION
- 3.1 OPERATING MODES
- 3.2 LOCKUP OF DATA

### 3.0 OPERATIONAL DESCRIPTION

#### 3.1 OPERATING MODES

Three basic operating modes of the system permitted by the RTU design are the data scan mode, control mode and status scan mode.

The design of the AES 81 RTU has emphasized efficient and high speed data acquisition, and it is expected that most applications will use the data scan mode. The control mode is also very basic and will be required on practically all applications.

The status scan mode will be used on applications where frequent updating of data at the master station is not required. These modes of operation are explained in the following.

##### 3.1.1 Data Scan Mode

In this mode of operation the master station can continuously keep its memory updated with the latest data and status information from all of the remote stations of the system. When the master station is not being asked by the operator to perform a control operation the master station can continuously request and receive data from the remote terminals. Thus, up-to-date data and status can always be stored in the master station central processor unit, from which they may be rapidly obtained when required for display or logging.

Data is addressable as described under MESSAGE STRUCTURE AND CODING. In this mode of operation the master station can continuously send out requests with addresses for data in accordance with a preprogrammed routine. Each data reply consists of 1 to 8 data messages containing from 24 to 192 bits of useful information. This data retrieval routine can be run on a continuous basis unless it is required to perform remote control operations or to bring back status indications.

In order to make the most efficient use of the system for data retrieval, status is not transmitted on a routine basis in reply to periodic interrogations. However, it is necessary that status changes be reported without unnecessary delay. Therefore, the organization of the system is such that it is not necessary to transmit status unless a change has occurred. In the data scan mode if there has been no change in status at a remote terminal receiving a data request, the requested data is transmitted and the master station

proceeds to request data from the next remote terminal unit in a similar manner. Now, assume a change of status has occurred in the remote terminal unit receiving a data request. A common change of status flag is set at the remote terminal unit. The remote terminal unit sends the requested data in the usual manner, but the function section of the first data message contains a change of status flag to inform the master station that there is a status change to be reported at a sub-remote of this station. The remote terminal unit will complete the data reply as originally requested. Then the master station can transmit a status request, which is very much like a data request, to the same remote terminal unit to obtain the necessary status changes and present status information.

After the request status and changes have been obtained the master station can proceed with the data scan as before.

Remote stations may each include two or more blocks of data readings, requiring two or more data requests per station and proportionately more time for transmission of data. When this is the case, it may be desirable to use an alternate scanning arrangement in order to avoid too much delay between visits to the individual stations for the purpose of learning of possible status changes. With this alternate scanning arrangement the first block of data would be requested from each remote station on the first scan cycle, then the second block of data from each station on the next scan cycle, and so on until all data has been obtained. Each data reply gives the remote station an opportunity to notify the master station that a status change has occurred.

### 3.1.2

#### Control Mode

When a control operation is requested, the normal data scan mode is momentarily interrupted. The master must first select the controlled device to be operated and then transmit the appropriate control (close, trip) message. As a security measure to minimize the time that a point remains selected at the remote station, there are no transmissions between the master and remote stations for control purposes until after the master control has been initiated. After the master control has been activated, the data scan mode can be interrupted permitting the following exchange of messages to occur.

- a) A selection message is transmitted from the master to the remote.
- b) A checkback message, similar to the selection message, is transmitted from the remote to the master.
- c) An activate message, which must agree with the selection message, is transmitted from the master to the remote to cause the operation to be performed.
- d) An activate acknowledge message is transmitted from the remote to the master.

Two important security measures are inherent in this message exchange for performing a control operation. The checkback message which is returned by the remote terminal in reply to the selection message transmitted by the master station can be compared for agreement with the selection message which was sent out. Upon verification of the checkback message, the master station can follow with the activate message. The second safeguard is that the activate message must agree with the selection message in order for the remote station to proceed with operation of the device. Upon receipt of the correct activate message the interposing relay is energized for a preset time and is then released. The acknowledge message which is returned to the master station verifies that the activate message was correctly received and the appropriate control action was initiated.

At this point the remote terminal is cleared of the point selection and the control operation. After the controlled device has operated, its new status will be reported to the master station when that remote terminal is again polled during the normal data scan mode. The system normally returns to the data (or status) scan mode immediately after the master station has received the activate acknowledge message from the remote terminal.

### 3.1.3

#### Status Scan Mode

The status scan mode may be used when frequent updating of data at the master station is not required. In this mode of operation the master station will continuously scan the remote terminals asking for status (status is addressable in the same manner as data). If there has been no change of status the remote terminal unit will reply with a single message, indicating in the function section of the message that there are no status changes to report. The master station then proceeds to interrogate the next remote terminal unit. If a change of status flag is reported in the initial reply, the master station will then request a report of status and status changes in the same manner as used in the data scan mode.

### 3.2

#### LOCKUP OF DATA (Optional)

It is often necessary, for the purpose of making system load and stability studies, to make data readings at all remote stations within a very short span of time. A unique feature of the AES 81 system is its ability to take readings which are very nearly simultaneous at all remote stations. Each remote station, while "at rest", is busy collecting and storing data in digital form at the rate of 25 A/D conversions per second. If each remote station is assumed, for example, to have 12 data readings, at any given time the oldest data in memory will be only one-half second old-or an average of one-fourth second for all readings at the station.

The remote station, upon receipt of a lockup signal from the master station, freezes all data in storage and prevents further A/D conversions from being entered. If lockup signals are sent from the master station to all remote stations at the same time assuming transmission times to all stations to be nearly equal all stations will have stored data whose measurements were all made within the same one-half second interval. After lockup, the master station then requests and obtains the stored

data in the usual manner. Following acquisition of the data, the master station then sends a lockup reset signal to allow resumption of the normal updating of data in storage.



4.0 MESSAGE STRUCTURE AND CODING

4.1 BASIC MESSAGE STRUCTURE

4.2 MESSAGE FORMATS

4.3 STATUS INDICATIONS

4.4 BCH-CYCLIC CODE FOR ERROR DETECTION

4.5 MESSAGE EXCHANGES

4.6 CODE ASSIGNMENTS FOR THE MESSAGE FORMATS

4.7 GENERAL INFORMATION

4.8 ERROR DETECTION

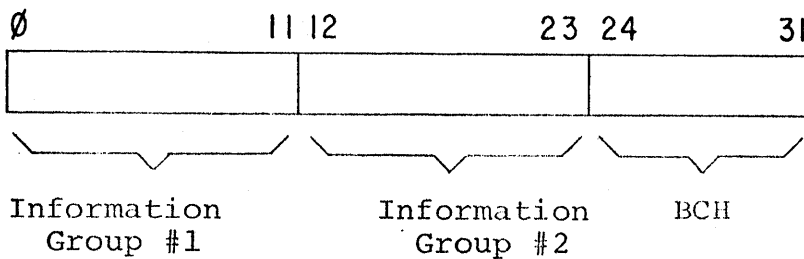
4.9 SYSTEM SECURITY

## 4.0 MESSAGE STRUCTURE AND CODING

### 4.1 Basic Message Structure

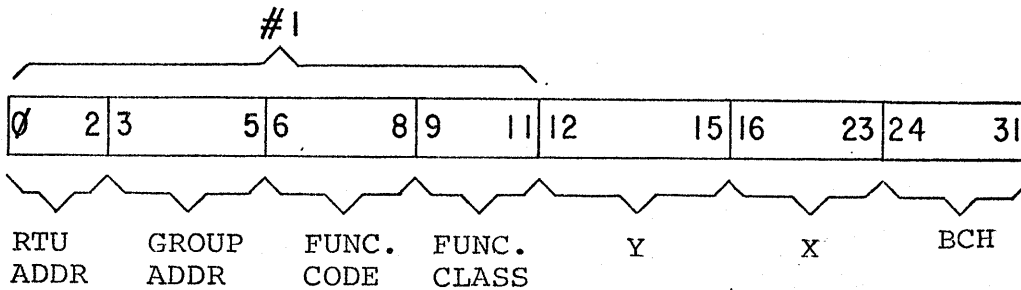
A fixed message length of 32 bits is used. Each message consists of two 12-bit information groups (0-11 and 12-23) and eight bits (24-31) for a cyclic parity code check (BCH). All messages transmitted by any station are of this length and structure. In general, octal coding is used for addressing and binary used for data.

Numbers shown above in parenthesis are the numbered bits as shown below:



### 4.2 Message Formats

#### 4.2.1 Master-to-Remote for selection of a control device.



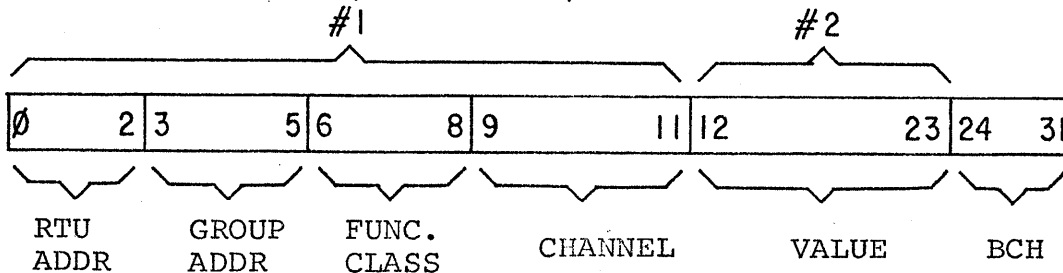
- Bits 0-2 specify the RTU address. A maximum of 12 stations can be addressed (4-15). Leaving 4 common addresses (0-3) which should be accepted by all connected stations.
- Bits 3-5 specify the address of the SUB-RTU as specified by the function class.
- Bits 6-8 specify the function class. The following classes have been assigned:

- ∅: Control selection
- 1: Momentary activate
- 2: Latching activate
- 3: Housekeeping
- 4: RTU-read
- 5: RTU-write
- 6: Set-point control
- 7: Special

- d) Bits 9-11 specify the function code. The interpretation of this code is related to the current function class (see code matrix).
- e) Bits 12-15 specify the address of the bit (1/16) to be set in the output sink board (y-selection).
- f) Bits 16-23 specify the bits to be set in the output source board (x-selection).

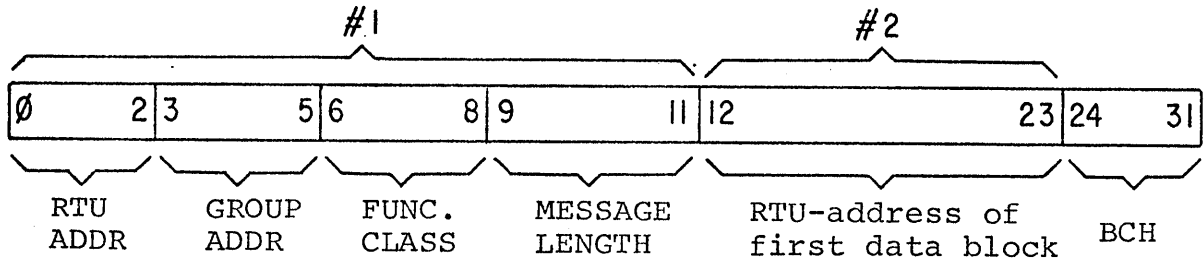
Note that the y-selection is in coded form, and that the x-selection is in linear form.

#### 4.2.2 Master-to-Remote, Set-Point, Set-Point Control Selection



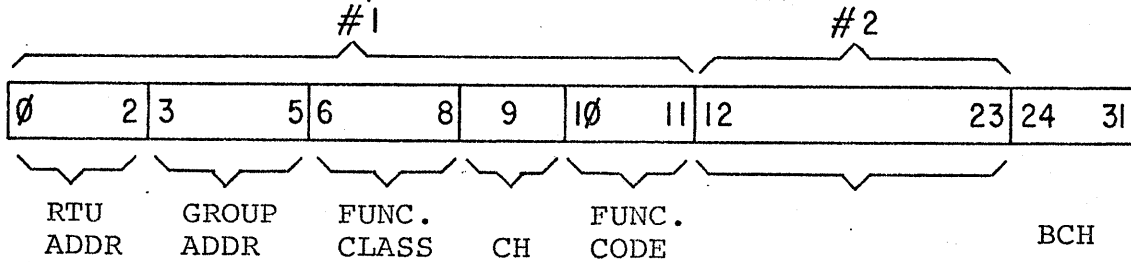
- a) Bits ∅-2 RTU address
  - b) Bits 3-5 Group address
  - c) Bits 6-8 Function class
- } The same as for 4.2.1
- d) Bits 9-11 specify the set-point channel address. Up to 4 channels can be addressed to each sub-RTU.
  - e) Bits 12-23 specify the analog value in sign plus magnitude form. The sign is located in bit-12, and MSB of the magnitude in bit-13.

4.2.3 Master-to-Remote, RTU-read or RTU-write.



- a) Bits 0-2 RTU address
  - b) Bits 3-5 Group address
  - c) Bits 6-8 Function Class
- } The same as for 4.2.1
- d) Bits 9-11 specify the number of pairs of data blocks the received or transmitted message should have. Up to 2 x 8 12-bit data blocks can be requested or transmitted from the master. Note that addresses 0-3777 are prevented from writing.

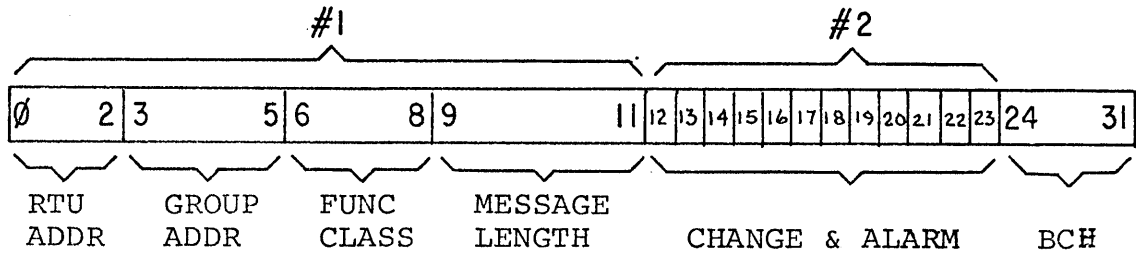
4.2.4 Remote-to-Master, Control confirmation



- a) Bits 0-2 As was received
- b) Bits 3-5 As was received
- c) Bits 6-8 As was received
- d) Bit 9 specifies a change or alarm condition in the RTU. A "1" indicates that the mentioned condition exists and a 0 indicates a normal condition. The Master can get a better picture of the abnormal condition by examining the header of a Remote-to-Master Interrogation message.
- e) Bit 10-11 function code, as received in control selection.
- f) 12-23 Selection Addresses, as received in control selection.

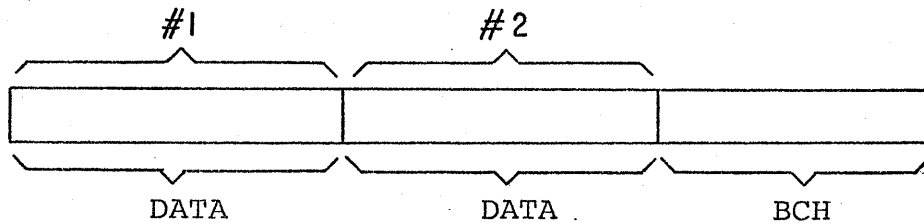
4.2.5 Remote-to-Master reply to RTU-read.

#### 4.2.5.1 Message Header



- a) Bits 0-2 RTU-address
  - b) Bits 3-5 Group address
  - c) Bits 6-8 Function address
  - d) Bits 9-11 Message length
- } As received in RTU Write Command
- e) Bit 12 Specifies general status change condition (COS)
  - f) Bit 13 specifies that a control action is in process.
  - g) Bit 14 specifies that the RTU has gone through a power on sequence.
  - h) Bit 15 specifies that a faulty condition has been detected in the output control circuits.
  - i) Bit 16 specifies that a status change has been detected on a digital input of class B, C or D for sub-RTU #0.
  - j) Bit 17 to 23 the same as for i) but for sub-RTU 1-7.

#### 4.2.5.2 Data Message



Note that the address of the first data block in the first data message is specified by the starting address (4.2.3).

#### 4.3 Status Indications

Status and change of status indications are handled in a similar manner to data, and are addressable in blocks of 12 indications. Up to fifteen 12-indication blocks may be obtained in reply to one request. The first reply message will contain the address and the first group of 12 indica-

tions. Subsequent reply messages in a multiple reply will each contain two 12-indication blocks.

In order to report rapid status changes such as trip-reclose or close-trip, each status memory has associated with it a momentary change memory. The momentary change indications are reported in the same manner as the current status. Therefore, for each block of 12 status indications there is a corresponding block of 12 change indications transmitted. The total of fifteen blocks in a reply will include eight blocks of status and seven blocks of change of status.

#### 4.4 BCH (Cyclic Code for Error Detection)

BCH is an acronym formed from the names of Messrs: Bose, Ray-Chaudhuri, and Hocquenghem because of their contribution to error detecting cyclic codes. A cyclic code is so described because of its property which allows the bits of the code to be cyclically shifted in some fashion without losing the identity or effectiveness of the code.

Transmission error detection employs a BCH cyclic code check utilizing eight parity check bits in each message. The use of the BCH coding permits detection of all (100%) single and double bit errors in a message block, all (100%) burst error patterns of length 8 bits or less, 94% detection of burst error patterns of length 9 bits, and 97% of all burst error patterns of length 10 bits or more. A burst is defined as the number of binary bits between two error bits, including the error bits. All or any number of bits in the burst may be in error.

The BCH code is generated by the primitive polynomial  $P(X) = X^8 + X^7 + X^6 + X^0$  checking on 40 bits. The Framing bits of the message structure are excluded. The method used to generate the 31 bit coded message polynomial,  $F(X)$ , is as follows:

- 1) The information polynomial,  $G(X)$ , consisting of 32 bits is multiplied by  $X^8$  to form  $X^8G(X)$ .
- 2)  $X^8G(X)$  is divided by the generator polynomial  $P(X) = X^8 + X^7 + X^6 + X^0$  to give a quotient  $Q(X)$  and a remainder  $R(X)$ .
- 3) The 40 bit coded message polynomial is the sum of  $X^8G(X)$  and  $R(X)$ .

$$F(X) = X^8.G(X)+R(X)$$

In checking, a received message is divided by the generator polynomial  $P(X)$ . If the resulting remainder is zero, either no error or an undetectable error has occurred. If the

remainder is not zero, an error has been detected.

#### 4.5 Message Exchanges

The following is a descriptive listing of the symbols used in the data blocks that follows:

RTU = RTU Address

G = Group (SUB-RTU) Address

FG = Function Class

FC = Function Code

L = Message Length

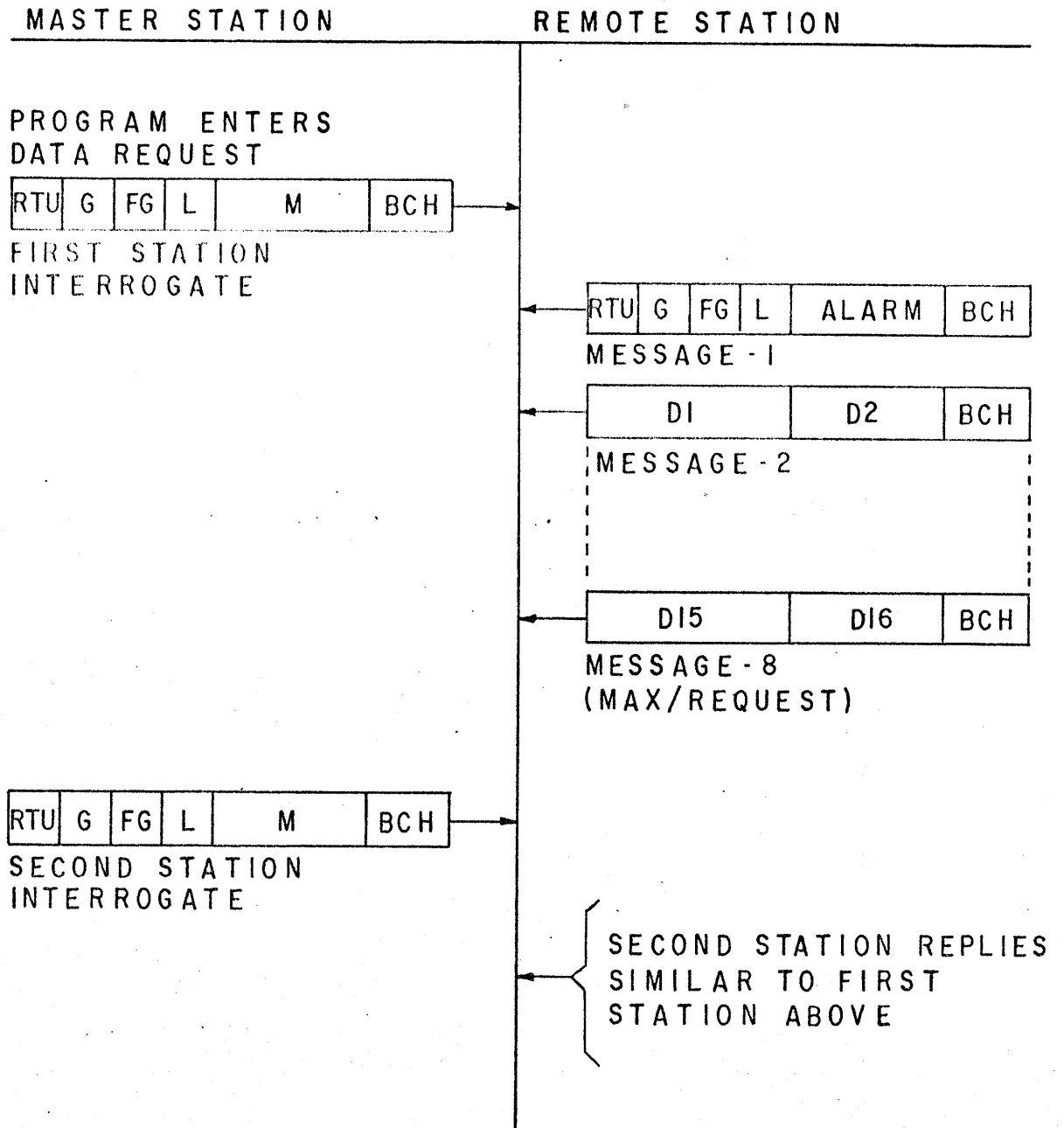
M = Address of First Reading

DX = 12-Bit Data Word

X = X-Selection

Y = Y-Selection

4.5.1 Normal Data Scanning



Sequence continues until last station is scanned or COS flag is reported. For continuous data up-dating, the cycle begins again.

- 1) Alternate scanning whereby the first 16 data words are requested on the first scan and the second set requested on the next system scan.

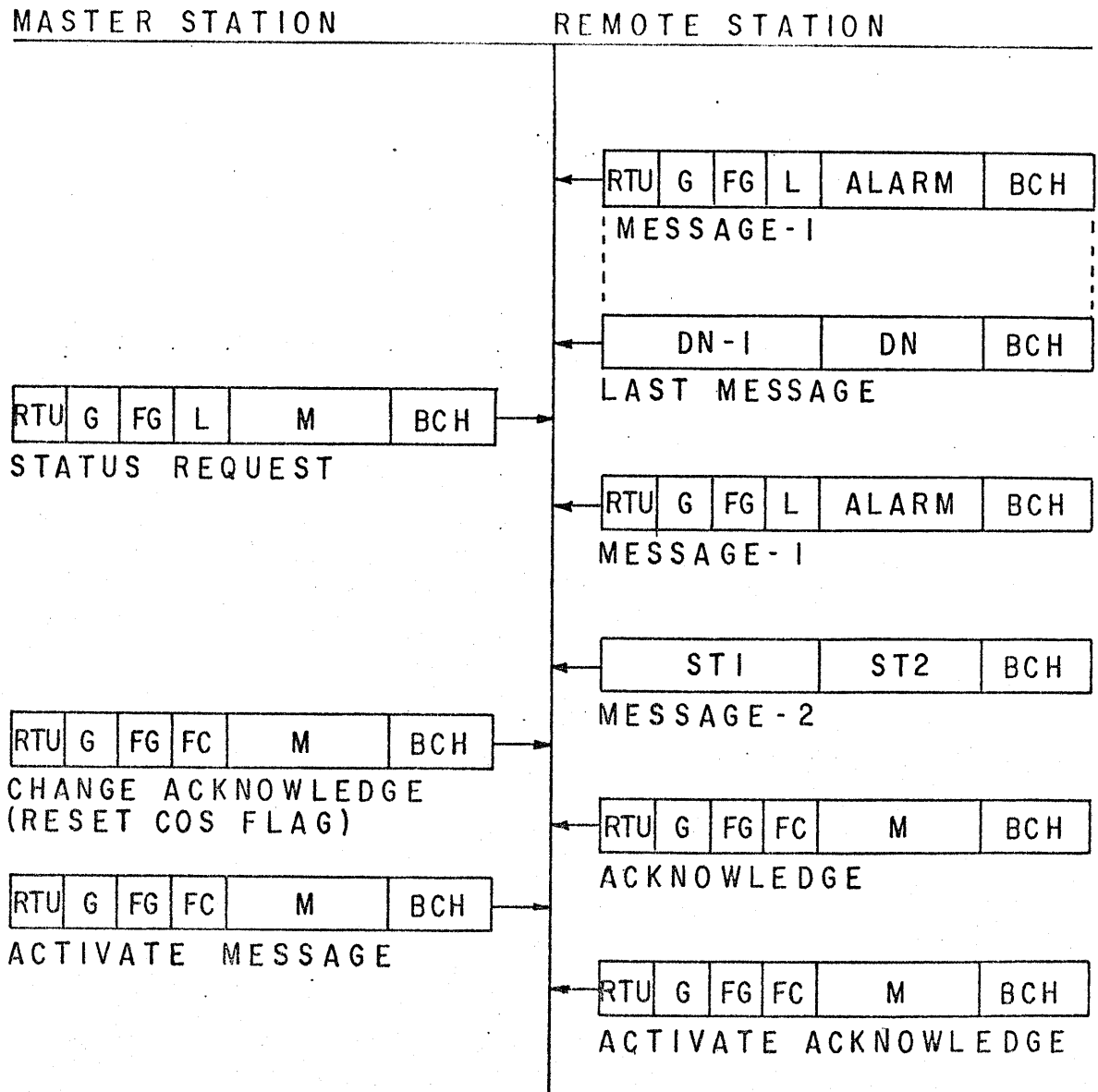


Up to 8 Data blocks (16 data words) are sent with each request. When more are required from a station, there are two programming operations depending on the system configuration and scan requirements, plus the particular need of data.

2) Consecutive scanning whereby the second request is made to same station after receiving first compl reply.

#### 4.5.2 Change of Status

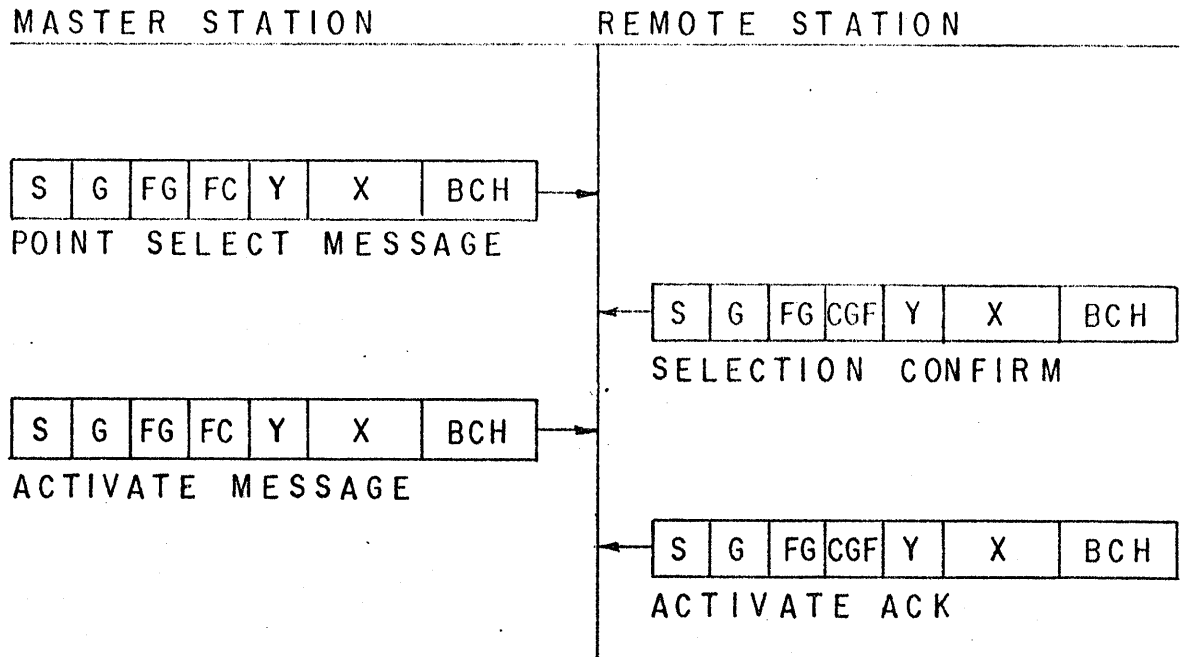
Assume during normal scanning above that a change of status (COS) occurs. Then on first message block of data reply the CGF flag indicates change.



Scan returns to position of data scan where interrupt occurred.

#### 4.5.3 Control Operation

The operator selects a point and control operation on the console. The sequence begins with the following substitute for the next programmed interrogation of associated station.



Data request is then sent to same station as programmed.

#### 4.5.4 Master-To-Remote Data Transferral

When a large amount of data has to be transferred from the master to the remote the following message exchange takes place:

MASTER STATION

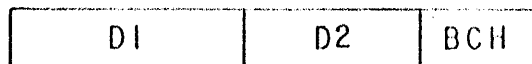
REMOTE STATION



MESSAGE - 1



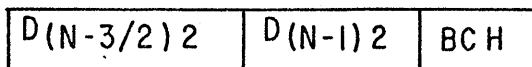
MESSAGE - 1



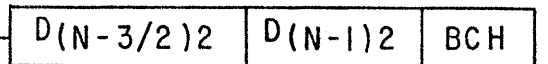
MESSAGE - 2



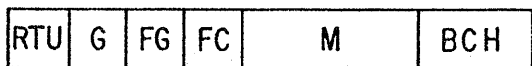
MESSAGE - 2



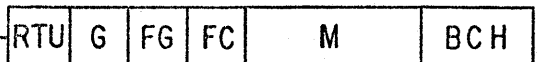
MESSAGE - N



MESSAGE - N



TRANSFER ACTIVATE



ACTIVATE ACKNOWLEDGE

Function Group/Code Matrix Bits 6-11

		Function Class 6-8							
		∅	1	2	3	4	5	6	7
Function Code 9-11	∅	-	General	General	-	1	1	∅	Automatic Update
	1	Open	Open	Open	Status Req.	2	2	1	A/D Lockup
	2	Close	Close	Close	Reset of Lockup	3	3	2	PA Lockup
	3	Open & Close	Open & Close	Open & Close	Reset of COS	4	4	3	-
	4					5	5		-
	5					6	6		-
	6					7	7		-
	7					8	8		-
		Contr. SEL	Mem ACT	Latch ACT.	House-keeping	RTU READ	RTU WRITE	Set-point SELECT	Special
						Message Length		Channel	

#### 4.6 Code assignments for the message formats

<u>Bit No.</u>	<u>Function</u>	<u>Value</u>
Ø-2	RTU-address	
	All stations- lockup	Ø
	Station-1	1
	-2	2
	-3	3
	-4	4
	-5	5
	-6	6
-7	7	
3-5	Group address	
	Sub-RTU-1	Ø
	-2	1
	-3	2
	-4	3
	-5	4
	-6	5
	-7	6
	-8	7

#### 4.7 General Information

- 4.7.1 If an expected message is not received or if parity check fails, the remote station will take no action.
- 4.7.2 If any message other than a control execute message is received by the remote station, a selected control point will be reset.
- 4.7.3 The lockup command is the only message which causes action at all remote stations. Two levels of lockup are defined;
- a) Lockup analog points only.
  - b) Lockup Pulse Counter points only.
- 4.7.4 Analog data values are twelve bits. The first bit, is sign (1 = +, Ø = -). The remaining eleven bits are the absolute value of the analog reading in binary form with most significant bit following sign bit. The return for the second half of message if the point does not exist will be all "Ø"s. The code for an overrange input

will be all "1"s. Counter values are twelve bits binary.

Upon receipt of an Analog Lockup command the current value of each analog data point will be stored in a digital memory. All data messages will contain that value until the reset of Lockup command is received.

Upon receipt of a Pulse Counter Lockup command the current value of each pulse counter is stored in a digital memory. All data messages will contain that value until the reset of Lockup command is received.

#### 4.8

##### Error Detection

There is evidence from studies made that the type of error which occurs most frequently in digital transmission over telephone lines is the burst error. Accordingly, for detecting transmission errors the AES-81 system uses a cyclic code which is particularly effective in detecting errors of short bursts. The particular class of codes has been generalized by Bose and Ray-Chaudhuri. In the AES-81 message format there are 24 information bits and 8 check bits which are involved in transmission error detection.

The effectiveness of the code varies with the nature of the errors and is a maximum for errors occurring in bursts up to the number of check bits used, which in this case is 8. A burst error is defined as a sequence of bits in which the first and last bits are in error, and any combination of errors or non-errors occurs in between. The code is effective in detecting errors as follows:

- a) All single bit errors.
- b) All combinations of two errors
- c) All burst errors of eight bits or less.
- d) Approximately 99.6% of all other error arrangements.

To provide even more effective detection of transmission errors when performing control functions, checkback is used. Actually, three messages are transmitted which must be in agreement: selection, checkback and activate. This redundancy, plus the cyclic code, provides an effectiveness which is very nearly 100 percent.

#### 4.9

##### System Security

Each message is exactly 32 bits in length, and starts with two synchronizing characters. The purpose of the synchronizing characters is to give the receiver a starting point for a message so it can begin registering the incoming bits.

In addition to the cyclic code check which is particularly effective in detecting burst errors, the use of select, checkback and activate messages for performing control functions provides an extremely high degree of insurance against improper operations. If an expected message is not received in its proper sequence, or if the cyclic code check indicates a transmission error, the remote station will take no action. If a device is selected for control and the remote station then receives any message other than a control execute message the selected control point is automatically reset.

At the RTU the method of status checking and comparison against a standard routine provides a measure of security over and above straight hardware checking. To be valid a message must be not only BCH acceptable, but it must also be in proper sequence to agree with the remote program.

- 5.0 FUNCTIONAL DESCRIPTION
- 5.1 REMOTE STATION HARDWARE
- 5.2 PROGRAMMABLE CONTROL UNIT
- 5.3 I/O STRUCTURE
- 5.4 CONTROL AND DISPLAY PANEL



## 5.0 FUNCTIONAL DESCRIPTION

### 5.1 REMOTE STATION HARDWARE

The AES 81/20 REMOTE TERMINAL UNIT comprises a programmable control unit, a data communications sub-system, a power supply, a digital input multiplexer, an analog input sub-system, and a digital output commutator.

### 5.2 PROGRAMMABLE CONTROL UNIT

- 5.2.1 The RTU is controlled by an AES 80 microprocessor. This control unit coordinates the data acquisition, control, and communications functions at the RTU via a fixed program resident in READ-ONLY MEMORY.
- 5.2.2 At the communications interface with the data modem, the control unit receives station scan and control messages and transmits selection and operation verifications as well as complete data telemetry messages.
- 5.2.3 At the system interface, the control unit scans analog, status, and alarm information through analog and digital input modules and outputs control actions through a digital output commutator.

### 5.3 I/O STRUCTURE

- 5.3.1 The control unit communicates with the input/output modules via a high speed party-line I/O bus. The I/O bus is a bi-directional common communication channel containing the data and control lines required for system communication. Communications between the control unit and an I/O module consists of two phases; the first phase is route set-up and the second is data transfer.
- 5.3.2 Each I/O module contains a party-line interface, mode and address logic, and one or more 8 bit data transfer registers. The control unit views the interface environment as a set of up to 256 full-duplex independently operating transfer registers.
- 5.3.3 Under RTU program convention, each DATA transfer register is associated with a specific processing function. Hence a given I/O handler communicates with a specific group of registers according to a fixed convention. Thus the strapping of an address on an interface module determines how the control unit will interpret data transfers.

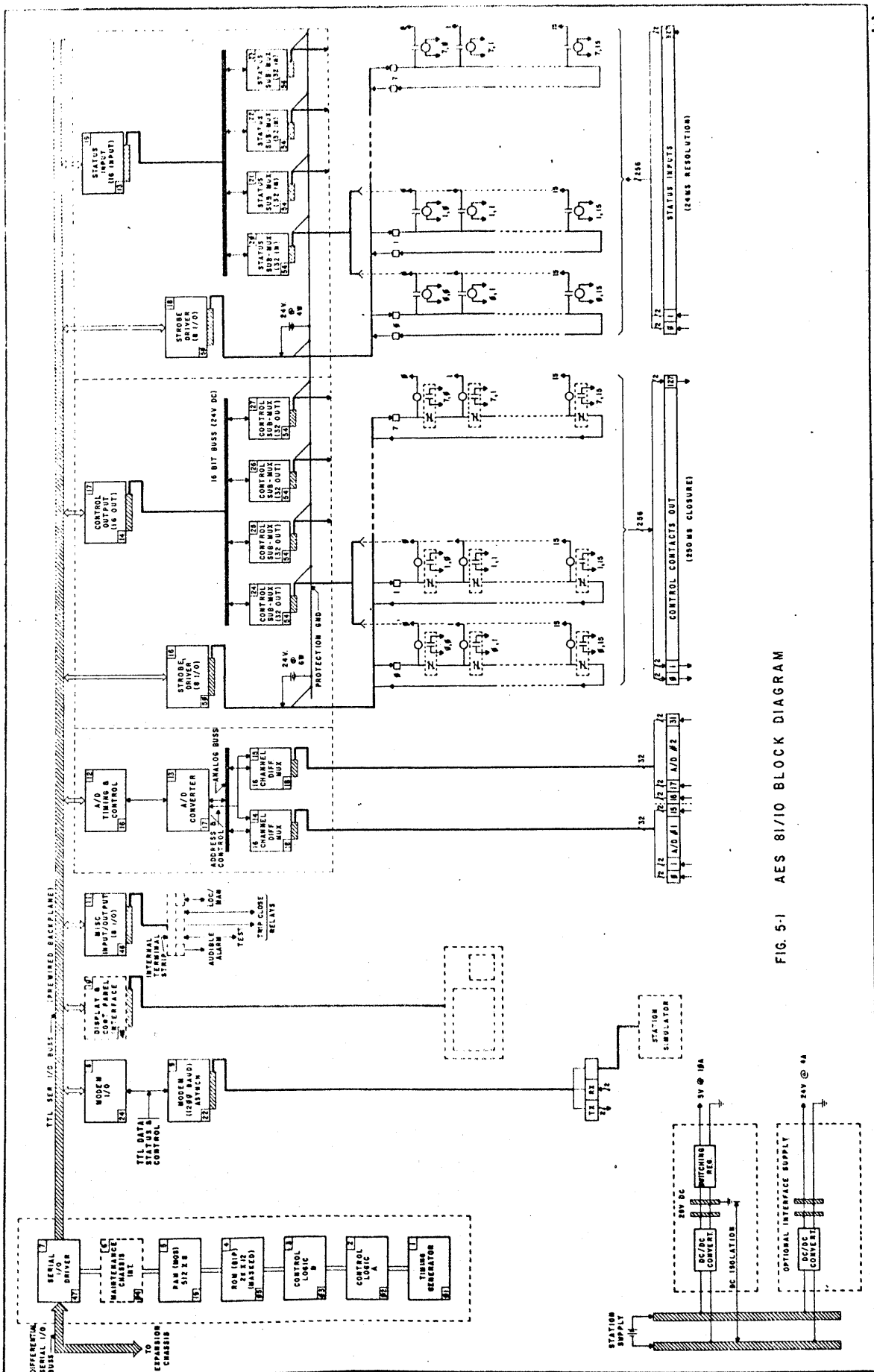


FIG. 5-1 AES 8/10 BLOCK DIAGRAM

## 5.4

### CONTROL AND DISPLAY PANEL

An optional feature, the RTU can be supplied with a control and display panel.

The purpose of the panel is to be able to operate and maintain the Remote Terminal Unit independently of the master station.

The panel consists of a set of switches and a numerical key board. An operator is able to monitor any activity in the data Memory or in the I/O.

The operator is also able to modify any location in any of above mentioned areas.

The following displays are available:

1. RAM and Serial I/O Display,
2. Analog input Display

#### 5.4.1

##### Display One:

Four 8 bit words can at any one time be displayed, and this is accomplished in a linear manner. The address of the first word is specified by the function and by the starting address.

The function specifies the following condition:

6 = RAM	000-777
1 = RAM	1000-1777
2 = SERIAL	I/O

To modify a location the machine is put in Mode-1 (HOLD), and the word indicated by the HOLD SELECT DISPLAY can be modified by a write command.

#### 5.4.2

##### Display Two:

The operator selects what to display through the Disp. Select switch. The operator then keys in a desired analog channel address and the analog value will be displayed in BCD form.

To be able to operate control points or set-point controls, the key switch must be turned into the enable position, and the different addresses can be keyed in.



# AES-81 CONTROL & DISPLAY

AUTOMATIC ELECTRONIC SYSTEMS INC

ADD	7	6	5	4	3	2	1	0
A	0	0	0	0	0	0	0	0
A+1	0	0	0	0	0	0	0	0
A+2	0	0	0	0	0	0	0	0
A+3	0	0	0	0	0	0	0	0

PAR/SER. ADDRESS	0128
KEYBOARD	5721

OCTAL ADDRESS	0256	ANALOG VALUE	1167 MV
---------------	------	--------------	---------

OFF ON LOCK

0	1	2	3	4
5	6	7	8	9
+	-	CLEAR		

RUN	PAR ADD	INCR	ALARM ACK	LAMP TEST
HOLD	SER ADD	DECR	TRANS MIT	RESET

CONT ADDR	S-P VALUE	CLOSE	LATCH ACT	WRITE	FALSE SEL ADDR
ANA ADDR	S-P ADDR	OPEN	MOM ACT	CANCEL	

6.0 FIRMWARE

6.1 GENERAL

6.2 FOREGROUND

6.3 BACKGROUND (PROCESSING)

6.2.1 CONTROL SELECTION

6.3.2 SCAN

6.3.3. MESSAGE DECODER

6.3.4 DISPLAY

6.4 DATA MEMORY LAYOUT

## 6.0 FIRMWARE DESCRIPTION

### 6.1 GENERAL

The program stored in the Read-Only Memory (ROM) is divided into a number of program levels.

Two basic levels exist, the foreground and the background program.

The foreground program handles all communication with input/output devices.

The background program consists of task routines and idle routines.

### 6.2 FOREGROUND

A task routine can only be initiated by an interrupt. When a task routine requires an input or output operation, the routine calls up a desired I/O handler located in the foreground program. The following interrupts have been assigned:

HIGHEST LEVEL	1 = REAL TIME, 10 mS.
	2 = COMMUNICATION RECEIVER
	3 = A/D - CONVERTER
	4 = COMMUNICATION TRANSMITTER
LOWEST LEVEL	5 = CONTROL PANEL.

The real time interrupt initiates the basic scanning sequence of all digital inputs, and increments a 16-bit counter. This counter is used throughout the software system for different timers and time out counters.

The communication receiver interrupt is set each time a message has been received by the communication subsystem. The I/O handler associated with this interrupt transfers the received 24 bit data word in three words of eight bits each, and the associated task routine is the message decoder. This routine validates the received message, and according to the content of the message initiates a set of operations. The basic message decoder is shown on flow chart No.2.

The converter interrupt is set each time a new reading is available from one of the four A/D converter subsystems. The associated I/O handler transfers the converted data from the subsystem to the image memory and initiates a new conversion. If the actual reading was related to a set-point control (digital) operation, the handler calculates the difference between the read value and the selected one and depending on the result, the handler generates either increase or decrease control signals for the selected set-point channel.

The transmitter interrupt is set when the transmitter buffer in the communication subsystem is empty and ready to accept a new 2 x 12 bit data message. If more than one message is contained in the response from the remote, the associated handler extracts required data from the image memory and formats three, eight bit words into the two by twelve bit word required by the message structure.

The lowest level of interrupt is associated with the control panel (optional). Each time a key or a switch is pressed on the control panel, the interrupt is set.

### 6.3

#### BACKGROUND

The background program consists of a set of low level routines each tied together in a program loop. See flow chart 1. The loop is entered when the system is turned on via the initialize routine. This routine comprises a RAM erase portion which clears all location's in the data memory, and a system configuration routine. The system conf. routine establishes the current system size by scanning the different I/O registers. While doing so, the routine also allocates buffer space in the data memory for the different input classes as they are scanned. Each class of data is represented by a two byte word (2 x 8 bits), containing the starting address in the data memory for the class and an available flag, which indicates that one or more I/O register's has been connected for that particular class.

The following basic routines are contained in the background program:

#### 6.3.1

##### THE CONTROL SELECTION ROUTINE:

Is stimulated by either the message decoder or the control panel routine when control of a digital output point has been requested. The routine makes the selection, and indicates to the message decoder that the selected point is operable. This check back operation initiates a confirmation message. Which is generated by the message decoder, but outputted by the transmit routine. When no selection sequence has been initiated, the control selection routine continuously scans the confirmation inputs from the selection relays, and verifies that no false selection has occurred through component failure. If a point has been false selected, the remote does not reply with a proper selection confirmation message when requested to do so.

### 6.3.2 SCAN ROUTINES

When not receiving or acting upon a received message, the RTU performs internal scan routines for the purpose of gathering and storing status and data. The scan routine is performed at a rapid rate and consists of looking at the status input contacts and pulse accumulation input contacts to determine whether changes have occurred, multiplexing analog inputs and performing A/D conversions. Current status, indications of status change (one per status point), pulse accumulation count and data in digital form are all stored in read/write memory, ready for transmission to the master station when requested. The scan subroutines that perform these functions are triggered by pseudo interrupts. Included in the scan routine, of course, is the sensing of pseudo interrupts which will trigger subroutines that have to do with transmitting or receiving messages.

The scan routine is initiated by the real time interrupt. The routine is illustrated by flow chart 3. Before the routine is entered, all digital input's are strobed into the associated I/O-registers. The scan routine then processes one class of data at a time. Or in other words, for each pass in the background loop the routine executes all required processing for one class of data and then returns the control of the microprocessor to the general background program as shown on Fig.1. The scan routine uses the information generated by the system configuration routine to establish the availability of a specific class of inputs.

### 6.3.3 MESSAGE DECODER (Flow Chart 2)

The message decoder routine is called up when a new message has been received by the remote. The routine checks the message for transmission error. If the message is valid, the routine proceeds to determine what action is to be taken by the remote, and also checks if the messages are received in a proper sequence for control selection and activation. The routine then calls up the appropriate subroutines for execution of the selected operation.

### 6.3.4 DISPLAY

The display routine is used to output selected data to the displays located on the control panel. For each pass through the background loop, the display routine outputs one eight bit word to be displayed.

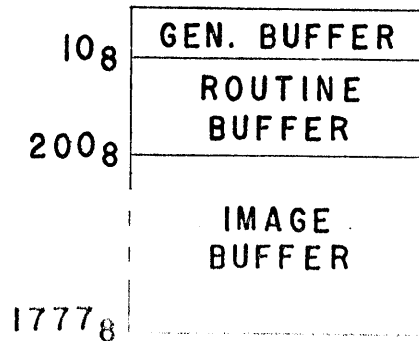


## 6.4

DATA MEMORY LAYOUT

The data memory is divided up in three areas as shown below.

The general buffer area consists of eight words, and is used as temporary storage of data during execution of a routine.



In the routine buffer area, all pointers and flag's associated with the different task routines are stored.

The image buffer is dynamically allocated by the system configuration routine as describe above the following rules are used for allocation of the different input classes.

- 1) All input data except class-D are divided in groups of twelve bits, hence requiring  $1\frac{1}{2}$  memory words.  
Class-D is divided in groups of eight bits.
- 2) All change information is interleaved with the status information, hence a twelve bit status group is followed by a twelve bit change group.





7.0

TECHNICAL CHARACTERISTICS

- 7.1 SERVICE CONDITION
- 7.2 MEMORY
- 7.3 I/O BUSS
- 7.4 MULTIPLEXED CONTACT INPUT
- 7.5 MULTIPLEXED CONTACT OUTPUT
- 7.6 MULTIPLEXED ANALOG INPUT
- 7.7 MODEM
- 7.8 POWER
- 7.9 TRANSIENT PROTECTION

## 7.1

### SERVICE CONDITION

#### NON-OPERATING CONDITION

All units of the system are designed in such a way that no mechanical or electrical damage and no permanent degradation in performance will result when stored or transported in its shipping crate under any combination of the following environmental conditions:

i) TEMPERATURE

From  $-30^{\circ}\text{C}$  to  $+90^{\circ}\text{C}$

ii) HUMIDITY

From zero to 99% without condensation

iii) ALTITUDE

Sea level to 20,000 Feet.

iv) ORIENTATION

Any position

v) SHOCK AND VIBRATION

Transportation and handling over secondary roads.

#### OPERATING CONDITION

i) TEMPERATURE

From  $-25^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$

ii) HUMIDITY

From zero to 99% without condensation

iii) ALTITUDE

From sea level to 15,000 feet

iv) SHOCK AND VIBRATION

Normal shock and vibration as encountered in a fixed installation.

## 7.2 MEMORY

### i) DATA MEMORY

TYPE = RANDOM ACCESS  
SIZE = 512 WORDS x 8 BITS  
TECHNOLOGY = MOS

### ii) INSTRUCTION MEMORY

TYPE = READ ONLY (ROM), RANDOM ACCESS  
SIZE = 2k WORDS x 12 BITS  
TECHNOLOGY = BIPOLAR (MASKED)

## 7.3 INPUT/OUTPUT BUSS

Two different busses are used, one buss which is connected to all I/O devices in the main processor chassis, and one buss which connects the processor to expansion chassis. The buss inside the processor chassis uses logic levels according to established standards for TTL (three-state) type of integrated circuits.

The extender bus is of differential type, with a driving capability of 40 mA (sink/source) and a common mode voltage rejection of up to  $\pm 15V$  at the receiving end.

## 7.4 MULTIPLEXED CONTACT INPUT

The input contacts are organized in a matrix, see system drawing. The columns of the matrix are driven by a strobe driver, which enables a set of 16 input contacts. These 16 inputs are submultiplexed together with another set of 16 inputs in a status sub mux board, the outputs (16) of which are connected to the status buss and sensed by a status input board. All isolation and filtering is done in the status input board.

### INPUT CHARACTERISTICS

#### i) ISOLATION:

- a) 2.5KV PEAK between any 2 signal points or between any signal and signal return
- b) 35VDC steady state as in a)
- c) In case of floating input, common mode signal potential limited to  $\pm 300VDC$  or 600V p-p AC w.r.t logic grd..

ii) RC TRANSIENT LIMITING  
FILTER DELAY = 3mS

iii) Signal conditioning time constant variable  $\emptyset$ -3mS

#### 7.5 MULTIPLEXED CONTACT OUTPUT

The digital control outputs are organized in a matrix, as shown on the system drawing.

The select relays are divided in groups of 16. All relays in one group have one side of the coils connected together and are driven by an output of the strobe driver board. The other side of the coil is drive in a linear way by the control sub-mux board.

#### OUTPUT CHARACTERISTICS

i) ISOLATION: as per 7.4. i)

ii) CLOSURE TIME: 1 sec max; 25 $\emptyset$ ms typical

#### 7.6 MULTIPLEXED ANALOG INPUT

Signalling conditioning and transient protection on mux board.

RESOLUTION	=	12 BITS
ACCURACY OF FULL SCALE	=	.1% ( $\emptyset$ to 7 $\emptyset^{\circ}$ C)
INPUT RANGE	=	$\pm 1\emptyset$ V
CONVERSION RATE	=	25 CONV/SEC
DIFF. REJECTION @6 $\emptyset$ Hz	=	3 $\emptyset$ db
COMMON MODE REJECTION @ 6 $\emptyset$ Hz @ 1 $\emptyset\emptyset$ VDC OR 145VAC	=	1 $\emptyset\emptyset$ db
No. OF INPUTS/MUX BOARD	=	16
No. OF INPUTS/SUBSYSTEM	=	32
TRANSIENT PROTECTION	SEE	7.4. i)

SPECIFICATIONS

OPERATING MODE:	Full-or half-duplex selected under software control.
DATA RATES:	150, 300, 600, 1200 baud. Two speeds selectable under software control.
DATA FORMAT:	Two start bits, 29 data bits, one stop bit.
ORDER OF BIT TRANSMISSION:	Low order bit first
DISTORTION INPUT:	Up to 40% per data frame allowed
DISTORTION OUTPUT:	Less than 3% per data frame
DATA SIGNALS:	TTL compatible for connection to AES modem. (Connections on backplane connector) optional EIA RS-232-C interface available on front edge connectors.
CONTROL SIGNALS:	All control signal connections compatible with Bell 103 and 202 type modems and are optionally available on front-edge connector (EIA-RS-232-C).
CLOCK:	Crystal controlled frequency of two times selected baud rate available at backplane connector for use by AES modem.
POWER REQUIREMENTS:	+ 5V $\pm$ 5% 1.3 A max.
GENERATED USING DC TO DC 5V TO $\pm$ 15V CONVERTER	+12V $\pm$ 20% 30 mA max. -12V $\pm$ 20% 30 mA max. Incl. in -5V consumption



OPERATING TEMPERATURE: -20°C to +85°C  
HUMIDITY: 20% - 95% non condensating  
PHYSICAL: One PC Board, size 7½" x 7½"

7.8 MODEM

7.8.1 OUTPUT CHARACTERISTICS

Asynchronous FM signal

MARK frequency : 2400Hz 1200Hz Strapping option  
SPACE Frequency : 1200Hz 2400Hz  
Output impedance : 600ohms ±5%  
Output level : Adjustable up to -5dBm  
Transmission rate : 1200 Baud

N

N = Integer number

7.8.2 RECEIVER CHARACTERISTICS

Input signal : Asynchronous FM signal  
MARK frequency : 2400Hz reversable by strapping  
SPACE frequency : 1200Hz  
Input impedance : 600Ohms ±5%  
Receiver sensitivity : Receiver gain can be adjusted  
for line signal levels between  
-5dbm and -55dbm  
Loss of Carrier Alarm : Threshold level for this alarm  
can be set to any level between  
0dbm and -40dbm  
Interface: TTL compatible  
Alarm = logic 1

Data rate : Same as being transmitted from opposite end (must be: 1200 Baud)

N

N = Integer

Receiver output : TTL compatible  
Logic 1 = MARK  
Logic 0 = SPACE

Operating modes : Half duplex only over two wire channels. Half duplex or full duplex over four wire channels.

### 7.8.3 SPECIFICATIONS

#### 7.8.3.1 TRANSMISSION MEDIUM REQUIREMENTS

- 3kHz bandwidth voice channel transmission facilities  
- A wire compatible with AT and T type 3002 unconditioned individual leased channels.

POWER REQUIREMENTS: +5V  $\pm$ 5% 1.0A

#### ENVIRONMENTAL:

Temperature -20°C to +85°C  
Humidity 10% to 95%  
non condensating

Physical  
PC Board size 7½" x 7½"

#### SIGNAL CONNECTIONS

CONNECTIONS TO LINES: on 44 pin front card edge connector

#### LOGIC LEVEL CONNECTIONS

AND POWER: 100 pin back card edge connector

### 7.8 POWER

#### 1. SYSTEM POWER

INPUT LEVEL = 1) 24V  
2) 48V  
3) 129V

POWER REQUIREMENT = 150W

## 2. INTERFACE POWER (OPTIONAL)

INPUT LEVEL = 1) 24V  
2) 48V  
3) 129V

POWER REQUIREMENTS = 10W

### 7.9 TRANSIENT PROTECTION

The inputs and outputs are designed to withstand surge voltage spikes at power network interfaces having a crest of 2.5kV at a frequency of 1.0Mhz to 1.5Mhz. The envelope of the first cycle will decay to 50% of the crest in not less than 6.0ms after the start of the wave.