ECMA

EUROPEAN COMPUTER MANUFACTURERS ASSOCIATION

STANDARD ECMA-71

HDLC
SELECTED PROCEDURES

January 1981

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BRIEF HISTORY

Work on a Data Link control protocol started in ECMA in September 1971, with the study of a dual numbering technique for control and error detection. This work was divided into separate phases.

The first phase, which defined the transmission envelope, was concluded in December 1973 with the adoption of Standard ECMA-40, HDLC Frame Structure. The third edition of this Standard is dated January 1980.

The more detailed second phase, which defined the commands, the responses and the error recovery principles was concluded in June 1976 with the adoption of Standard ECMA-49, HDLC Elements of Procedure. The second edition of this Standard is dated August 1979.

A third phase introduced a set of guidelines, or "Codes of Practice", prepared in order to map Standards ECMA-40 and ECMA-49 into particular systems. This phase was concluded in June 1979 with the adoption of Standards ECMA-60 , HDLC Unbalanced Class of Procedure, and ECMA-61, HDLC Balanced Class of Procedure.

A further phase, intended to select and fully describe a limited number of procedures from Standards ECMA-60 and ECMA-61 was concluded in July 1980 with the submission from TC 24 to the General Assembly of ECMA of this draft Standard on HDLC Selected Procedures.

This Standard ECMA-71 has been adopted by the General Assembly of ECMA on December 18, 1980.

TABLE OF CONTENTS

1. SCOPE

High Level Data Link Control Procedures (HDLC) are designed to cover a wide range of applications, e.g. TWA or TWS communication between computers, concentrators and terminals, as a wide range of data link configurations, e.g. multipoint or point-to-point, switched or non-switched.

Standards ECMA-40 and ECMA-49 define frame formats, operational modes, commands, responses and exception recovery techniques. These functions used in various combinations provide the full range of HDLC capability.

The majority of HDLC implementations will not require the full range of capability. Subsequent ECMA Standards have therefore defined certain selections of these functions for specific types of application.

Standard ECMA-60 defines a Class of HDLC Procedure using the Unbalanced modes of operation (UNR or UAR) and certain optional functions. Selected procedures 1 and 2 in this Standard ECMA-71 are specific implementation within this Unbalanced Class.

Standard ECMA-61 defines a Class of HDLC Procedure using the Balanced mode of operation (BA) and certain optional functions. Selected Procedure 3 in this Standard ECMA-71 is a specific implementation within this Balanced Class.

The Selected Procedures in this Standard are expected to meet the majority of requirements in the immediate future. They contain no optional features for user selection, so that conformance with them can be precisely and simply achieved.

Additional Selected procedures may be defined to meet any additional requirements as they are identified.

2. CONFORMANCE

An HDLC application can claim to conform with one of the procedures in this Standard if the requirements of section 6 are satisfied and if the commands transmitted and the responses accepted are those defined in section 7 for the chosen procedure and have the structure and the characteristics defined in Standards ECMA-40 and ECMA-49.

NOTE 1:

The ability to handle frames larger than those defined in section 6 is not considered non-conformance, provided that in the application the limit defined in section 6 is observed.

3. REFERENCES

ECMA-40	HDLC - Frame Structure
ECMA-49	HDLC - Elements of Procedure
ECMA-60	HDLC - Unbalanced Class of Procedure
ECMA-61	HDLC - Balanced Class of Procedure

4. DEFINITIONS

The relevant definitions of Standards ECMA-40 and ECMA-49 apply. In addition, for the purpose of this Standard, the following definitions also apply.

4.1 Two-Way Alternate (TWA)

The transfer of frames in either but not both directions at the same time, as seen by the Secondary.

4.2 Two-Way Simultaneous (TWS)

The simultaneous transfer of frames in both directions at the same time, as seen by the Secondary.

4.3 Loop Delay

The sum of propagation delays in both directions, and turn around delays at the stations.

NOTE 2:

It is used to give an indication of the time required to receive a response to a transmitted frame.

5. SELECTION PARAMETERS

In order to define the Selected procedures the following parameters have been considered:

- Communications: TWA, TWS
- Configuration point-to-point (pt-pt), multipoint (mpt).

From the above parameters three possible procedures have been defined as summarized in the table below.

PARAMETERS		PROCEDURES	
Communication	Configuration	No.	Definition
TWA	mpt	1	UNR (no options)
	pt-pt		
TWS	mpt	2	UNR (2)
	pt-pt	3	BA (2,8) BA (2,8,10)

The above procedures can be used for switched or non-switched services.

For Selected procedure No. 3 when

bit rate (bit/s) X loop delay (s) $\geq$ 5000 (bit)

the extended version (with option 10) shall be used.

The table below summarizes the options from Standard ECMA-61 required by selected procedures 2 and 3.

OPTION NUMBER	OPTIONAL FUNCTION	COMMAND	RESPONSES	OTHER CHANGES
2	Provides the ability for more timely reporting of I frame sequence errors	Add REJ	Add REJ	
8	Limits the procedure to allow I frame to be commands only		Delete I	
10	Provides the ability to use extended sequence counts (modulo 128)	Add SABME Delete SABM		uses extended control field (see ECMA-49)

6. COMMON FEATURES

For all Selected procedures defined in this Standard the following common features shall apply:

- all supervisory and unnumbered commands shall be transmitted with the P bit set to ONE;
- the maximum frame length between, but not including, the opening and closing flags shall be a multiple of 8 and not greater than 4096 (i.e. the maximum number of octets shall be 512) 512 octets;
- the basic retransmission of I frames shall be initiated by P/F bit checkpointing.

7. SELECTED PROCEDURES

7.1 Procedure 1

TWA, non-extended

UNR (no option)

Commands	Responses
I	I
RR	RR
RNR	RNR
SNRM	UA
DISC	DM
	FRMR

7.2 Procedure 2

TWS, multipoint, non-extended

UNR (2)

Commands	Responses
I	I
RR	RR
RNR	RNR
REJ	REJ
SNRM	UA
DISC	DM
	FRMR

7.3 Procedure 3

7.3.1 Non extended

TWS, point-to-point, non-extended

BA (2, 8)

Commands	Responses
I	
RR	RR
RNR	RNR
REJ	REJ
SABM	UA
DISC	DM
	FRMR

NOTE 3:

This procedure is compatible with X.25 LAP B.

7.3.2 Extended

TWS, point-to-point, extended

BA (2, 8, 10)

Commands	Responses
I	
RR	RR
RNR	RNR
REJ	REJ
SABME	UA
DISC	DM
	FRMR

8. DESCRIPTION OF THE PROCEDURES

The Selected procedures in this Standard have been described in Annexes A and B by means of finite state diagrams. The objectives of using this technique are:

- to provide a more formal description avoiding ambiguity of interpretation,
- to specify more accurately the interfaces with other levels,
- to provide an abstract implementation to ensure compatibility,
- to serve as a visual representation for illustration of the procedure.

The notation used for the finite state diagrams is introduced in Annex A; models for the selected procedures are defined in Annex B.

ANNEX A

FINITE STATE MACHINE NOTATION

A.1 THE FINITE STATE MACHINE

This model assumes that a procedure can be described in terms of the operation of a finite state machine. This machine has a memory holding the state variable which may assume one and only one value at any one time. The machine reacts to events: an individual event, combined with the values of internal condition variables and the current state of the machine, will determine how the machine reacts. The reaction consists of up-dating the state variable, possibly to the same value. The machine may thus move to a new state or react in the same state. Additionally, the machine may react to an event by executing a sequence of actions. The sequence of actions cannot be interrupted. Actions may update internal condition variables or may generate external actions.

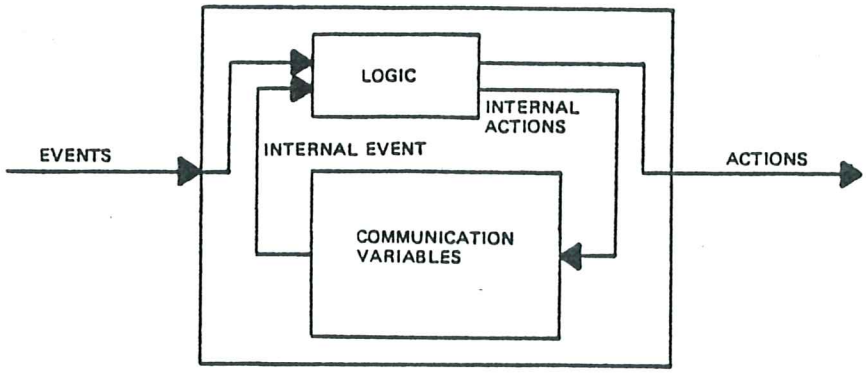


Fig. A.1 - Finite State Machine

Communication Variables:
State Variables and Conditions

A.2 FINITE STATE MODULE

The action of one selected procedure could be specified by a single finite state machine. However, for clarity of presentation, one finite state machine can be replaced by several interacting machines called modules.

To understand how these modules are combined consider two finite state machines.

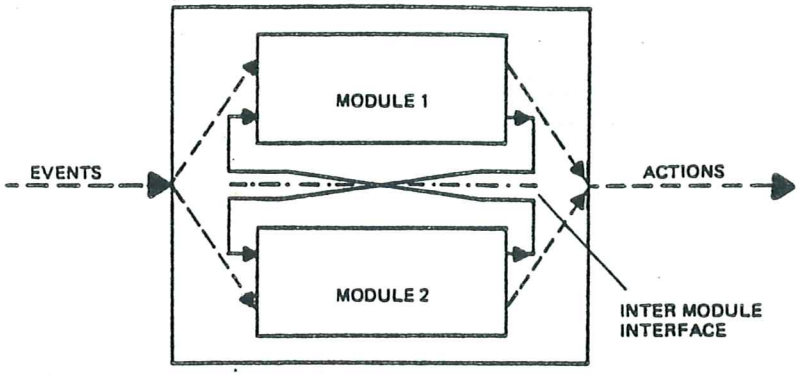


Fig. A.2 - Machine consisting of two combined Modules

Each module has a state variable, say S(1) and S(2). These state variables take only a finite number of values, say m and n respectively. The combination of these two modules is equivalent to one machine having a state variable which can take only one (m x n) values. Each value of this single state variable corresponds to one and only one of the (m x n) combinations of S(1) and S(2).

Considering next the events which cause module 1 to react, these can either be external to the combination or will be caused by the actions of module 2. Similarly the actions of module 1 will be external actions or could be events causing module 2 to react. Thus some actions of one module are events of the other and vice versa. This exchange of actions and events occurs at the inter-module interface.

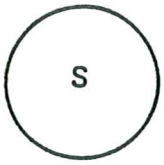
The modules hold separate condition variables. If a change of a condition variable is relevant to the operation of the other module, the change must be communicated by an action or an event. This will trigger the other module to react to the detected change.

Again, like the state variables, the combination of the values of the separate condition variables forms the set of condition variables of the overall finite state machine.

A.3 FINITE STATE DIAGRAM NOTATION

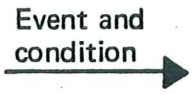
The operation of the logic of each module is described by means of state diagrams.

These diagrams comprise four basic elements:



States

This symbol denotes one value of the allowable range of values for the state variable.

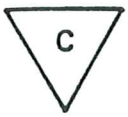


Events and Conditions

On each exit from a state, the event and conditions causing the transition are specified. The transition may lead back to the same state.

Action

The action or sequences of actions carried out on each transition shall be specified. The sequence of actions and the transition to the next state cannot be interrupted.

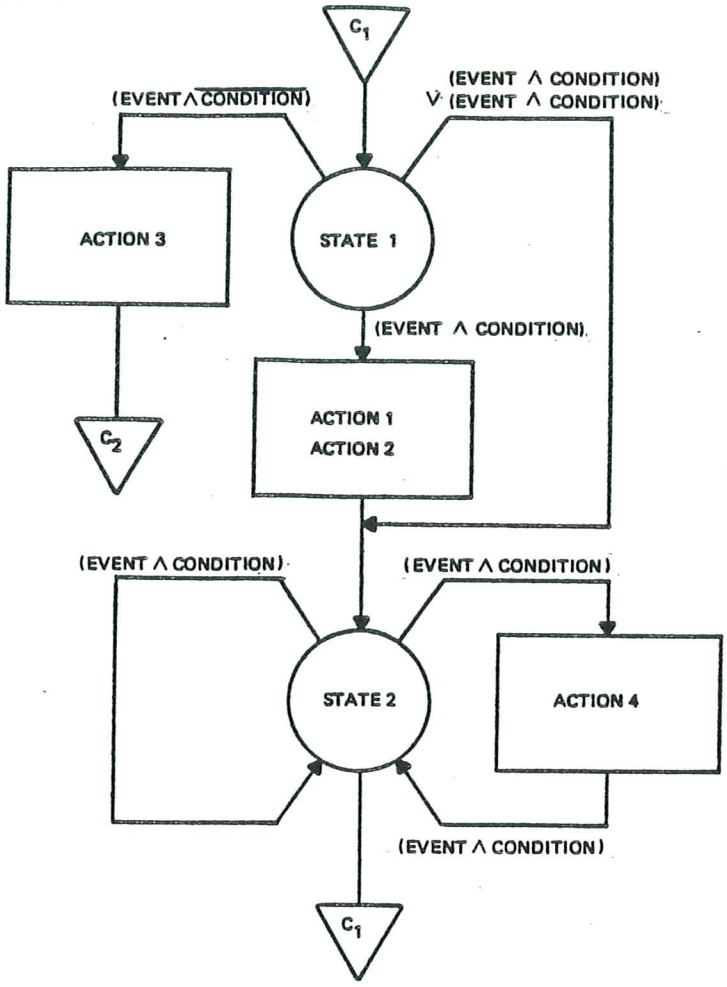


Connector

The connector serves to link parts of the finite state diagram which have been segmented for clarity of presentation. Only one entry connector with a given label may be used. Exit connectors may not be unique if there are numerous transitions to the given state.

NOTE A.1:

Events and conditions that do not result either into a change of state or into performing an action are not indicated in the diagrams.



Boolean "AND"

Boolean "OR"

$\overline{X}$ Boolean "NOT"

Fig. A.3 - Finite State Diagram Example

ANNEX B

DESCRIPTION OF THE SELECTED PROCEDURES

B.1 THE MODEL

Data Terminal Equipment DTE incorporating the HDLC class of procedure is represented by a model as shown in Fig. B.1.

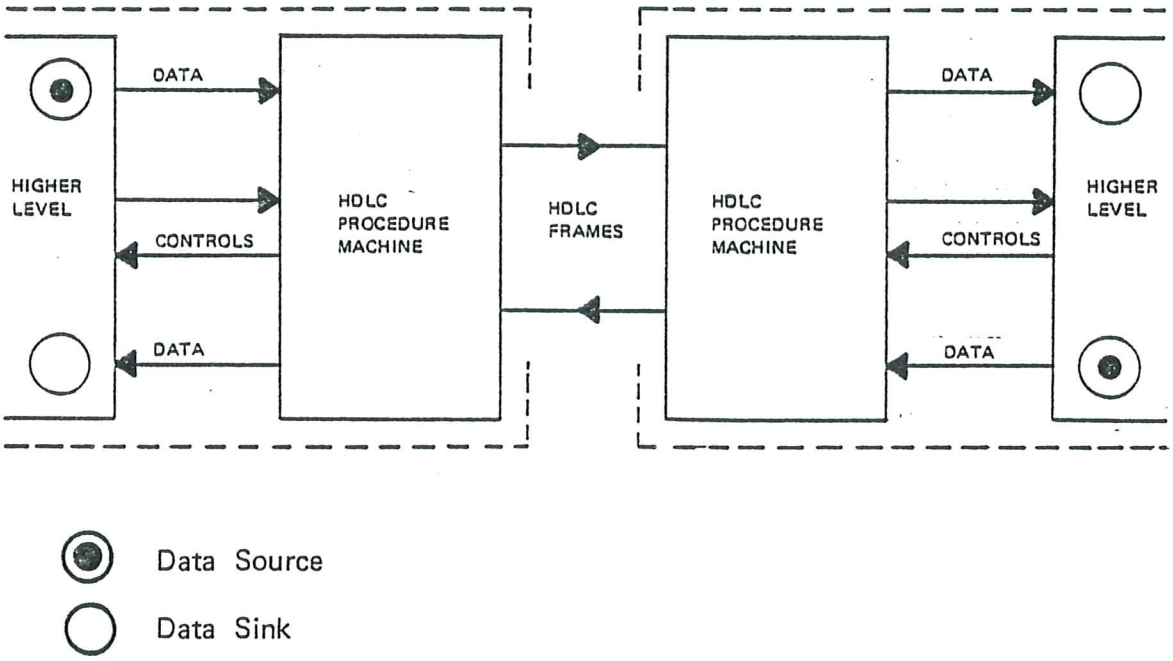


Fig. B.1 DTE Model

Two DTEs are shown connected together. For clarity, the Data Communication Equipments (DCEs) are not shown. The interface between the two DTEs consists of the command frames and response frames as defined by the relevant class of procedure employed. Within the DTE is a finite state machine describing the operation of the relevant HDLC class of procedure. The interface to the rest of the DTE enables transfer of data to, and from, the data sink / data source and exchange of control information. This is the upper boundary of the finite state machine.

The internal structure of the machine is described in two layer

- Station control module. This module co-ordinates the lower level module to effect overall station-control.
- Basic control modules. The HDLC procedure may contain one or more basic control modules depending upon the configuration required (e.g. primary, secondary or combined).
  The lower boundary of the finite state machine is the interface to the line control modules which contain the necessary logic to interface to the DCE.

In the description that follows, the lower level modules are not considered. Therefore, only three interfaces are used as shown in Fig. B.2. These interfaces are distinguished by the three indices shown.

The primitives (commands and responses between modules) used across these interfaces are represented by upper case strings such as RESET. When there is a differentiation required between primitives applying to a primary or secondary module a "P" or "S" is used to qualify the primitive. The interface index is also appended to the primitive (e.g. RESETP2 would be the reset action or event traversing interface 2 between the station control module and the primary basic control module).

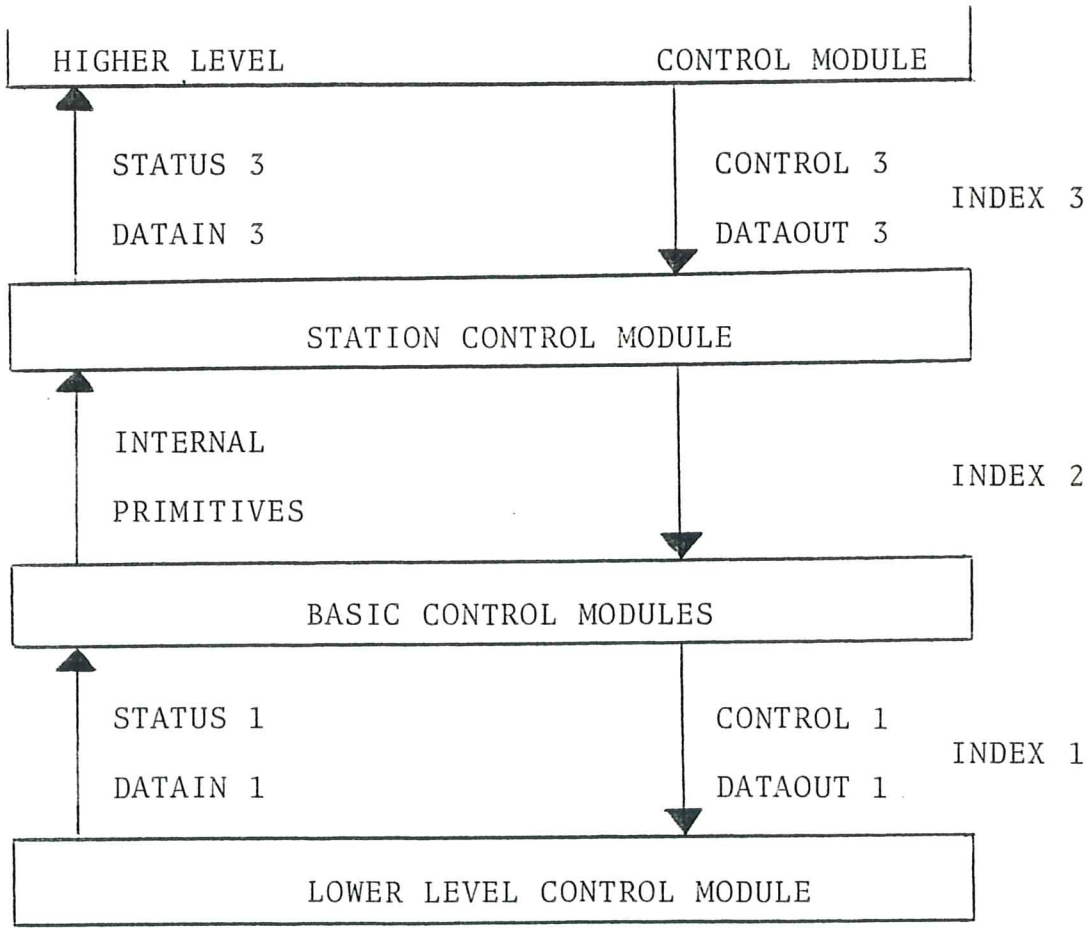


Fig. B.2 Primitives

B.2 INDEX 1 INTERFACE PRIMITIVES

Control 1: Used by the HDLC procedure to request control of the DCE. A change of status of the DCE is normally expected in response. Control 1 is used with qualifiers, such as the following:

- DTR Set the lead DTR of the modem to denote that the DTE is active
- RTS Set the lead RTS of the modem to denote that transmission is required
- IDLE Transmit an idle sequence of 15 or more contiguous ONE bits

Status 1: used by the HDLC procedure to detect changes of status of the transmission equipment. Status 1 is used with qualifiers, such as the following:

- DCD To detect presence of carrier (i.e. ability to receive data)
- IDLE To detect the receipt of an idle sequence of 15 or more contiguous ONE bits
- DSR To detect loss of modem facilities
- TEST To detect modem in test mode.

DATAOUT 1: The lower level control module is instructed to transmit a frame. The HDLC procedure generates address, control, N(R), N(S) and P/F fields. The lower level is assumed to add FCS and flag sequences as appropriate.

DATAIN 1: The lower level control module has received a frame with correct FCS and containing 32 or more bits. The decoding of Address, Control, N(R), N(S) fields P/F bit is carried out by the HDLC procedure and the interpretation of these cause different events to be processed (e.g.I, DM, etc.).

B.3 INDEX 3 INTERFACE PRIMITIVES

Control 3: used by the higher level to trigger HDLC procedure actions for the operation of the data link. HDLC procedure generally will react to a level 3 CONTROL request with a STATUS response. It is used with one of the following qualifiers:

- INIT: Go into operational mode
- CLEAR: Go immediately into disconnected mode
- TERM: Go into disconnected mode in a controlled way
- SETBUSY: Set the local BUSY CONDITION (i.e. do not accept additional I FRAMES from the remote station)

- RESETBUSY: Clear the local BUSY CONDITION

Status 3: used by HDLC procedure to report to the higher level the status of the data link whenever circumstances require it. It is used with one or more of the following qualifiers:

- OP: The data link is operational
- INOP: The local station has detected that th data link is inoperable
- DMIN: The local station has received a DM response with the F bit equal to ONE from the remote station
- PBUSY: Retransmission counter overflow because of continuing BUSY condition at the remote station
- FRMRIN: The local station has received a FRMR response
- FRMROUT: The local station has transmitted a FRMR response
- DISC: The local station has entered disconne ted mode
- NOTACK: Number of transmitted but unacknowledg I frames [it is equal to: $(V(S)-V_{SU})$ modulus MOD]
- IC: Information counter: number of I frame ready for transmission

DATAOUT 3: Send this data unit to the remote station

DATAIN 3: Accept this data unit, arrived from the remote station.

B.4 UNR, INTERNAL PRIMITIVES (Index 2)

B.4.1 Station control to Basic controls

INITP 2 : Primary, go into operational mode

TERMP 2 : Primary, go into disconnected mode in a controlled way.

CLEARP 2 : Primary, go immediately in NDM state

CLEARS 2 : Secondary, go immediately in NDM state

SETBUSY 2 : Set the local BUSY condition

RESETBUSY 2 : Reset the local BUSY condition

B.4.2 Basic controls to Station control

PINOP 2 : The primary has detected that the data link is inoperable

POP 2 : The primary has sent SNRM and received the appropriate UA

PBUSY 2 : The remote secondary has changed its temporary BUSY condition into a long term

exception condition

PDISC 2 : A DISC command has been acknowledged via an UA response, the primary is in the NDM state

DMIN 2 : The primary has received a DM response with the F bit equal to ONE from the remote secondary

FRMRIN 2 : The primary has received a FRMR response

NEFIN 2 : The primary has received a not expected I frame (NEF)

DISCIN 2 : The secondary has received a DISC command and has sent an UA response

SFRMR 2 : The secondary has received a not expected I frame (NEF) and has sent a FRMR response

SOP 2 : The secondary has responded with an UA response to an SNRM command

DATAIN 2 : Accept this data unit (I frame), arrived in sequence from the remote data station

B.4.3 List of States

State names without a prefix are states of the station control module. The state names of the primary basic control modules are prefixed with a P, the state names of the secondary basic control modules are prefixed with an S.

NDM, PNDM, SNDM	normal disconnected mode	
WOP	waiting for operational mode	
OP		operational mode
POPA	transmit I commands	
POPB	transmit S commands	
POPC	receive I responses	
SOPA	transmit I responses	
SOPB	transmit S responses	
SOPC	receive commands	
SFRMR	frame reject	
WNDM, PWNDM	waiting for normal disconnected mode	

B.4.4 List of Communication Variables

IC : Information counter
The number of I frames ready for transmission. IC ≠ 0 means that there are frames ready for transmission.

RC : Recovery retransmission counter

RCB : Retransmission counter: indicates the remote BUSY condition

END : Termination condition for the I command control of the primary

VSU : Sequence number of the lowest unacknowledged I command/response

V(S) : Send state variable

V(R) : Receive state variable

DIFF : (V(S) - VSU) modulo M if V(S) $\geq$VSU

(MODULUS + V(S) - VSU) modulo M if V(S) <V

$0 \leq DIFF \leq K$

K : Maximum number of outstanding, unacknowledged I commands or responses

$K \leq MODULUS-1$

NEF : Not expected frame
Frame containing:

- a control field which is invalid or not implemented; or
- an information field which is not permitted with this frame or which exceeds the agreed maximum information field length; or
- an invalid N(R).

T_1 : Response timer

BUSY : The local BUSY condition, could be set by internal constraints or by the higher layer

BUSYR : The remote BUSY condition is set by receipt of a RNR frame. It is reset by the receipt of a non RNR frame with the P/F bit set to ONE.

PF : Denotes the right to transmit a P/F-bit set to ONE

NP : State variable of the primary. The value V(S) that exists following transmission of a frame with P bit set to ONE.

REJ : State variable of the primary and of the secondary. Denotes the right to transmit a REJ frame.

W, X, Y, Z : FRMR variables

NOTE:

The change of a communication variable could be interpreted as an event.

B.4.5 UNR Modules

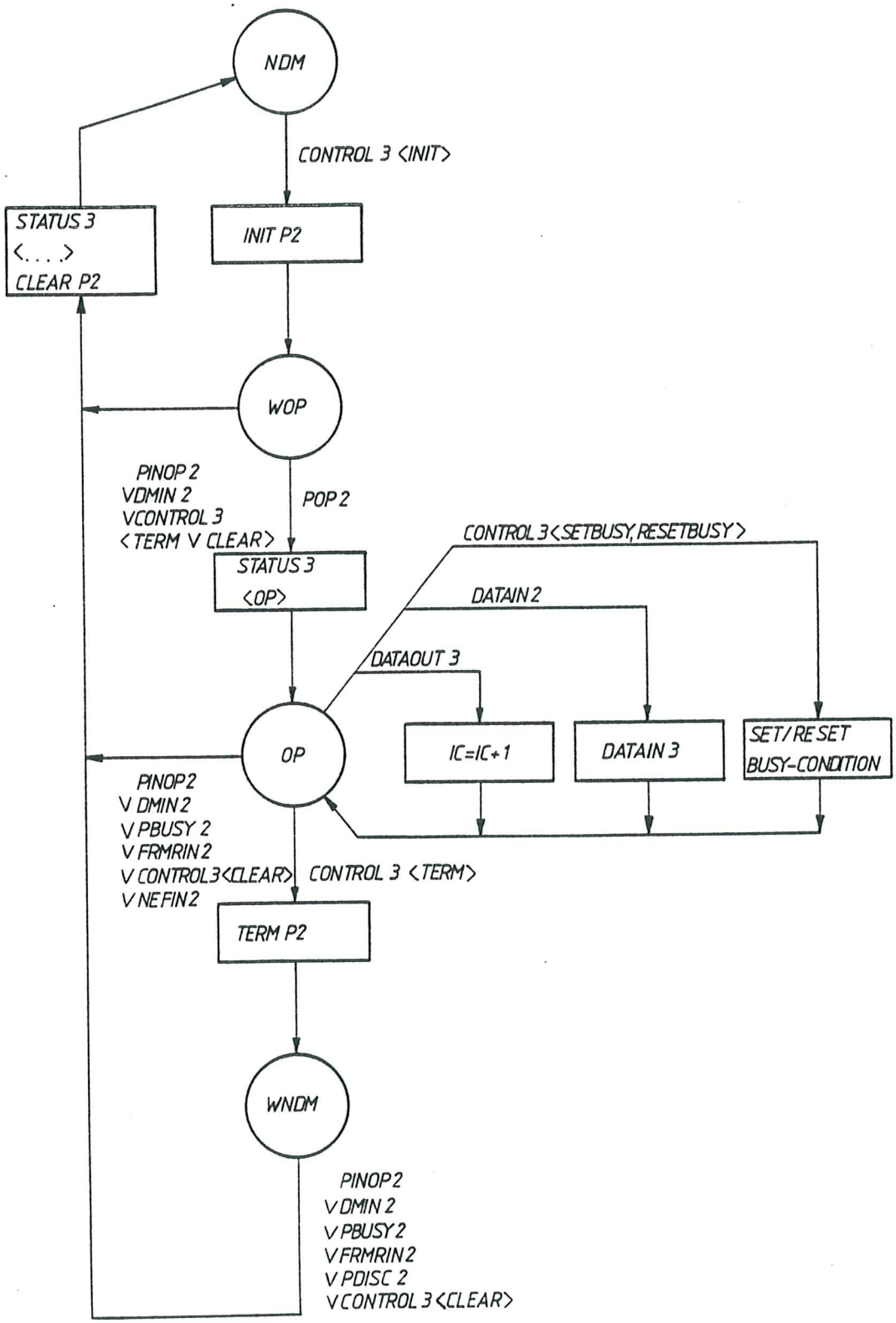
B.4.5.1 UNR Primary Modules

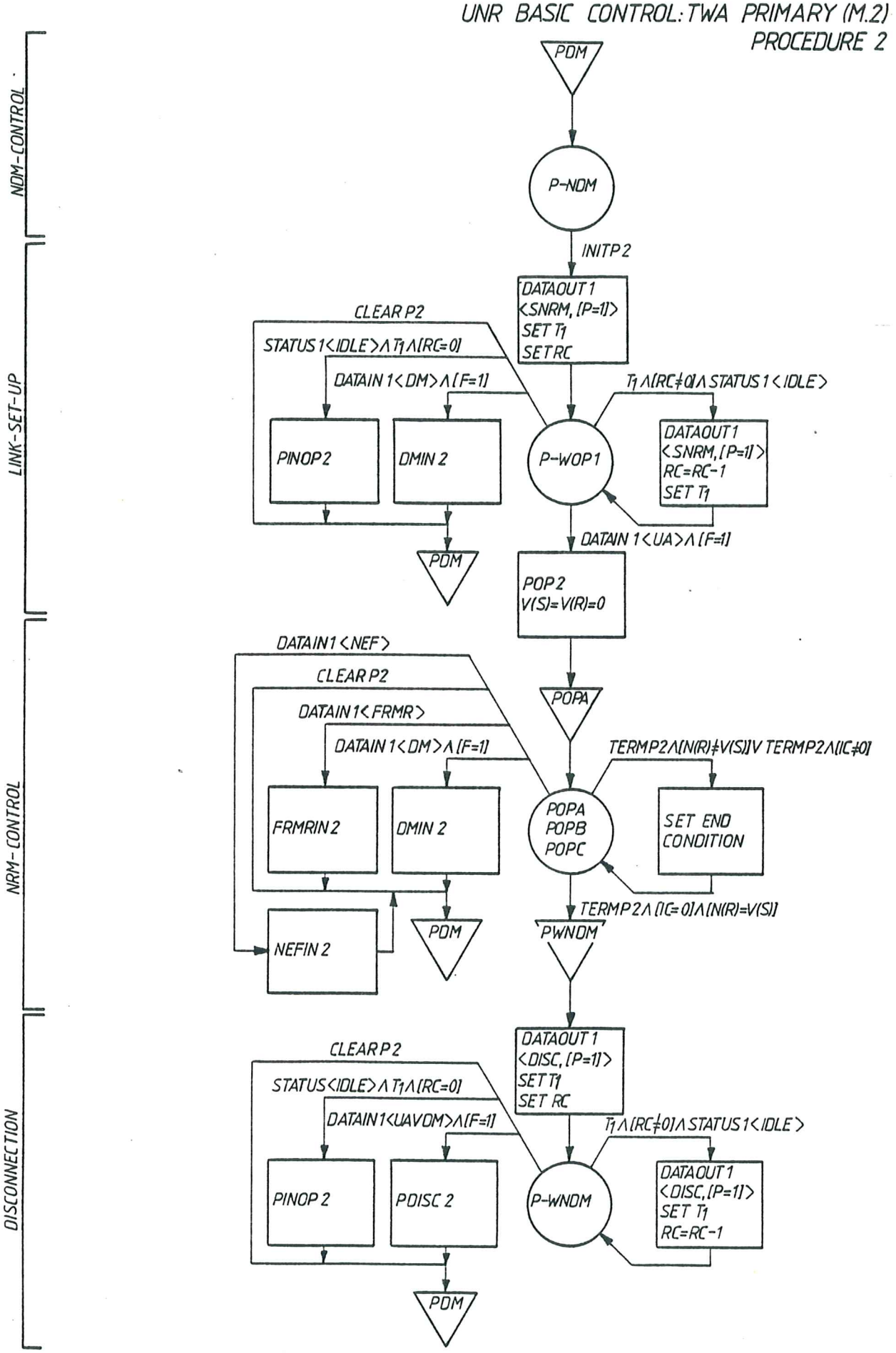
- Station Control Module		UNR-M.1
	- Basic Control Modules	
- TWA-NDM	- Control	UNR-M.2
	- Link Set-Up	
	- NRM Control	
	- Disconnection	
- TWS-NDM	- Control	UNR-M.3
	- Link Set-Up	
	- NRM Control	
	- Disconnection	
- TWA	- Transmit I Commands	UNR-M.4
	- Transmit S Commands	
	- Receive Responses	
- TWS	- Transmit I Commands	UNR-M.5.1
	- Transmit S Commands	
	- Receive Responses	UNR-M.5.2

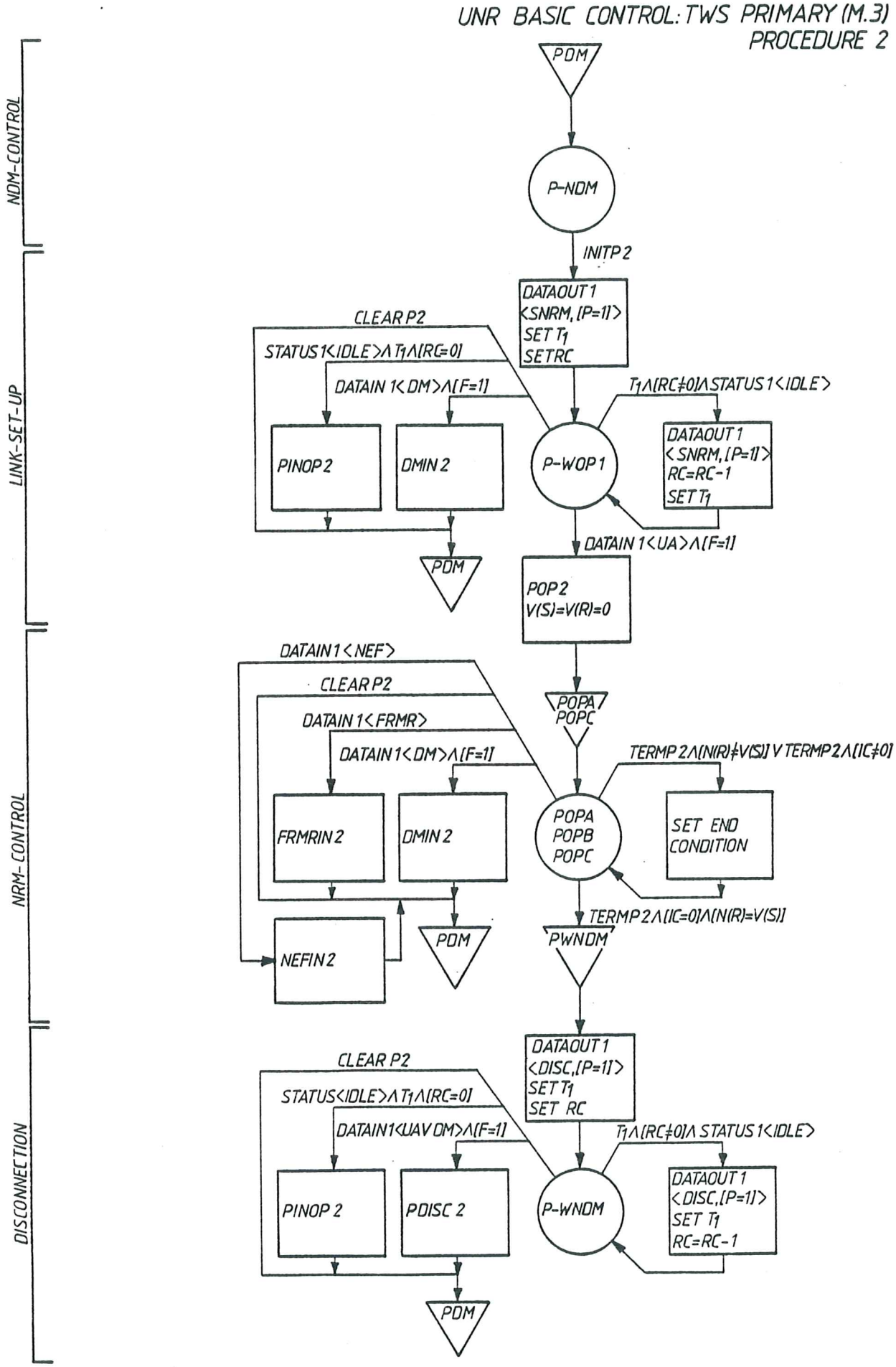
B.4.5.2 UNR Secondary Modules

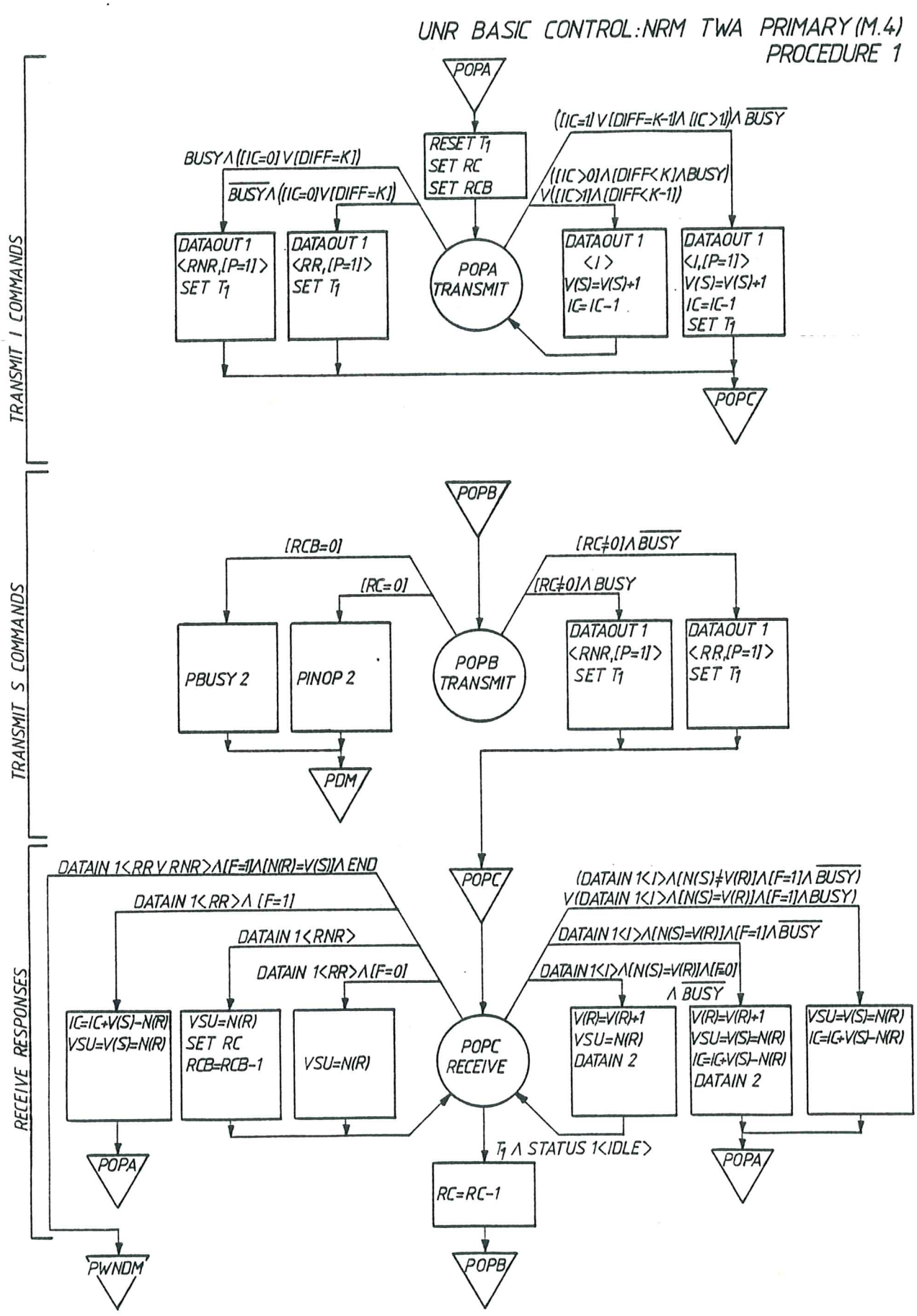
- Station Control Module		UNR-M.6
	- Basic Control Modules	
- TWA-NDM	- Control	UNR-M.7
	- Link Set-Up	
	- NRM Control	
- TWS-NDM	- Control	UNR-M.8
	- Link Set-Up	
	- NRM Control	
- TWA	- Transmit I Responses	UNR-M.9
	- Transmit S Responses	
	- Receive Commands	
- TWS	- Transmit S Responses	UNR-M.10.1
	- Receive	
	- Transmit I Responses	UNR-M.10.2
- Frame Rejection		UNR-M.11

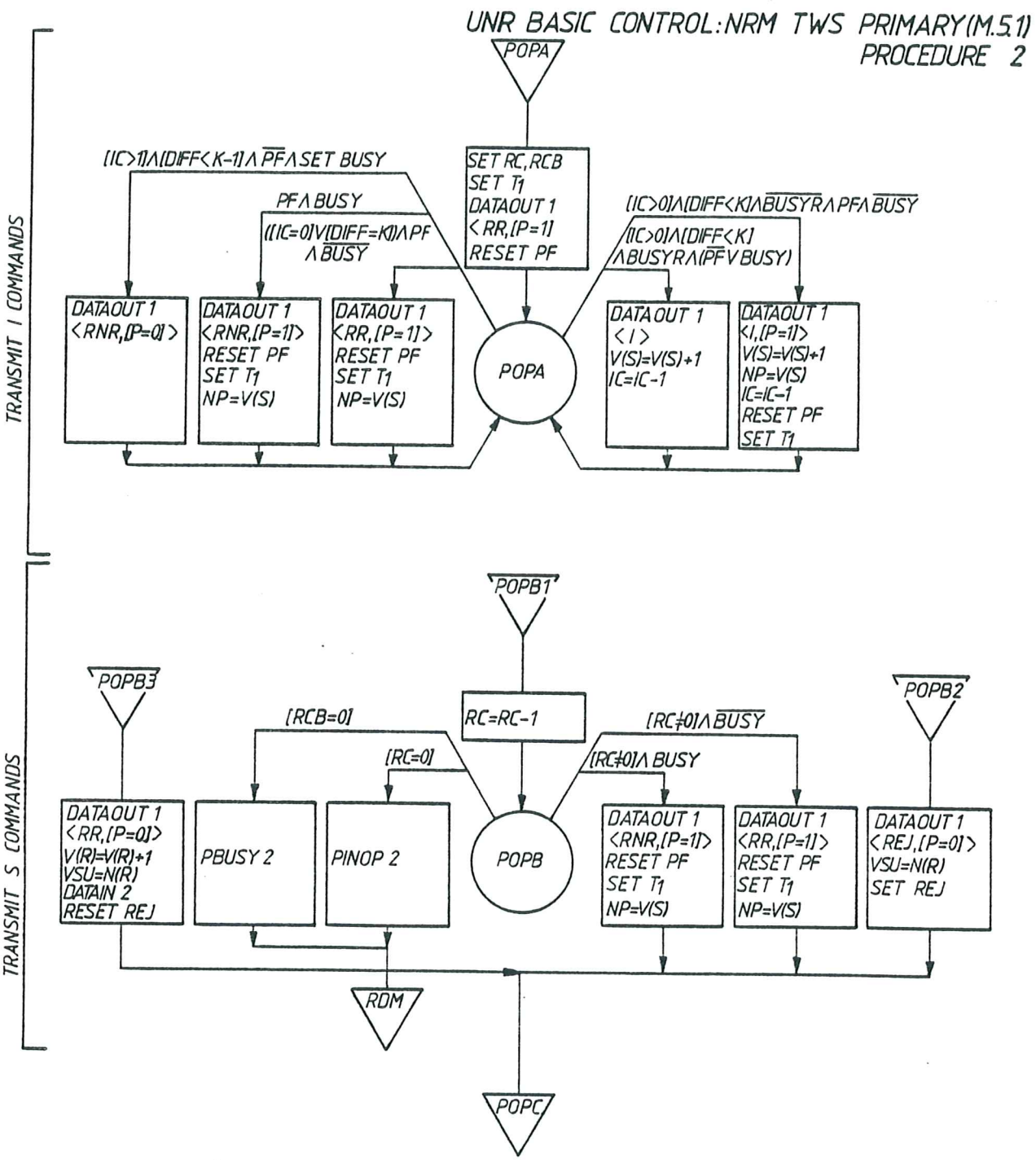
UNR STATION CONTROL: PRIMARY (M.1)
PROCEDURES 1 AND 2



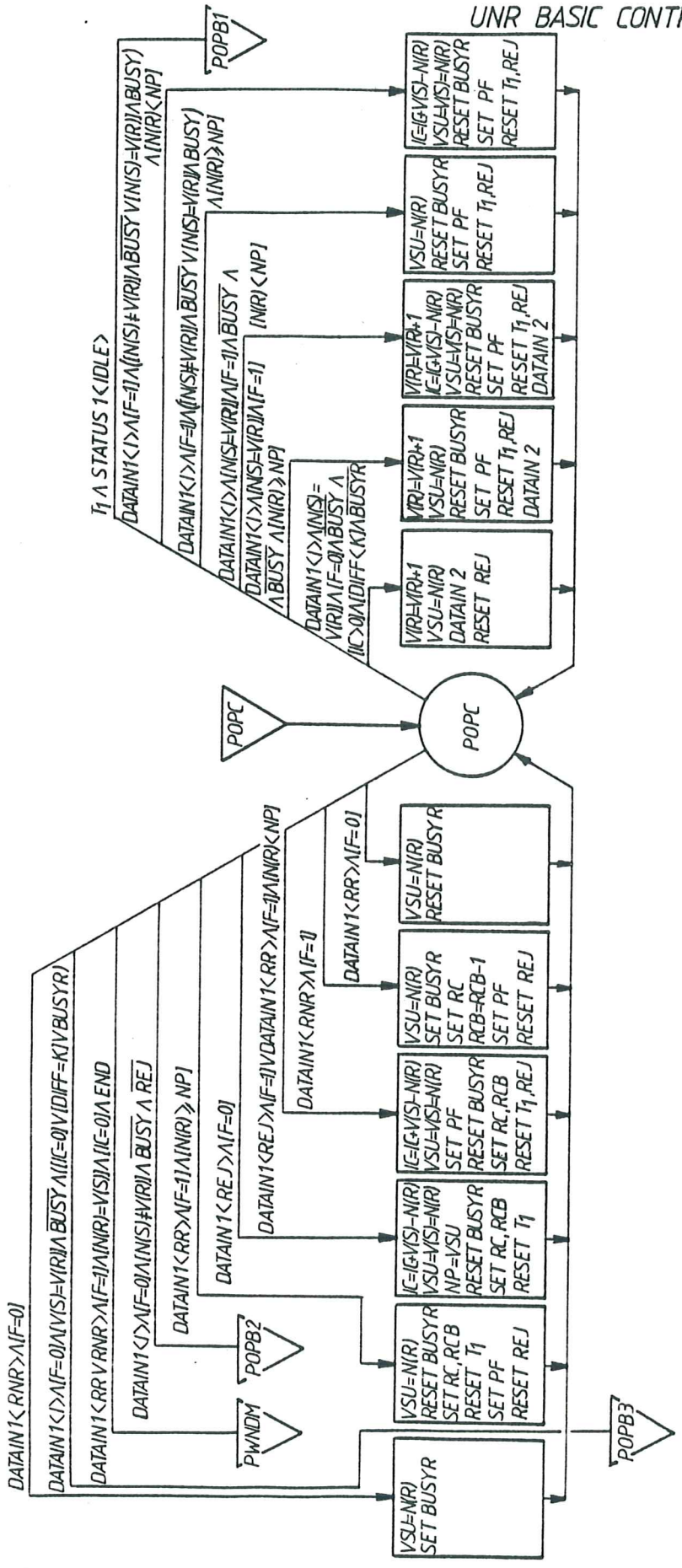

UNR BASIC CONTROL: TWA PRIMARY (M.2)
PROCEDURE 2
NDM-CONTROL
LINK-SET-UP
NRM-CONTROL
DISCONNECTION
PDM
P-NDM
INITP 2
DATAOUT 1
<SNRM, [P=1]>
SET T1
SET RC
CLEAR P2
STATUS 1<IDLE> Λ T1 Λ [RC=0]
DATAIN 1<DM> Λ [F=1]
T1 Λ [RC≠0] Λ STATUS 1<IDLE>
PINOP 2
DMIN 2
P-WOP 1
DATAOUT 1
<SNRM, [P=1]>
RC=RC-1
SET T1
DATAIN 1<UA> Λ [F=1]
PDM
POP 2
V(S)=V(R)=0
DATAIN 1<NEF>
CLEAR P2
DATAIN 1<FRMR>
DATAIN 1<DM> Λ [F=1]
POPA
TERMP2 Λ [N(R)≠V(S)] V TERMP2 Λ [IC≠0]
FRMRIN 2
DMIN 2
POPA
POPB
POPC
SET END
CONDITION
TERMP2 Λ [IC=0] Λ [N(R)=V(S)]
NEFIN 2
PDM
PWNDM
CLEAR P2
DATAOUT 1
<DISC, [P=1]>
SET T1
SET RC
STATUS<IDLE> Λ T1 Λ [RC=0]
DATAIN 1<UAVDM> Λ [F=1]
T1 Λ [RC≠0] Λ STATUS 1<IDLE>
PINOP 2
PDISC 2
P-WNDM
DATAOUT 1
<DISC, [P=1]>
SET T1
RC=RC-1
PDM


UNR BASIC CONTROL: TWS PRIMARY (M.3)
PROCEDURE 2
NDM-CONTROL
LINK-SET-UP
NRM-CONTROL
DISCONNECTION
PDM
P-NDM
INITP 2
DATAOUT 1
<SNRM, [P=1]>
SET T1
SETRC
CLEAR P2
STATUS 1<IDLE> ∧ T1 ∧ [RC=0]
DATAIN 1<DM> ∧ [F=1]
T1 ∧ [RC≠0] ∧ STATUS 1<IDLE>
PINOP 2
DMIN 2
P-WOP 1
DATAOUT 1
<SNRM, [P=1]>
RC=RC-1
SET T1
PDM
DATAIN 1<UA> ∧ [F=1]
POP 2
V(S)=V(R)=0
DATAIN 1<NEF>
CLEAR P2
DATAIN 1<FRMR>
DATAIN 1<DM> ∧ [F=1]
POPA
POPC
TERMP 2 ∧ [N(R)≠V(S)] V TERMP 2 ∧ [IC≠0]
FRMRIN 2
DMIN 2
POPA
POPB
POPC
SET END
CONDITION
NEFIN 2
PDM
TERMP 2 ∧ [IC=0] ∧ [N(R)=V(S)]
PWNDM
DATAOUT 1
<DISC, [P=1]>
SET T1
SET RC
CLEAR P2
STATUS<IDLE> ∧ T1 ∧ [RC=0]
DATAIN1<UAV DM> ∧ [F=1]
T1 ∧ [RC≠0] ∧ STATUS 1<IDLE>
PINOP 2
PDISC 2
P-WNDM
DATAOUT 1
<DISC, [P=1]>
SET T1
RC=RC-1
PDM

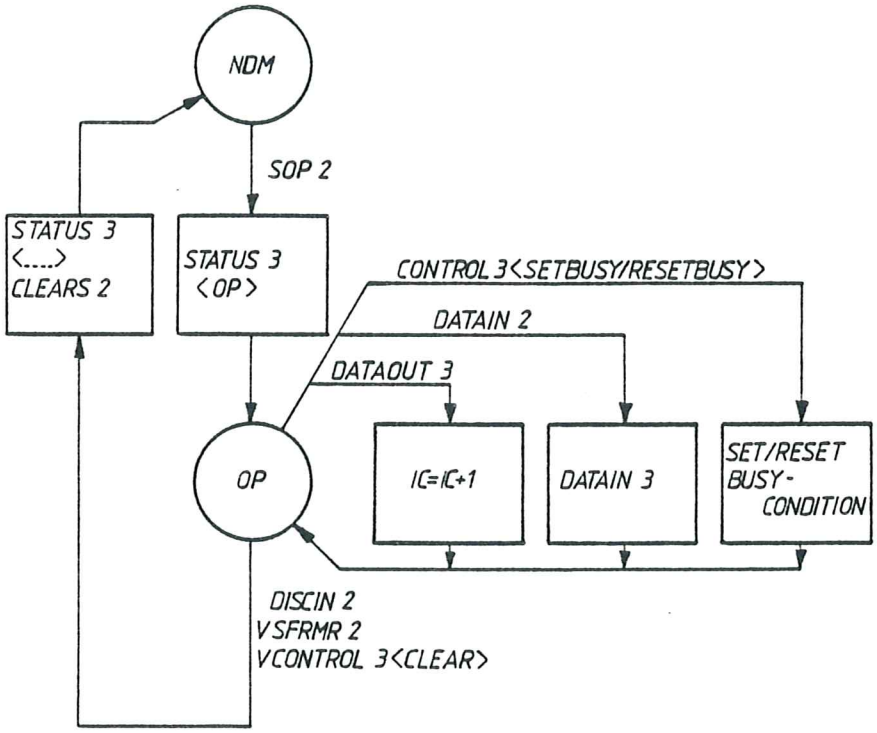

UNR BASIC CONTROL: NRM TWA PRIMARY (M.4)
PROCEDURE 1
TRANSMIT I COMMANDS
TRANSMIT S COMMANDS
RECEIVE RESPONSES
POPA
RESET T1
SET RC
SET RCB
BUSY ∧ ([IC=0] V [DIFF=K])
BUSY ∧ ([IC=0] V [DIFF=K])
([IC=1] V [DIFF=K-1] ∧ [IC>1]) ∧ BUSY
([IC>0] ∧ [DIFF<K] ∧ BUSY)
V ([IC>1] ∧ [DIFF<K-1])
DATAOUT 1 <RNR,[P=1]> SET T1
DATAOUT 1 <RR,[P=1]> SET T1
POPA TRANSMIT
DATAOUT 1 <I> V(S)=V(S)+1 IC=IC-1
DATAOUT 1 <I,[P=1]> V(S)=V(S)+1 IC=IC-1 SET T1
POPC
POPB
[RCB=0]
[RC=0]
[RC≠0] ∧ BUSY
[RC≠0] ∧ BUSY
PBUSY 2
PINOP 2
POPB TRANSMIT
DATAOUT 1 <RNR,[P=1]> SET T1
DATAOUT 1 <RR,[P=1]> SET T1
PDM
POPC
DATAIN 1<RR V RNR> ∧ [F=1] ∧ [N(R)=V(S)] ∧ END
DATAIN 1<RR> ∧ [F=1]
DATAIN 1<RNR>
DATAIN 1<RR> ∧ [F=0]
(DATAIN 1<I> ∧ [N(S)≠V(R)] ∧ [F=1] ∧ BUSY)
V (DATAIN 1<I> ∧ [N(S)=V(R)] ∧ [F=1] ∧ BUSY)
DATAIN 1<I> ∧ [N(S)=V(R)] ∧ [F=1] ∧ BUSY
DATAIN 1<I> ∧ [N(S)=V(R)] ∧ [F=0] ∧ BUSY
IC=IC+V(S)-N(R) VSU=V(S)=N(R)
VSU=N(R) SET RC RCB=RCB-1
VSU=N(R)
POPC RECEIVE
V(R)=V(R)+1 VSU=N(R) DATAIN 2
V(R)=V(R)+1 VSU=V(S)=N(R) IC=IC+V(S)-N(R) DATAIN 2
VSU=V(S)=N(R) IC=IC+V(S)-N(R)
POPA
POPA
T1 ∧ STATUS 1<IDLE>
RC=RC-1
PWNDM
POPB


UNR BASIC CONTROL: NRM TWS PRIMARY (M.5.1)
PROCEDURE 2
TRANSMIT I COMMANDS
TRANSMIT S COMMANDS
POPA
SET RC, RCB
SET T1
DATAOUT 1
<RR,[P=1]
RESET PF
[IC>1]∧[DIFF<K-1]∧PF∧SET BUSY
PF∧BUSY
([IC=0]∨[DIFF=K])∧PF∧BUSY
[IC>0]∧[DIFF<K]∧BUSY R∧PF∧BUSY
([IC>0]∧[DIFF<K]∧BUSY R∧(PF∨BUSY)
DATAOUT 1
<RNR,[P=0]>
DATAOUT 1
<RNR,[P=1]>
RESET PF
SET T1
NP=V(S)
DATAOUT 1
<RR,[P=1]>
RESET PF
SET T1
NP=V(S)
POPA
DATAOUT 1
<I>
V(S)=V(S)+1
IC=IC-1
DATAOUT 1
<I,[P=1]>
V(S)=V(S)+1
NP=V(S)
IC=IC-1
RESET PF
SET T1
POPB1
POPB3
POPB2
RC=RC-1
[RCB=0]
[RC=0]
[RC≠0]∧BUSY
[RC≠0]∧BUSY
DATAOUT 1
<RR,[P=0]>
V(R)=V(R)+1
VSU=N(R)
DATAIN 2
RESET REJ
PBUSY 2
PINOP 2
POPB
DATAOUT 1
<RNR,[P=1]>
RESET PF
SET T1
NP=V(S)
DATAOUT 1
<RR,[P=1]>
RESET PF
SET T1
NP=V(S)
DATAOUT 1
<REJ,[P=0]>
VSU=N(R)
SET REJ
RDM
POPC

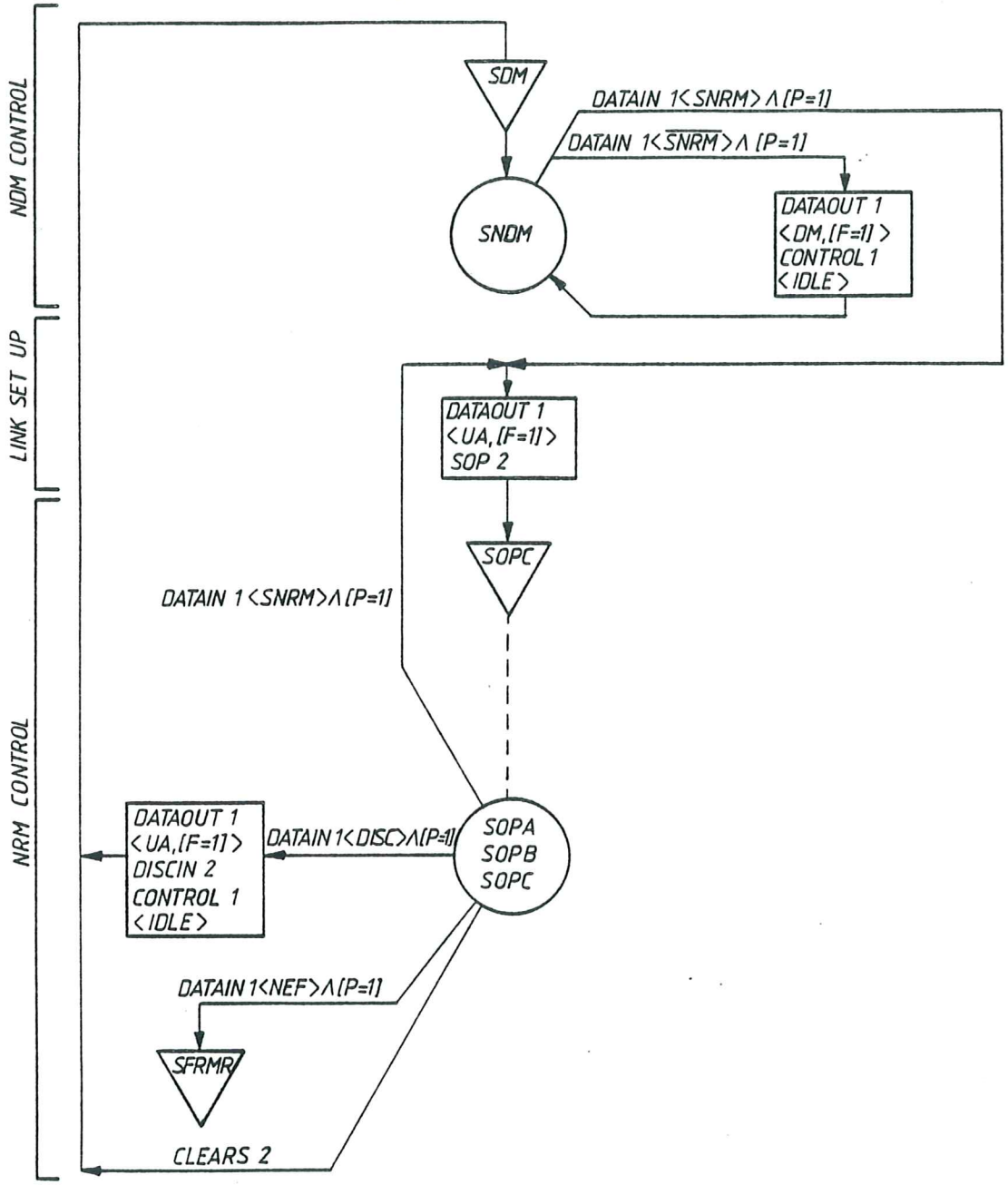
UNR BASIC CONTROL:NRM TWS PRIMARY(M.5.2)
PROCEDURE 2



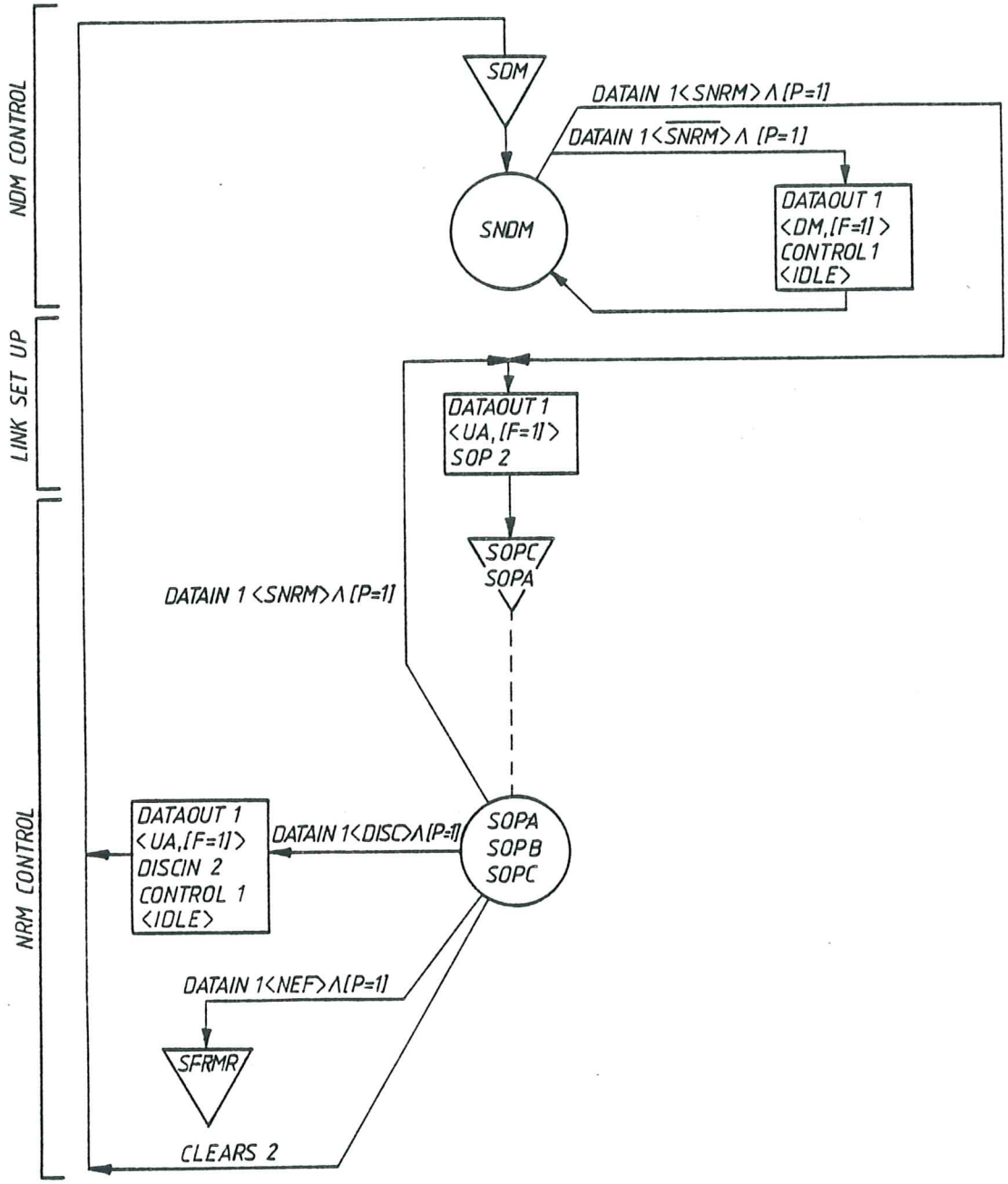
UNR STATION CONTROL: SECONDARY (M.6)
PROCEDURES 1 AND 2



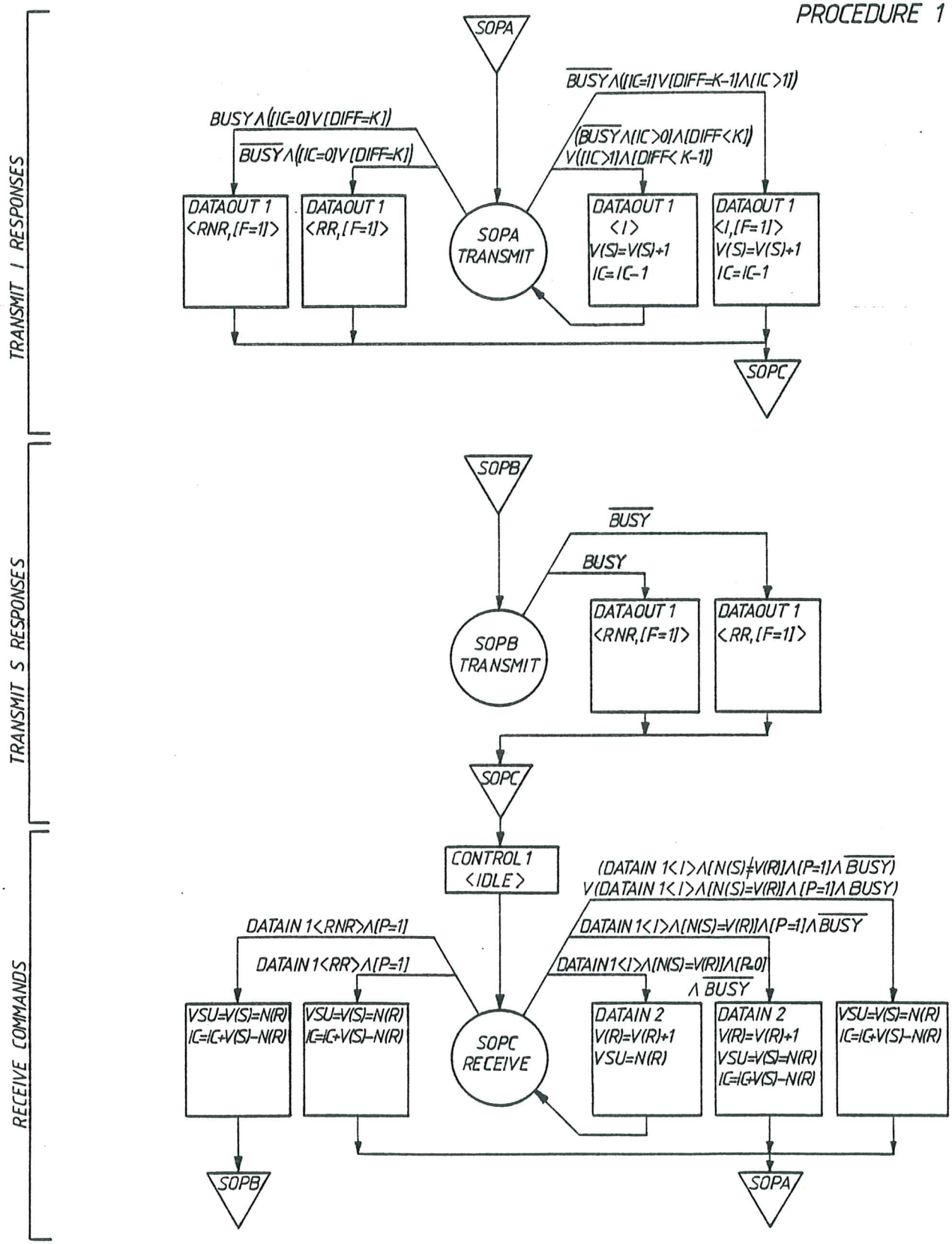
UNR BASIC CONTROL: TWA SECONDARY (M.7)
PROCEDURE 1



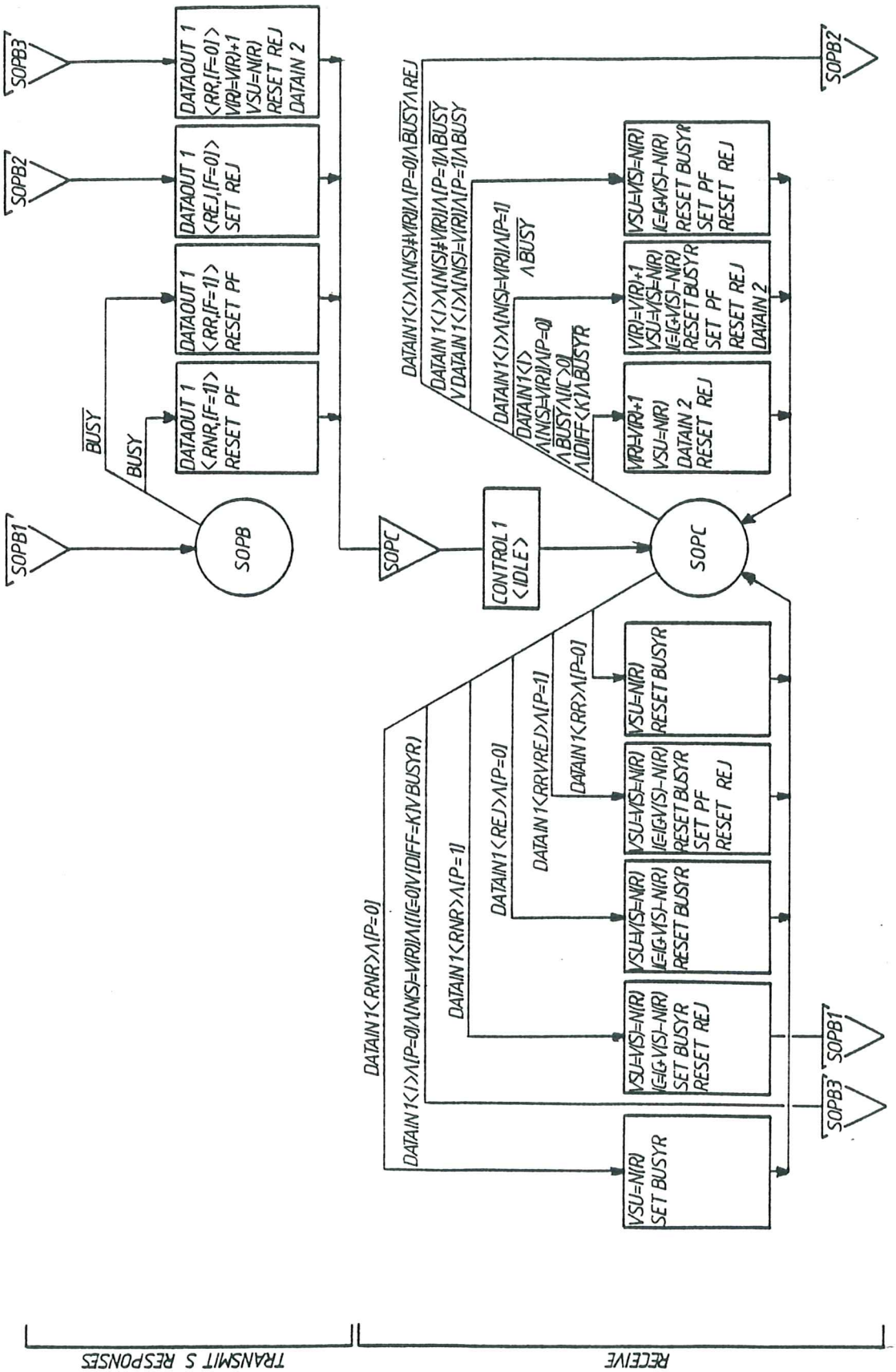
UNR BASIC CONTROL TWS SECONDARY (M.8)
PROCEDURE 2



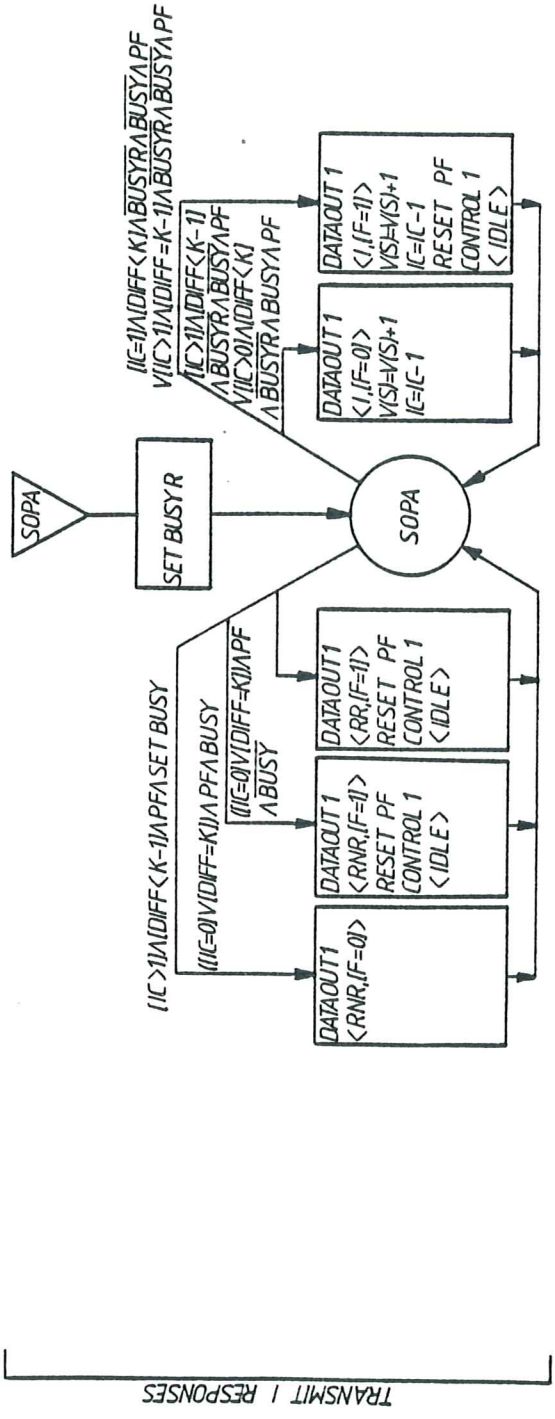
UNR BASIC CONTROL: NRM TWA SECONDARY (M.9) PROCEDURE 1



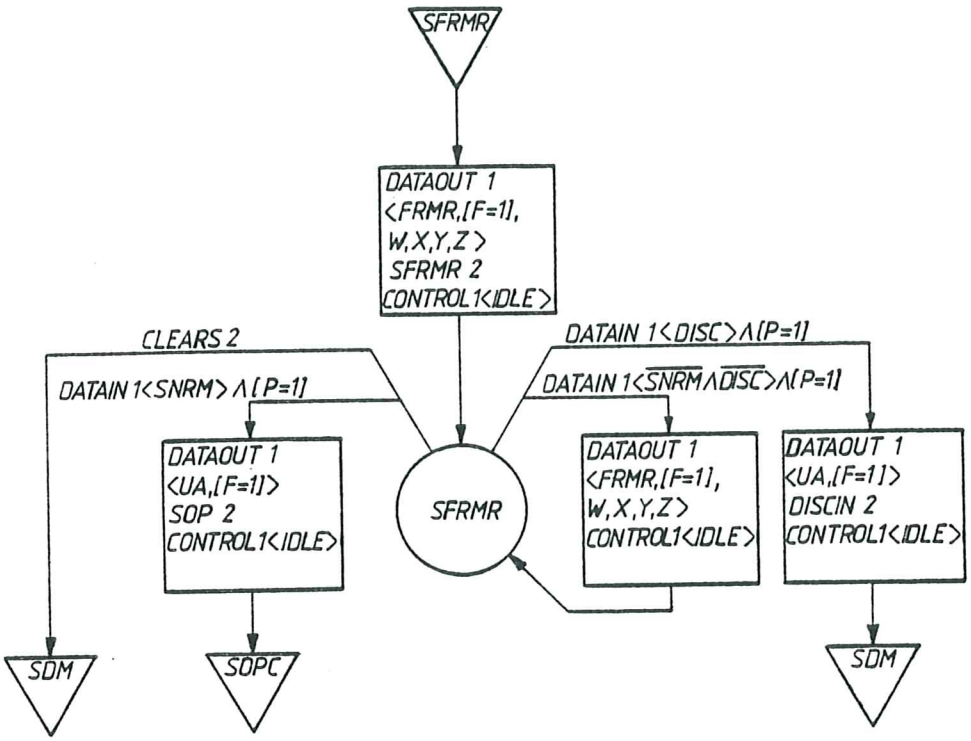
UNR BASIC CONTROL: NRM TWS SECONDARY (M.10.1)
PROCEDURE 2



UNR BASIC CONTROL: NRM TWS SECONDARY (M.10.2)
PROCEDURE 2



UNR BASIC CONTROL: FRAME REJECTION (M.11)
PROCEDURES 1 AND 2



B.5 BA, INTERNAL PRIMITIVES (Index 2)

B.5.1 Station Control to Basic Controls

INITP 2	: Primary, go into operational mode
TERMP 2	: Primary, go into disconnected mode in a controlled way.
CLEARP 2	: Primary, go immediately into ADM state
CLEARS 2	: Secondary, go immediately into ADM state
RESETP 2	: Primary, set the send state variable V(S) to zero
RESETS 2	: Secondary, set the receive state variable V(R) to zero
TERMS 2	: Secondary, go into disconnected mode
FRMRS 2	: Secondary transmit the FRMR response
SETBUSY 2	: Set the local BUSY condition
RESETBUSY 2	: Reset the local BUSY condition

B.5.2 Basic controls to Station control

PINOP 2	: The primary has detected that the data link is inoperable
POP 2	: The primary has sent SABM and received the appropriate UA
PBUSY 2	: The remote secondary has changed its temporary BUSY condition into a long term exception condition
PDISC 2	: A DISC command has been acknowledged via an UA response, the primary is in ADM
PWADM 2	: The primary has transmitted a DISC command and is in the WADM state
DMIN 2	: A primary has received a DM (F=1) response from the remote secondary
FRMRIN 2	: The primary has received a FRMR response
NEFIN 2	: The primary has received a not expected frame
MSR 2	: Mode set request from the remote station (DM (F=0)).
DISCIN 2	: The secondary has received a DISC command and has sent an UA response
SFRMR 2	: The secondary has received a not expected frame (NEF) and has sent a FRMR response
SOP 2	: The secondary has responded with an UA response to an SABM command
DATAIN 2	: Accept this data unit (I frame) arrived in sequence from the remote data station

B.5.3 List of States

State names without a prefix are states of the station control module. The state names of the primary basic control modules are prefixed with a P, the state names of the secondary basic control modules are prefixed with an S.

ADM PADM SADM	asynchronous disconnected mode	
WOP	waiting for operational mode	
OP		
POPA	transmit I commands	
POPB	transmit S commands	
SOPA	receive I commands	operational mode
SOPB	reject	
SOPC	busy	
SFRMR	frame reject	
WADM PWADM SWADM	waiting for asynchronous disconnected mode	

B.5.4 List of Communication Variables

IC : Information counter.
The number of I frames ready for transmission. IC ≠ 0 means that there are frames ready for transmission

RC : Recovery retransmission counter

RCB : Retransmission counter to indicate the remote BUSY condition

END : Termination condition for the ABM control of the primary

VSU : Sequence number of the lowest unacknowledged I command

V(S) : Send state variable

V(R) : Receive state variable

DIFF : (V(S) - VSU)Modulo M if V(S)≥VSU

(MODULUS + V(S)-VSU) modulo M if V(S)<VSU

$$0 \leq DIFF \leq K$$

K : The maximum number of outstanding, unacknowledged I commands

$$K \leq MODULUS-1$$

NEF : Not expected frame
Frame containing:

- a control field which is invalid or not implemented; or
- an information field which is not permitted with this frame or which exceed the agreed maximum information field length; or
- an invalid N(R).

PF : State variable of the primary for the check-pointing.
PF indicates whether it is allowed to transmit an I command with a P bit set to ONE

NP : State variable of the primary. The value V(S) that exists following transmission of a frame with the P bit set to ONE.

T_1 : Checkpointing timer

T_2 : Response timer

BUSY : The local BUSY condition, could be set by internal constraints or by the higher layer

W, X, Y, Z : FRMR variables

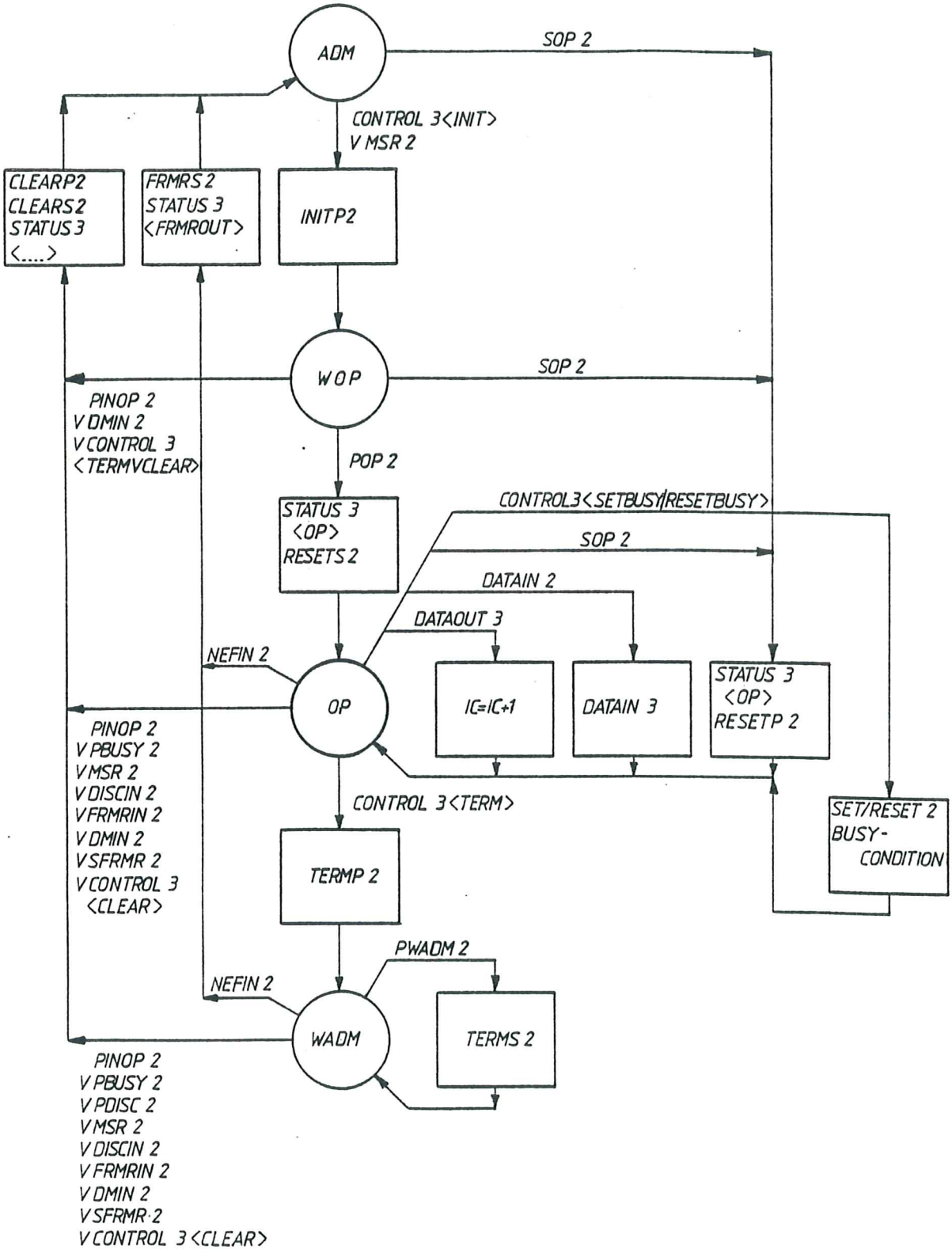
NOTE:

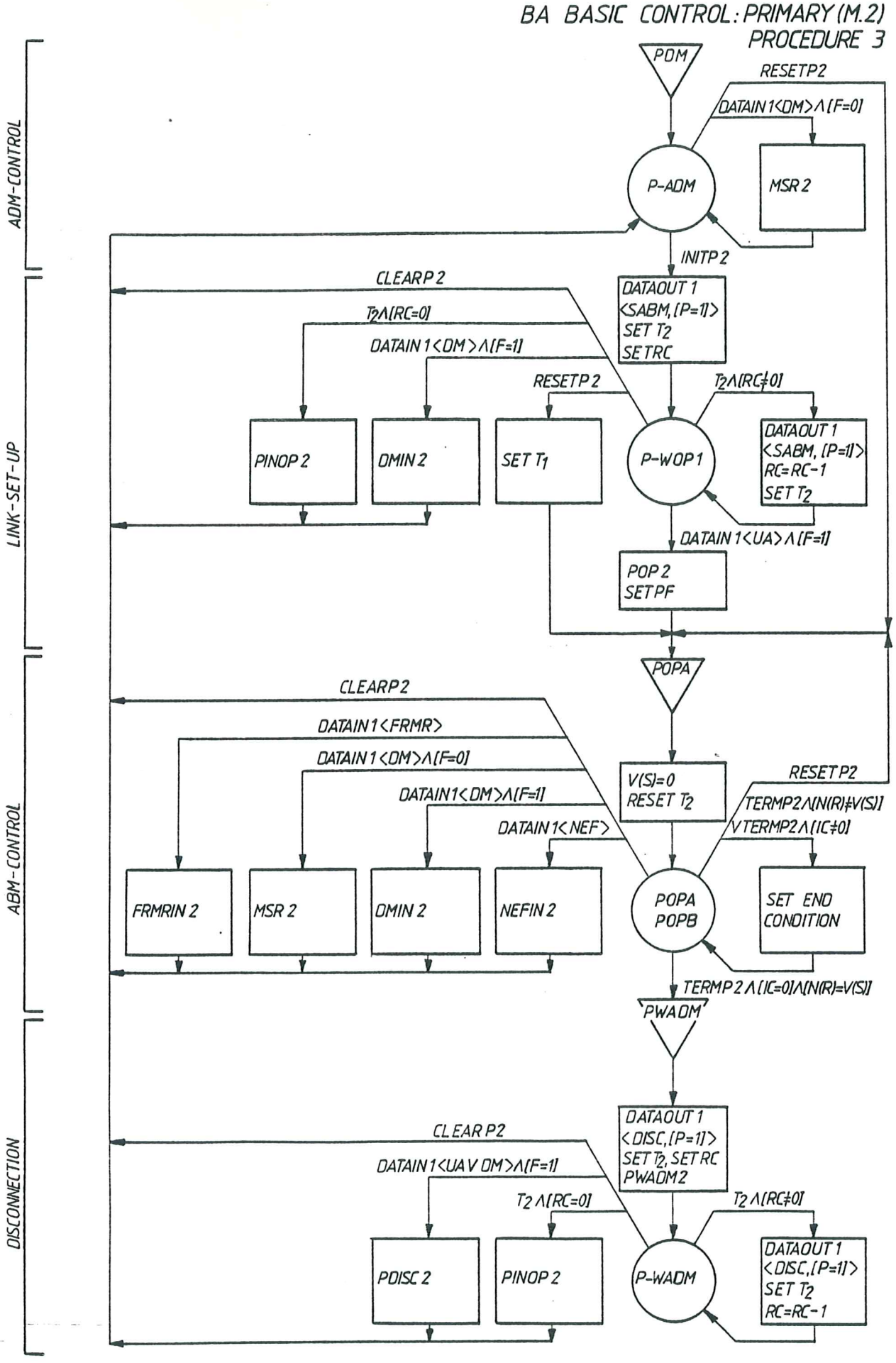
The change of a communication variable could be interpreted as an event.

B.5.5 BA Modules

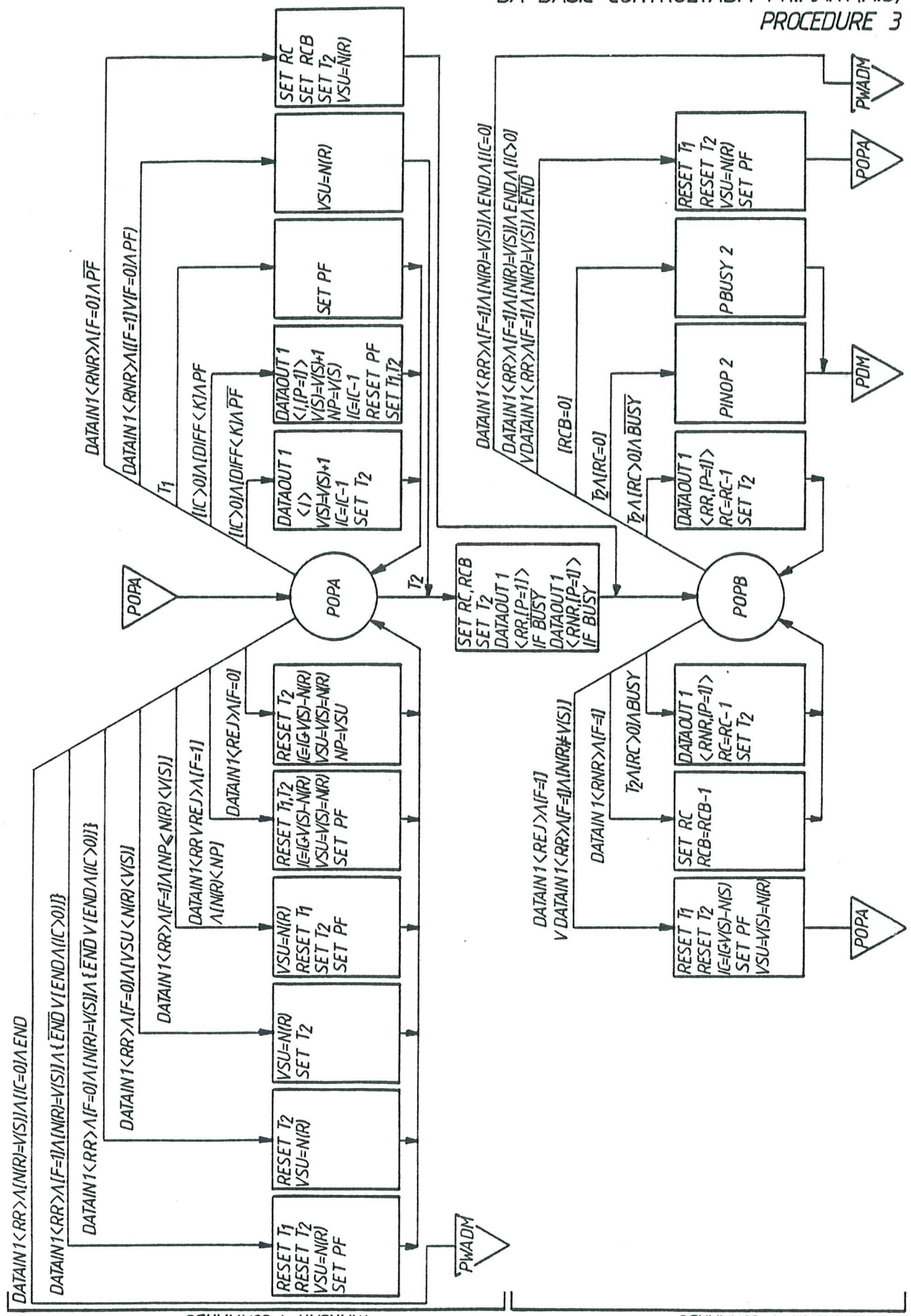
- Station Control Module		BA-M.1
	- Basic Control Modules	
- Primary	- ADM Control	BA-M.2
	- Link Set-Up	
	- ABM Control	
	- Disconnection	
	- Transmit I Commands	BA-M.3
	- Transmit S Commands	
- Secondary	- ADM Control	BA-M.4
	- Link Set-Up	
	- ABM Control	
	- Disconnection	
	- Receive I Commands	BA-M.5
	- Reject	
	- Busy	
- Secondary	- Frame Rejection	BA-M.6

BA STATION CONTROL (M.1)
PROCEDURE 3

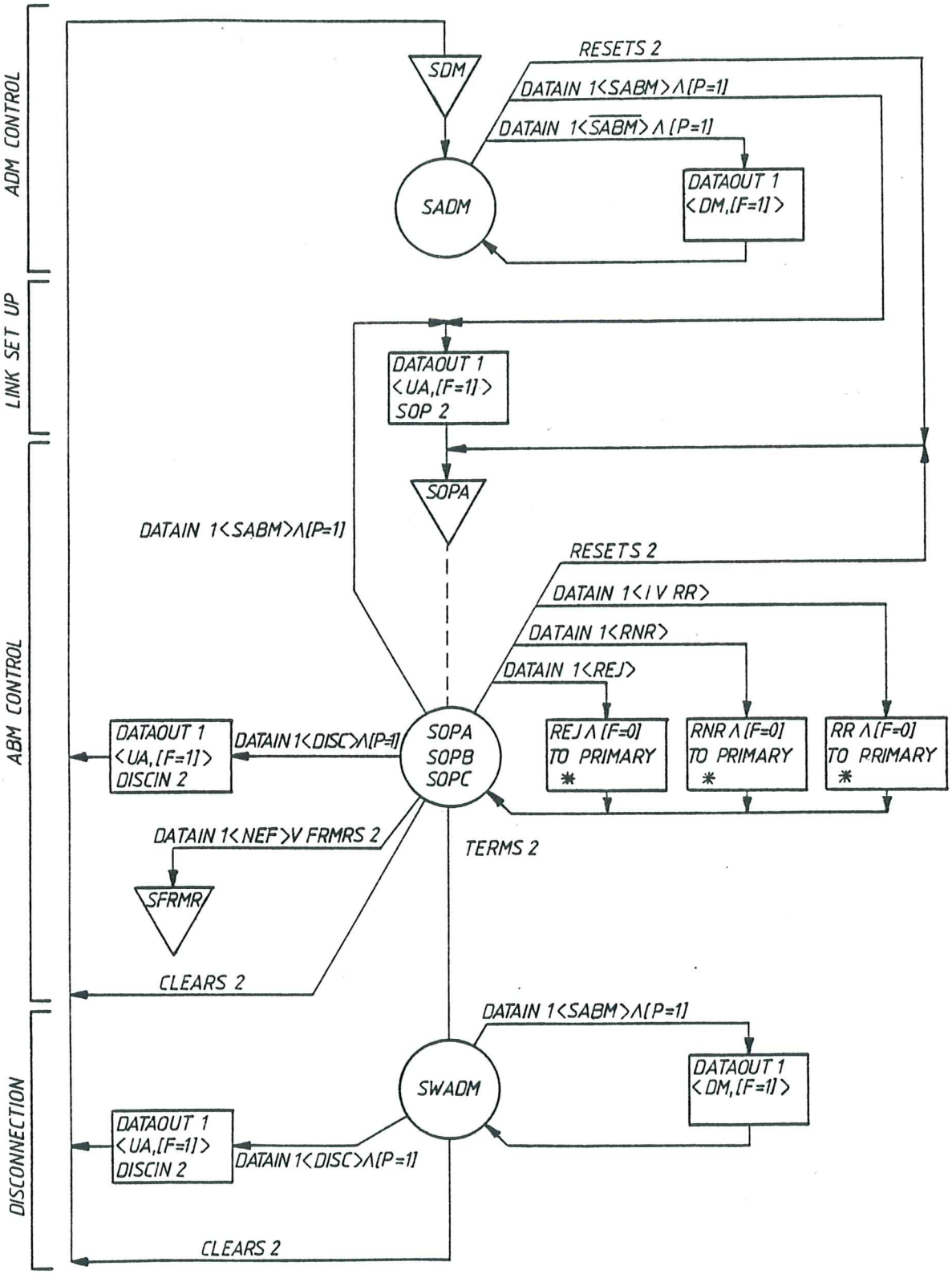



BA BASIC CONTROL: PRIMARY (M.2)
PROCEDURE 3
ADM-CONTROL
LINK-SET-UP
ABM-CONTROL
DISCONNECTION
POM
RESETP2
DATAIN 1<DM>∧[F=0]
P-ADM
MSR 2
INITP 2
CLEARP 2
DATAOUT 1
<SABM, [P=1]>
SET T2
SETRC
T2∧[RC=0]
DATAIN 1<DM>∧[F=1]
RESETP 2
T2∧[RC≠0]
PINOP 2
DMIN 2
SET T1
P-WOP 1
DATAOUT 1
<SABM, [P=1]>
RC=RC-1
SET T2
DATAIN 1<UA>∧[F=1]
POP 2
SETPF
POPA
CLEARP2
DATAIN 1<FRMR>
DATAIN 1<DM>∧[F=0]
DATAIN 1<DM>∧[F=1]
DATAIN 1<NEF>
V(S)=0
RESET T2
RESET P2
TERMP2∧[N(R)≠V(S)]
∨TERMP2∧[IC≠0]
FRMRIN 2
MSR 2
DMIN 2
NEFIN 2
POPA
POPB
SET END
CONDITION
TERMP 2∧[IC=0]∧[N(R)=V(S)]
PWADM
DATAOUT 1
<DISC, [P=1]>
SET T2, SET RC
PWADM2
CLEAR P2
DATAIN 1<UA∨DM>∧[F=1]
T2∧[RC=0]
T2∧[RC≠0]
PDISC 2
PINOP 2
P-WADM
DATAOUT 1
<DISC, [P=1]>
SET T2
RC=RC-1

BA BASIC CONTROL: ABM PRIMARY(M.3)
PROCEDURE 3

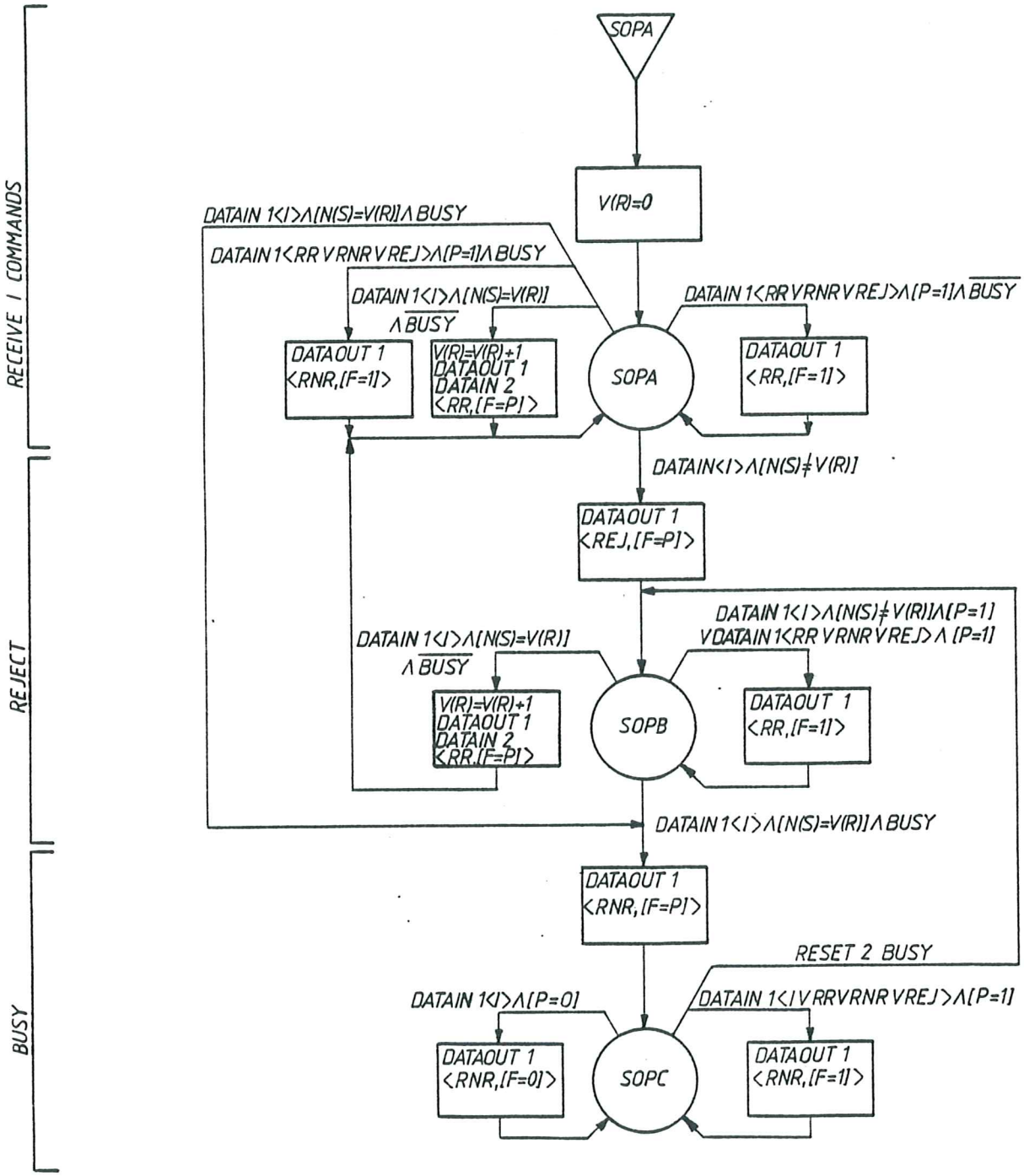


BA BASIC CONTROL: ABM SECONDARY (M.4)
PROCEDURE 3



*THESE ARE SIMULATED RESPONSES

BA BASIC CONTROL: ABM SECONDARY (M.5)
PROCEDURE 3



BA BASIC CONTROL: FRAME REJECTION (M.6)
PROCEDURE 3