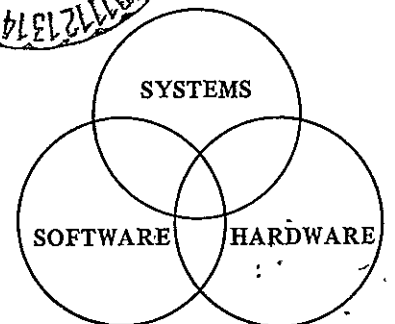
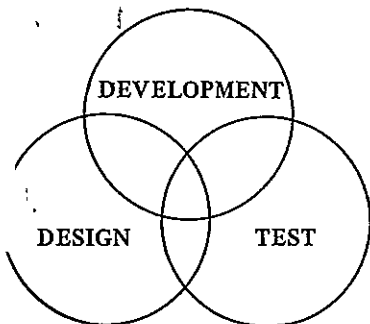
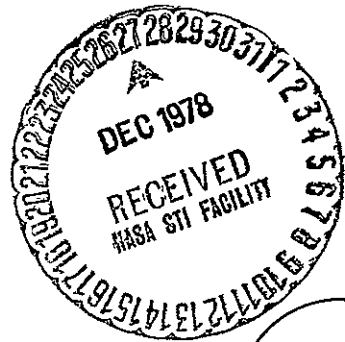


(NASA-CR-150862) MICROCOMPUTER TECHNOLOGY APPLICATIONS: CHARGER AND REGULATOR SOFTWARE FOR A BREADBOARD PROGRAMMABLE POWER PROCESSOR Final Report (Green Research, Madison, Ala.) 74 p HC A04/MF A01 CSCL 09B G3/61 N79-12773 Unclas 39015

MICROCOMPUTER TECHNOLOGY APPLICATIONS

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FINAL REPORT FOR:

CHARGER AND REGULATOR SOFTWARE
FOR A BREADBOARD PROGRAMMABLE POWER PROCESSOR
CONTRACT NAS8-32896

PREPARED FOR:

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DATE: October 26, 1978

No. 0011

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Abstract

Software programs have been written in 8080 assembly language for the Programmable Control Interface (PCI) of the Programmable Power Processor (P³). Two software systems are described, one which implements a voltage regulation function, and one which implements a charger function with peak-power tracking of its input. The software, written in modular fashion, is intended as a vehicle for further experimentation with the P³ system. A control teleprinter, allows an operator to make parameter modifications to the control algorithm during experiments. The programs require 3K ROM and 2K RAM each. User Manuals for each system are included as well as a third program for simple I/O control.

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1. Introduction

1.1 Overview

The concept of programmable power processors (P³) as controllers of standardized power modules has been under development by NASA-MSFC's EC-12 group for several years. This concept offers two distinct advantages. First, it allows for real-time modification of the system's parameters to adapt to changes in the operating environment or other conditions. Secondly, it allows the power circuits to have the same structure whether used as a power regulator, charger, etc. This means less design time since only minor software changes need be made to accommodate configuration changes.

The programmable power processor concept is still in the development stage. This concept will be used in the "High Voltage Power Subsystem Test". This "High Voltage Power Subsystem Test" is currently planned as a step towards development of the 25kw Power Module for Shuttle-payloads. This long duration test will consist of a single power circuit similar to Figure 1.1.1. As seen in the figure, two programmable power processors are to be used.

A necessary requirement for the performance of this test is the development of 8080 software programs to perform the logic functions associated with battery charging and bus regulation. Flow diagrams and algorithms for these functions have been developed by EC-12.

This report documents the implementation of these flow diagrams and algorithms into two 8080 microprocessor programs capable of running on the MSFC breadboard programmable control interface of the programmable power processor. A third program, useful for interface testing, is also described.

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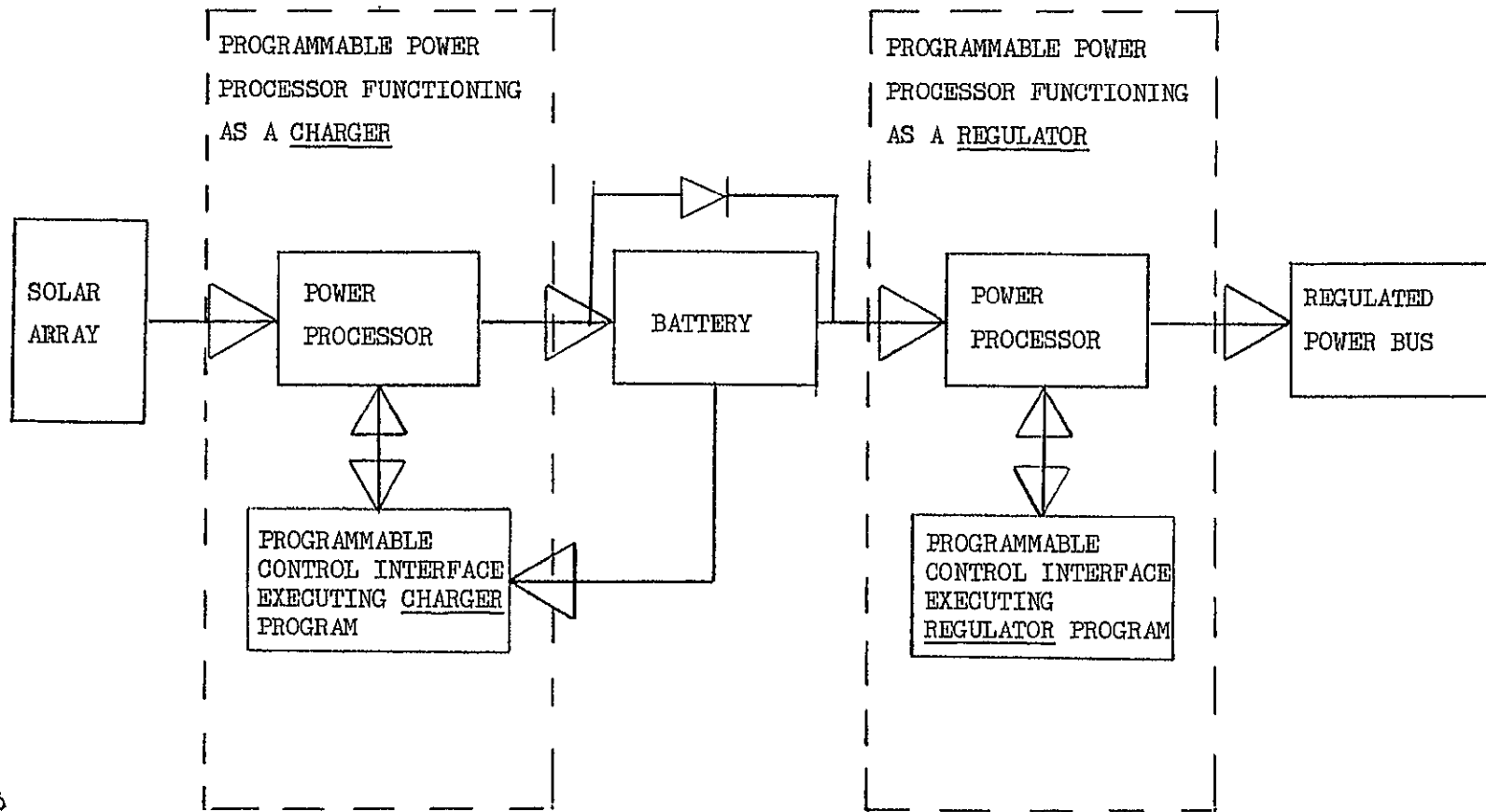


Figure 1.1.1 Test setup similar to planned "High Voltage Power Subsystem Test"

1.2 Technical Approach

NASA-MSFC has developed the concept of programmable power processors for use in space power systems. These power processors are standardized hardware with flexibility due to their programmable nature. The programmable power processor is divided into two portions: the power handling circuitry, the power processor; and the software programmable control element, the programmable control interface (PC/I). Figure 1.2.1 shows a diagram of the programmable power processor system. The nature of the operation of this system is dependent on the software programs within the programmable control interface.

A breadboard of the programmable control interface hardware exists at MSFC. It is based on the Intel 8080 microprocessor and is block diagrammed in Figure 1.2.2. The elements in dashed lines are to be added for use in the "High Voltage Power Subsystem Test". Current software for the system consists of basic hardware test programs and a development program.

Green Research has developed two 8080 microprocessor programs, based on flow diagrams furnished by MSFC EC-12, capable of running on the MSFC breadboard programmable control interface. These two programs are intended for use in the "High Voltage Power Subsystem Test". The first of these programs will cause the programmable power processor to act as a battery charger. The second program will enable the programmable power processor to perform a bus regulation function. Both programs have been written such that the parameters specified by MSFC personnel can be changed during the test allowing some real-time flexibility.

Since development in this area is still in the experimental stage, the software has been developed in modular fashion to enhance modifications rather than ultimate speed of execution. Added advantages of the modular software approach include large duplication of code in both programs, improved reliability, and the ability to "prove" the program. This modularity will also decrease the development time of future similar programs as well as decreasing the development time of these programs.

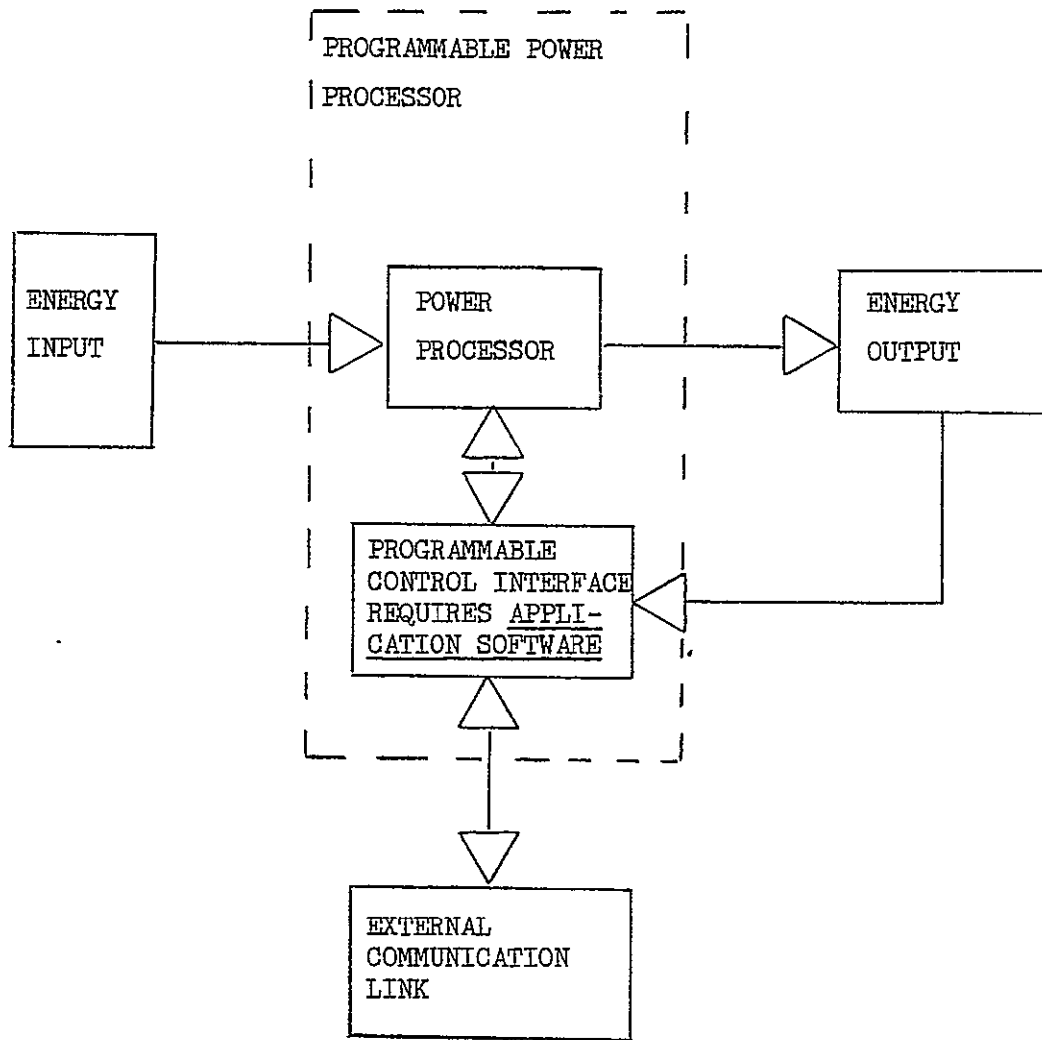


Figure 1.2.1 Programmable power processor system.

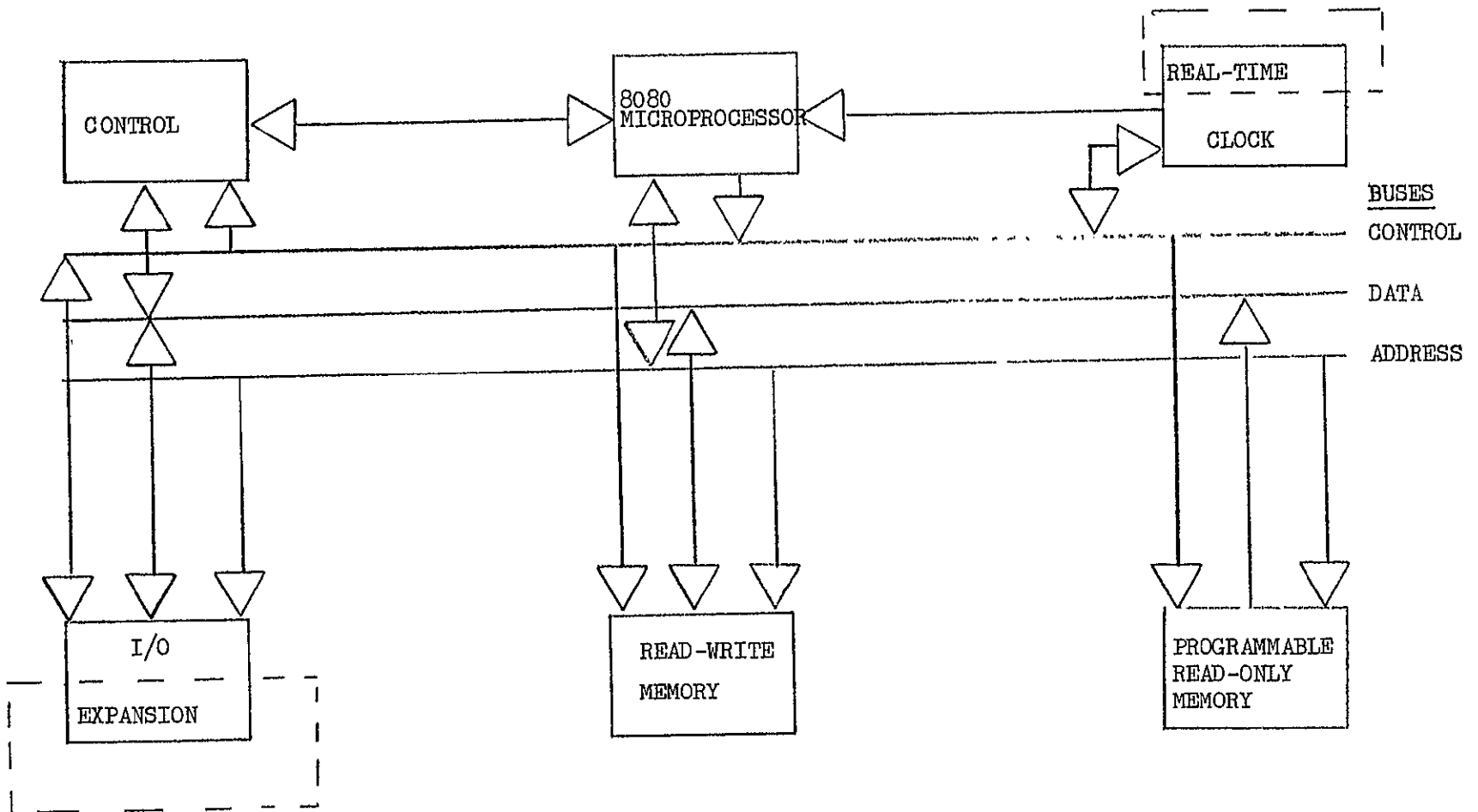


Figure 1.2.2 Block diagram of programmable control interface breadboard.

Each program was attacked in the same manner. First, each program (and its flow diagram as supplied by MSFC) was studied in great detail to determine, functionally, how best to modularize the program. This work was done in conjunction with MSFC personnel to ensure that these function modules were appropriate for the planned future uses of the program. After the tasks were broken into modules, each module was studied and flowcharted for eventual implementation on an 8080 system. These modules execute under a task-oriented supervisor program on the 8080 system. With the exception of the input/output (I/O) which must be tested on the actual 8080 breadboard, all modules were individually coded and tested on an 8080 development system furnished by MSFC. The I/O portions were tested on the MSFC breadboard programmable control interface. Next, modules were combined and tested as a subsystem on the MSFC furnished 8080 development system. Finally, this subsystem was combined with the I/O routines, tested on the MSFC breadboard, and delivered. The developed software was written in such a way to facilitate the programs being placed in Read Only Memory with only parameters and variables placed in Read-Write Memory.

The programs were delivered in three forms: an object code paper tape, a MSFC furnished programmable Read Only Memory, and a source code paper tape. Also furnished were commented listings of the programs assembly and a Programmer's Reference Manual on the Regulator/Charger Software system.

This technical approach was organized into three tasks:

- (1) Detailed design of the charger and regulator programs.
- (2) Conversion of the design into debugged 8080 machine code.
- (3) Verification of the programs by system operational test and development of software documentation.

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2. A Simple I/O Controller

2.1 Purpose

This manual documents and details the use of the MANUAL I/O CONTROLLER program. This program was written for MSFC to checkout PCI hardware interfaces using the teleprinter as a control console.

2.2 Overview

This program allows an operator, using the teleprinter, to exercise the I/O bus of an 8080 system. Through the use of appropriate commands, an I/O device may be readied and tested by the operator. Figure 2.2.1 details the algorithm which the program implements. The program is completely self-contained. It requires a small amount of read-write memory for data space and the program resides in a single 256 x 8 read-only memory.

2.3 Operations Provided

The program allows two basic operations; input and output. The input operation samples any specified input port while the output operation outputs a specified eight bit value to a specified output port. All numerical values are specified in hexadecimal.

2.4 Data Structure

The program requires 11 bytes of read-write memory. The first byte will either be set to 0DBH (IN instruction) or 0D3H (OUT instruction) depending on the present operation commanded. The second byte will be the I/O port specified. The third byte is set to 0C9H (RET instruction). The remaining eight bytes are used for stack space. The first three bytes are a subroutine which actually perform the requested I/O operation.

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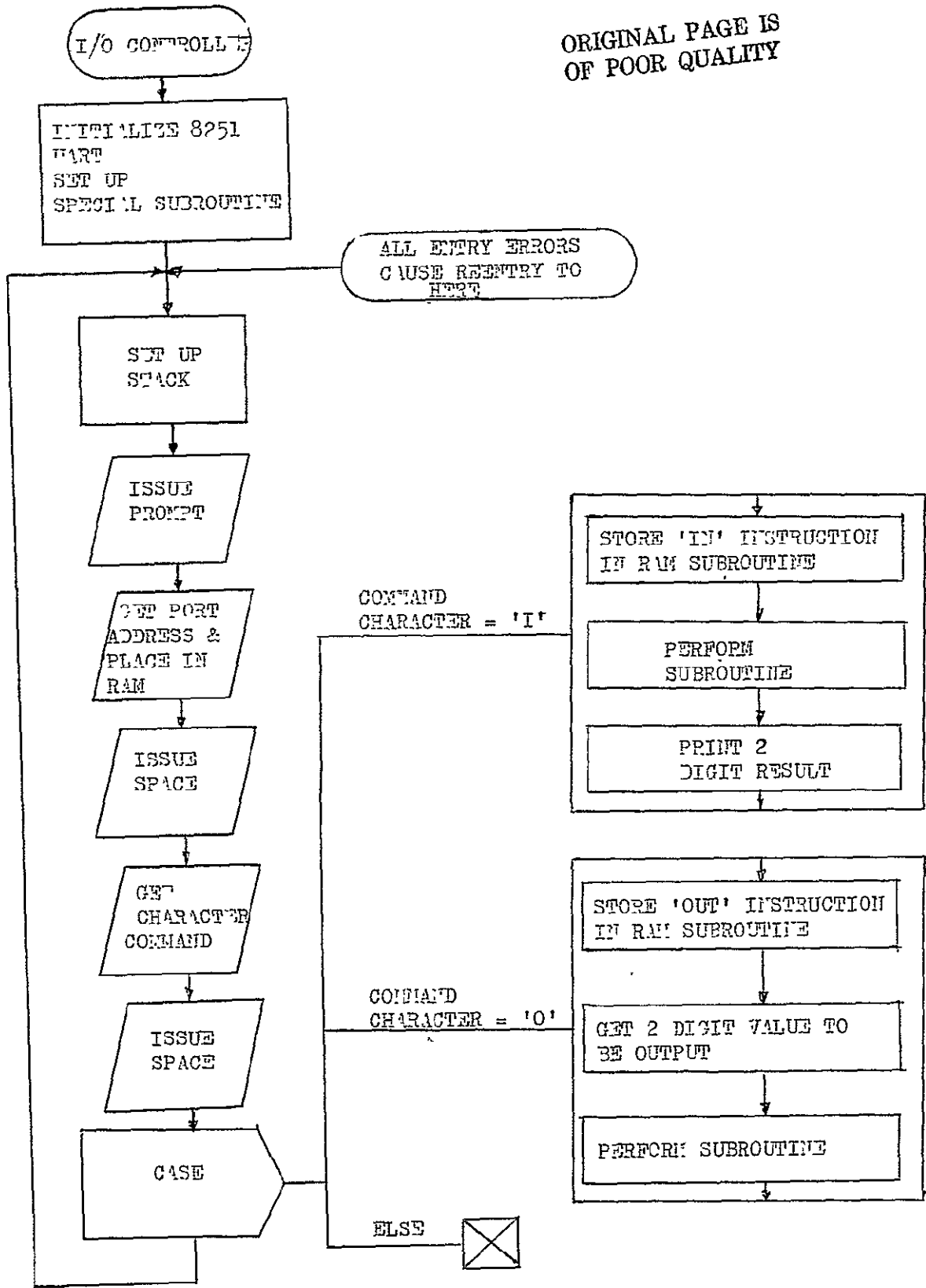


Figure 2.2.1 Flowchart of I/O Controller

2.5 Use

The form of the command issued by the operator for an input operation is

$$\underline{?} \{PV\} \underline{I} \underline{CC}$$

where underscored characters are issued by the program and set brackets enclose a parameter. The ? is the prompt character issued by the program. {PV} is the I/O port number on which the operation is to be performed. The I designates an input operation which is commanded and CC represents the value inputted by the program from input port {PV}. Both {PV} and CC are considered to be 2 digit hexadecimal values.

The form of an output command is

$$\underline{?} \{PV\} \underline{O} \underline{\{OV\}}$$

where the same conversions hold as described in the input command and {OV} represents the two digit hexadecimal value to be sent to output port {PV}.

Any input error of the operator will cause the command to be aborted and a new prompt character (?) to be printed on the next line. Normally {PV} values corresponding to the teleprinter (00 and 01 in the supplied version) should not be used so that the I/O interface used for control is not placed in an undefined status.

Examples:

$$\underline{?} \underline{23} \underline{I} \underline{FF}$$
$$\underline{?} \underline{23} \underline{O} \underline{22}$$
$$\underline{?} \underline{23} \underline{K}$$
$$\underline{?}$$

2.6 Listing

The listing of the assembly of the Simple I/O Controller starts on the next page.

... LLEF V:.

;\$* COMMANDS: <PORT I INPUT FROM PORT
;\$* <PORT O DB OUTPUT <DB TO PORT

;\$* USER JUST TYPES HEX VALUES AND 'I' OR 'O'.
;\$* PROGRAM TAKES CARE OF SPACING. ILLEGAL
;\$* ENTRIES ABORT COMMAND AND CAUSE NEW PROMPT ('?').

0000 ECHO EQU 0 ; NO ECHO
1C00 INSTR EQU 1C00H ; MUST BE 11 SPARE RWM BYTES
; OF WHICH INSTR IS THE LOWEST.
00CF MODE EQU 0CFH ; 8251 UASRT
0037 CMD EQU 037H
0001 CSF EQU 1 ; CONTROL/STATUS PORT
0000 DP EQU 0 ; DATA PORT
000D CR EQU 0DH
000A LF EQU 0AH
0020 SPACE EQU 020H
003F PROMPT EQU '?'
00DB IIN EQU 0DBH ; IN INSTRUCTION
00D3 IOUT EQU 0D3H ; OUT INSTRUCTION
00C9 IRET EQU 0C9H ; RET INSTRUCTION

0000 ;
ORG 0

RST0:

0000 3ECF MVI A,MODE ; SET UP 8251
0002 D301 OUT CSF
0004 3E37 MVI A,CMD
0006 D301 OUT CSF

;\$
;\$ ACTUAL WORK DONE BY SUBROUTINE BUILT BY
;\$ THIS PROGRAM IN RAM. FORMAT :

;\$ INSTR: DB <IN>/<OUT> ;INPUT
;\$ DB <PORT> ;INPUT
;\$ DB RET ;STANDARD
;\$

0008 3EC9 MVI A,IRET ; MOVE STANDARD RET TO RAM
000A 32021C STA INSTR+2

STACK: ; REINITIALIZE

000D 310B1C LXI SP,INSTR+11
0010 0E0D MVI C,CR ; CR,LF,PROMPT
0012 CD6600 CALL OCHAR
0015 0E0A MVI C,LF
0017 CD6600 CALL OCHAR
001A 0E3F MVI C,PROMPT
001C CD6600 CALL OCHAR
001F CD9C00 CALL INUM ; GET <PORT>
0022 32011C STA INSTR+1 ; PLACE IN RAM
0025 0E20 MVI C,SPACE ; SPACE ON TTY
0027 CD6600 CALL OCHAR
002A CD5A00 CALL ICHAR ; GET COMMAND
002D F5 PUSH PSW ; SAVE IT
002E 0E20 MVI C,SPACE ; ANOTHER SPACE
0030 CD6600 CALL OCHAR
0033 F1 POP PSW ; COMMAND
0034 FE49 CPI 'I' ; INPUT?
0036 C24700 JNZ NO

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```

0029 3ED8          NVI      A,IN  ; SETUP IN INSTRUCTION
0038 32001C       STA      INSTR
003E CD001C       CALL     INSTR ; DO IT
0041 CD7100       CALL     OHEX  ; PRINT INPUTTED DATA
0044 C30100       JMP      STACK ; DONE
;
;
0047 FE4F          CPI      '0'  ; OUTPUT?
0049 C20100       JNZ     STACK ; NO - IGNORE
;
; * O COMMAND
;
004C 3ED3          NVI      A,IOUT ; SET UP OUT INSTRUCTION
004E 32001C       STA      INSTR
0051 CD9C00       CALL     INUM   ; GET VALUE TO OUTPUT
0054 CD001C       CALL     INSTR ; DO IT
0057 C30D00       JMP      STACK ; DONE
;
; * INPUT CHARACTER (STRIP PARITY & LEAVE IN A)
;
ICHR:
005A DB01          IN       CSP
005C E602          ANI     2
005E CA5A00       JZ      ICHAR  ; NO CHAR
0061 DB00          IN       DP    ; GET CHAR
;
;
;
;
;
;
0063 E67F          ANI     07FH  ; STRIP PARITY
0065 C9           RET
;
; * OUTPUT CHARACTER (FROM C)
;
OCHAR:
0066 DB01          IN       CSP
0068 E601          ANI     1
006A CA6600       JZ      OCHAR  ; NOT READY
006D 79           MOV     A,C
006E D300          OUT     DP    ; SEND IT
0070 C9           RET
;
; * OUTPUT HEX OF A
;
OHEX:
0071 F5           PUSH    PSW   ; SAVE
0072 0F           RRC
0073 0F           RRC
0074 0F           RRC
0075 0F           RRC          ; MSB -> LSB
0076 CD7A00       CALL    CSHEX ; SEND MSB
0079 F1           POP     PSW
;
;
; SEND LSB
CSHEX:
007A E60F          ANI     0FH  ; LSB ONLY

```

```

0077 00
0081 27
0082 4F
0083 C36600
      DEI
      ADI
      DAA
      MOV
      JMP
      A
      CMA
      OCHAR

```

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```

;
;* INPUT 1 HEX DIGIT TO A
;

```

INHEX1:

```

0086 CD5A00      CALL    ICHAR
0089 D630        SUI     3CH      ; CONVERT & ERROR CHECKS
008F DA0D00      JC      STACK
008E FE0A        CPI     0AH
0090 D8          RC
0091 D607        SUI     7
0093 DA0D00      JC      STACK
0096 FE10        CPI     10H
0098 D8          RC
0099 C30D00      JMP     STACK

```

```

;
;* INPUT 2 HEX DIGITS TO A
;

```

INUM:

```

009C CD8600      CALL    INHEX1  ; MSB
009F 07          RLC
00A0 07          RLC
00A1 07          RLC
00A2 07          RLC
00A3 47          MOV     B,A
00A4 CD8600      CALL    INHEX1  ; LSB
00A7 80          ADD     B      ; COMBINE
00A8 C9          RET

```

```

;
      END
;

```

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USER'S MANUAL FOR THE REGULATOR PROGRAM

3.1 Scope

This manual is intended to detail the use of the REGULATOR SOFTWARE SYSTEM. Descriptions within this manual relate to the operational software and user inputs which turn the regulator on, reset the software, and examine and/or modify internal parameters. Also included are an overview of the program control flow, definitions of signals utilized by the software, and operational characteristics of the program when run on the present (August 1978) MSFC Programmable Control Interface (PCI).

This manual is not intended as documentation of the PCI hardware (see appropriate MSFC documentation), or of the REGULATOR program's internal structure or operation. A separate manual exists to detail the program's internal structure.

All supplied documentation assumes that the program is installed in Read-Only Memory (ROM) in a hardware configuration identical to the present (August 1978) NASA MSFC EC-12 PCI system.

3.2 Overview

The regulator software system is intended to be used in Programmable Power Processor (P³) hardware to cause the standard hardware to function as a regulator (see Figure 3.2.1). The software located in ROM performs necessary configuration actions, participates in control in a closed loop network, and provides a mechanism for local or remote modification of control parameters.

The regulator software is modularized into modules called tasks. An executive program causes each task to be performed in the proper sequence and allows new tasks (modification or data display) to be performed. To minimize the impact of the relatively slow input/output (I/O) via the external teleprinter, character by character communication between the PCI and the teleprinter is handled on an interrupt basis by the regulator software. In this

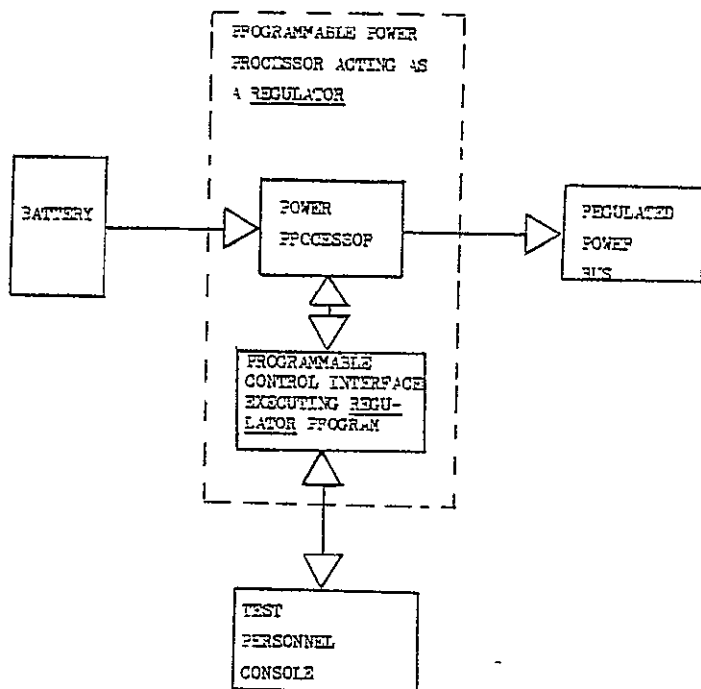


Figure 3.2.1 Functional view of the programmable power processor in a Regulator environment

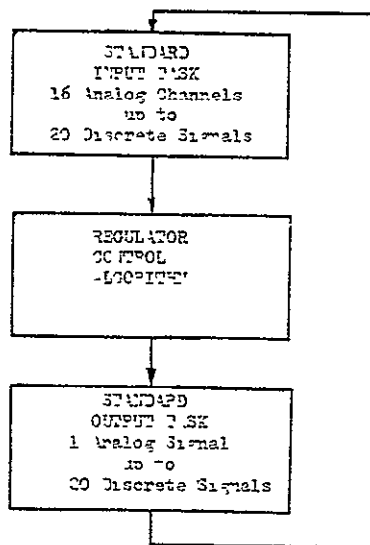


Figure 3.2.2 Functional overview of the Regulator Program

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manner, teleprinter operation does not impact system cycle time. The REGULATOR SOFTWARE SYSTEM consists of four packages: the EXECUTIVE (version 3), the REGULATION TASKS (version 4), the REGULATOR INTERRUPT AND TELE-PRINTER HANDLER (version 4), and the list of the REGULATOR INITIAL TASKS (version 4). Additional details exist in the REGULATOR/CHARGER PROGRAMMER'S REFERENCE MANUAL.

Figure 3.2.2 shows a functional overview of the regulator program. Each module is a task called into operation by the executive program. Not shown are tasks created to satisfy requests made by the user via the teleprinter. All inputs except those from the teleprinter are sampled by the input routine and all outputs except those to the teleprinter are updated by the output task. Not all the inputs/outputs are currently utilized by the hardware. Only those which impact the control of the P³ are detailed within this manual.

3.3 Signals

This section describes the abbreviations used as control parameters, input/output signals (relative to the program) and other terms used in the functional description of section 4. Table 3.3.1 details the control parameters, and Table 3.3.2 the input/output signals.

3.4 Control Algorithm

This section describes the operation of the PCI under control of the REGULATOR SOFTWARE SYSTEM from a macro view. Figure 3.4.1 depicts this operation.

The initialize section, sets the original control parameters (K1, K2, K3, DELTA, NDELTA, and TDLY), puts all I/O devices in a known state, and causes an identifying prompt character to be issued on the teleprinter. The prompt character for the regulator is a "greater than" symbol (>).

The actual control algorithm is repeated for as long as power exists to the system. POV (programmed output voltage) and FRS are the control

DELTA - Minimum Change in POV.
K1 - Initial POV at turn on.
K2 - Commanded output voltage.
K3 - Maximum IBR.
NDELTA - Jump back of POV for large IBRs.

Table 3.3.1. Control Parameters

FLR - Flag loss of regulation from P².
FRS - Flag regulator status to P².
IBR - Input current to battery reconditioning circuit.
OV - Output voltage measured.
POV - Programmed output voltage.
RS - Regulator status from user.

Table 3.3.2 I/O Signals

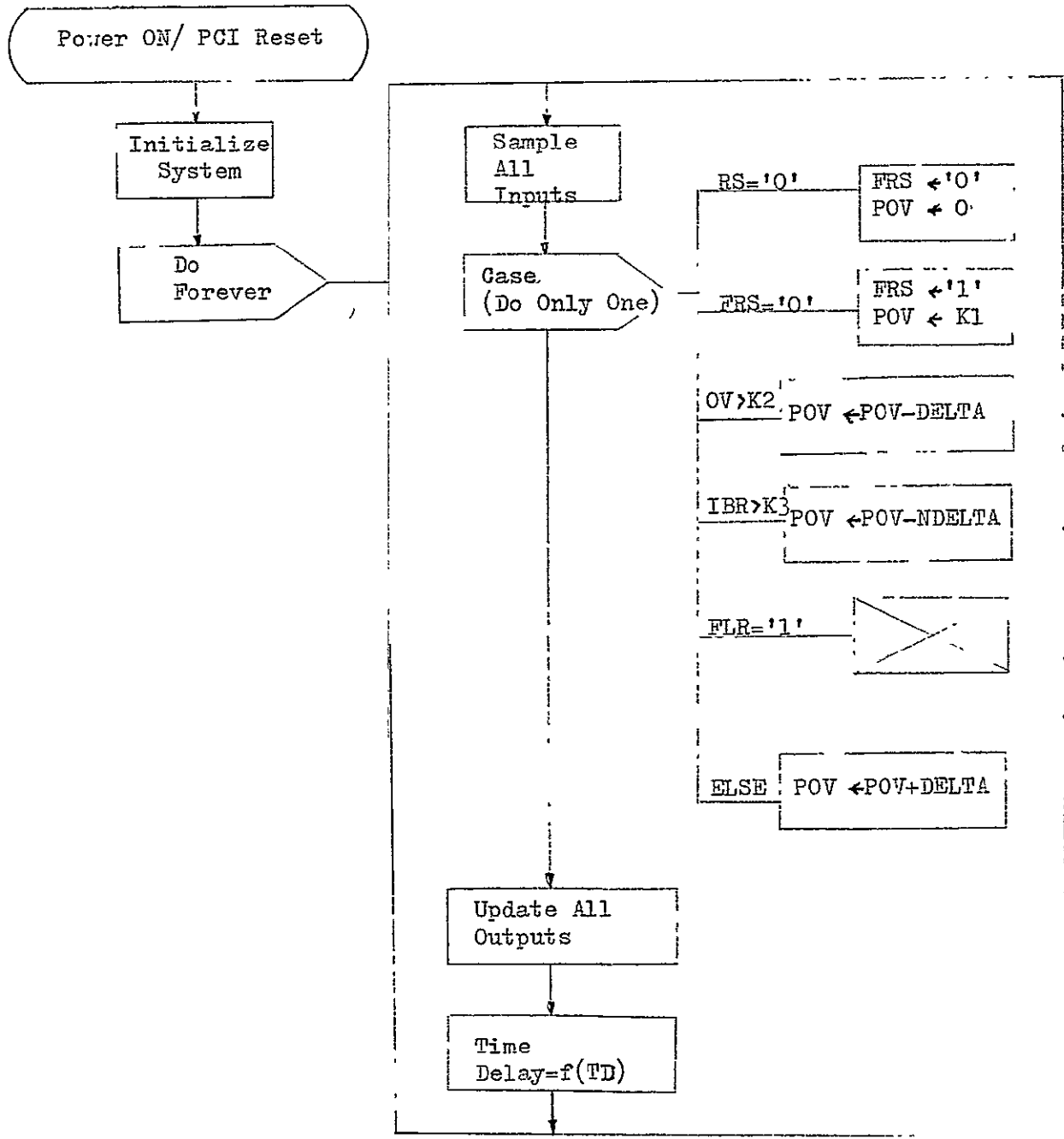


Figure 3.4.1 Regulator Software System Control of PCI

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outputs while RS, OV (actual output voltage) and FLR are the inputs. The other terms are various parameters modifiable by the user via the teleprinter.

The user should connect analog channel 0 to 0 volts at the source of all other analog voltages. The software subtracts the A/D value of channel 0 from the A/D value of all other sensed values. This removes the linear offset error of the Analog to Digital (A/D) convertor and the signal cables as well as reducing other sources of error from the analog channels. Refer to the preceding section for correspondence of channels to variables within the program.

3.5 Control Inputs

The two direct user inputs to the control algorithm are RS (regulator status) and RESET. The user may also affect operation by parameter modification as discussed in the next section.

RESET performs the same function as does power on. The software performs initialization and then goes back into the control algorithm. Note initial parameters are stored in ROM and commanding RESET sets all parameters to their initial values regardless of modifications previously made by the user via the teleprinter. The ROM must be changed in order to affect the initial values of the parameters.

RS is the usual ON/OFF command to the regulator. RS = '1' is equivalent to ON, and RS = '0' is the same as OFF. Note this affects only the output of the P^3 (a voltage) and does not imply power shutdown of the microcomputer or termination of the regulator program. Note that going from OFF to ON with RS does not destroy any parameter modifications made by the user.

3.6 Parameter modification and data acquisition

This section discusses the use of the teleprinter to modify the control parameters of the regulator and to display internal data of the program on the teleprinter.

3.6.1 General comments

Commands from the teleprinter are only accepted by the program when a prompt character ('>') is displayed on the teleprinter. All valid inputs are terminated by a carriage return (designated by ↵ in the examples) by the user. Commands are not analyzed for errors or action until this carriage return key is typed. After this carriage return, no more inputs from the teleprinter are accepted until another prompt character is issued.

If the user discovers an entry error prior to hitting the carriage return, all input (from the last prompt) may be deleted by typing U^c. This character is made by holding down the "CNTL" key and striking the "U" key. This keyin also terminates the input mode until a " U" and new prompt character are printed on the teleprinter.

When commands are terminated by a carriage return and if either an undefined command is requested or an improper argument given, the program will print a "?" and issue a new prompt character.

While equations discussed in this manual are in decimal, all numerical inputs and outputs from the program are in hexadecimal. Refer to the hexadecimal - decimal tables in the appendix for conversion.

3.6.2 Commands

The regulator software recognized three different commands from the teleprinter: display memory (D command), examine internal value or parameter (X command), and set an internal parameter to a new value (S command). In examples that follow, underlined portions are printed by the PCI while non-underlined portions represent user inputs. Set brackets { } enclose variable information dependent on desired operation and square brackets [] denote optional quantities.

3.6.2.1 D - Display command

This command is used to display a selected portion of the PCI's memory. This command is provided for obtaining diagnostic information about the PCI

system and is not generally useful in regulator operation. The form of this command is

$\underline{\geq} D$ [SPACE(S)] {START} {SEP} {STOP} [{SEP}]

where START represents a hexadecimal address at which to start displaying data (in bytes); {SEP} represents either a comma or at least one space; and {STOP} represents a hexadecimal address at which after displaying the data stored there, the command will be completed. In other words, data bytes from memory addresses {START} through {STOP} are displayed. Note if {STOP} is not greater than {START}, only the data at address {START} is displayed. The program expects 4 digit values and assumes leading zeros if less than 4 are entered. If more than 4 digits are entered, only the four least significant (last typed) digits are used. If any of the digits are not hexadecimal, or illegal characters are used for separators, or any character precedes D, an error results.

The D command results in the printing of the starting address for a line. Data from that address and up to 15 other bytes on that line are also printed. If the request is for more than 16 bytes multiple lines will be printed. The last byte on any display line other than the line which contains the byte from the {STOP} address is of the form XXXFH.

Examples:

```

>D 0,F
0000 31 00 20 CD CE 00 21 00 00 22 06 1C 22 08 1C CD
-----
>D F,0
000F CD
-----
>D XYZ
?
-----
>D 12340000,0022
0000 31 00 20 CD CE 00 21 00 00 22 06 1C 22 08 1C CD
0010 0A 01 C3 3B 00 C3 E6 01 C3 B9 01 C3 C1 01 00 00
0020 C3 9D 01
-----
> MD
?
-----
>

```

Table 3.6.1 (Page 1 of 4) Internal Values and Parameters

Two Character Code	Meaning	# Bits	Defining Equations
CHARACTER CODES NOT USED WITH S COMMAND			
C0	Analog Channel 0. System offset error used to correct other channels	12	Note 1
C1	Analog Channel 1. Suggested: Regulator Input Voltage.	12	
C2	Analog Channel 2. Suggested: Regulator Input Current	12	
C3	Analog Channel 3. Regulator Output Voltage (OV)	12	Note 2
C4	Analog Channel 4. Suggested: Regulator Output Current	12	
C5	Analog Channel 5. Unassigned	12	
C6	Analog Channel 6. Battery Reconditioning Current (IBR)	12	Note 3
C7	Analog Channel 7. Unassigned	12	
C8	Analog Channel 8. Unassigned	12	
C9	Analog Channel 9. Unassigned	12	
CA	Analog Channel 10. Unassigned	12	
CB	Analog Channel 11. Unassigned	12	
CC	Analog Channel 12. Unassigned	12	
CD	Analog Channel 13. Unassigned	12	
CE	Analog Channel 14. Unassigned	12	
CF	Analog Channel 15. Unassigned	12	

Table 3.6.1 (Page 2 of 4) Internal Values and Parameters

Two Character Code	Meaning	# Bits	Defining Equations
D1	Digital Byte 1	8	
	Bit 7 - Unassigned	1	
	Bit 6 - Unassigned	1	
	Bit 5 - Unassigned	1	
	Bit 4 - Unassigned	1	
	Bit 3 - Unassigned	1	
	Bit 2 - Unassigned	1	
	Bit 1 - Unassigned	1	
	Bit 0 - Unassigned	1	
D2	Digital Byte 2	8	
	Bit 7 - Unassigned	1	
	Bit 6 - Unassigned	1	
	Bit 5 - Unassigned	1	
	Bit 4 - Unassigned	1	
	Bit 3 - Unassigned	1	
	Bit 2 - Unassigned	1	
	Bit 1 - RS - Command In	1	Note 4
	Bit 0 - FLR - Input from P2	1	Note 5
D3	Digital Byte 3	8	
	Bit 7 Used as part of POV	1	
	Bit 6 Used as part of POV	1	

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Table 3.6.1 (Page 3 of 4) Internal Values and Parameters

Two Character Code	Meaning	# Bits	Defining Equations
D3	Bit 5 Used as part of POV	1	
	Bit 4 Used as part of POV	1	
	Bit 3 Unassigned	1	
	Bit 2 MODE	1	Note 6
	Bit 1 Timer Reset	1	Note 7
	Bit 0 FRS - Output to P2	1	Note 8
CHARACTER CODE CAN BE USED FOR S COMMAND			
DE	DELTA - Basic Hunt Increment	8	Note 9
K1	Start Up Voltage	16*	Note 9
K2	Desired Regulated Voltage	16*	Note 2
K3	Battery Reconditioning Trip Point	16*	Note 3
ND	NDELTA - Fast decrement amount when battery reconditioning current exceeds K3	16*	Note 9
TD	Time Delay Amount	16	Note 10

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* Setting these parameters to values greater than 4095 (0FFFH) will cause meaningless operation modes.

Note 1 $EV = \frac{\text{Internal Value (IV)}}{4096} \times 10 \text{ Volts}$

Note 2 $EV = \frac{IV}{4096} \times 150 \text{ Volts}$

Note 3 $EV = \frac{IV}{4096} \times 5 \text{ Amps}$

Note 4 "1" = P3 ON, "0" = P3 OFF

Note 5 "1" = Can't Regulate, "0" = Can Regulate

Note 6 "1" = AO is I, "0" = AO is V

Table 3.6.1 (Page 4 of 4) Internal Values and Parameters

Note 7 "1"= RESET, "0"= OPERATE

Note 8 "1"= ON, "0"= OFF

Note 9 $EV = \frac{IV}{4096} \times 200$ Volts

Note 10 $EV = 26$ micro-seconds + $\frac{(IV-1)}{65,536} \times 1.006$ seconds

3.6.2.2 X - Examine internal values and parameters.

This command is the one most commonly used to obtain regulator data on the teleprinter. The user merely gives two characters which correspond to the variable {VC} desired (see Table 3.6.1) and terminates the input:

> X [SPACE(S)] {VC}↵

Any number of spaces (including 0) may separate the X from the variable code and any number and type of characters may be between the two character {VC} and the carriage return. The only possible improper entry is an undefined two letter {VC} which would result in a "?" and new prompt.

The reader is referred to subsection 6.3 for information as to the meaning of the data received from an X command.

Examples:

> X TD↵
0001
> X ND↵
0020
> X C0↵
0003
> X TM↵
?
> X ABC^U
>

3.6.2.3 S - Set internal parameters.

This command is the only teleprinter command which can significantly effect the operation of the program. Various parameters may be changed (see the second column of Table 3.6.1.) causing various modifications of the control algorithm. Note by using this "set parameter approach" instead of a "set memory approach" many problems such as operator error and the need to know details of the memory allocations are reduced or eliminated. The command sets the specified parameter to a new value given in hexadecimal notation. Only some of the parameters displayable by the X command are modifiable by the S

command as shown in Table 3.6.1. The table also shows the bit resolution of the parameter. Only the last 4 digits entered are used, as with the D command, but setting the character codes K1, K2, and NO greater than 4095 (0FFFH) will cause meaningless operation modes. The form of the S command is

$\geq S$ [{SEP}] {VC} [{SEP}] {VALUE} [{SEP}] ←

As shown all {SEP} , space(s) or a comma, are optional. The {VC} is a two character code from Table 3.6.1 which is valid for the S command.

Restraints on {VALUE} have already been mentioned.

The command can be read "Set parameter {VC} to {VALUE} ". Errors in either {VC} or {VALUE} are handled as previously discussed.

Examples:

$\geq S$ TD 1FF ←
 $\geq S$ DE 1 ←
 $\geq S$ C0 ←
 ?
 \geq

3.6.3 Relating Internal and External values.

Internal values of the parameters are in hexadecimal value ranging from 0 to 2^N-1 where N is the number of bits in the number given for each parameter as shown in Table 3.6.1. Also shown in the table are equations relating this internal value to the external value. This external value for analog signals has some meaning at the PCI and P² interface and that is what the equation conveys. All signals regardless of actual range have been scaled from 0 to +10 volts.

The "settable" parameters are initialized by the regulator software when power is applied and when RESET is commanded. Table 3.6.2 lists the initial values in decimal, hexadecimal and external value format. The user of this manual can use this table for verifying his understanding of the conversion equations of Table 3.6.1.

Table 3.6.2

INITIAL VALUES OF "SETTABLE" PARAMETERS

TWO CHARACTER CODE	EXTERNAL VALUE	INTERNAL ---	
		DECIMAL	HEXADECIMAL
DE	0.049 Volts	1	1
K1	29.3 Volts	600	258
K2	29.3 Volts	800	320
K3	0.61 AMPS	500	1F4
ND	1.57 Volts	32	20
TD	26 Micro-sec	1	1

3.7 Operational Characteristics

It is difficult to provide accurate meaningful information on the regulator software since it is dependent on the configuration of the PCI and P² which are not part of this document. Approximate timing and other information is provided in this section in the hopes that the information will be of use to the regulator software user. The timing information was obtained on the MSFC EC-12 breadboard PCI with an 8080-based microcomputer with a 500 NS cycle time and two wait states for each memory or I/O access. The times were measured by address tracing using an HP 1610 and its internal time base.

Table 3.7.1 shows various system timings. The times shown are only approximate. The overhead of the executive varies somewhat depending on which of the various functions it must do between tasks. The average overhead accounts for approximately 15% of the system cycle time. The major contributor to system cycle time is task 3 (sample all inputs) which accounts for about 80% of the system cycle. Note that the normal system consists of tasks 3, 4, 5 and 6: sample inputs, compute outputs, update outputs, and time delay. The other tasks are involved in initialization or are inserted to satisfy user requests from the teleprinter. For additional details see the programmer's reference manual.

Table 3.7.1 Regulator Software Timing

Routine or Task	Approximate Run Time (See text for details)
Executive Initialization	7 MS
Regulator Initialization	.5 MS
Issue Prompt Task* (Task 2)	.6 MS
Sample all inputs (Task 3)	6 MS
Control Algorithm (Task 4)	.6 MS (less when RS = 0)
Update all outputs (Task 5)	.07 MS
Time Delay (Task 6)	.03 - 1000 MS
Display Task*	6 MS/line of display ⁺
Examine Task*	3 MS
Set Parameter Task*	2 MS
Overhead of Executive (average)	.3 MS/Task
System cycle time	7.5 - 1000 MS (dependent on Time delay)
Time from output to sample CHL3	2 MS - 1000 MS

* These tasks merely take an entire input stream and compute an output stream. Actual character by character I/O occurs on an interrupt basis and does not significantly effect system cycle time. Only the update task (5) or the time delay task (6) with TD very small would notice any significant execution time difference.

+ This task computes a line, then returns control to the executive (and other tasks) until the line is output via interrupt driven I/O and then the task computes a new line if necessary. Therefore, the effect of this task on system cycle time is never greater than about 6 MS.

The time delay task was inserted late in the development process when it became apparent that the P² took a great deal of time (approximate 5 MS) to execute a voltage change command from the regulator software. Table 3.7.2 shows delay from output voltage command (POV) to sampling of analog channel 3 which is the sampled output voltage. These times were obtained in the same manner as were those in Table 3.7.1. Note that these times do not represent the execution of the delay task (6) for various values of TD but rather that time plus one task's worth of executive overhead plus 2 channels worth of analog signal sampling. MSFC anticipates using a total delay of about 10 MS which would mean a system cycle time of about 15 MS and the executive would be in use about 8% of the time.

Table 3.7.3 summarized the memory requirements the program places on the PCI and Figure 3.7.1 and Table 3.7.4 show how the software is spread out in the MSFC hardware. The modules are physically apart to allow for further developments to be incorporated with minimum restructuring of the layout.

3.8 Normal Operating Procedure

First, set up all PCI (with Regulator PROMs) and P² hardware as described in appropriate MSFC EC-12 documentation. Power up P³ system, observe a prompt character (' > ') displayed on the teleprinter. If no character is displayed, hit RESET switch. If still no characters are printed, a hardware problem exists. If characters are printed but not the correct prompt, verify that the teleprinter and PCI are set to the same baud rate and that the regulator (not the charger) software PROMs are installed. When it is desired to begin regulation place RS to a logical "1". At any time after the prompt character is displayed, the user may modify the parameters as described in section 6.

HEXADECIMAL

0000	EXECUTIVE Program
01FF 0200	REGULATOR Task Program
03FF	Unused ROM REGULATOR Expansion
0700	Initial Task List
0720	Unused ROM Task List Expansion
0800	INTERRUPT HANDLER And TELEPRINTER Command Handler
0BFF 0C00	Unused ROM External communication Expansion
0FFF 100D	Undesignated
1BFF 1C00	EXECUTIVE Data Space
1D35 1D36	REGULATOR Data Space
1D65 1D66	Unused RAM REGULATOR Expansion
1DFF 1E00	INTERRUPT And TELEPRINTER HANDLER Data Space
1E49 1E50	Unused RAM Handler/ Stack Expansion
1F80	Stack Space
1FFF 2000	Undesignated
FFFF	Undesignated

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Figure 3.7.1 PCI Memory Map with Regulator Software Installed.

Table 3.7.2 Time delay between output of POV to sample of C3 for various values of TD.

TD (Hexadecimal values)	DELAY
1	2 MS
88	4 MS
18D	8 MS
210	10 MS
396	16 MS
1900	100 MS

Table 3.7.3 Approximate Memory Requirements of various modules of the Regulator Program

MODULE	ROM	RWM
EXECUTIVE	504 bytes	309 bytes*
REGULATOR TASKS	510 bytes	50 bytes
REGULATOR INTERRUPT HANDLER	900 bytes	80 bytes
Regulator Initialization Table	25 bytes	0
STACK SPACE	—	> 250 bytes

*Allows 50 Tasks to exist simultaneously.

Table 3.7.4 REGULATOR ROM UTILIZATION

ROM SOCKET	USED	ADDRESS RANGE (Hexadecimal)	MODULE
0	X	0000-00FF	Executive
1	X	0100-01FF	Executive
2	X	0200-02FF	Regulator
3	X	0300-03FF	Regulator
4		0400-04FF	
5		0500-05FF	
6		0600-06FF	
7	X	0700-07FF	Initial Task Table List
8	X	0800-08FF	RI&T Handler *
9	X	0900-09FF	RI&T Handler
A	X	0A00-0AFF	RI&T Handler
B	X	0B00-0BFF	RI&T Handler
C		0C00-0CFF	
D		0D00-0DFF	
E		0E00-0EFF	
F		0F00-0FFF	

* Regulator Interrupt and Teleprinter Handler.

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USER'S MANUAL FOR THE CHARGER PROGRAM

4.1 Scope

This manual is intended to detail the use of the CHARGER SOFTWARE SYSTEM. Descriptions within this manual relate to the operational software and user inputs which turn the charger on, reset the software, and examine and/or modify internal parameters. Also included are an overview of the program control flow, definitions of signals utilized by the software, and operational characteristics of the program when run on the present (August 1978) MSFC Programmable Control Interface (PCI).

This manual is not intended as documentation of the PCI hardware (see appropriate MSFC documentation), or of the CHARGER program's internal structure or operation. A separate manual exists to detail the program's internal structure.

All supplied documentation assumes that the program is installed in Read-Only Memory (ROM) in a hardware configuration identical to the present (August 1978) NASA MSFC EC-12 PCI system.

4.2 Overview

The CHARGER SOFTWARE SYSTEM is intended to be used in Programmable Power Processor (P³) hardware to cause the standard hardware to function as a charger (see Figure 4.2.1). The software located in ROM performs necessary configuration actions, participates in control in a closed loop network, and provides a mechanism for local or remote modification of control parameters.

The charger software is modularized into modules called tasks. An executive program causes each task to be performed in the proper sequence and allows new tasks (modification or data display) to be performed. To minimize the impact of the relatively slow input/output (I/O) via the external

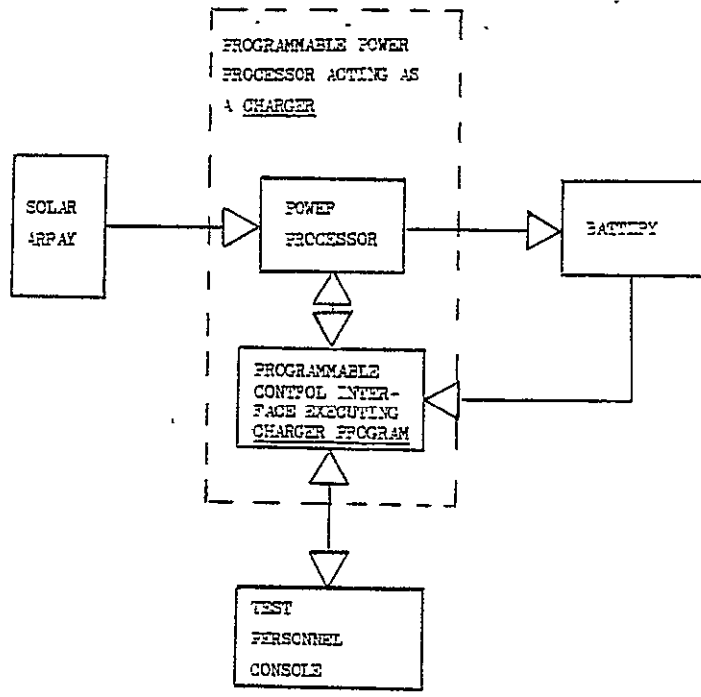
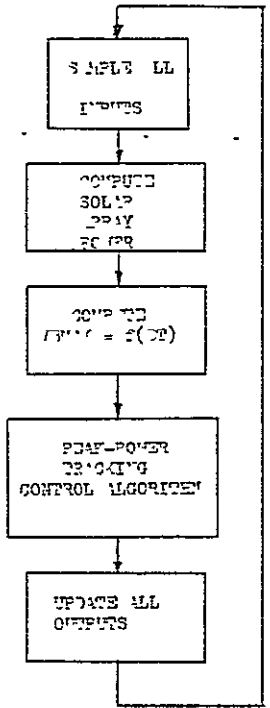


Figure 4.2.1 Functional view of the programmable power processor in a Charger environment



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Figure 4.2.2 Functional overview of the Charger program.

teleprinter, character by character communication between the PCI and the teleprinter is handled on an interrupt basis by the charger software. In this manner, teleprinter operation does not impact system cycle time. The CHARGER SOFTWARE SYSTEM consists of four packages: the EXECUTIVE (version 3), the CHARGER TASKS (version 4), the CHARGER INTERRUPT AND TELEPRINTER HANDLER (version 4), and the list of the CHARGER INITIAL TASKS (version 4). Additional details exist in the REGULATOR/CHARGER PROGRAMMER'S MANUAL.

Figure 4.2.2 shows a functional overview of the charger program. Each module is a task called into operation by the executive program. Not shown are tasks created to satisfy requests made by the user via the teleprinter. All inputs except those from the teleprinter are sampled by the input routine and all outputs except those to the teleprinter are updated by the output task. Note that there is a task inserted by interrupt from the real time clock that keeps track of the condition of battery charge. Not all the inputs/outputs are currently utilized by the hardware. Only those which impact the control of the P³ are detailed within this manual.

4.3 Signals

This section describes the abbreviations used as control parameters, input/output signals (relative to the program) and other terms used in the functional description of Section 4. Table 4.3.1 details the control parameters, and Table 4.3.2 the input/output signals, and Table 4.3.3 the internal parameters.

4.4 Control Algorithm

This section describes the operation of the PCI under control of the CHARGER SOFTWARE SYSTEM from a macro view. Figure 4.4.1 depicts this operation.

The initialize section, sets the original control parameters (AHC, BIMAX, BIT, BVCOUNT, BVMAX, DELTA, NDELTA, ISS, K1, K2, K5, K7, N1, PWR,

BIMAX	- Maximum battery current.
BIT	- Battery current trip point.
BVCOUNT	- Number of major cycles between BVMAX calculations. (0 - No change from present value).
DELTA	- Hunt increment.
K1	- Maximum battery voltage at -20°C.
K2	- Temperature derating of K1.
K5	- Recharge fraction (efficiency).
K7	- Depth of discharge before allowing full charge rate.
NDELTA	- Collapsed array jump back.
N1	- Number of major cycles FSS must be the same.

Table 4.3.1 Control Parameters

BI	- Battery current.
BT	- Battery temperature.
BV	- Battery voltage.
CS	- Charger status from user.
FCA	- Flag collapsed array from P ² .
FCS	- Flag charger status to P ² .
FSS	- Flag sunset from P ² .
PSAI	- Programmed solar array current.
SAI	- Measured solar array current.
SAV	- Measured solar array voltage.

Table 4.3.2 I/O signals

AHC	- Amp hour charge of battery (0 = fully charged).
BVMAX	- Maximum battery voltage computed as function of BT.
FHP	- Flag hunt polarity.
FPD	- Flag power derivative.
FRC1	- Flag recharge complete 1.
FRC2	- Flag recharge complete 2.
ISS	- Index of number of cycles FSS is 1.
PWR	- Power of present cycle.
PWRL	- Power last cycle.

Table 4.3.3 Internal Parameters

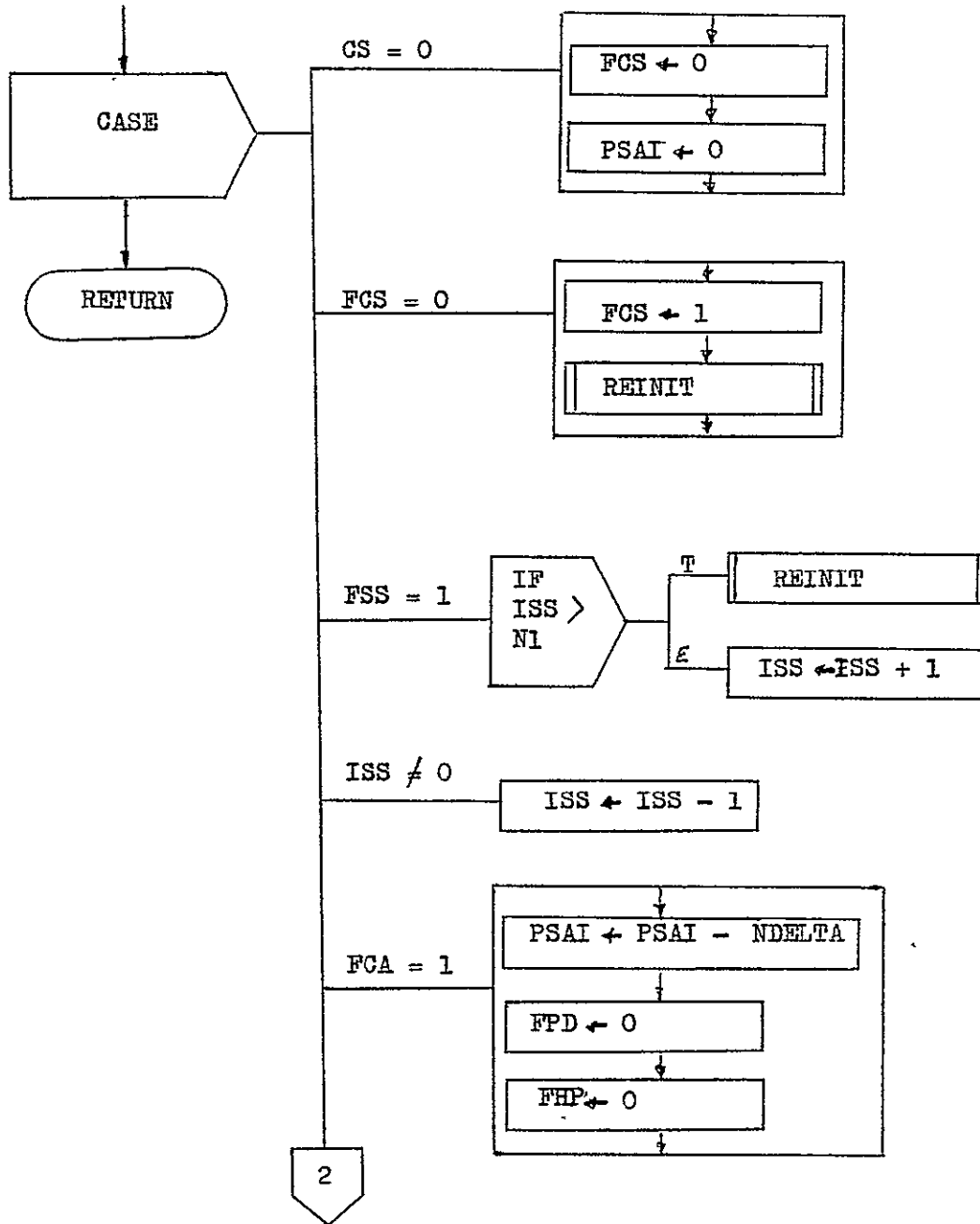


Figure 4.4.1 (1 of 4) Algorithm Task

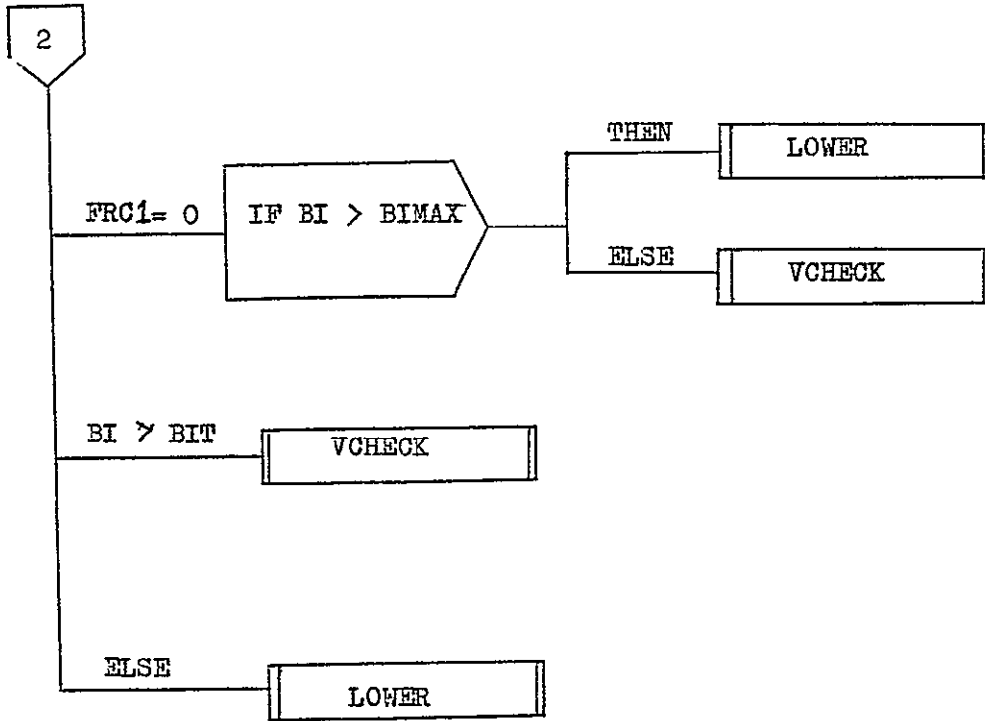


Figure 4.4.1 (2 of 4) Algorithm Task

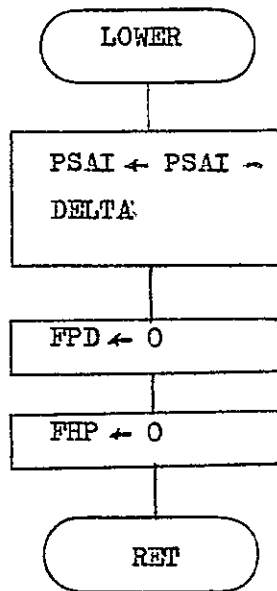
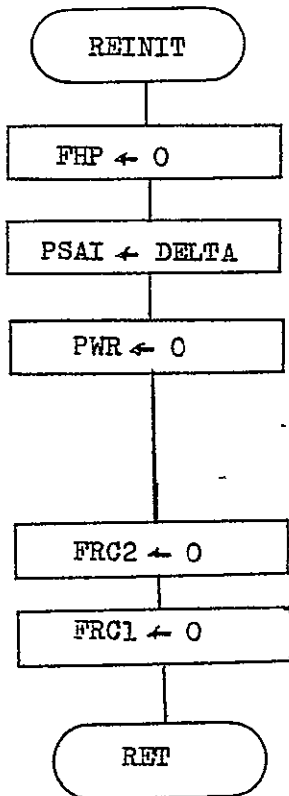
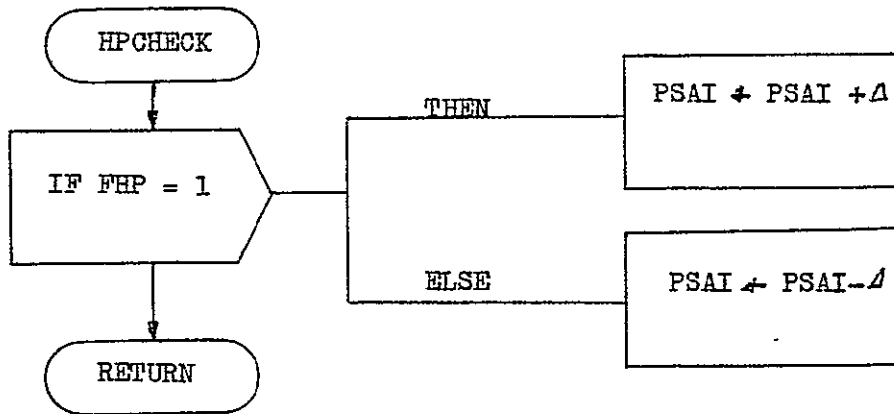


Figure 4.4.1 (3 of 4) Algorithm Task

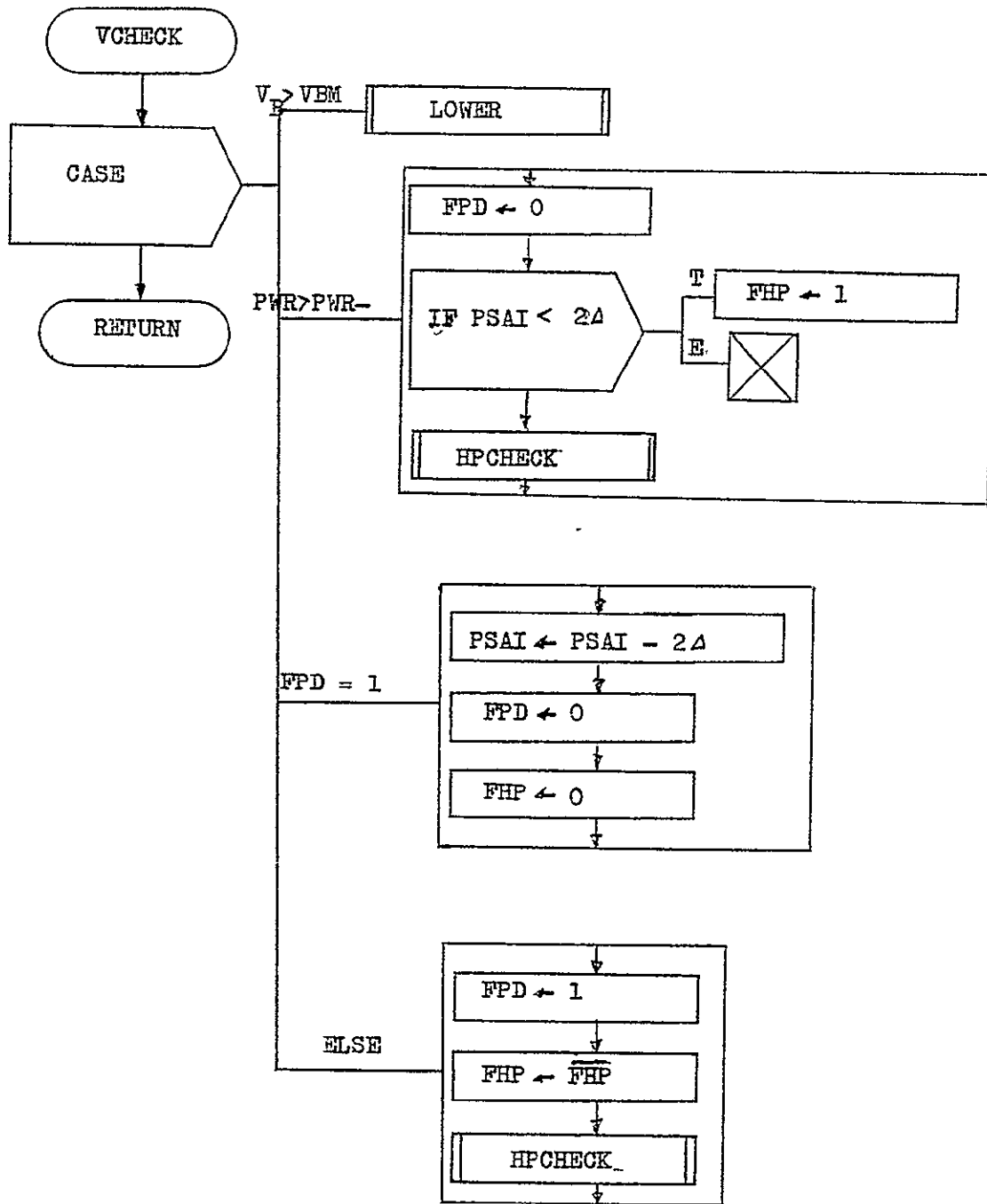


Figure 4.4.1 (4 of 4) Algorithm Task

and TDLY), puts all I/O devices in a known state, and causes an identifying prompt character to be issued on the teleprinter. The prompt character for the charger is an asterisk symbol (*).

The actual control algorithm is repeated for as long as power exists to the system. PSAI (programmed solar array current) and FCS are the control outputs while CS, FCA, FSS, SAI, SAV, BV, BI, and BT are the inputs. The other terms are internal variables and various parameters modifiable by the user via the teleprinter. The TASK which computes the power (PWR) executes once per system cycle while the TASK which computes the maximum battery voltage (BVMAX) as a function of battery temperature (BT) only is executed every BVCOUNT system cycles.

Figure 4.4.2 shows the interrupt driven TASK which keeps up with the battery charge condition. This TASK is placed in the TASK list for execution approximately once per second. This TASK also controls when to go to/from normal charge from/to trickle charge. Incorporated into the algorithm is a parameter which accounts for a battery's recharge efficiency.

The user should connect analog channel 0 to 0 volts at the source of all other analog voltages. The software subtracts the A/D value of channel 0 from the A/D value of all other sensed values. This removes the linear offset error of the Analog to Digital (A/D) convertor and the signal cables as well as reducing other sources of error from the analog channels. Refer to the preceding section for correspondence of channels to variables within the program.

4.5 Control Inputs

The two direct user inputs to the control algorithm are CS (charges status) and RESET. The user may also affect operation by parameter modification as discussed in the next section.

RESET performs the same function as does power on. The software performs initialization and then goes back into the control algorithm. Note initial parameters are stored in ROM and commanding RESET sets all

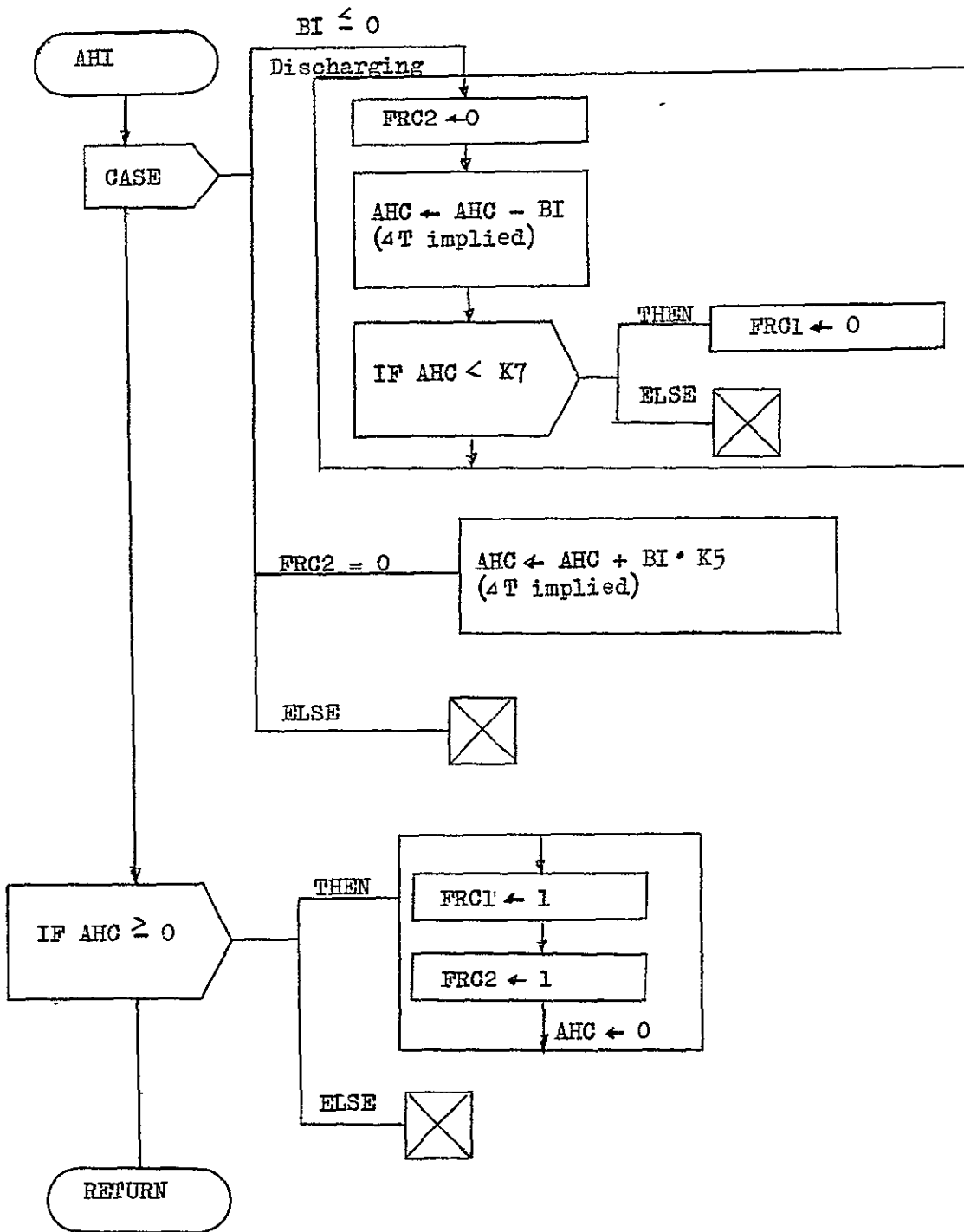


Figure 4.4.2 AMP Hour Integration Task

parameters to their initial values regardless of modifications previously made by the user via the teleprinter. The ROM must be changed in order to affect the initial values of the parameters.

CS is the usual ON/OFF command to the charger. CS = '1' is equivalent to ON, and CS = '0' is the same as OFF. Note this affects only the input of the P³ (a current) and does not imply power shutdown of the microcomputer or termination of the charger program. Note that going from OFF to ON with CS does not destroy any parameter modifications made by the user.

4.6 Parameter modification and data acquisition

This section discusses the use of the teleprinter to modify the control parameters of the charger and to display internal data of the program on the teleprinter.

4.6.1 General comments

Commands from the teleprinter are only accepted by the program when a prompt character ('*') is displayed on the teleprinter. All valid inputs are terminated by a carriage return (designated by ↵ in the examples) by the user. Commands are not analyzed for errors or action until this carriage return key is typed. After this carriage return, no more inputs from the teleprinter are accepted until another prompt character is issued.

If the user discovers an entry error prior to hitting the carriage return, all input (from the last prompt) may be deleted by typing U^C. This character is made by holding down the "CNTL" key and striking the "U" key. This keyin also terminates the input mode until a "↑U" and new prompt character are printed on the teleprinter.

When commands are terminated by a carriage return and if either an undefined command is requested or an improper argument given, the program will print a "?" and issue a new prompt character.

While equations discussed in this manual are in decimal, all numerical inputs and outputs from the program are in hexadecimal. Refer to the hexadecimal - decimal tables in the appendix for conversion.

4.6.2 Commands

The command software recognizes three different commands from the teleprinter: display memory (D command), examine internal value or parameter (X command), and set an internal parameter to a new value (S command). In examples that follow, underlined portions are printed by the PCI while non-underlined portions represent user inputs. Set brackets $\{ \}$ enclose variable information dependent on desired operation and square brackets $[]$ denote optional quantities.

4.6.2.1 D - Display command

This command is used to display a selected portion of the PCI's memory. This command is provided for obtaining diagnostic information about the PCI system and is not generally useful in charger operation. The form of this command is

* D [SPACE(S)] $\{ \text{START} \}$ $\{ \text{SEP} \}$ $\{ \text{STOP} \}$ [$\{ \text{SEP} \}$]

where $\{ \text{START} \}$ represents a hexadecimal address at which to start displaying data (in bytes); $\{ \text{SEP} \}$ represents either a comma or at least one space; and $\{ \text{STOP} \}$ represents a hexadecimal address at which after displaying the data stored there, the command will be completed. In other words, data bytes from memory addresses $\{ \text{START} \}$ through $\{ \text{STOP} \}$ are displayed. Note if $\{ \text{STOP} \}$ is not greater than $\{ \text{START} \}$, only the data at address $\{ \text{START} \}$ is displayed. The program expects 4 digit values and assumes leading zeros if less than 4 are entered. If more than 4 digits are entered, only the four least significant (last typed) digits are used. If any of the digits are not hexadecimal, or illegal characters are used for separators, or any character precedes D an error results.

The D command results in printing of starting address for a line, the data from that address and up to 15 other bytes on that line. If the request is larger than this, multiple lines will be printed. The last byte on any display line other than the line which contains the byte from the {STOP} address is of the form XXXFH.

Examples:

```
* D 0,F ✓
0000 31 00 20 CD CE 00 21 00 00 22 06 1C 22 08 1C CD
-----
* D F,0 ✓
000F CD
-----
* D XYZ ✓
?
-----
* D 12340000,0022 ✓
0000 31 00 20 CD CE 00 21 00 00 22 06 1C 22 08 1C CD
0010 0A 01 C3 3B 00 C3 E6 01 C3 B9 01 C3 C1 01 00 00
0020 C3 9D 01
-----
* MD
?
-----
```

4.6.2.2 X - Examine internal values and parameters.

This command is the one most commonly used to obtain regulator data on the teleprinter. The user merely gives two characters which correspond to the variable {VC} desired (see Table 4.6.1) and terminates the input:

```
* X [ {SPACE(S)} ] {VC} ✓
```

Any number of spaces (including 0) may separate the X from the variable code and any number and type of characters may be between the two character {VC} and the carriage return. The only possible improper entry is an undefined two letter {VC} which would result in a "?" and new prompt.

The reader is referred to subsection 6.3 for information as to the meaning of the data received from an X command.

Examples:

```
* X TD ✓
0001
-----
* X ND ✓
0020
-----
* X C0 ✓
0003
-----
* X TM ✓
?
-----
* X ABC ^U
```

Table 4.6.1 (Page 1 of 4) Internal Values and Parameters

Two Character Code	Meaning	# Bits	Defining Equations
CHARACTER CODES NOT USED WITH S COMMAND			
AH	Amp-hour charge taken from battery	32	Note 1
C0	Analog Channel 0. System offset error used to correct other channels	12	Note 2
C1	Analog Channel 1. Solar Array Voltage (SAV)	12	Note 3
C2	Analog Channel 2. Solar Array current (SAI)	12	Note 4
C3	Analog Channel 3. Battery Voltage (BV)	12	Note 5
C4	Analog Channel 4. Battery Current (BI)	12	Note 6
C5	Analog Channel 5. Battery temperature	12	Note 7
C6	Analog Channel 6. Unassigned	12	
C7	Analog Channel 7. Unassigned	12	
C8	Analog Channel 8. Unassigned	12	
C9	Analog Channel 9. Unassigned	12	
CA	Analog Channel 10. Unassigned	12	
CB	Analog Channel 11. Unassigned	12	
CC	Analog Channel 12. Unassigned	12	
CD	Analog Channel 13. Unassigned	12	
CE	Analog Channel 14. Unassigned	12	
CF	Analog Channel 15. Unassigned	12	
D1	Digital Byte 1	8	
	Bit 7 - Unassigned	1	
	Bit 6 - Unassigned	1	
	Bit 5 - Unassigned	1	
	Bit 4 - Unassigned	1	
	Bit 3 - Unassigned	1	
	Bit 2 - Unassigned	1	
	Bit 1 - Unassigned	1	
	Bit 0 - Unassigned	1	

Table 4.6.1 (Page 2 of 4) Internal Values and Parameters

Two Character Code	Meaning	# Bits	Defining Equations
D2	Digital Byte 2	8	
	Bit 7 - Unassigned	1	
	Bit 6 - Unassigned	1	
	Bit 5 - Unassigned	1	
	Bit 4 - Unassigned	1	
	Bit 3 - Unassigned	1	
	Bit 2 - FCA-Input from P ² (Collapsed Array)	1	Note 8
	Bit 1 - CS - Command In	1	Note 9
	Bit 0 - FSS - Input from P ² (sunset)	1	Note 10
D3	Digital Byte 3	8	
	Bit 7 Used as part of PSAI	1	
	Bit 6 Used as part of PSAI	1	
	Bit 5 Used as part of PSAI	1	
	Bit 4 Used as part of PSAI	1	
	Bit 3 Unassigned	1	
	Bit 2 MODE	1	Note 11
	Bit 1 Timer Reset	1	Note 12
Bit 0 FCS - Output to P ²	1	Note 9	
D5	Digital Byte 5	8	
	Bit 7 Unassigned	1	
	Bit 6 Unassigned	1	
	Bit 5 Unassigned	1	
	Bit 4 Unassigned	1	
	Bit 3 FRC2 - Recharge Flag 2	1	Note 13
	Bit 2 FRC1 - Recharge Flag 1	1	Note 14
	Bit 1 FHP - Hunt polarity	1	Note 15
	Bit 0 FPD - Power derivative	1	Note 16
K7	High Charge Rate Trip Point (MSBs called 7H and LSBs called 7L for S command)	32	Note 1

Table 4.6.1 (Page 3 of 4) Internal Values and Parameters

Two Character Code	Meaning	# Bits	Defining Equations
PI	Programmed current (same as PSAI)	12	Note 4
PL	Power last cycle (same as PWRL)	12	Note 17
PW	Power this cycle (same as PWR)	12	Note 17

CHARACTER CODE CAN BE USED FOR S COMMAND

DE	DELTA - Basic Hunt Increment	8	Note 4
K1	Maximum battery voltage at -20°C	16*	Note 5
K2	Derating factor of maximum battery voltage	16*	Note 18
K5	Recharge efficiency	16*	Note 19
ND	NDELTA - Fast decrement when array collapses	16*	Note 4
N1	Number of cycles FSS should be true before charging attempted	16	Note 20
TD	Time delay amount	16	Note 21
VM	Present maximum battery voltage	16*	Note 5
VC	Count for compute VBMAX task	16	Note 20
7H	MSBs of K7	16	Note 1
7L	LSBs of K7	16	Note 1

*Setting these parameters to values greater than 4095 (OFFFH) will cause meaningless operation modes.

Note 1 External Value (EV) = $\frac{-\text{Internal Value (IV)}}{2^{32}} \times 105 \times 10^6 \text{ Amp SECS}$

Note 2 EV = $\frac{\text{IV}}{4096} \times 10 \text{ Volts}$

Note 3 EV = $\frac{\text{IV}}{4096} \times 400 \text{ Volts}$

Note 4 EV = $\frac{\text{IV}}{4096} \times 40 \text{ Amps}$

Note 5 EV = $\frac{\text{IV}}{4096} \times 200 \text{ Volts}$

Table 4.6.1 (Page 4 of 4) Internal Values and Parameters

Note 6 $EV = \frac{IV-2048}{4096} \times 50 \text{ Amps}$

Note 7 $EV = \frac{IV}{4096} \times 60 - 20 \text{ }^\circ\text{C}$

Note 8 "1" - Collapsed, "0" - Not collapsed

Note 9 "1" - On, "0" - Off

Note 10 "1" - Sunset, "0" - Not sunset

Note 11 "1" - AO is I, "0" - AO is V

Note 12 "1" - reset, "0" - arm

Note 13 "1" - Don't change AHC, "0" - Change AHC as charging continues

Note 14 "1" - Trickle charge, "0" - full charge rate

Note 15 "1" - Increment PSAI, "0" - Decrement PSAI

Note 16 "1" - "1" - Last change caused power increase, "0" - Last change caused power decrease

Note 17 $EV = \frac{IV}{4096} \times 16000 \text{ Watts}$

Note 18 $EV = \frac{IV}{1227} \text{ Volt}/^\circ\text{C}$

Note 19 $EV = \frac{IV}{4096} \%$

Note 20 $EV = IV \text{ cycles}$

Note 21 $EV = 26 \text{ microseconds} + \frac{(IV-1)}{65,536} \times 1.006 \text{ seconds}$

4.6.2.3 S - Set internal parameters.

This command is the only teleprinter command which can significantly effect the operation of the program. Various parameters may be changed (see the second column of Table 4.6.1) causing various modifications of the control algorithm. Note by using this "set parameter approach" instead of a "set memory approach" many problems such as operator error and the need to know details of the memory allocations are reduced or eliminated. The command sets the specified parameter to a new value given in hexadecimal notation. Only some of the parameters displayable by the X command are modifiable by the S command as shown in Table 4.6.1. The table also shows the number of bits of resolution of the parameter. Only the last 4 digits entered are used, as with the D command, but setting the character codes K1, K2, and NO greater than 4095 (0FFFH) will cause meaningless operation modes. The form of the S command is

*S [{SEP}] {VC} [{SEP}] {VALUE} [{SEP}]

As shown all {SEP}, space(s) or a comma, are optional. The {VC} is a two character code from Table 4.6.1 for which the S command is valid.

The command can be read "Set parameter {VC} to {VALUE}". Errors in either {VC} or {VALUE} are handled as previously discussed.

Examples:

```
*S TD 1FF  
*S DE 1  
*S C0  
?  
-
```

4.6.3 Relating Internal and External values.

Internal values of the parameters are in hexadecimal value ranging from 0 to $2^N - 1$ where N is the number of bits in the number given for each parameter as shown in Table 4.6.1. Also shown in the table are equations relating this internal value to the external value. This external value for analog signals has some meaning at the PCI and P^2 interface and that is what the equation conveys.

All signals regardless of actual range have been scaled from 0 to +10 volts.

The "settable" parameters are initialized by the regulator software when power is applied and when RESET is commanded. Table 4.6.2 lists the initial values in decimal, hexadecimal and external value format. The user of this manual can use this table for verifying his understanding of the conversion equations of Table 4.6.1.

4.7 Operational Characteristics

It is difficult to provide accurate meaningful information on the charger software as it is dependent on the configuration of the PCI and P² which are not part of this document. Approximate timing and other information is provided in this section in the hopes that the information will be of use to the charger software user. The timing information was obtained on the MSFC EC-12 breadboard PCI with an 8080-based microcomputer with a 500 NS cycle time and two wait states for each memory or I/O access. The times were measured by address tracing using an HP 1610 and its internal time base.

Table 4.6.1 shows various system timings. The times shown are only approximate. The overhead of the executive varies somewhat depending on which of the various functions it must do between tasks. The average overhead accounts for approximately 11% of the system cycle time (TD=1). The major contributors to system cycle time are TASK 3 (input all signals) and TASK 4 (compute power of the solar array), and TASK 6 (control), which together account for 40% of a normal system cycle. Note that the normal cycle consists of TASKS 3, 4, 6, 7, and 8: sample inputs, compute solar array power, compute BVMAX (done only every BVCOUNT cycles), control calculation, update outputs, and time delay. Every second the AHC TASK is performed causing a slightly longer system cycle to occur approximately 1 out of 90 times. The other tasks are involved in initialization or are inserted to satisfy user requests from the teleprinter. For additional information see the programmer's reference manual.

Table 4.6.2

INITIAL VALUES OF "SETTABLE" PARAMETERS

TWO CHARACTER CODE	EXTERNAL VALUE	INTERNAL DECIMAL	INTERNAL --- HEXADECIMAL
DE	.01 Amp	1	1
IM	40 Amps	3686	0E66
IS	0	0	0
IT	40 Amps	3686	0E66
K1	175 Volts	3581	DFD
K2	1 Volt/°C	1227	4CB
K5	80%	3274	CCA
ND	.31 Amps	32	20
N1	30 cycles	30	1E
VM	100 Volts	2048	800
VC	Use present value	0	0 ⁺
7H	200 Amp SEC	-4000	FFFF
7L	200 Amp SEC	-4000	F060
TD	26 US	1	1

⁺ Present value initially comes from PROM7 which calls for 10 system cycles per calculation of BVMAX.

Table 4.6.2 shows the delay from commanded PSAI to sampling of analog channel 1. These times were obtained in the same manner as were those in Table 4.7.1. Note that these times do not represent the execution of the delay task (8) for various values of TD but rather that time plus one task's worth of executive overhead plus 1 channel's worth of analog signal sampling. MSFC anticipates using a total delay of about 10 MS which would mean a system cycle time of about 19.5MS and the executive would be in use about 6% of the time.

Table 4.7.3 summarized the memory requirements the program places on the PCI and Figure 4.7.1 and Table 4.7.4 show how the software is spread out in the MSFC hardware. The modules are physically apart to allow for further developments to be incorporated with minimum restructuring of the layout.

4.8 Normal Operating Procedure

First, set up all PCI (with Charger PROMs) and P² hardware as described in appropriate MSFC EC-12 documentation. Power up P³ system, observe a prompt character ('*') displayed on the teleprinter. If no character is displayed, hit RESET switch. If still no characters are printed, a hardware problem exists. If characters are printed but not the correct prompt, verify that the teleprinter and PCI are set to the same baud rate and that the charger (not the regulator) software PROMs are installed. When it is desired to begin regulation, place CS to a logical "1". At any time after the prompt character is displayed, the user may modify the parameters as described in Section 6.

Table 4.7.1 Charger Software Timing

Routine or Task	Approximate Run Time (See text for details)
Executive Initialization	7 MS
Charger Initialization (TASK 1)	.6 MS
Issue Prompt Task* (TASK 2)	.6 MS
Sample all inputs (TASK 3)	6 MS
Power computation (TASK 4)	1.5 MS
Maximum Battery voltage computation (TASK 5)	1.5 MS
Control Algorithm (TASK 6)	1 MS (less when CS = 0)
Update all outputs (TASK 7)	.07 MS
Time Delay (TASK 8)	.03 - 1000 MS
Amp-hour Computation TASK	1.6 MS
Display Task*	6 MS/line of display +
Examine Task*	3 MS
Set Parameter Task*	2 MS
Overhead of Executive (average)	.3 MS/Task
System cycle time	11 - 1000 MS (dependent on Time de
Time from output to sample CHL1	1 - 1000 MS

* These tasks merely take an entire input stream and compute an output stream. Actual character by character I/O occurs on an interrupt basis and does not significantly effect system cycle time. Only the update task (7) or the time delay task (8) with TD very small would notice any significant time difference.

+ This task computes a line, then returns control to the executive (and other tasks) until the line is output via interrupt driven I/O and then the task computes a new line if necessary. Therefore, the effect of this task on system cycle time is never greater than about 6 MS.

Table 4.7.2 Time delay between output of PSAI to sample of C1 for various values of TD.

TD (Hexadecimal values)	DELAY
1	1.1 MS
38	2 MS
C0	4 MS
1BF	8 MS
241	10 MS
3C8	16 MS
1927	100 MS

Table 4.7.3 Approximate Memory Requirements of various modules of the Charger Program

MODULE	ROM	RWM
EXECUTIVE	504 bytes	309 bytes*
CHARGER TASKS	1200 bytes	80 bytes
CHARGER INTERRUPT HANDLER	1000 bytes	80 bytes
CHARGER Initialization Table	32 bytes	0
STACK SPACE	-	> 250 bytes

*Allows 50 Tasks to exist simultaneously.

Table 4.7.4 CHARGER ROM UTILIZATION

ROM SOCKET	USED	ADDRESS RANGE (Hexadecimal)	MODULE
0	X	0000-00FF	Executive
1	X	0100-01FF	Executive
2	X	0200-02FF	Charger
3	X	0300-03FF	Charger
4	X	0400-04FF	Charger
5	X	0500-05FF	Charger
6	X	0600-06FF	Charger
7	X	0700-07FF	Initial Task Table List
8	X	0800-08FF	CI&T Handler*
9	X	0900-09FF	CI&T Handler
A	X	0A00-0AFF	CI&T Handler
B	X	0B00-0BFF	CI&T Handler
C		0C00-0CFF	
D		0D00-0DFF	
E		0E00-0EFF	
F		0F00-0FFF	

*Charger Interrupt and Teleprinter Handler.

HEXADECIMAL

0000	EXECUTIVE Program
01FF 0200	CHARGER Task Program
0660	Unused ROM CHARGER Expansion
0700	Initial Task List
0720	Unused ROM Task List Expansion
0800	INTERRUPT HANDLER And TELEPRINTER Command Handler
0BFF 0C00	Unused ROM External Communication Expansion
0FFF 100D	Undesignated
1BFF 1C00	EXECUTIVE Data Space
1D35 1D36	CHARGER Data Space
1D7E 1D7F	Unused RAM CHARGER Expansion
1DFF 1E00	INTERRUPT And TELEPRINTER HANDLER Data Space
1E49 1E50	Unused RAM Handler/ Stack Expansion
1F80	Stack Space
1FFF 2000	Undesignated
FFFF	

Figure 4.7.1 PCI Memory Map with CHARGER Software Installed.

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5. Conclusions and Recommendations

The MSFC specified Flow diagrams have been successfully converted to 8080 assembly language programs. Furthermore, testing at MSFC has shown that the charger function and regulator function can be realized by a P³ system. The cycle time of the software is such that further sophistications can be made to the algorithm without increasing the cycle time to the point where system control will be affected.

The software delivered in both paper tape and PROM form configures the P³ system. In other words, the only necessary change needed to convert the P³ system from regulator function to charger function is to change the PROMs.

The Simple I/O Controller has proven valuable for PCI I/O device checking. This program is contained within one 256x8 PROM and is useful for initial checkout of a constructed PCI.

The software is designed so that further additions and enhancements may be made. Software additions that will have to be made when the P³ system becomes a system considered for flight include caution and warning signals and interface to telemetry. Examples of enhancements that can be made to the present system include load slope regulation, PCI self test for initial checkout, and rescaling of signals so that the absolute accuracy of the analog signals is increased.

Two other areas of possible future work are conversion of the algorithm to the 1802 microprocessor or the 6100 microprocessor if a CMOS PCI is needed, and a study of mechanisms (both hardware and software) to allow for global optimization of a system of P³ systems.

APPENDIX

Hexadecimal-Decimal Integer Conversion Table

For direct conversion of decimal integers in the range of 0 to 4095
and for hexadecimal integers in the range of 0 to FFF.

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	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
000	00000	00001	00002	00003	00004	00005	00006	00007	00008	00009	00010	00011	00012	00013	00014	00015
010	00016	00017	00018	00019	00020	00021	00022	00023	00024	00025	00026	00027	00028	00029	00030	00031
020	00032	00033	00034	00035	00036	00037	00038	00039	00040	00041	00042	00043	00044	00045	00046	00047
030	00048	00049	00050	00051	00052	00053	00054	00055	00056	00057	00058	00059	00060	00061	00062	00063
040	00064	00065	00066	00067	00068	00069	00070	00071	00072	00073	00074	00075	00076	00077	00078	00079
050	00080	00081	00082	00083	00084	00085	00086	00087	00088	00089	00090	00091	00092	00093	00094	00095
060	00096	00097	00098	00099	00100	00101	00102	00103	00104	00105	00106	00107	00108	00109	00110	00111
070	00112	00113	00114	00115	00116	00117	00118	00119	00120	00121	00122	00123	00124	00125	00126	00127
080	00128	00129	00130	00131	00132	00133	00134	00135	00136	00137	00138	00139	00140	00141	00142	00143
090	00144	00145	00146	00147	00148	00149	00150	00151	00152	00153	00154	00155	00156	00157	00158	00159
0A0	00160	00161	00162	00163	00164	00165	00166	00167	00168	00169	00170	00171	00172	00173	00174	00175
0B0	00176	00177	00178	00179	00180	00181	00182	00183	00184	00185	00186	00187	00188	00189	00190	00191
0C0	00192	00193	00194	00195	00196	00197	00198	00199	00200	00201	00202	00203	00204	00205	00206	00207
0D0	00208	00209	00210	00211	00212	00213	00214	00215	00216	00217	00218	00219	00220	00221	00222	00223
0E0	00224	00225	00226	00227	00228	00229	00230	00231	00232	00233	00234	00235	00236	00237	00238	00239
0F0	00240	00241	00242	00243	00244	00245	00246	00247	00248	00249	00250	00251	00252	00253	00254	00255
100	00256	00257	00258	00259	00260	00261	00262	00263	00264	00265	00266	00267	00268	00269	00270	00271
110	00272	00273	00274	00275	00276	00277	00278	00279	00280	00281	00282	00283	00284	00285	00286	00287
120	00288	00289	00290	00291	00292	00293	00294	00295	00296	00297	00298	00299	00300	00301	00302	00303
130	00304	00305	00306	00307	00308	00309	00310	00311	00312	00313	00314	00315	00316	00317	00318	00319
140	00320	00321	00322	00323	00324	00325	00326	00327	00328	00329	00330	00331	00332	00333	00334	00335
150	00336	00337	00338	00339	00340	00341	00342	00343	00344	00345	00346	00347	00348	00349	00350	00351
160	00352	00353	00354	00355	00356	00357	00358	00359	00360	00361	00362	00363	00364	00365	00366	00367
170	00368	00369	00370	00371	00372	00373	00374	00375	00376	00377	00378	00379	00380	00381	00382	00383
180	00384	00385	00386	00387	00388	00389	00390	00391	00392	00393	00394	00395	00396	00397	00398	00399
190	00400	00401	00402	00403	00404	00405	00406	00407	00408	00409	00410	00411	00412	00413	00414	00415
1A0	00416	00417	00418	00419	00420	00421	00422	00423	00424	00425	00426	00427	00428	00429	00430	00431
1B0	00432	00433	00434	00435	00436	00437	00438	00439	00440	00441	00442	00443	00444	00445	00446	00447
1C0	00448	00449	00450	00451	00452	00453	00454	00455	00456	00457	00458	00459	00460	00461	00462	00463
1D0	00464	00465	00466	00467	00468	00469	00470	00471	00472	00473	00474	00475	00476	00477	00478	00479
1E0	00480	00481	00482	00483	00484	00485	00486	00487	00488	00489	00490	00491	00492	00493	00494	00495
1F0	00496	00497	00498	00499	00500	00501	00502	00503	00504	00505	00506	00507	00508	00509	00510	00511
200	00512	00513	00514	00515	00516	00517	00518	00519	00520	00521	00522	00523	00524	00525	00526	00527
210	00528	00529	00530	00531	00532	00533	00534	00535	00536	00537	00538	00539	00540	00541	00542	00543
220	00544	00545	00546	00547	00548	00549	00550	00551	00552	00553	00554	00555	00556	00557	00558	00559
230	00560	00561	00562	00563	00564	00565	00566	00567	00568	00569	00570	00571	00572	00573	00574	00575
240	00576	00577	00578	00579	00580	00581	00582	00583	00584	00585	00586	00587	00588	00589	00590	00591
250	00592	00593	00594	00595	00596	00597	00598	00599	00600	00601	00602	00603	00604	00605	00606	00607
260	00608	00609	00610	00611	00612	00613	00614	00615	00616	00617	00618	00619	00620	00621	00622	00623
270	00624	00625	00626	00627	00628	00629	00630	00631	00632	00633	00634	00635	00636	00637	00638	00639
280	00640	00641	00642	00643	00644	00645	00646	00647	00648	00649	00650	00651	00652	00653	00654	00655
290	00656	00657	00658	00659	00660	00661	00662	00663	00664	00665	00666	00667	00668	00669	00670	00671
2A0	00672	00673	00674	00675	00676	00677	00678	00679	00680	00681	00682	00683	00684	00685	00686	00687
2B0	00688	00689	00690	00691	00692	00693	00694	00695	00696	00697	00698	00699	00700	00701	00702	00703
2C0	00704	00705	00706	00707	00708	00709	00710	00711	00712	00713	00714	00715	00716	00717	00718	00719
2D0	00720	00721	00722	00723	00724	00725	00726	00727	00728	00729	00730	00731	00732	00733	00734	00735
2E0	00736	00737	00738	00739	00740	00741	00742	00743	00744	00745	00746	00747	00748	00749	00750	00751
2F0	00752	00753	00754	00755	00756	00757	00758	00759	00760	00761	00762	00763	00764	00765	00766	00767

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	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
300	00768	00769	00770	00771	00772	00773	00774	00775	00776	00777	00778	00779	00780	00781	00782	00783
310	00784	00785	00786	00787	00788	00789	00790	00791	00792	00793	00794	00795	00796	00797	00798	00799
320	00800	00801	00802	00803	00804	00805	00806	00807	00808	00809	00810	00811	00812	00813	00814	00815
330	00816	00817	00818	00819	00820	00821	00822	00823	00824	00825	00826	00827	00828	00829	00830	00831
340	00832	00833	00834	00835	00836	00837	00838	00839	00840	00841	00842	00843	00844	00845	00846	00847
350	00848	00849	00850	00851	00852	00853	00854	00855	00856	00857	00858	00859	00860	00861	00862	00863
360	00864	00865	00866	00867	00868	00869	00870	00871	00872	00873	00874	00875	00876	00877	00878	00879
370	00880	00881	00882	00883	00884	00885	00886	00887	00888	00889	00890	00891	00892	00893	00894	00895
380	00896	00897	00898	00899	00900	00901	00902	00903	00904	00905	00906	00907	00908	00909	00910	00911
390	00912	00913	00914	00915	00916	00917	00918	00919	00920	00921	00922	00923	00924	00925	00926	00927
3A0	00928	00929	00930	00931	00932	00933	00934	00935	00936	00937	00938	00939	00940	00941	00942	00943
3B0	00944	00945	00946	00947	00948	00949	00950	00951	00952	00953	00954	00955	00956	00957	00958	00959
3C0	00960	00961	00962	00963	00964	00965	00966	00967	00968	00969	00970	00971	00972	00973	00974	00975
3D0	00976	00977	00978	00979	00980	00981	00982	00983	00984	00985	00986	00987	00988	00989	00990	00991
3E0	00992	00993	00994	00995	00996	00997	00998	00999	01000	01001	01002	01003	01004	01005	01006	01007
3F0	01008	01009	01010	01011	01012	01013	01014	01015	01016	01017	01018	01019	01020	01021	01022	01023
400	01024	01025	01026	01027	01028	01029	01030	01031	01032	01033	01034	01035	01036	01037	01038	01039
410	01040	01041	01042	01043	01044	01045	01046	01047	01048	01049	01050	01051	01052	01053	01054	01055
420	01056	01057	01058	01059	01060	01061	01062	01063	01064	01065	01066	01067	01068	01069	01070	01071
430	01072	01073	01074	01075	01076	01077	01078	01079	01080	01081	01082	01083	01084	01085	01086	01087
440	01088	01089	01090	01091	01092	01093	01094	01095	01096	01097	01098	01099	01100	01101	01102	01103
450	01104	01105	01106	01107	01108	01109	01110	01111	01112	01113	01114	01115	01116	01117	01118	01119
460	01120	01121	01122	01123	01124	01125	01126	01127	01128	01129	01130	01131	01132	01133	01134	01135
470	01136	01137	01138	01139	01140	01141	01142	01143	01144	01145	01146	01147	01148	01149	01150	01151
480	01152	01153	01154	01155	01156	01157	01158	01159	01160	01161	01162	01163	01164	01165	01166	01167
490	01168	01169	01170	01171	01172	01173	01174	01175	01176	01177	01178	01179	01180	01181	01182	01183
4A0	01184	01185	01186	01187	01188	01189	01190	01191	01192	01193	01194	01195	01196	01197	01198	01199
4B0	01200	01201	01202	01203	01204	01205	01206	01207	01208	01209	01210	01211	01212	01213	01214	01215
4C0	01216	01217	01218	01219	01220	01221	01222	01223	01224	01225	01226	01227	01228	01229	01230	01231
4D0	01232	01233	01234	01235	01236	01237	01238	01239	01240	01241	01242	01243	01244	01245	01246	01247
4E0	01248	01249	01250	01251	01252	01253	01254	01255	01256	01257	01258	01259	01260	01261	01262	01263
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EB0	03712	03713	03714	03715	03716	03717	03718	03719	03720	03721	03722	03723	03724	03725	03726	03727
E90	03728	03729	03730	03731	03732	03733	03734	03735	03736	03737	03738	03739	03740	03741	03742	03743
EA0	03744	03745	03746	03747	03748	03749	03750	03751	03752	03753	03754	03755	03756	03757	03758	03759
EB0	03760	03761	03762	03763	03764	03765	03766	03767	03768	03769	03770	03771	03772	03773	03774	03775
EC0	03776	03777	03778	03779	03780	03781	03782	03783	03784	03785	03786	03787	03788	03789	03790	03791
ED0	03792	03793	03794	03795	03796	03797	03798	03799	03800	03801	03802	03803	03804	03805	03806	03807
EE0	03808	03809	03810	03811	03812	03813	03814	03815	03816	03817	03818	03819	03820	03821	03822	03823
EF0	03824	03825	03826	03827	03828	03829	03830	03831	03832	03833	03834	03835	03836	03837	03838	03839

ORIGINAL PAGE IS
OF POOR QUALITY

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F00	03840	03841	03842	03843	03844	03845	03846	03847	03848	03849	03850	03851	03852	03853	03854	03855
F10	03856	03857	03858	03859	03860	03861	03862	03863	03864	03865	03866	03867	03868	03869	03870	03871
F20	03872	03873	03874	03875	03876	03877	03878	03879	03880	03881	03882	03883	03884	03885	03886	03887
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F80	03968	03969	03970	03971	03972	03973	03974	03975	03976	03977	03978	03979	03980	03981	03982	03983
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FA0	04000	04001	04002	04003	04004	04005	04006	04007	04008	04009	04010	04011	04012	04013	04014	04015
FB0	04016	04017	04018	04019	04020	04021	04022	04023	04024	04025	04026	04027	04028	04029	04030	04031
FC0	04032	04033	04034	04035	04036	04037	04038	04039	04040	04041	04042	04043	04044	04045	04046	04047
FD0	04048	04049	04050	04051	04052	04053	04054	04055	04056	04057	04058	04059	04060	04061	04062	04063
FE0	04064	04065	04066	04067	04068	04069	04070	04071	04072	04073	04074	04075	04076	04077	04078	04079
FF0	04080	04081	04082	04083	04084	04085	04086	04087	04088	04089	04090	04091	04092	04093	04094	04095