HUBBLE SPACE TELESCOPE SIX-BATTERY TEST BED

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**Abstract**

A test bed for a large space power system breadboard for the Hubble Space Telescope (HST) was designed and built to test the system under simulated orbital conditions. A discussion of the data acquisition and control subsystems designed to provide for continuous 24-hour per day operation and a general overview of the test bed is presented. The data acquisition and control subsystems provided the necessary monitoring and protection to assure safe shutdown with protection of test articles in case of loss of power or equipment failure over the life of the test (up to 5 years).
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HUBBLE SPACE TELESCOPE SIX-BATTERY TEST BED

BACKGROUND

A power system test bed has been developed to test the Hubble Space Telescope (HST) power system using nickel-cadmium (Ni-Cd) batteries. The test bed provides orbital simulation for charging and discharging the batteries under various operational configurations. Orbital sequencing and data acquisition is accomplished by the data acquisition system (DAS) with solar array simulation (SAS) and load sequencing controlled by the control computer (CC).

The test bed provides space and control for a six-battery power system configuration. The batteries are assembled from Eagle-Picher type 44 Ni-Cd cells, assembled in flight type cases and incorporate battery protection and reconditioning circuits (BPRC).

Test operations are designed for continuous, unattended, operations 24 hours a day, 365 days a year. This type of long term operation (3 to 5 years) requires special considerations for accumulation of data, failure protection, and protection of the test articles and supporting equipment.

PURPOSE

The HST six-battery Ni-Cd test bed was designed to provide a testing facility for the HST power system flight configuration. Testing operations were designed to simulate the HST power operations at liftoff, solar array deployment, orbital insertion, and in-orbit operations. The facility also simulates battery environment temperatures. Data collection and subsequent analysis require large volumes of data for trend analysis and anomaly investigation.

SYSTEM CONFIGURATION

A diagram of the HST flight operating system is shown in figure 1. Figure 2 is a block diagram of the test bed. Total duplication of the flight system is, of course, impossible, but every attempt was made to duplicate flight operations on the batteries and their operation in the system. Certain modifications were made to the physical battery configuration to allow insertion in an environmental chamber and for additional nonflight instrumentation, such as cell pressures, cell voltages, and additional temperature measurements. The test bed is located in building 4475, rooms 139 and 140. The test bed configuration design also includes provisions for real-time, real-data transmission to an expert system development test bed (NICBES).
CHAMBER AND BATTERY PHYSICAL CONFIGURATION

The environmental chamber employed in a test bed has a 64 ft³ (4x4x4 ft) operating space with a conditioned gas inlet at the bottom rear and an exhaust outlet at the top rear. The chamber is purged with dry nitrogen as the environmental medium. The nitrogen reduces the likelihood of condensation during operation and when the chamber must be opened for test bed repairs or reconfiguration of physical devices. The nitrogen is under a slight positive pressure and is vented to the outside of the building. The chamber is easily capable of maintaining a set temperature in the operating range of -10 °C to 30 °C with a 1-kW heating load.

The batteries are divided into two groups of three batteries. Each of the battery groups is mounted on a cold plate. The cold plates have imbedded heaters to allow separate control of the battery group temperatures. The cold plates, with batteries, are stacked vertically in a support frame. Insulation surrounds the battery groups on top, sides, and ends to force most generated heat to be extracted via the cold plates. Baffling exists in the chamber to direct the circulating ambient environment to the cold plates for proper heat transfer. The battery physical arrangement thus provides a thermal path similar to that expected in space operation.

A physical modification to the battery cases has been made to accommodate the individual cell pressure transducers and their attendant cabling and to allow wiring to each cell terminal to obtain cell voltages. This modification is accomplished by using 1-inch spacers between the battery case and lid. The lid is still within the insulation surrounding the groups for thermal integrity.

Figure 3 is a depiction of the chamber physical layout. Figure 4 is a photograph of the installed batteries.

TEST CONTROL AND DATA ACQUISITION

Signals from the DAS control the orbital day/night time of the test bed. Day/night orbital times are synchronized with the DAS 1-min scan rate to preclude data acquisition during the battery charge-discharge transitions, and to allow stabilization of operating parameters between readings. The DAS also performs limit checking on the data to alert to failure conditions of support equipment such as environmental chamber cooling failure, building power failure, SAS equipment failure, and cell-battery failure.

Table 1 lists the types and distribution of data types read by the DAS, while appendices A through C list the channel assignments. The DAS is a system assembled by DSP Inc. utilizing a LSI-11/23 DEC board computer as the processor. The operating system is RT-11 with the operating programs written in BASIC for ease of modification and interactive operator control. Data scanning is accomplished using 16-channel, flying-capacitor, reed-relay multiplexors. Network completion circuits are also provided for resistance measurements of thermistor temperature circuits.

Figure 5 is a block diagram of the DAS system. A typical control circuit for a single battery is shown in figure 6.
The DAS also incorporates a switch panel to provide operator control of scan data printouts, recycling of orbital position to the beginning of day or night (start of new orbit), and forcing discharge during day or charge during night phase.

To accommodate the accumulation and retention of large amounts of data (370 items per scan), an external “AT” class computer has been attached to a RS232 port. This computer incorporates an optical disk of the “write once-read many” (WORM) technology. Two hundred megabytes of storage are available per disk. This represents about 3 weeks of data. This same data is also routed to an expert system test bed for real-time development of artificial intelligence (AI) technologies as applied to large space power systems.

The DAS also has two printer outputs. One printer is used for listing orbital summary data (fig. 11) and the second printer lists failure conditions and scan data requests (fig. 12).

Appendix D is the control and data acquisition program for the LSI-11/23 with comments added for clarity. Also included are the DAS operating instructions.

SOLAR ARRAY SIMULATORS

The HST orbital configuration consists of 20 solar panels divided into groups of 3 panels for each battery, with the remaining 2 panels connected directly to bus C. For test simulation, two power supplies per battery are employed. One power supply (type 1) of the pair simulates a single solar panel, the second supply (type 2) simulates the output of two solar panels. The SAS control circuits can thus simulate the power delivered by type 1, 2, or 3 panels, as determined by the charge current controllers (CCC). A type 2 supply simulates the two solar power arrays (SPA’s) connected to bus C.

LOAD BUSES

The HST three-flight load buses are replicated by three programmable load banks. Each load bank is independently controlled by the CC to perform in the predicted orbital configuration, including the failure SAFEMODE.

CHARGE CURRENT CONTROLLER

The charge voltage of each battery is controlled by a CCC. Each CCC controls the number and battery cut-off voltages of the SPA’s (SAS) charging each battery. The cutoff voltages are temperature compensated to reduce charging stress at higher temperatures.
CONTROL COMPUTER

The control computer is an inhouse designed and fabricated microprocessor system. The CC has an operator interface for entry of desired orbital operating parameters. A TI 9900 chip is used as the central processing unit (CPU) with series supporting chips and 2k bytes of EPROM memory. The CC provides for independent SAS control (simulating HST orientation and SPA degradation), load bank control (simulating various load conditions), and monitoring of CCC operation, battery temperature, battery voltage, and DAS operation. The CC circuits also provide failure monitoring of the SAS and CCC. The CC incorporates a 16-channel multiplexor and 12-bit analog/digital (A/D) converter for analog data monitoring. CC output control is accomplished via two 16-bit I/O chips with relay driver interface. The CC logic and board circuitry are shown in figures 7 through 10.

The CC operating program is programmed into the EPROM memory. Appendix E is a listing of the two programs for CC operation and operator interface.

TEST SHUTDOWN AND FAILURE PROTECTION

The number of individual subsystems and integrated operation of the test bed requires several levels of failure protection and test shutdown. Since the test bed is earthbound and dependent on utility power for operations, an uninterruptable power source supplies the operating power for the DAS and CC. Since the test bed is designed for continuous, unattended, operation all circuits have FAIL-SAFE provisions, and the DAS and CC are connected to an autodialer circuit to notify test personnel of a failure night or day.

Protection of the test articles (batteries) and the test bed equipment is an important consideration, therefore the conditions listed in table 2 are considered faults and initiate the indicated actions. Test shutdown for failures requires operator intervention for restart, even if the fault self corrects. This is a safety precaution to verify that the fault cause is found and properly cleared or corrected.
Figure 1. HST power system.
Figure 2. Test bed block diagram.
Figure 3. Chamber physical layout.
Figure 4. Installed batteries.
Figure 5. DAS system block diagram.
Figure 6. Single battery control circuit.
Figure 8. Input/output board.
Figure 9. Analog interface board.
<table>
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<tr>
<th>BAT ORBIT</th>
<th>SUNSET TIME</th>
<th>BAT WHO</th>
<th>BAT EFF</th>
<th>DCH</th>
<th>CHG</th>
<th>RR</th>
<th>DOD</th>
<th>AHO</th>
<th>BFRM</th>
<th>AH</th>
<th>CHI</th>
<th>T-CAY</th>
<th>T-CLO</th>
<th>T-DAY</th>
<th>T-DLO</th>
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</tr>
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<td>CHI CV--CNO--AV CV--CLO CV--CNO</td>
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<td>CHI CV--CNO--AV CV--CLO CV--CNO</td>
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Figure 11. Orbital summary data.
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Figure 12. Failure conditions and scan data requests.
Table 1. Data types read by the DAS.

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<th>type of signal</th>
<th>Quan.</th>
<th>Use</th>
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<td>ANALOG</td>
<td>0-+/− 2.4 v</td>
<td>256</td>
<td>cell volt. and cell press.</td>
</tr>
<tr>
<td>0-255</td>
<td>0-+/− 2.4 v</td>
<td>80</td>
<td>same as above</td>
</tr>
<tr>
<td>256-335</td>
<td>0-100k ohms</td>
<td>40</td>
<td>theristor temperature</td>
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<td>336-375</td>
<td>0-200 v</td>
<td>24</td>
<td>battery and load volts.</td>
</tr>
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<td>376-399</td>
<td>0-+/− 100 mv</td>
<td>16</td>
<td>battery and SAS curr.</td>
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<td>400-415</td>
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<tr>
<td>DIGITAL</td>
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<td>cc contol</td>
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<tr>
<td>0-63</td>
<td>switches</td>
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<td>alarm and level control</td>
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<td>0-15</td>
<td>28 v level</td>
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<td>16-31</td>
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<td>battery status</td>
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Table 2. Fault conditions.

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<th>Fault</th>
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<td>Environmental chamber temp. too high</td>
<td>Shutdown</td>
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<tr>
<td>Environmental chamber temp. too low</td>
<td>Shutdown</td>
</tr>
<tr>
<td>SAS current too high</td>
<td>Alarm</td>
</tr>
<tr>
<td>DAS not scanning</td>
<td>Shutdown</td>
</tr>
<tr>
<td>Cell voltage too high</td>
<td>Shutdown</td>
</tr>
<tr>
<td>Cell voltage too low</td>
<td>Shutdown</td>
</tr>
<tr>
<td>Bus current too high</td>
<td>Shutdown</td>
</tr>
<tr>
<td>SAS curr. too low at start of charge</td>
<td>Alarm</td>
</tr>
<tr>
<td>Utility power failure</td>
<td>Alarm</td>
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### Appendix A

**ANALOG SIGNALS**

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<thead>
<tr>
<th>Channel</th>
<th>Use</th>
<th>Voltage (Volts) (+ or -)</th>
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## Appendix B

**Digital Inputs**

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### Appendix C

**Digital outputs**

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*Page 31*
## Appendix C Cont.

### Digital Outputs

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APPENDIX D

HUBBLE SPACE TELESCOPE
NICD 6 BATTERY SYSTEM
TEST OPERATIONS PROGRAM WITH COMMENTS
REVISED FEB 27, 1990
DATA ACQUISITION SYSTEM STARTUP PROCEDURE

1. DADS RACK MAIN POWER SWITCH "ON" (BOTTOM PANEL)
2. RESET EXTERNAL CLOCK (TOP PANEL) & PRESS "STOP" SWITCH
3. SET EXTERNAL CLOCK TO CURRENT DAY & TIME
4. START CLOCK
5. TURN ON VIDEO DISPLAY
   MESSAGE SHOULD READ: (AFTER BEEP)
   V14F1 TEST OK
6. TURN ON PRINTER A AND VERIFY IS "ON LINE"
7. TURN ON PRINTER B AND VERIFY IT IS "ON LINE"
8. CONNECT MODEM
9. TURN ON LOWER "CAMAC" CRATE
10. TURN ON UPPER "CAMAC" CRATE
11. TURN ON BACKPLANE POWER (SHORT RACK)
    ENABLE SWITCH "UP", LTC SWITCH "UP"
12. TURN ON MAG TAPE POWER SWITCH
13. PUT "TAPE OFF LINE" SWITCH UP (AUX PANEL)
14. INSERT DISK "A" INTO DRIVE "0" (LEFT)
15. INSERT DISK "B" INTO DRIVE "1" (RIGHT)
16. VERIFY VIDEO DISPLAY IS OK
    MESSAGE SHOULD READ:
    V14F1 TEST OK
17. DEPRESS "BOOT" SWITCH ON UPPER "CAMAC" CRATE
18. THE FOLLOWING WILL BE DISPLAYED
   (ENTER BOLDFACED DATA, DATA SHOWN ARE EXAMPLES ONLY)
   (BOLD LETTERS ARE OPERATOR RESPONSES)
   (<> INDICATES "RETURN" KEY)
   o D 56 = 5015
   o SET TT SCOPE
   o D56 = 0
   o INITIALIZE VMO:
     VMO INITIALIZE; ARE YOU SURE? Y <>
     o COPY DYO: RT11SJ.SYS VMO:
       FILES COPIED
       DYO:RT11SJ.SYS TO VMO:RT11SJ.SYS
     o COPY DYO: SWAP.SYS VMO:
       FILES COPIED
       DYO:SWAP.SYS TO VMO:SWAP.SYS
     o COPY DYO: TT.SYS VMO:
       FILES COPIED
       DYO:TT.SYS TO VMO:TT.SYS
     o COPY DYO: DY.SYS VMO:
FILES COPIED
DYO:DY.SYS TO VMO:DY.SYS
COPY DYO:VM.SYS VMO:
FILES COPIED
DYO:VM.SYS TO VMO:VM.SYS
COPY DYO:MS.SYS VMO:
FILES COPIED
DYO:MS.SYS TO VMO:MS.SYS
COPY DYO:LS.SYS VMO:
FILES COPIED
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FILES COPIED
DYO:NL.SYS TO VMO:NL.SYS
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FILES COPIED
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COPY DYO:TV.SYS VMO:
FILES COPIED
DYO:TV.SYS TO VMO:TV.SYS
COPY DYO:DIR.SYS VMO:
FILES COPIED
DYO:DIR.SYS TO VMO:DIR.SYS
COPY DYO:PIP.SYS VMO:
FILES COPIED
DYO:PIP.SYS TO VMO:PIP.SYS
COPY DYO:DUP.SAV VMO:
FILES COPIED
DYO:DUP.SAV TO VMO:DUP.SAV
COPY DYO:RESORC.SAV VMO:
FILES COPIED
DYO:RESORC.SAV TO VMO:RESORC.SAV
COPY DYI:INIT.BAS VMO:
FILES COPIED
DYI:INIT.BAS TO VMO:INIT.BAS
COPY DYI:MAINOP.BAS VMO:
FILES COPIED
DYI:MAINOP.BAS TO VMO:MAINOP.BAS
COPY DYO:BASICO.SAV VMO:
FILES COPIED
DYO:BASICO.SAV TO VMO:BASICO.SAV
COPY DYO:STARTX.COM VMO:STARTS.COM
COPY BOOT VMO:RT11SJ.SYS VMO:
BOOT VMO:
RT-11SJ (S) V05-01
D 56 = 5015
A.

RUN BASICO <>
BASIC-11/RT-11 V02-03
OPTIONAL FUNCTIONS (ALL, NONE, OR INDIVIDUAL)? A <>
READY
RUN INIT <>
CRATE 4 STATUS
E205 INSTALLED IN STATION 1
E220 INSTALLED IN STATION 2
E220 INSTALLED IN STATION 3
E220 INSTALLED IN STATION 4
E220 INSTALLED IN STATION 5
E220 INSTALLED IN STATION 6
E220 INSTALLED IN STATION 7
E220 INSTALLED IN STATION 8
E220 INSTALLED IN STATION 9
E220 INSTALLED IN STATION 10
E220 INSTALLED IN STATION 11
E220 INSTALLED IN STATION 12
E220 INSTALLED IN STATION 13
E220 INSTALLED IN STATION 14
E220 INSTALLED IN STATION 15
E220 INSTALLED IN STATION 16
E220 INSTALLED IN STATION 17
ENTER 1 TO CONTINUE
? 1 <>
CRATE 5 STATUS
E120 INSTALLED IN STATION 2
E140 INSTALLED IN STATION 3
E140 INSTALLED IN STATION 4
E140 INSTALLED IN STATION 5
E205 INSTALLED IN STATION 6
E240 INSTALLED IN STATION 7
E205 INSTALLED IN STATION 8
E220 INSTALLED IN STATION 9
E220 INSTALLED IN STATION 10
E220 INSTALLED IN STATION 11
E220 INSTALLED IN STATION 12
E220 INSTALLED IN STATION 13
E220 INSTALLED IN STATION 14
E220 INSTALLED IN STATION 15
E220 INSTALLED IN STATION 16
E220 INSTALLED IN STATION 17
ENTER 1 TO CONTINUE
? 1 <>
ENTER ORBIT COUNT
? 1 <>
ENTER CURRENT YEAR
? 1986 <>
ENTER DISCHARGE MIN.
? 35 <>
ENTER CHARGE MIN.
? 60 <>
ENTER ORBITS TO SKIP
? 0 <>
(Delay to next line will be approx 10 sec.)
STOP AT LINE 590
(Any set up changes may be made at this point)
(DISCH MIN = C3 =
(CHARGE MIN = C1 =
(SHUTDOWN FLAG = F9 = 0)
(BATT'S 1, 2, 3 HI LIMIT = L1= )
(BATT'S 4, 5, 6 HI LIMIT = L2= )
(ALL BATT'S LO LIMIT = L8= )
(ORBIT NO. = O1 = )
(ORBITS TO SKIP = S1 = )
GOTO 600 <>

(PROGRAM & SCANNING START WITH NIGHT [DISCHARGE] AND SCAN OF 0)
(The following will be displayed after completion of each scan)
"DISCHARGE TIME 1 C3=35 ORBIT 1" OR "CHARGE TIME 1 C1=60 ORBIT 1"
After checking for time display above, magnetic tape may be put on line by putting "TAPE OFF LINE" switch to the down position.
VARIABLE DESCRIPTIONS

A =Average temperature in hi/lo subroutine.
A1(6) =Amp-min in summation.
A2(6) =Amp-min out summation.
A3(6) =BPRC ahr summation.
A6(6) =Orbit high pressure.
A7(6) =Orbit high pressure cell no.
A8(3) =Bus current.
A9(3) =Bus voltage.

B1(6) =Discharge hi cell voltage.
B2(6) =Discharge hi cell no.
B3(6) =Discharge lo cell voltage.
B4(6) =Discharge lo cell no.
B5(6) =Discharge average cell voltage.
B6(6) =Discharge battery voltage at lo cell.
B7(7) =Discharge hi temperature.
B8(6) =Discharge lo temperature.
B9(6) =Discharge average temperature.

C1 =Charge time of orbit.
C2 =Charge elapsed min. counter.
C3 =Discharge time of orbit.
C4 =Discharge elapsed min. counter.
C5(6) =Reconditioning counter.
C8 =Print value of C2.
C9 =Print value of C4.
C$ ="."

D1(6,23)=Cell voltage.
D2(6) =Battery voltage.
D3(6) =Battery current.
D5(6) =Battery temperature.
D6(13) =SAS/PS current.
D7(6) =Last scan current.
D8(6,23)=Cell pressure.
D9(6) =BPRC current.

E1(6) =Charge hi cell voltage.
E2(6) =Charge hi cell no.
E3(6) =Charge lo cell voltage.
E4(6) =Charge lo cell no.
E5(6) =Charge average cell voltage.
E6(6) =Charge battery volts at hi cell.
E7(6) =Charge hi temperature.
E8(6) =Charge lo temperature.
E9(6) =Charge average temperature.

F1(0) =Dig. input, power fail.
F1(1) =Dig. input, battery 1 print request.
F1(2) =Dig. input, battery 2 print request.
F1(3) =Dig. input, battery 3 print request.
F1(4) =Dig. input, battery 4 print request.
F1(5) =Dig. input, battery 5 print request.
F1(6) =Dig. input, battery 6 print request.
F1(7) =Dig. input, bus data print request.
F1(8) =Dig. input, tape off line.
F1(9) =Dig. input, skip scan on mag. tape.
F1(10) =
F1(11) =Dig. input, force day.
F1(12) =Dig. input, begin night.
F1(13) =Dig. input, begin day.
F1(14) =Dig. input, force night.
F1(15) =bad
F2(0) =
F2(1) =Dig. input, reconditioning battery 1.
F2(2) =Dig. input, reconditioning battery 2.
F2(3) =Dig. input, reconditioning battery 3.
F2(4) =Dig. input, reconditioning battery 4.
F2(5) =Dig. input, reconditioning battery 5.
F2(6) =Dig. input, reconditioning battery 6.
F2(7) =Dig. input, trickle charge.
F2(8) =
F2(9) =
F2(10) =Dig. input, 1ppm log pulse.
F2(11) =Dig. input, time BCD 1.
F2(12) =Dig. input, time BCD 2.
F2(13) =Dig. input, time BCD 4.
F2(14) =Dig. input, time BCD 8.
F2(15) =bad
F3 =Roll flag.
F7 =SOC reset flag.
F8 =Discrete trickle flag.
F9 =Shutdown flag.

G1 =Temporary battery WHO for print.
G2 =Temporary battery EFF for print.
G3 =Temporary battery RR for print.
G4 =Temporary battery DCH or Dcc for print.
G5 =Temporary battery DOD for print.
G6 =Temporary battery AHO for print.
G7 =Temporary battery BPSC_WH for print.

H =Hi temperature in hi\lo temperature routine.
I =Temporary counter, usually battery no.
I1 =Temporary counter.

J =Temporary counter, usually cell no.
J1 =Temporary counter.

K1 =AHO constant (1/60).
L = Lo temperature in hi\lo temperature routine.
L1 = Battery 1,2,3 hi cell limit.
L2 = Battery 4,5,6 hi cell limit.
L8 = Battery 10 limit.
L9 = Current cell limit in use.

M% = Multiplexor and ADC setup values.
M1 = Mag tape off line flag.

N = Temporary no. storage.
N1(9) = Temporary no. storage in time calc..

01 = Orbit no.

P1 = Battery "printed" flag.
P2 = Phase flag, 0 = disc., 1 = chrg.
P3 = Forced night flag.
P4 = Forced day flag.
P5 = Printout phase flag.
P8 = Flag to check P.S. during 1st 5 min of day.
P9 = Flag to check load during night.

R = Temporary resistor value.
R2 = Constant for DOD calc. (1.01)
R9(5,9) = RR from 10 orbits.

S1 = Orbits to skip value.
S2 = Skip counter.
S3 = Skip scan counter.
S4(6) = SOC max value.
S5(6) = SOC accumulative.
S6 = SOC print value.
S7(6) = SOD print value.

T1(4) = Storage for scan time.
T2(4) = Converted time characters.
T3(6,4) = Sunset time.
T9 = No. of scans on tape counter.

U1 = Print request counter.
U2 = Retry counter.

V = Temporary value in temperature calc.
V1 = Power fail flag.
V2 = First scan flag.
V3(6) = Reconditioning flag.
V4(6) = Capacity test complete flag.
V5(13) = SAS/PS failure flag.
V6(6) = Battery current failure flag.
V7 = Begin night flag.
V8 = Begin day flag.

W1(6) = Battery watt-min in summation.
W2(6) = Battery watt-min out summation.
$Z_1$ = ADC and switch reg. output values.
$Z_2$ = Temporary output value.
### WHERE TO CHANGE NON-VARIABLE LIMITS

<table>
<thead>
<tr>
<th>LINE NO.</th>
<th>DESCRIPTION</th>
<th>CURRENT VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>565</td>
<td>SOC BASE VALUE</td>
<td>55</td>
</tr>
<tr>
<td>2700</td>
<td>BATT RECOND. 1ST LIMIT</td>
<td>26.45 (VOLTS)</td>
</tr>
<tr>
<td>3020</td>
<td>BATT. I UPPER LIMIT AT NIGHT</td>
<td>5 (AMPS)</td>
</tr>
<tr>
<td>4073</td>
<td>EXTRANEOUS CELL VOLTAGE DEVIATION BETWEEN SCANS (EXCEPT FIRST OF PHASE)</td>
<td>.01 (VOLTS)</td>
</tr>
<tr>
<td>4151</td>
<td>EXTRANEOUS CELL PRESS.</td>
<td>10 (PSI)</td>
</tr>
<tr>
<td>4241</td>
<td>DEVIATION</td>
<td></td>
</tr>
<tr>
<td>4311</td>
<td>EXTRANEOUS BATT. V DEV.</td>
<td>.1 (VOLTS)</td>
</tr>
<tr>
<td>4390-4420</td>
<td>CORRECTION FACTORS FOR CURRENTS</td>
<td></td>
</tr>
<tr>
<td>4490</td>
<td>BATT TEMP. O.C. VALUE</td>
<td>2.2303 (VOLTS)</td>
</tr>
<tr>
<td>4500</td>
<td>BATT. TEMP. SHRT. CIR.</td>
<td>-1.2575 (VOLTS)</td>
</tr>
<tr>
<td>7080</td>
<td>BATT. DISC. CURR. LIMIT</td>
<td>-30 (AMPS)</td>
</tr>
<tr>
<td>7090</td>
<td>BATT. CHRG. CURR. LIMIT</td>
<td>25 (AMPS)</td>
</tr>
<tr>
<td>7620</td>
<td>SAS P.S. DISC. LIMIT</td>
<td></td>
</tr>
<tr>
<td>7830</td>
<td>SAS P.S. CHRG 5 MIN LIMIT</td>
<td></td>
</tr>
<tr>
<td>8580</td>
<td>BATT. AVE. HI TEMP. LIMIT</td>
<td>30 (DEG. C)</td>
</tr>
<tr>
<td>8590</td>
<td>BATT. AVE. LO TEMP. LIMIT</td>
<td>-10 (DEG. C)</td>
</tr>
</tbody>
</table>
THIS SECTION IS THE FIRST PROGRAM GROUP AND WILL CHAIN TO THE MAIN OPERATING PROGRAM WHEN COMPLETE

1   REM "INIT" Routine to initialize crates and modules
2   *Define the variables common to both program sections
50  COMMON O1,C3,C1,T1(4),S1
6   *The next section initializes crate #4 and checks for
7   *the module codes.
100 CALL CRATE(4) \ CALL INIT \ CALL INH(0)
8   *Print status header
110 PRINT "CRATE 4 STATUS"
9   *Set up module loop
120 FOR J=1 TO 17
10   *Get module ID numbers
130 CALL C(J,0,1,I)
11   *Print module ID no.
140 PRINT "E";I;" INSTALLED IN POSITION ";J
12   *Get another module ID
150 NEXT J
13   *Print operator instruction
160 PRINT "ENTER 1 TO CONTINUE"
14   *Get input
170 INPUT J1
15   *Verify input is a 1
180 IF J1<>1 GOTO 160
16   *The next part initializes crate #5 and checks
17   *the ID of all modules
190 CALL CRATE(5) \ CALL INIT \ CALL INH(0)
18   *Print status header
200 PRINT "CRATE 5 STATUS"
19   *Set up module loop
210 FOR J=2 TO 17
20   *Get module ID's
220 CALL C(J,0,1,I)
21   *Print status
230 PRINT "E ";I;" INSTALLED IN POSITION ";J
22   *Next module
240 NEXT J
23   *Print instruction
250 PRINT "ENTER 1 TO CONTINUE"
24   *Get input
260 INPUT J1
25   *Verify input is a 1
270 IF J1<>1 GOTO 250
26   *This section gets the starting orbit no. and year
27   *Print instruction
280 PRINT "ENTER ORBIT COUNT"
28   *Get starting orbit count
290 INPUT O1
29   *Print instruction
300 PRINT "ENTER CURRENT YEAR"
30   *Get current year
INPUT T1(0)  **T1(0) IS YEAR IN TIME ARRAY
*print instruction
PRINT "ENTER DISCHARGE MIN."
*Get discharge time
INPUT C3  **C3 IS LENGTH OF NIGHT
*print instruction
PRINT "ENTER CHARGE MIN."
*Get charge time
INPUT C1  **C1 IS LENGTH OF DAY
*print instruction
PRINT "ENTER ORBITS TO SKIP"
*Get skip count
INPUT S1
*clear clock buffers and send clock hold pulse
CALL C(4,1,16,(2^15)) \ CALL C(4,1,16,0)
*Set up time input loop
FOR I=1 TO 9
*Set up to get digit
CALL C(4,1,16,(2^14)) \ CALL C(4,1,16,0)
*Get a time digit
CALL C(2,1,0,ZI%)
*Get another
NEXT I
*Reset counter and reset hold
CALL C(4,1,16,(2^15)) \ CALL C(4,1,16,(2^13)) \ CALL C(4,1,16,0)
*Go to next program segment
CHAIN "MAINOP"
END
REM "MAINOP" main operating program
*Set up common variables
COMMON O1,C1,C3,T1(4),S1
*Dimension arrays
DIM A1(6),A2(6),B1(6),B2(6),B3(6),B4(6),B5(6)
DIM B6(6),B7(6),B8(6),B9(6),C5(6),D2(6),D3(6)
DIM D6(13),D7(6),E1(6),E2(6),E3(6),E4(6),E5(6)
DIM E6(6),E7(6),E8(6),E9(6),F1(16),F2(16)
DIM T2(9),V3(7),V4(6),V5(13),V6(6),W1(6),W2(6)
DIM D9(6),A8(3),A9(3),A6(6),A7(6),A4(6)
DIM S4(6),S5(6),S6(6),S7(6)
DIM D1(6,23),D5(6,6),D8(6,23),T3(6,4),R9(5,9)
S6=48 \ FOR I=1 TO 6 \ S4(I)=S6 \ NEXT I
*The next section initializes flags and summations
FOR I=1 TO 6 \ B3(I)=2 \ S5(I)=S4(I) \ NEXT I
FOR I=0 TO 5 \ FOR J=0 TO 9 \ R9(I,J)=0 \ NEXT J \ NEXT I
LI=1.55 \ L2=1.55 \ L8=0 \ C$=":" \ C2=0 \ C4=0 \ P2=0 \ V1=0 \ V2=0
*stop here to catch up ( type continue to resume)
STOP
*Set crate no. and set to discharge phase
CALL CRATE(5) \ CALL C(5,0,16,2^2) \ CALL C(5,0,16,0)
*Clear 1ppm log input
CALL C(4,1,16,(2^12)) \ CALL C(4,1,16,0)
*Set up initial values
R2=1.01 \ F3=0 \ El=I/60
T8=0
*Get input switch closures
GOSUB 5000
*check for shutdown
IF F9=1 GOTO 1900
*check power failure signal if zero skip to next check
IF F1(0)=1 GOTO 1080
*check power fail flag, if set go check signal again
IF V1=1 GOTO 1900
*power fail signal "on" flag not set so print out notice header
GOSUB 1810
*print power fail message
PRINT #2,"POWER FAILED SINCE"
*print blanks, close output, & set power fail flag
PRINT #2 \ CLOSE #2 \ V1=1
*go beginning to check for power return
GOTO 1000
*if flag is zero continue normal input check
IF V1=0 GOTO 1150
*power was off, now on, get current time
CALL C(4,1,16,(2^15)) \ CALL C(4,1,16,0) \ GOSUB 5200
*open output line & print header
1100 GOSUB 1810
*print out message
1110 PRINT #2,"POWER RETURNED"
*close output line & reset flag
1120 PRINT #2 \\ CLOSE #2 \\ V1=0
*clear out 1ppm signal
1130 CALL C(4,1,16,(2^12)) \ CALL C(4,1,16,0)
*go back to checking input signals
1140 GOTO 1000
*if flag set go scan branch
1150 IF F2(10)=1 GOTO 2000
*set up battery loop to check print requests
1160 FOR I=1 TO 7
*if recored sw set, set recored flag
1170 IF F2(I)=1 THEN V3(I)=1
*if printed flag set skip printing
1180 IF F1(I)=1 GOTO 1210
*if print flag not set go check another
1190 IF F1(I)=0 GOTO 1210
*if print requested set flag
1200 UI=I
*get next
1210 NEXT I
*if prints not requested skip
1220 IF UI=0 GOTO 1400
*print header
1230 GOSUB 1810
*set up battery loop
1240 FOR I=1 TO 6
*skip if battery print not requested
1250 IF F1(I)=0 GOTO 1340
*print battery values
1270 PRINT #2,"BATTERY=","V=","D2(I)","I=";D3(I);"BPRC I=";D9(I);"SOC=";S5(I);"AHO=";(-1*A2(I))/60
*set up to print cell voltages
1280 A=1 \ N=12 \ GOSUB 1850
*print some more
1290 PRINT #2 \ A=13 \ N=23 \ GOSUB 1850
*print temperatures
1300 PRINT #2 \ FOR II=1 TO 6 \ PRINT #2, USING "###.##",D5(I,II) ; \ NEXT II \ PRINT #2
1310 FOR I=1 TO 12 \ PRINT #2, USING "###.##",D8(I,II) ; \ NEXT I \ PRINT #2
1320 FOR I(1)=13 TO 23 \ PRINT #2, USING "###.##",D8(I,II) ; \ NEXT I1
*add spaces
1330 PRINT #2 \ PRINT #2
*get another
1340 NEXT I
*check bus data request
1350 IF F1(7)=0 GOTO 1380
*print header
1360 PRINT #2,"BUS VOLTS CURR"
*print data
1370 FOR I=1 TO 3 \ PRINT #2, USING "$# #.### #.###", I,A9(I),A8(I) \ NEXT I
*close up print & set "printed" flag
1380 P1=1 \ CLOSE #2 \ U1=0
*if sw not set skip force night routine
1400 IF F1(14) = 0 GOTO 1430
*if already forced to night skip
1410 IF P3=1 GOTO 1430
*force night, set flag & clear begin flags
1420 CALL C(5,0,16,2'2) \ CALL C(5,0,16,0) \ PRINT "FORCE NIGHT" \ P3=1 \ P4=0 \ V7=0 \ V8=0
*if sw not set skip force day routine
1430 IF F1(11)=0 GOTO 1460
*if already forced to day skip
1440 IF P4=1 GOTO 1460
*force day, set flags and clear begin flags
1450 CALL C(5,0,16,2'1) \ CALL C(5,0,16,0) \ PRINT "FORCE DAY" \ P4=1 \ P3=0 \ V7=0 \ V8=0
*if sw not set skip begin night routine
1460 IF F1(12)=0 GOTO 1500
*if already begin night skip
1470 IF V7=1 GOTO 1460
*print message & set/reset flags
1480 PRINT "BEGIN NIGHT" \ V7=1 \ P3=0 \ P4=0 \ V8=0 \ C4=0
*go to 'end of orbit' routine
1490 GOTO 2530
*if sw not set, skip begin day routine
1500 IF F1(13)=0 GOTO 1540
*if already begin day skip
1510 IF V8=1 GOTO 1540
*set day output & set phase flag to change
1520 CALL C(5,0,16,2'1) \ CALL C(5,0,16,0) \ P2=1
*print message & set/reset flags
1530 PRINT "BEGIN DAY" \ V8=1 \ P3=0 \ P4=0 \ V7=0 \ C2=0
*test to see if tape on line
1540 IF F1(8)=1 GOTO 1570
*switch off was it on?
1550 IF M1=1 GOTO 1590
*was off return to beginning
1560 GOTO 1000
*tape off line sw. on, was it before?
1570 IF M1=1 GOTO 1000
*new off line request, close tape
1580 CLOSE #9 \ MI=1 \ GOTO 1000
*new on-line request, turn on tape output
1590 OPEN "MSO:DATA" FOR OUTPUT AS FILE #9, FILESIZE 1
*set flags and return
1600 M1=0 \ T9=0 \ GOTO 1000
*send out shutdown closure & set flag
1790 CALL C(5,0,16,(2'14)) \ F9=1
*send out alarm closure
1800 CALL C(5,0,16,(2'15)) \ CALL C(5,0,16,0)
*open printer file
1810 OPEN "LT:" FOR OUTPUT AS FILE #2
*print header data
1820 PRINT #2,TI(0);C$;TI(1);C$;TI(2);C$;TI(3);C$;TI(4);
"ORB=";02;"P=";P5;"C2=";C8;"C4=";C9 \ RETURN
*print cell data
1850 FOR I1=A TO N \ PRINT #2,USING "####.####",D1(I,I1); \ NEXT I1 \ RETURN
*send ppm pulse
1900 CALL C(3,0,16,3) \ CALL C(3,0,16,0)
*return to beginning
1910 GOTO 1000

2000 REM SCAN BRANCH
*send "latch" pulse to clock
2010 CALL C(4,1,16,(2*12+2*15)) \ CALL C(4,1,16,0)
*send "scanning" pulses out
2020 CALL C(3,0,16,3) \ CALL C(3,0,16,0)
*go scan all data & convert as necessary
2030 GOSUB 4000
*go get "now" time
2040 GOSUB 5200
*go check hi-lo limits
2050 GOSUB 7000
*test for "initial" flag
2060 IF V2=1 GOTO 2090
*store starting time
2070 FOR I=1 TO 6 \ FOR J=0 TO 4 \ T3(I,J)=TI(J) \ NEXT J \ NEXT I
*set "initial" flag
2080 V2=1
*set up loop
2090 FOR I=1 TO 6
*check phase
2100 IF P2=1 GOTO 2130
*check for first discharge phase scan if no skip
2110 IF C4>0 GOTO 2150
*skip
2120 GOTO 2140
*check for first phase scan if no skip
2130 IF C2>0 GOTO 2150
*set up last scan value
2140 D7(I)=D3(I)
*calculate current average
2150 N=(D3(I)+D7(I))/2
2152 IF D3(I)>0 GOTO 2154
2153 S5(I)=S5(I)+N*K1 \ GOTO 2155
2154 S5(I)=S5(I)+N*K1/R2
2155 IF F3=0 GOTO 2160
2156 IF P2=1 GOTO 2170
*check for negative current
2160 IF D3(I)<0 GOTO 2180
*calculate amps. in
2170 A1(I)=A1(I)+N \ W1(I)=W1(I)+(N*D2(I)) \ GOTO 2190

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*calculate amps. out
2180 A2(I)=A2(I)+N \ W2(I)=W2(I)+(N*D2(I))
*update last current
2190 D7(I)=D3(I) \ (A3(I)=A3(I)+D9(I))
*temporarily store phase flag
2191 Y1=P2
*check trickle charge flag
2194 IF F8=0 GOTO 2200
*tickles charge on, reset SOC values
2196 S5(I)=S4(I) \ F7=1 \ T8=C2
*set trickle charge flag for output
2197 Y1=P2+10
2200 IF P2=0 GOTO 2230
*in charge find hi cells
2210 GOSUB 8350
*check if still in recond.
2230 IF V3(I)=I GOTO 2670
*get another battery
2240 NEXT I
2245 IF F7=1 THEN F8=0
*check load bank total current
2250 A8(0)=A8(1)+A8(2)+A8(3) \ IF A8(0)<99 GOTO 2280
*out of limit go to shutdown
2260 GOSUB 1790
*print message
2270 PRINT #2,"TOTAL BUS I=";A8(0) \ CLOSE #2
*transmit data to smart system & mag tape
2280 GOSUB 5500
*set print parameters
2290 P5=P2 \ O2=01
*check phase
2300 IF P2=1 GOTO 2430
*update discharge counter & display
2310 C4=C4+1 \ PRINT "DISC MIN=";C4;"C3=";C3;"ORBIT NO.;
2320 IF C9=C4 \ C8=C2
2330 GOSUB 3000
*check for "Forced Day"
2330 IF P4=1 GOTO 2350
*go check power supply limits
2340 GOSUB 7600
*discharge time not up return to main
2350 IF C4<C3 GOTO 1000
*set up loop
2360 FOR I=1 TO 6
2362 S7(I)=S5(I)
*go check disch. hi-lo cells
2370 GOSUB 8200
*go get E-O-D H-L temps
2380 GOSUB 8500
*store results
2390 B9(I)=A \ B8(I)=L \ B7(I)=H
*next batt.
2400 NEXT I
*send out day pulse & set day flag * reset force & begin
CALL C(5,0,16,2)`1 \ CALL C(5,0,16,0) \ P2=1 \ P4=0 \ V7=0 \ V8=0
*return to main program
GOTO 1000
*update charge counter
C2=C2+1 \ PRINT "CHRG MIN=";C2;"C1=";C1;"ORBIT NO.";01 \ C8=C2
*go check power supply limits
GOSUB 7800
*if charge time not up go to main
IF C2<C1 GOTO 1000
*update orbit count
O1=O1+1
*update orbit skip counter
S2=S2+1
*check its value
IF S2>0 THEN S2=-S1
*set up loop
FOR I=1 TO 6
*go get END-O-PHASE temps
S6(I)=S5(I)
GOSUB 8500
*store results
E9(I)=A \ E8(I)=L \ E7(I)=H
*go get next
NEXT I
*send out night pulse & set day flags & reset force - begin flags
CALL C(5,0,16,2)`2 \ CALL C(5,0,16,0) \ P2=0 \ P3=0 \ V7=0 \ V8=0
*set up loop
OPEN "LS:" FOR OUTPUT AS FILE #1
*open line to printer
FOR I=1 TO 6
*if in recon. skip printer
IF V3(I)=1 GOTO 2590
*go print batt results
G4=C4
*go print batt. orbital data
GOSUB 6000
*next batt
NEXT I
*close print
T8=99
CLOSE #1
*zero chrg-disch counters
J9=J9+1
IF J9>9 THEN J9=0
C2=0 \ C4=0
*set up batt loop
FOR I=1 TO 6
*test for recon. skip time if yes
IF V3(I)=1 GOTO 2650
*load new sunset time

2640 FOR J=0 TO 4 \ T3(I,J)=T1(J) \ NEXT J

*next batt.

2650 NEXT I

*go to main

2660 GOTO 1000

*update discharge recond counter

2670 C5(I)=C5(I)+1

*check if recond still on

2680 IF F2(I)=0 GOTO 2770

*check if captest complete

2690 IF V4(I)=1 GOTO 2240

*check for end of captest

2700 IF D2(I)>26.45 GOTO 2240

*set captest complete flag

2710 V4(I) = 1

*set disch min, to captest time

2720 G4=C5(I)

*open output for captest info

2730 OPEN "LS:" FOR OUTPUT AS FILE #I

2735 GOSUB 8200

*go print orb (captest) info

2740 GOSUB 6000

*close output

2750 CLOSE #I

*return to next batt.

2760 GOTO 2240

*record over clear flags & set up output

2770 V3(I)=0 \ V4(I)=0 \ G4=C5(I)

*clear disch (captest) counter

2780 C5(I) = 0

*go print summary data

2790 GOTO 2730

*subroutine to check bus current for day

3000 IF P9=0 GOTO 3060

*set up loop

3010 FOR I=1 TO 3

*check for good bus-current

3020 IF A8(I)>5 GOTO 3050

*bad limit go alarm

3030 GOSUB 1800

*print message

3040 PRINT #2, "BUS No.";I:"CURR=";A8(I) \ CLOSE #2

*get another

3050 NEXT I

*return

3060 RETURN

4000 REM SCAN DATA

*set up crate & clear begin/force flags

4010 CALL CRATE (4)

*set up battery loop

4020 FOR I=1 TO 6

*set up cell loop

4030 FOR J=1 TO 23
*set up char. no.
4040 M% = 23*(I-1)+J+512 \ H=D1(I,J) \ U2=0
*set up mux & adc at gain of 4 (+-2.56v)
4050 CALL C(1,0,16,M%)
*set LAM status
4051 CALL C(1,0,27,,Q,X)
*if not set try again
4052 IF Q=0 GOTO 4051
*get adc results
4060 CALL C(1,1,0,Z1%)
*convert to voltage
4070 D1(I,J)=(Z1%*78.125*10^(-6))
*check for initial phase scan
4071 IF C4=0 GOTO 4080
4072 IF C2=0 GOTO 4080
4073 IF ABS(H-D1(I,J))<.01 GOTO 4080
*check tries
4074 IF U2>2 GOTO 4080
*increment counter & go try again
4075 U2=U2+1 \ GOTO 4050
*next cell
4080 NEXT J
*next batt.
4090 NEXT I
*set up batt. loop
4100 FOR I=1 TO 5
*set up cell loop
4110 FOR J=1 TO 23
*set up char no.
4120 M% = 652+23*(I-1)+J \ H=D8(I,J) \ U2=0
*set up mux & adc (gain 1 +-2.56v)
4130 CALL C(1,0,16,M%)
*check if conversion complete
4131 CALL C(1,0,27,,Q,X)
*if not ready try again
4132 IF Q=0 GOTO 4131
*get results
4140 CALL C(1,1,0,Z1%)
*convert to voltage & pressure (30mv=150psig)
4150 D8(I,J)=(Z1%*78.125*10^(-5))*4.97
*check jump in reading
4151 IF ABS(H-D8(I,J))<10 GOTO 4160
*check if enough tries
4152 IF U2>2 GOTO 4160
*not too many try again
4153 U2=U2+1 \ GOTO 4130
*check for highest pressure
4160 IF A6(I)<D8(I,J) THEN A6(I)=D8(I,J) \ A7(I)=J
*next cell
4170 NEXT J
*next batt.
4180 NEXT I
*change to crate 5
4190 CALL CRATE(5)
*set up cell loop
4200 FOR J=1 TO 23
  *set up to check for bad readings
4210 H=D8(6,J) \ U2=0
  *set up mux & adc
4220 CALL C(8,0,16,(511+J))
  *check if conversion complete
4221 CALL C(8,0,27,,Q,X)
  *if not try again
4222 IF Q=0 GOTO 4221
  *get adc results
4230 CALL C(8,1,0,Z1%)
  *convert to volt & pressure
4240 D8(6,J)=(Z1%*78.125*10^-5)*4.97
  *check jump in readings
4241 IF ABS(H-D8(6,J))<I0 GOTO 4250
  *too many tries
4242 IF U2>2 GOTO 4250
  *go try again
4243 U2=U2+1 \ GOTO 4220
  *check for high pressure
4250 IF A6(6)<D8(6,J) THEN A6(6)=D8(6,J) \ A7(6) = J
  *next cell
4260 NEXT J
*set up batt loop
4270 FOR I=1 TO 6
  *set up char no. & reset print flag
4280 M%=I19+I \ H=D2(I) \ U2=0
  *set up mux & adc
4290 CALL C(8,0,16,M%)
  *check LAM
4291 CALL C(8,0,27,,Q,X)
4292 IF Q=0 GOTO 4291
  *get adc results
4300 CALL C(8,1,0,Z1%)
  *convert to volt
4310 D2(I)=(Z1%*6.26)/1000
  *check batt v jump
4311 IF ABS(H-D2(I))<.1 GOTO 4320
  *check tries
4312 IF U2>2 GOTO 4320
  *try again
4313 U2=U2+1 \ GOTO 4290
  *set up mux & adc
4320 CALL C(6,0,16,(I-1))
  *check LAM
4321 CALL C(6,0,27,,Q,X)
  *if not ready try again
4322 IF Q=0 GOTO 4321
  *get results
4330 CALL C(6,1,0,Z1%)
  *convert to volt & store it batt I
4340 D3(I)=Z1%*2.50000E-03
  *set up mux for BPRC current
4350 CALL C(6,0,16,(517+I))  *check LAM
4351 CALL C(6,0,27,,Q,X)  *if not ready try again
4352 IF Q=0 GOTO 4351  *get results
4360 CALL C(6,1,0,Z1%)  *convert and store BPRC current
4370 D9(I)=Z1%*.25000E-04  *next battery
4380 NEXT I  *current correction factors
4390 D3(1)=D3(1)+0\D3(2)=D3(2)+0\D3(3)=D3(3)+0
4400 D3(4)=D3(4)-0\D3(5)=D3(5)+0\D3(6)=D3(6)+0
4410 D9(1)=D9(1)-2.00000E-03 \ D9(2)=D9(2)-1.00000E-03 \ D9(3)=D9(3)-8.00000E-03
4420 D9(4)=D9(4)-7.00000E-03 \ D9(5)=D9(5)-6.00000E-03 \ D9(6)=D9(6)-.011
4430 FOR I=1 TO 6  *set up batt loop
4440 FOR J=1 TO 6  *set up meas. loop
4450 M%=335+6*(I-1)+J  *set up adc & mux
4460 CALL C(8,0,16,M%)  *get results
4470 CALL C(8,1,0,Z1%)  *convert to volts
4480 V=Z1%*.15625/1000  *test for too high
4490 IF V>2.2303 THEN V=2.2303  *test for too low
4500 IF V<-1.2575 THEN V=-1.2575  *convert to res.
4510 R=((V+2.515)/(2.515-V))*3000  *convert to deg c
4520 D5(I,J)=(5153.2/(LOG(R)+7.03721))-317.688  *next meas
4530 NEXT J  *next batt.
4540 NEXT I  *set up loop for sas/ps.
4550 FOR I=1 TO 13  *set up mux & adc data
4560 M%=578+I  *set up mux & adc
4570 CALL C(8,0,16,M%)  *check to see if conversion complete
4571 CALL C(8,0,27,,Q,X)  *if not done try again
4572 IF Q=0 GOTO 4571  *get results
4580 CALL C(8,1,0,Z1\%)
*convert to amps
4590 D6(I)=Z1\%*78.125*10^(-3)
*next sas
4600 NEXT I
*set up loop for bus data
4610 FOR I=1 TO 3
*adjust range and chan
4620 M\%=575+I
*set up mux
4630 CALL C(8,0,16,M\%)
*check to see if conversion complete
4631 CALL C(8,0,27,,Q,X)
*if not done try again
4632 IF Q=0 GOTO 4631
*get result
4640 CALL C(8,1,0,Z1\%)
*convert data
4650 A8(I)=(Z1\%*78.125*10^(-5))*2
*adjust chan
4660 M\%=125+I
*set up mux
4670 CALL C(8,0,16,M\%)
*get results
4680 CALL C(8,1,0,Z1\%)
*convert to volts
4690 A9(I)=(Z1\%*6.26)/1000
*next bus
4700 NEXT I
*reset print flag
4710 P1=0
4720 RETURN
5000 REM SUBROUTINE TO GET SWITCH CLOSURES
*set up crate/get ok from module
5010 CALL CRATE(5)
*get first set of inputs (iso-inputs)
5020 CALL C(2,0,0,Z1\%)
*get second set of inputs (non-iso)
5030 CALL C(2,1,0,Z2\%)
*convert both words to proper format
5040 Z1\%=ABS(1+Z1\%) \ Z2\%=ABS(1+Z2\%)
*set up loop to check inputs
5050 FOR L=0 TO 15
*set up compare valve & clear flags
5060 N=2^(15-L) \ F1(15-L)=0 \ F2(15-L)=0
*compare a flag if no-go skip to next check
5070 IF Z1\%-N<0 GOTO 5090
*reduce input by compared valve & set flag
5080 Z1\%=Z1\%-N \ F1(15-L)=1
*compare a flag if no-go skip to next check
5090 IF Z2\%-N<0 GOTO 5110
*reduce input by compared valve & set flag
5100 Z2\%=Z2\%-N \ F2(15-L)=1
*get next get to compare
5110 NEXT L
*return to main program
5120 IF F2(7)=0 GOTO 5150
5130 IF F7=1 GOTO 5160
5140 F8=1 \ GOTO 5160
5150 F7=0
5160 RETURN

5200 REM GETIME
*set up crate & set hold/reset
5210 CALL CRATE(5)
*set up loop
5220 FOR I=1 TO 9
*advance char. counter in clock
5230 CALL C(4,1,16,(2^14)) \ CALL C(4,1,16,0)
*get inputs
5240 CALL C(2,1,0,Z1%)
*adjust results
5250 N1(I)=ABS(1+Z1%)
*next input
5260 NEXT I
*reset counter \ and release hold
5270 CALL C(4,1,16,(2^15)) \ CALL C(4,1,16,(2^13)) \ CALL C(4,1,16,0)
*set up decode loop
5280 FOR I=1 TO 9
*clear clock char
5290 T2(I)=0
*set up bit loop
5300 FOR J=0 TO 3
*set up compare no.
5310 N=2^(14-J)
*compare bits if yes continue
5320 IF N1(I)-N<0 GOTO 5350
*adjust value
5330 N1(I)=N1(I)-N
*add bit to char word
5340 T2(I)=T2(I)+2^(3-J)
*next bit
5350 NEXT J
*next char
5360 NEXT I
*build days
5370 T1(1)=100*T2(1)+16*T2(2)+T2(3)
*build hours
5380 T1(2)=10*T2(4)+T2(5)
*build minutes
5390 T1(3)=10*T2(6)+T2(7)
*build seconds
5400 T1(4)=10*T2(8)+T2(9)
*return
5410 RETURN

5500 REM SUBROUTINE TO TRANSMIT DATA TO "SMART" SYSTEM
*open file #3 (rs232 output to "smart" system)
5510 OPEN "TV:" FOR OUTPUT AS FILE #3
*transmit start char
5520 PRINT #3,"A"
*set loop and transmit time
5530 FOR I=0 TO 4 \ PRINT #3,T1(I) \ NEXT I
*transmit header data
*output orbit count, phase, and charge counters
5540 PRINT #3,01 \ PRINT #3,Y1 \ PRINT #3,C2 \ PRINT #3,C4
*set up batt loop
5550 FOR I=1 TO 6
*output batt. no.
5560 PRINT #3,I
*output cell volt.
5570 FOR J=1 TO 23 \ PRINT #3,D1(I,J) \ NEXT J
*output cell press
5580 FOR J1=1 TO 23 \ PRINT #3,D8(I,J1) \ NEXT J1
*output bat v & bat I
5590 PRINT #3,D2(I) \ PRINT #3,D3(I) \ PRINT #3,D9(I)
*output temps
5600 FOR J=1 TO 6 \ PRINT #3,D5(I,J) \ NEXT J
*output record flags
5610 PRINT #3,V3(I)
*get another
5620 NEXT I
*output sas currents
5630 FOR I=1 TO 13 \ PRINT #3,D6(I) \ NEXT I
*output bus data
5640 FOR J=1 TO 3 \ PRINT #3,A8(J) \ PRINT #3,A9(J) \ NEXT J
*close file
5650 CLOSE #3
*check for mag tape record
5660 IF M1=1 GOTO 5880
*check skip orbit
5670 IF S2<0 GOTO 5880
*check skip scan
5680 IF F1(9)=0 THEN S3=0 \ GOTO 5710
*check for skip
5690 IF S3=0 GOTO 5710
*reset skip flag
5700 S3=-1 \ GOTO 5870
*increment record counter
5710 T9=T9+1
*check for too many records
5720 IF T9<3700 GOTO 5740
*too many print message
5730 PRINT "OUT OF TAPE" \ GOTO 5880
*print start char
5740 PRINT #9,"A"
*record time
5750 FOR I=0 TO 4 \ PRINT #9,T1(I) \ NEXT I
*record header data
5760 PRINT #9,01 \ PRINT #9,P2 \ PRINT #9,C2 \ PRINT #9,C4
*set up for battery loop
5770 FOR I=1 TO 6
*record batt no.
5780 PRINT #9,I
*set up loop and record cell volt
5790 FOR J=1 TO 23 \ PRINT #9,D1(I,J) \ NEXT J
*set up loop and record cell press
5800 FOR J1=1 TO 23 \ PRINT #9,D8(I,J1) \ NEXT J1
*record batt data
5810 PRINT #9,D2(I) \ PRINT #9,D3(I) \ PRINT #9,D9(I)
*record batt temps
5820 FOR J=1 TO 6 \ PRINT #9,D5(I,J) \ NEXT J
*record record. flag
5830 PRINT #9,V3(I)
*get another batt
5840 NEXT I
*set up loop to record sas data
5850 FOR I=1 TO 13 \ PRINT #9,D6(I) \ NEXT I
*set up loop for bus data
5860 FOR J=1 TO 3 \ PRINT #9,A8(J) \ PRINT #9,A9(J) \ NEXT J
*add to skip counter
5870 S3=S3+1
*return
5880 RETURN
6000 REM ORBDAT SUBROUTINE TO PRINT OUT ORBIT DATA
*print first part of 1st line
6010 PRINT #1,"BAT ORBIT SUNSET TIME BAT WHO
BAT EFF DCH CHG RR ";
*print second part of 1st line
6020 PRINT #1," DOD AHO BPRC AH CHI T-CAV T-CLO T--
DHI T-DAV T-DLO T"
*print first part of 1st data line
6030 PRINT #1,USING " # ###:###:###:###:###",I,01-1,
T3(I,0),T3(I,1),T3(I,2),T3(I,3),T3(I,4);
*check for zeros & set to limit valves
6040 IF A1(I)=0 THEN A1(I)=10000
6050 IF A2(I)=0 THEN A2(I)=1
6060 IF W1(I)=0 THEN W1(I)=1
6070 IF W2(I)=0 THEN W2(I)=1
*calculate data
6080 G1=-1*W2(I)/60 \ G2=-1*W2(I)/W1(I) \ G3=A1(I)/(-1*A2(I))
6082 IF F3=0 THEN A4(I)=0
6084 G5=(-1*A2(I)/33)+A4(I)
6086 A4(I)=G5-(A1(I)/(R2*33)) \ G8=A4(I)
*calculate data
6090 G6=-1*A2(I)/60 \ G7=A3(I)/60
6092 R9(I-1,J9)=G3 \ V=0
6094 FOR I=0 TO 9 \ V=V+R9(I-1,I2) \ NEXT I2 \ R=V/10
*print data
6100 PRINT #1 USING " ###:###:###:###:###",G1,G2; \ PRINT #1,
TAB(49),G4;TAB(54);C2;" ";
print data
6110 PRINT #1,USING "###:###:###:###:###:###:###:###:###
,G3,G5,G6
,G7;
*print data
6120 PRINT #1,USING "###:###:###:###:###:###:###:###:###
,E7(I),E9(I),E8(I),B7(I),B9(I),B8(I)
*print first part of second header
6130 PRINT #1,"DHI CV--CNO--AV CV--DLO CV--CNO";
*print 2nd part of 2nd header
6140 PRINT #1, TAB(40);"CHI CV--CNO--AV CV--CLO CV--CNO";
  B5=E6(I)/23 \ E5=E6(I)/23
6150 PRINT #1, TAB(80);"HI PRESS--CNO DODD SOC SOD
TTT RRAV:
*print the data
6061 PRINT #1, USING "#.### #.### #.### #.### #.### #.### #.### #.### #.###",B1(I),
  B2(I),B5,B3(I),B4(I);
6170 PRINT #1, TAB(40); \ PRINT #1, USING "#.### #.### #.### #.### #.### #.### #.### #.### #.###",E1(I),E2(I),E5,E3(I),E4(I);
6180 PRINT #1, TAB(80); \ PRINT #1, USING "#.### #.### #.### #.### #.### #.### #.### #.### #.###",A6(I),A7(I),A4(I),S6(I),S7(I),
T8,R
*print space
6190 PRINT #1
  *skip if batt in recond
6200 IF V3(I)=1 GOTO 6230
  *clear sums
6205 FOR J=1 TO 6 \ S4(J)=S6 \ NEXT J
6210 A1(I)=0 \ A2(I)=0 \ W1(I)=0 \ W2(I)=0 \ A3(I)=0
6220 E1(I)=0 \ B3(I)=2 \ A6(I)=0
  *return
6230 RETURN
7000 REM ROUTINE TO CHECK HI-LO LIMITS
  *set limit value
7010 L9=L1
  *set up batt loop
7020 FOR I=1 TO 6
  *check for limit
7030 IF I>3 THEN L9=L2
  *set up cell loop
7040 FOR I1=1 TO 23
  *check limit, if out go shutdown
7050 IF D1(I,I1)>L9 GOTO 7140
  *check lo limit
7060 IF D1(I,I1)<L8 GOTO 7140
  *next cell
7070 NEXT I1
  *check batt curr
7080 IF D3(I)<-30 GOTO 7120
  *check batt curr hi
7090 IF D3(I)>25 GOTO 7120
  *get another batt
7100 NEXT I
  *return
7110 RETURN
  *go shutdown
7120 GOSUB 1790
  *print message
7130 PRINT #2,"BATTERY NO.";I;"CURRENT=";D3(I) \ CLOSE #2 \ GOTO 7100
  *go shutdown
7140 GOSUB 1790
*print message
7150 PRINT #2,"BATT=":;I;"CELL=":;II;"V=":;D1(I,II) \ CLOSE #2 \ GOTO 7070
7600 FOR I=1 TO 13
7610 U2=0
*check limit
7620 IF D6(I)<5 THEN V5(I)=0 \ GOTO 7700
*check if new out of limit
7630 IF V5(I)=1 GOTO 7700
7640 CALL CRATE(5) \ IF U2>2 GOTO 7680
7650 CALL C(8,0,16,(578+I))
*check LAM
7651 CALL C(8,0,27,,Q,X)
*if not ready try again
7652 IF Q=0 GOTO 7651
7660 CALL C(8,1,0,ZI%)
D6(I)=ZI%*78.125 * 10^(3)
7670 U2=U2+1 \ GOTO 7620
*go alarm
7680 GOSUB 1800
*print message
7690 PRINT #2,"SUPPLY NO.":;I;"CURR=:;D6(I) \ CLOSE #2 \ V5(I) =1
*get another
7700 NEXT I
7710 RETURN
*special night routine
*check flag
7800 IF P8=0 GOTO 7870
*over 5 min. into phase
7810 IF C2>5 GOTO 7870
*set up loop
7820 FOR I=1 TO 13
*check limit
7830 IF D6(I)>5 GOTO 7860
*out of limit go alarm
7840 GOSUB 1800
*print message
7850 PRINT #2,"SUP #:;I;"I=:;D6(I) \ CLOSE #2
*get another
7860 NEXT I
*return
7870 RETURN
8200 REM SUBROUTINE TO GET HI-LO CELLS DURING DISCHARGE
*set flag
8210 U=0
*set up loop
8220 FOR J=1 TO 23
*compare if lower skip to replace
8230 IF B3(I)<=D1(I,J) GOTO 8250
*replace with new valve & set replace cell no. and set new hi
8240 B3(I)=D1(I,J) \ B6(I)=0 \ B4(I)=J \ U=1
*if higher get next
8250 NEXT J
*check flag if 0 skip
8260 IF U=0 GOTO 8320
*set limit
8270 B1(I)=0
*set loop
8280 FOR J1=1 TO 23
*if less than high skip
8290 B6(I)=B6(I)+D1(I,J1) \ IF B1(I)>D1(I,J1) GOTO 8310
*replace high
8300 B1(I)=D1(I,J1) \ B2(I)=J1
*get another
8310 NEXT J1
8320 RETURN
8350 REM SUBROUTINE TO GET HI-LO CELLS DURING CHARGE
8360 U=0
*set up loop
8370 FOR J=1 TO 23
*reset "try" counter
8380 U2=0
*check for higher cell if yes skip to replace
8390 IF E1(I)>D1(I,J) GOTO 8410
*replace hi cell and batt v & get cell no. v
8400 E1(I)=D1(I,J) \ E6(I)=0 \ E2(I)=J \ U=1
*get another
8410 NEXT J
8420 IF U=0 GOTO 8480
*set lo cell
8430 E3(I)=2
*set up loop
8440 FOR J1=1 TO 23
*compare for lows
8450 E6(I)=E6(I)+D1(I,J1) \ IF E3(I)<D1(I,J1) GOTO 8470
*replace values
8460 E3(I)=D1(I,J1) \ E4(I)=J1
*get another
8470 NEXT J1
8480 RETURN
8500 REM SUBROUTINE TO GET HI-LO TEMPS
*set up limit
8510 H=-15 \ L=25 \ N=0
*set up loop
8520 FOR J=1 TO 6
*get sums
8530 N=N+D5(I,J)
*check for new lo
8540 IF L>D5(I,J) THEN L=D5(I,J)
*check for new hi
8550 IF H<D5(I,J) THEN H=D5(I,J)
*get another
8560 NEXT J
*compute average
8570 A=N/6
*check for out of limit average
8580 IF A>25 GOTO 8610
   *check for lo out of limit
8590 IF A<-5 GOTO 8610
8600 RETURN
   *chamber shutdown and alarm
8610 CALL C(5,0,16,(2^13)) \ GOSUB 1790
   *print message
8620 PRINT #2,"BATTERY";I;"TEMP=";A \ CLOSE #2 \ GOTO 8600
9999 END
APPENDIX E

NAME ST6BINT
SECTION ST6B2
LIST DBG

;********************************************************************
;********************************************************************
;***** SPACE TELESCOPE
;***** SIX BATTERY TEST
;***** INTERRUPT HANDLER ROUTINE
;***** BY: JOHN R. BUSH, JR.
;***** LATEST VERSION: 02/09/88
;********************************************************************
;********************************************************************

CR EQU ODH
LF EQU OAH
CU EQU 15H
EOT EQU 04H
SP EQU 20H
TTYBASE EQU 00COH

GLOBAL TTYINT,TTYSETUP,WP2
; INTERRUPT ENTRY POINT

TTYINT TB 21 ; IF SET, RECEIVED A CHAR
JEQ RCHAND ; GO TO RECEIVER HANDLER
TXHAND MOV @TXBUFF(R4),RO ; GET NEXT CHAR TO XMIT
SRL RO, 8
CI RO,EOT ; IS IT THE END?
JEQ LASTCHAR ; YES, JUMP
CI RO,3CH ; < INDICATES MORE DATA ON "D" COMMAND
JEQ MORED
INC R4 ; NO POINT TO NEXT CHAR
BL @TXCHAR ; TRANSMIT RO
RTWP ; THROUGH THIS TIME
LASTCHAR CLR RO ; NULL
CLR R4
BL @TXCHAR ; TO CLEAR INTERRUPT
SBZ 19 ; DISABLE 9902 INTERRUPT
RTWP
TXCHAR SBO 16 ; TURN ON XMITTER
TXRDY TB 22 ; SEE IF XMITTER READY
JNE TXRDY ; NO, JUMP
SLA RO, 8 ; SHIFT FOR LDCR
LDCR RO, 8 ; SEND CHAR
SBZ 16 ; TURN OFF XMITTER
B *R11 ; RETURN

; MORED B MOREDISP ; GET IN RANGE

; ; CONVERT RO TO ASCII

TASCII AI RO,30H ; FOR ALL ASCII
CI RO,3AH ; A - F?
JLT NOCONV ; NO, OK
AI RO,7 ; FOR LETTERS
NOCONV B *R11

;
; IF JUST RECEIVED A CHAR YOU ARE HERE

RCHAND  STCR  RO, 8  ; GET IT
         SRL   RO, 8  ; SHIFT TO LSB
         SBO   18  ; RESET INTERRUPT
         ANDI  RO, 007FH  ; STRIP PARITY
         CI    RO, CU  ; IS IT A CONTROL U?
         JEQ   CUTASK  ; GO DO IT
         CI    RO, CR  ; IS IT A CR?
         JEQ   CRTASK  ; GO DO IT
         BL    @TXCHAR

;SLA   RO, 8  ; ELSE, ECHO CHARACTER
         MOVB  RO, @RCBUFF (R3)  ; TXCHAR ALSO SHIFTS SO
         INC   R3  ; DONT NEED
         RTWP

; CONTROL U TASK

CUTASK  CLR   R3
         CLR   R4
         MOVB  @CUMSG (R4), @TXBUFF (R4)
         INC   R4
         MOVB  @CUMSG (R4), @TXBUFF (R4)
         INC   R4
         BL    @PROMPT
         RTWP

; CR TASK ... HERE GOES

CRTASK  SLA   RO, 8  ; STORE CR
         MOVB  RO, @RCBUFF (R3)
         FDCS  CLR   R3
         CLR   R4
         MOVB  @RCBUFF (R3), RO
         INC   R3
         SRL   RO, 8
         CI    RO, "X"  ; X?
         JEQ   XTASK
         CI    RO, "S"  ; S?
         JEQ   STASK
         CI    RO, "D"  ; D?
         JEQ   DTASK
         BL    @QTASK
         RTWP

; NEXT STEP HERE....

MOV      RO, @RCBUFF (R3)  ; STORE CHAR
         INC   R3  ; INC RCBUFF POINTER
         RTWP

; CONTROL U TASK

CUTASK  CLR   R3
         CLR   R4
         MOVB  @RCBUFF (R3), RO
         INC   R3
         SRL   RO, 8
         CI    RO, "X"  ; X?
         JEQ   XTASK
         CI    RO, "S"  ; S?
         JEQ   STASK
         CI    RO, "D"  ; D?
         JEQ   DTASK
         BL    @QTASK
         RTWP

; NEXT STEP HERE....

MOV      RO, @RCBUFF (R3)  ; STORE CHAR
         INC   R3  ; INC RCBUFF POINTER
         RTWP

; CONTROL U TASK

CUTASK  CLR   R3
         CLR   R4
         MOVB  @RCBUFF (R3), RO
         INC   R3
         SRL   RO, 8
         CI    RO, "X"  ; X?
         JEQ   XTASK
         CI    RO, "S"  ; S?
         JEQ   STASK
         CI    RO, "D"  ; D?
         JEQ   DTASK
         BL    @QTASK
         RTWP

; NEXT STEP HERE....

MOV      RO, @RCBUFF (R3)  ; STORE CHAR
         INC   R3  ; INC RCBUFF POINTER
         RTWP

67
X COMMAND ROUTINE

; XTABLE
; LI R1,XTABE
; LI R2,XTAB
; BL @LDPAR
; MOV RO,RO
; JEQ PQTASK
; MOV *RO,R1
; MOV R1,RO
; BL @NEWLINE
; BL @CONTBUFF
; BL @PROMPT
RTWP

; STASK
; LI R1,STABE
; LI R2,STAB
; LI R6,5
; BL @LDPAR
; MOV RO,RO
; JEQ PQTASK
; BL @CKDEL
; BL @GDATAAD
; MOV R1,R1
; JEQ PQTASK
; BL @GDATAAD
; MOV R1,R1
; JEQ PQTASK
; MOV R2,*RO
; CLR R4
; BL @PROMPT
RTWP

; S TABLE END ADDRESS
; S TABLE START ADDRESS
; GET PARAMETER ADDRESS
; CHECK FOR ERROR
; NOT SUCCESSFUL, ABORT
; GET DATA
; COPY TO RO
; PUT CR,LF INTO TXBUFF
; CONVERT TO ASCII, THEN TO TXBUFF
; ADD A PROMPT
; AND RETURN

; ABORT POSITION FOR CR AT WRONG PLACE
; GET PARAMETER ADDRESS
; SEE IF CLEAR
; UNSUCCESSFUL, ABORT
; GOOD DELIMITER?
; SEE IF CLEAR
; NO, ABORT
; TO GET DATA FROM RCBUFF
; SEE IF CLEAR
; YES, NOT SUCCESSFUL, ABORT
; STORE NEW DATA,
; AND
; GET
; OUT
; D TASK COMMAND ROUTINE
;
DTASK LI R6,2 ; ABORT POSITION FOR CR
CLR R7
CLR R8
BL @GDATAAD ; GET START ADDR
MOV R1,R1 ; SEE IF CLEAR
JEQ PQTASK ; YES, ABORT
LI R7,1 ; MAKE START ADDRESS TO
SZC R7,R2 ; BE THE NEXT LOWEST
MOV R2,R7 ; ADDRESS
;
CI R9,ODOOH ; IF IT WAS ODD. SAVE IN
JNE COND R7.
;
SDADD BL @NEWLINE ; WAS LAST CHAR A CR?
MOVR7,RO ; NO
BL @CONTBUFF ; START A NEWLINE
BL @ADSPCE ; PUT ASCII IN TXBUFF
MOV *R7,RO ; ADD A SPACE
BL @CONTBUFF ; GET DATA
BL @PROMPT ; TO TXBUFF
RTWP ; ADD A PROMPT
;
; CHECK FOR SECOND ADDRESS
;
COND BL @GDATAAD ; GET END ADDRESS
MOVR1,R1 ; SEE IF CLEAR
JEQ PQTASK ; ABORT
LI R8,1 ; MAKE END ADDRESS TO BE
SZC R8,R2 ; NEXT LOWEST ADDRESS IF IT
MOV R2,R8 ; WAS ODD.
MOV R7,R2 ; SAVE END ADDRESS
C R2,R8 ; START ADDR
JHE SDADD ; MAKE SURE END IS >
; THAN START
;
JHE SDADD ; IT WAS NOT, SO JUST DO
ONE
; IF HERE, START LOADING TXBUFF ONE LINE AT A TIME, ENDING
; THE LINE ON XXXEH WITH THE LAST CHARACTER BEING A "<" (3CH)
; IF DTASK IS NOT FINISHED, START NEW LINES ON XXXOH.
; WHEN LAST DATA IS LOADED, DO "BL @PROMPT".

MOREDISP BL @NEWLINE ; START A NEW LINE
    MOV R7, RO
    BL @CONTBUFF

MOREDL BL @ADSPCE ; LOAD ADDR IN TXBUFF
    MOV *R7, RO
    BL @CONTBUFF
    C R7, R8
    JHE DEND ; ADD A SPACE

    MOV R7, RO ; LOAD DATA
    ANDI RO, OFH
    CI RO, OEH
    JEQ ADLA ; CHECK FOR END

    INCT R7
    JMP MOREDL ; STRIP ALL BUT LSN

    ADLA LI RO, 3COOH ; IS IT AN E?
    MOVB RO, @TXBUFF(R4)
    INCT R7
    CLR R4
    SBO 19
    RTWP ; YES, ADD LEFT ARROW

    DEND BL @PROMPT ; ELSE, INC TO NEXT ADDRESS
    RTWP ; AND DO AGAIN

; ENABLE 9902 INTERRUPT
; SUBROUTINE TO LOAD A PARAMETER FROM RCBUFF
; SEARCH TABLE STARTING AT R2, ENDING AT R1 AND RETURN ADDRESS OF PARAMETER IN RO.
; IF INPUT WAS JUST XC, WILL SUBSTITUTE D8040,805E IN ORDER TO DISPLAY ALL ANALOG INPUT CHANNELS.
; IF UNSUCCESSFUL, RETURNS OS IN RO.

LDPAR CLR RO
CLR R5
MOVB @RCBUFF(R3),RO ; FIRST CHAR
INC R3
MOVB @RCBUFF(R3),R5 ; SECOND CHAR
INC R3
SRL R5,8
A R5,RO ; RO HAS PARAMETER
CI RO,430DH ; WAS IT JEST XC?
JEQ DCS
FPARL C RO,*R2+ ; MATCH?
JEQ FPAR ; YES
INCT R2 ; NO, SKIP OVER ADDRESS
C R2,R1 ; END OF TABLE?
JHE NPAR ; YES, NO MATCH
JMP FPARL ; NO MATCH YET, TRY AGAIN
FPAR MOV *R2,RO ; LOAD ADDRESS OF PARAMETER
B *R11
NPAR CLR RO ; NO MATCH, RETURN ZERO
B *R11
DCS CLR R3
DCSL MOVB @DDCS(R3),@RCBUFF(R3)
MOVB @DDCS(R3),RO
INC R3
SRL RO,8
CI RO,CR
JNE DCSL
B FDCS

; SUBROUTINE TO CHECK NEXT RCBUFF CHAR FOR A VALID DELIMITER (BLANK OR COMMA), RETURNS ZERO IN R1 IF NOT SUCCESSFUL.
CKDEL CLR R1
MOVB @RCBUFF(R3),R1
INC R3
CI R1,2000H ; SPACE?
JEQ GDDEL ; YES
CI R1,2COOH ; COMMA?
JEQ GDDEL ; YES
CLR R1 ; NOT SUCCESSFUL
GDDEL B *R11 ; BRANCH OUT
; SUBROUTINE TO GET DATA FROM RCBUFF, R3 IS OFFSET,
; SEARCH RCTABLE UNTIL FIND GOOD DELIMITER OR CR,
; ROTATING GOOD DATA INTO R2; IF FIND BAD ASCII CHAR,
; RETURN ZEROS IN R1. DO NOT USE RO !!

GDATAAD  MOV  R11, R10
          CLR  R2
          CLR  R1
          MOVB  @RCBUFF(R3), R1
          INC  R3
          MOV  R1, R9
          CI  R1, 2000H
          JEQ  FDELCR
          CI  R1, 2COOH
          JEQ  FDELCR
          CI  R1, 0DOOH
          JEQ  FDELCR
          BL  @FRASCII
          MOV  R5, R5
          JEQ  BDDATA
          SLA  R2, 4
          A  R1, R2
          JMP  GDTL

FDELCR  C  R3, R6
          JEQ  BDDATA
          SETO  R1
          B  *R10
          BDDATA  CLR  R1
          B  *R10

FRASCII  SRL  R1, 8
          AI  R1, -30H
          JLT  NOTAC
          CI  R1, 10
          JLT  GDAC
          AI  R1, -7
          JLT  NOTAC
          CI  R1, 0FH
          JGT  NOTAC
          SETO  R5
          B  *R11

GDAC  B  *R11

NOTAC  CLR  R5
          B  *R11
; SUBROUTINE TO CONVERT RO TO ASCII AND STORE
; IN TXBUFF. DESTROYS RO
;
CONTBUFF MOV R11,R10 ; FOR NESTED SUBROUTINE
      MOV RO,R1 ; LINKAGE
      SRL RO,12 ; COPY DATA
      BL @BUFFSUB ; SHIFT TO FIRST CHAR
      SRL RO,8 ; CONVERT AND STORE
      BL @BUFFSUB
      SRL RO,4
      BL @BUFFSUB
      BL @BUFFSUB
      B *R10

BUFFSUB MOV R11,R9 ; FOR NESTED LINKAGE
      ANDI RO,OFH ; STRIP ALL BUT LSN
      BL @TASCII ; TO ASCII
      SLA RO,8
      MOVB RO,@TXBUFF(R4)
      INC R4
      MOV R1,RO
      B *R9

; SUBROUTINE TO PUT CR,LF INTO TXBUFF
;
NEWLINE LI R1,ODOOH
      CLR R4
      MOVB R1,@TXBUFF(R4)
      INC R4
      LI R1,OAOOH
      MOVB R1,@TXBUFF(R4)
      INC R4
      B *R11

; SUBROUTINE TO ADD SPACE TO TXBUFF
;
ADSPCE LI R1,2000H
      MOVB R1,@TXBUFF(R4)
      INC R4
      B *R11
; Q TASK
;
QTASK  CLR  R4
QTLP   MOVB  @QMSG(R4),@TXBUFF(R4)
        MOVB  @TXBUFF(R4),RO
        SRL   RO,8
        INC   R4
        CI    RO,"?"
        JNE   QTLP
PROMPT CLR  R3
PRLP   MOVB  @PMSG(R3),@TXBUFF(R4) ; MOVE CHAR
        MOVB  @TXBUFF(R4),RO ; CHECK FOR EOT
        SRL   RO,8
        INC   R3
        INC   R4
        CI    RO,EOT
        JNE   PRLP
        CLR   R3
CLRL   R4
SBO    19 ; ENABLE 9902 INTERRUPT
B      *R11
; TABLE OF X PARAMETERS
;
XTAB ASCII "CO"
WORD 8040H
ASCII "C1"
WORD 8042H
ASCII "C2"
WORD 8044H
ASCII "C3"
WORD 8046H
ASCII "C4"
WORD 8048H
ASCII "C5"
WORD 804AH
ASCII "C6"
WORD 804CH
ASCII "C7"
WORD 804EH
ASCII "C8"
WORD 8050H
ASCII "C9"
WORD 8052H
ASCII "CA"
WORD 8054H
ASCII "CB"
WORD 8056H
ASCII "CC"
WORD 8058H
ASCII "CD"
WORD 805AH
ASCII "CE"
WORD 805CH
ASCII "CF"
WORD 805EH
ASCII "DE"
WORD 8092H
ASCII "TD"
WORD 8094H
ASCII "R1"
WORD 8060H
ASCII "R2"
WORD 8062H
ASCII "R3"
WORD 8064H
ASCII "A1"
WORD 8066H
ASCII "A2"
WORD 8068H
ASCII "A3"
WORD 806AH
ASCII "HI"
WORD 806CH
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ASCII "NS"
WORD  80AAH
ASCII "KI"
WORD  80B0H
ASCII "PO"
WORD  80A2H
ASCII "CT"
WORD  80B2H
ASCII "SO"
WORD  80BAH
ASCII "TS"
WORD  80BCH
ASCII "PL"
WORD  80BEH
ASCII "ET"
WORD  80C4H
ASCII "NR"
WORD  80CAH
ASCII "PR"
WORD  80CCH
ASCII "EP"
WORD  80D4H
ASCII "D1"
WORD  80D6H
ASCII "D2"
WORD  80D8H
ASCII "D3"
WORD  80DAH
ASCII "D4"
WORD  80DCH
ASCII "D5"
WORD  80DEH
ASCII "D6"
WORD  80E0H

XTABE EQU $
### TABLE OF S PARAMETERS

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ASCII "M3"
WORD 809AH
ASCII "I1"
WORD 809CH
ASCII "I2"
WORD 809EH
ASCII "I3"
WORD 80A0H
ASCII "PS"
WORD 80A4H
ASCII "ES"
WORD 80A6H
ASCII "TR"
WORD 80A8H
ASCII "NS"
WORD 80AAH
ASCII "KI"
WORD 80B0H
ASCII "TS"
WORD 80BCH
ASCII "PL"
WORD 80BEH
ASCII "ET"
WORD 80C4H
ASCII "NR"
WORD 80CAH
ASCII "PR"
WORD 80CCH
ASCII "EP"
WORD 80D4H
ASCII "D1"
WORD 80D6H
ASCII "D2"
WORD 80DBH
ASCII "D3"
WORD 80DAH
ASCII "D4"
WORD 80DCH
ASCII "D5"
WORD 80DEH
ASCII "D6"
WORD 80E0H
STABE EQU $
;
QMSG BYTE CR,LF,"?",CR
PMSSG BYTE CR,LF,">",EOT
CUMSG ASCII "\U"
DDCS ASCII "D8040 805E"

BYTE CR,0
TTYSETUP    WORD    WP2
      WORD    $+2
      CLR    R3
      CLR    R4
      LI    R12,TTYBASE
      BL    @PROMPT
      RTWP
ZZZ    EQU    $
;

SECTION    INTHRWM,ABSOLUTE
ORG    8100H
RCBUFF    BLOCK    16
TXBUFF    BLOCK    50
END
APPENDIX E (cont.)

NAME ST6BTASK
TITLE "ST6B TASKS"
SECTION ST6B1,ABSOLUTE
LIST ME,DBG
GLOBAL TTYINT,TTYSETUP,WP2
EQU 8000H

RWM
;
;******************************************************************************
;******************************************************************************
;******
;****** SPACE TELESCOPE
;****** SIX BATTERY TEST
;****** CONTROLLER
;******
;****** BY: JOHN R. BUSH, JR.
;****** LATEST VERSION: 02/09/88
;******
;******************************************************************************
;******************************************************************************

; ASSIGN INTERRUPT VECTORS
;
ORG 0
WORD WP1 ; FIRST WORKSPACE
WORD START ; ST6B SOFTWARE START
WORD WP2 ; TTY INTERRUPT WORKSPACE
WORD TTYINT ; TTY INTERRUPT SOFTWARE START

; BEGIN ST6B SOFTWARE
;
ORG 80H
;
; SET UP A TO D
;
ATOD EQU 0
ADEOC EQU 13 ; END OF CONVERT
ADSC EQU 24 ; START CONVERT
SHMD EQU 23 ; MODE OF S/H
MPXEN EQU 18 ; MULTIPLEXER ENABLE
ADLSB EQU 1 ; A/D LSB
MPXAL EQU 19 ; MULTIPLEXER ADDRESS
;
START ST6B SOFTWARE
;
START LIMI 0 ; DISABLE INTERRUPTS
LI R12,ATOD ; A/D BASE ADDRESS
SBZ MPXEN ; ENABLE LOW
SBO ADSC ; START CONVERT HIGH
SBZ SHMD ; MODE LOW
;
; SET UP D TO A
;
DA1 EQU 0100H ; BASE OF D/A 1
DA2 EQU 0140H ; BASE OF D/A 2
DA3 EQU 0180H ; BASE OF D/1 3
BVH EQU 28 ; CRU BIT BAT V HIGH
DALSBEQU16 ; PORT OF LSB
PULSE EQU 28 ; PULSE BIT CRU POSITION
TFLAG EQU 29 ; TRIP FLAG (TR RELAYS HAVE TRIPPED)
V15 EQU 5 ; 15 VOLT SENSE
;
LI R12,DA1 ; D/A BASE ADDRESS
SBO 1 ; ENABLE ONE INTERRUPT FOR TTY
SBZ PULSE ; ZERO PULSE
SBZ TFLAG ; ZERO TRIP FLAG
SETORO ; ALL ONES
LI R12,DA1+(DALSBE*2) ; BASE FOR DIGITAL DATA
LDCR RO,12 ; OUTPUT ALL ONES TO D/A
LI R1,0700H ; OTHER 2 D/AS
LI R12,DA2+(DALSBE*2)
LDCR RO,12
LI R12,DA2+(BVH*2) ; BUS OVERVOLTAGE
LDCR R1,4 ; AND HEATER TAPE
LI R12,DA3+(DALSBE*2)
LDCR RO,12
LI R12,DA3+(BVH*2)
LDCR R1,4
;
; SETUP VDT CONTROL (9902)
;
RTRATE EQU 209 ; RECEIVE AND TRANSMIT RATE
(CWITH 2 MHZ CLOCK)
CNTWD EQU 0E200H ; CONTROL WORD (MOST SIG BYTE)
TTYBASE EQU 00COH ; ADDRESS OF 9902
;
;
LI R12,TTYBASE ; 9902 BASE ADDRESS
LI RO,CNTWD
LI R1,RTRATE
SBO 31 ; RESETS 9902
LDCR RO,8 ; OUTPUT CNT WD, RESETS LDCTRL
SBZ 13 ; NOTHING INTO INTERVAL REGISTER
LDCR R1,12 ; DATA RATE, ALSO SETS ALL INTERNAL
    ; FLAGS...READY TO GO
    ; ENABLES 9902 RCV INT
SBO 18

; SET UP CCC WATCHER AND POWER SUPPLY CONTROL
CCCIN EQU 40H ; ADDRESS OF CCC INPUTS
POUT EQU 80H ; ADDRESS OF POWER SUPPLY OUTPUTS
CCCLSB EQU 1
POUTLSB EQU 16
LI R12, POUT+(POUTLSB*2) ; FOR OUTPUT, DON'T NEED INPUT
CLR R1 ; ALL 0S
LDCR R1,13

; INITIALIZE ALL PARAMETERS
DIN EQU 1 ; INITIAL DELTA
ITD EQU 88H ; INITIAL TIME DELAY
H1I EQU 0CA9H ; INITIAL DIODE TRIP POINT HIGH
L1I EQU 0C05H ; INITIAL DIODE TRIP POINT LOW
H2I EQU 0F99H ; INITIAL DIODE TRIP POINT HIGH
L2I EQU 0ECCH ; INITIAL DIODE TRIP POINT LOW
H3I EQU 0F99H ; INITIAL DIODE TRIP POINT HIGH
L3I EQU 0ECCH ; INITIAL DIODE TRIP POINT LOW
H4I EQU 0F99H ; INITIAL DIODE TRIP POINT HIGH
L4I EQU 0ECCH ; INITIAL DIODE TRIP POINT LOW
H5I EQU 0F99H ; INITIAL DIODE TRIP POINT HIGH
L5I EQU 0ECCH ; INITIAL DIODE TRIP POINT LOW
H6I EQU 0F99H ; INITIAL DIODE TRIP POINT HIGH
L6I EQU 0ECCH ; INITIAL DIODE TRIP POINT LOW
UHI EQU 2ABH ; INITIAL PLATE TEMPS TOP HIGH
ULI EQU 290H ; UPPER LOW
LHI EQU 2ABH ; LOWER HIGH
LLI EQU 290H ; LOWER LOW
APRV1I EQU 410 ; INITIAL GUESS FOR PRVS (10 A)
APRV2I EQU 410
APRV3I EQU 410
P1I EQU 733 ; 731W INITIAL
P2I EQU 717
P3I EQU 733
M1I EQU 0E66H
M2I EQU 0E66H
M3I EQU 0E66H
I1I EQU 1229 ; 30 AMPS (LOAD BANK I, 15/BATT)
I2I EQU 1229
I3I EQU 1229
PSI EQU 0 ; POWER SUPPLY CONTROL
TRI EQU 1 ; NO. OF TRIPS BEFORE P.S. SHUTOFF
NSI     EQU     8     ; TOTAL NO. OF SPAS OFF AT TR=CCC TRIPS
TSI     EQU     0FFFFH  ; MAX AVG TEMP ON PLATES
PLI     EQU     50    ; CYCLES BETWEEN PULSES
TRFI    EQU     0     ; TRIP BACK FLAG
DNFI    EQU     0     ; DAY NIGHT FLAG
ETI     EQU     14    
ETCCI   EQU     100H  
EPI     EQU     325   
D1I     EQU     50    ; DELTA POWER FOR ADD FIRST TIME OUT
D2I     EQU     50    ; DELTA POWER FOR SUB SECOND TIME OUT
D3I     EQU     83    ; DELTA...
D4I     EQU     83    
D5I     EQU     67    
D6I     EQU     67    
;
;
MACRO   WINIT   ; MACRO DEFINITION
LI      RO, '1'
MOV     RO, '@'2'
ENDM
;
;
WINIT   DIN, DE
WINIT   ITD, TDLY
WINIT   H1I, H1
WINIT   L1I, L1
WINIT   H2I, H2
WINIT   L2I, L2
WINIT   H3I, H3
WINIT   L3I, L3
WINIT   H4I, H4
WINIT   L4I, L4
WINIT   H5I, H5
WINIT   L5I, L5
WINIT   H6I, H6
WINIT   L6I, L6
WINIT   UHI, UH
WINIT   ULI, UL
WINIT   LHI, LH
WINIT   LLI, LL
WINIT   APRV1I, APRV1
WINIT   APRV2I, APRV2
WINIT   APRV3I, APRV3
WINIT   P1I, P1
WINIT   P2I, P2
WINIT   P3I, P3
WINIT   M1I, M1
WINIT   M2I, M2
WINIT   M3I, M3
WINIT   I1I, I1
MOV     R0, @I2
SAMPLE LI R2,CHL0 ; CHANNEL 0 STORAGE ADDRESS
LI R1,0016 ; COUNTER
CLR R0 ; ADDR OF MPX ANALOG INPUT
SAMPLoop LI R12,MPXAL*2 ; BASE OF MPX ADDR
SLA RO,8 ; GET TO MSB FOR LDCR
LDCR RO,4 ; SEND OUT ADDR
SRL RO,8 ; GET BACK FOR INC
LI R12,ATOD ; BASE
LIMI 0 ; MUST DISABLE INTERRUTS
SBO MPXEN ; ENABLE MPX
SBO SHMD ; SAMPLE
SBO SHMD ; WAIT
SBZ SHMD ; HOLD
SBZ MPXEN ; DISABLE MPX
SBZ ADSC ; START CONVERSION
SBO ADSC ; PROCESS
NOTEoc TB ADEOC ; SEE IF THROUGH
JEQ       NOTEOC ; NO, WAIT
LI       R12, ADLSB*2 ; BASE OF ADLSB
STCR     R4, 12; GET DIGITAL DATA
LIMI     1; ENABLE INTERRUPTS
INV      R4; A/D INVERTING TYPE
ANDI     R4, OFFFH; STRIP LEADING ONES FROM INV
MOV      R4, *R2+; STORE INVERTED DATA
INC      R0; INC ADDR OF MPX
DEC      R1; DEC COUNTER
JNE      SAMPLLOOP; DO 16 TIMES

; CORRECT CHLS 1-9 WITH CHLO (OFFSET).

; LI       R1, 0
LI       R2, CHL1
CLOOP    S @CHLO, *R2
JGT      NNEG
CLR      *R2
NNEG     INCT    R2
DEC      R1
JNE      CLOOP

; FIRST OF ALL, SEE IF IN TRICKLE CHARGE/CAP TEST (CONSTANT CURRENT DISCHARGE MODE) (KI = 1). IF SO AND IN NIGHT THEN PRVS = I1, I2, I3. IF IN DAY THEN DO THIS...
; IF (VB1 + VB2) / 2 > M1 THEN PRV1 = 2048 (APRVS INC SLOWLY IN OUTPRV).
; ELSE PRV1 = 0. SAME FOR 3-4, AND 5-6.

MOV      @KI, @KI
JEQ      CLOAD
LI       R12, DA1
TB       4
JEQ      TRC
MOV      @I1, @PRV1
MOV      @I2, @PRV2
MOV      @I3, @PRV3
B         OUTPRV
TRC      LI       R2, 2048
MOV      @VB1, R1
A @VB2, R1
SRL      R1, 1
C R1, @M1
JLT      ZPRV1
MOV      R2, @PRV1
JMP      CKV3V4
ZPRV1    CLR      @PRV1
CKV3V4   MOV      @VB3, R1
A @VB4, R1
SRL      R1, 1
C R1, @M2
JLT      ZPRV2
MOV      R2, @PRV2
JMP      CKV5V6
ZPRV2 CLR @PRV2
CKV5V6 MOV @VB5,R1
A @VB6,R1
SRL R1,1
C R1,@M3
JLT ZPRV3
MOV R2,@PRV3
JMP OUTPRV
ZPRV3 CLR @PRV3
JMP OUTPRV
;
; CALCULATE V TO OUTPUT TO LOAD BANKS AT .1V/AMP
; P1,P2,P3 = EACH LB POWER DESIRED; VLB1,VLB2,VLB3=
; EACH LB VOLTAGE RANGED 0-40V (CHL1,2,3, 0-10V IN)
; EQUATION IS:
; P1(,2,3)*4095/VLB1(,2,3)*4095/4000 WHERE VLB1(,2,3)>
; 63 (MIN VOLTAGE FOR 32 BITS AT 1000W) AND FINAL
; ANSWER < 2048 (MAX INPUT TO LOAD BANKS)
;
CLOAD LI R3,4095
LI R4,4000
MOV @P1,R1
CI R1,0
JEQ CON2
MOV R1,@PRV1
BL @CALC
CON2 MOV R1,@PRV1
MOV R2,R1
CI R1,0
JEQ CON3
MOV R1,@PRV2
BL @CALC
CON3 MOV R1,@PRV2
MOV R3,R1
CI R1,0
JEQ CON4
MOV R1,@PRV3
BL @CALC
CON4 MOV R1,@PRV3
JMP OUTPRV
CALC MOV @TRF,R7
JNE CALCC
MOV @PR,R7
JEQ CALCC
MOV @EPCC,R7
JEQ TEPC
DEC @EPCC
JMP LBRT1
TEPC MOV @EPC,R7
JEQ LBRT
DEC @EPC
JMP LBRT2
LBRT INC @LBCNT
MOV @EP,@EPC
LBRT2  LI  R7,ETCCI
MOV  R7,@EPCC
LBRT1  MOV  @LBCNT,R7
CI  R7,1
JNE  CLBCNT1
MOV  @D1,R8
JMP  CALCCA
CLBCNT1  CI  R7,2
JNE  CLBCNT2
MOV  @D2,R8
JMP  CALCCS
CLBCNT2  CI  R7,3
JNE  CLBCNT3
MOV  @D3,R8
JMP  CALCCA
CLBCNT3  CI  R7,4
JNE  CLBCNT4
MOV  @D4,R8
JMP  CALCCS
CLBCNT4  CI  R7,5
JNE  CLBCNT5
MOV  @D5,R8
JMP  CALCCA
CLBCNT5  CI  R7,6
JNE  CALCC
MOV  @D6,R8
CALCCS  S  R8,R1
JMP  CALCC
CALCCA  A  R1,R1
CALCC  CI  R5,63
JIT  ZERO1
CI  R1,1000
JIT  CON1
LI  R1,1000
CON1  MPY  R3,R1
DIV  R5,R1
MPY  R3,R1
DIV  R4,R1
ZERO1  CLR  R1
FCALC  B  *R11
OUTPRV  LI  R1,2048
C  @PRV1,@APRV1
JEQ  RV2
JGT  INCP1
C  @APRV1,@DE
JLE  RV2
S  @DE,@APRV1
JMP  RV2
INCP1  A  @DE,@APRV1
C JLT RV2 @APRV1, R1 ; SEE IF TOO BIG
JLT RV2
MOV R1, @APRV1 ; ETC 3 TIMES
MOV @APRV1, R1

RV2 C @PRV2, @APRV2
JEQ RV3
JGT INCP2
C @PRV2, @DE
JLE RV3
S @DE, @APRV2
JMP RV3
INCP2 A @APRV2, @DE
C @APRV2, RI
JLT RV3
MOV RI, @APRV2

RV3 C @PRV3, @APRV3
JEQ OUTP
JGT INCP3
C @PRV3, @DE
JLE OUTP
S @DE, @APRV3
JMP OUTP
INCP3 A @APRV3, @DE
C @APRV3, RI
JLT OUTP
MOV RI, @APRV3

; IF STATUS OFF (EXT SWITCH TO GND)
; THEN ALL OUTPUTS TO 0
;
OUTP LI R12, DA1 ; BASE FOR DIGITAL INPUT
TB 3 ; CRU ADDR OF SW
JEQ COUTP ; HIGH, CONTINUE
CLR @APRV1 ; CLR ALL APRVS
CLR @APRV2
CLR @APRV3
SETO R1
LI R12, DA1+(DALSB*2) ; ALL 1S

LDCR R1, 12
LDCR R1, 12
LDCR R1, 12
LDCR R1, 12
JMP CKVBS ; TO CHECK BUS VOLTS
COUTP MOV @APRV1, R1 ; OUTPUT APRVS
INV R1 ; D/A INVERTING TYPE
LI R12, DA1+(DALSB*2) ; BASE OF PRV1
LDCR R1, 12
MOV @APRV2, R1
INV R1
LI R12, DA2+(DALSB*2)
LDCR R1, 12
MOV @APRV3, R1
INV R1
LDCR R1,12

; IF ANY TWO DIODE BUSSES > H1 THEN OPEN RELAYS
; (ADD DIODES).
; IF ANY TWO DIODE BUSSES < L1 THEN CLOSE RELAYS.
;
CKVBS LI R12,DA2+BVH*2
CLR R1
CLR R2
C @VLB1,@H1
JLT CKB2H
INC R1

CKB2H C @VLB2,@H1
JLT CKB3H
INC R1

CKB3H C @VLB3,@H1
JLT CKR1H
INC R1

CKR1H CI R1,2
JLT CKB1L
LDCR R2,3
LI R12,DA3+BVH*2
LDCR R2,3

CKB1L LI R12,DA2+BVH*2
CLR R1
SETO R2
C @VLB1,@L1
JGT CKB2L
INC R1

CKB2L C @VLB2,@L1
JGT CKB3L
INC R1

CKB3L C @VLB3,@L1
JGT CKR1L
INC R1

CKR1L CI R1,2
JLT DOTEMP
LDCR R2,3
LI R12,DA3+BVH*2
LDCR R2,3

; AVERAGE 3 EACH THERMISITOR ON EACH PLATE
; (UPPER AND LOWER), IF > UH (OR LH) THEN TURN OFF HEATER, IF < UL (OR LL) THEN TURN ON HEATER.
; UH IS THE UPPER PLATE HIGH TEMP, LH IS THE LOWER PLATE HIGH TEMP.
; UL IS THE UPPER PLATE LOW TEMP, LL IS THE LOWER PLATE LOW TEMP.
;

DOTEMP LI R12,DA2
LI R3,3
CLR R1
MOV @T1,R2
A @T2,R2
A @T3,R2 ; SUM
DIV R3,R1
MOV R1,R6
C R1,@UH
JLT CKLT
SBZ BVH+3 ; WAS TOO HIGH, OFF HEATER
JMP CKHB
C R1,@UL
JGT CKHB
SBO BVH+3 ; WAS TOO LOW, ON HEATER
CKHB LI R12,DA3
CLR R1
MOV @T4,R2
A @T5,R2
A @T6,R2
DIV R3,R1
A R1,R6
SRL R6,1
MOV R6,@TAVG
C R1,@LH
JLT CKLB
SBZ BVH+3
JMP TRRT
CKLB C R1,@LL
JGT TRRT
SBO BVH+3

; TRIP BACK ROUTINE
;
; TR IS NO. OF CCC TRIPS (CCCT) THAT OCCUR BEFORE
; ANY POWER SUPPLIES ARE CUT OFF. IF TR = 0 THIS
; ROUTINE IS SKIPPED.
;
; NS IS THE TOTAL NO. OF EQUIVALENT SPAS TAKEN OFF.
; IF THE CCC DISCONNECTS A P.S. THEN THE OTHER P.S. FOR THAT
; BATTERY IS LEFT ALONE. THE ROUTINE FIRST CHECKS IF IT CAN
; REMOVE NS SPAS WITH THE REMAINING 1 SPA P.S.'S BEGINNING
; WITH THE 1 SPA P.S. RIGHT AFTER THE BATTERY (OR THE FIRST
; ONE IT SEES) THAT THE CCC CUT OFF. IF IT CAN IT DOES, ELSE
; IT GOES BACK, ADDS THE ONE SPA P.S. AND TAKES OUT THE 2 SPA
; P.S. (ALL THIS IS CHECKED BEFORE ANY ARE ACTUALLY SHUT OFF)
; ONCE THE ROUTINE CUTS OFF THE P.S.'S, IT DOESN'T CHECK
; ANYMORE.
;
; POWER SUPPLIES CAN BE COMMANDED OFF BY SETTING THE
; PARAMETER "PS" IN BINARY (YOU FIGURE THE HEX INPUT TO THE
; TTY)
; ANY "1" IN THE WORD MEANS "OFF".
; IN CASE YOU MESS UP AND TURN OFF TOO MANY IN THE ROUTINE,
; P.S.'S CAN BE TURNED BACK ON THIS DAY ONLY BY SETTING THE
; PARAMETER "ES". ANY "ONE" MEANS ON.
; THE FORMAT IS ES,B6K2,B6K1,B5K2,B5K1,...,B2K2,B2K1,B1K2,
B1K1.(13 BITS)
; WHERE ES IS THE EXTRA 2 SPAS.
MACRO AND
MOV @'1',R7
INV R7
MOV @'2'(R2),R8
INV R8
SOC R7,R8
INV R8
ENDM
;
TRRT
LI R12,DA1
TB 4
JEQ TODAY ; 0 IF NIGHT, 1 IF DAY
SETO @PSOUT ; ALL PSS OFF
CLR @ES ; RESET THOSE THAT WERE TURNED ON
CLR @STT ; JUST IN CASE
CLR @TRF ; RESET TRIP FLAG IF NIGHT
CLR @DNF ; DAY NIGHT FLAG TO 0
SBZ TFLAG ; TRIP FLAG ALWAYS 0 IN NIGHT
BACK
;
TODAY
B OUTPS ; TO OUTPUT
B OUTPS
MOV @DNF,@DNF ; CHECK FLAG
JNE TETR ; WAS SET, JUMP
INC @DNF
CLR @STT
CLR @TRF
CLR @CCCT
LI R9,0FFFH
MOV R9,@SLTN
CLR @TRF
CLR @STT
CLR @SPOFF
CLR @PSOUT
JMP BACK ; FIRST TIME THROUGH GO TO OUTPUT
;
TETR
MOV @TR,@TR ; IF 0 GET OUT
JEQ BACK
MOV @TRF,@TRF ; IF 1 GET OUT
JEQ MAJR
MOV @NEWRF,R0 ; GO TO NEW ROUTINE?
JEQ BACK
B NEWR
;
;
MAJR
LI R12,CCCIN+(CCCLSB*2)
STCR @STT,12 ; INPUT FROM CCC
CLR R2
AND @STT,SILTN ; IF 0, NOTHING CHANGED
MOV R8,STTSILTN ; SAVE IT, IF 0 NOTHING CHANGED
JEQ STEP6 ; JUMP AHEAD IN CASE TR
CS PA
SPO1
NKTRB
STEP6
STEP7
STEP8
STEP9
STEP10B
STEP10A

ANDI
MOV
CLR
CSPA
AND
JEQ
AND
INC
INC
INC
INCT
INC
INC
INC
INCT
C
JNE
CSPA
STEP6
C
JGT
INC
CLR
CLR
CLR
LI
LI
LI
LI
LI
LI
LI
STEP7
CL
CL
STEP8
AND
JNE
INC
DEC
JNE
CLR
JMP
STEP9A
STEP9
LI
MOV
STEP10B
JEQ
JLT
AND
JNE
SOC
STEP10A
DEC
JEQ
INCT
R7,OFFH
R7, @SLTN
R2
STTSLTN, MB1
NKTRB
STTSLTN, B1S1
SPO1
@SPOFF
@SPOFF
@CCCT
INCT R2
R2, 12
CSPA
@TR, @CCCT
OUTPSB
@TRF
@LCBNT
@EPCC
@EPC
R12, DA1
TFLAG
@STT, @PSOUT
@NEWRF, R0
STEP7
@ET, @ETC
R0, ETCCI
R0, @ETCC
NEWR
R1, 5
STEP8
R2
R1
STEP9A
STEP9
R2
R1
STEP10A
STEP10B
@NS, @SPOFF
OUTPSB
OUTPSB
PSOUT, MB1
STEP10A
@B1S1(R2), @PSOUT
SPOFF
R1
STEP11A
R2

CHANGED
; STRIP LEADING 0S
; SAVE INVERTED STT
; SEE IF TRIP ON EACH
; BATTERY
; NO, JUMP
; SEE HOW MANY WENT
; IF 0, 2 WENT
; IF NOT ZERO, 1 WENT
; COUNT TRIPS
; IF TR > CCCT, NOT YET
; TIME TO DO IT
; SIGNAL TRIPBACK
; NEW ROUTINE?
; FIND ONE THAT CCC BID
; LOOK AGAIN 4 MORE
; TIMES OR...
; ONLY HERE IF B6
; SEE IF CAN TAKE OFF
; 1SPA PS
; IF 0, CAN DO
; OR INTO PSOUT WORD
; INC NO. OF SPA OFF
; SIX BATTs?
; NEW ROUTINE
; TAKE OFF 1 SPA EVERY X SECONDS (DETERMINED BY SETTING
; THE CAP ET) BEGINNING WITH BATTERY 1 AND GOING THROUGH
; ALL 6 UNTIL HAVE TAKEN OFF NS SPAS. THIS DOES NOT REMOVE
; ANY SPAS FROM A BATTERY WHOSE CCC TRIPPED OFF A POWER
; SUPPLY.
;
; NEWRL1
CLR R2
MOV @ET, @ETC
LI R0, @ETCCI
MOV R0, @ETCC
JMP OUTPS

; TIME TO DO SOMETHING
; GETTING READY FOR NEXT TIME

; IF 1, GO TO NEXT BATT
; IF 0, CHECK PSOUT FOR 1 OR 2 SPAS

INCT R2
CI R2, 12
JEQ OUTPS
JMP NEWRL2
NEWRL3 AND PSOUT,B1S2 ; IF NOT 0, 2 SPA IS ALREADY OUT
JNE NEWRL5 ; GO TO NEXT BATTERY
AND PSOUT,B1S1 ; IF 0, TAKE OUT 1 SPA
JNE NEWRL4 ; AND GET OUT
SOC @BIS1(R2),@PSOUT
INC @SPOFF
JMP OUTPS
NEWRL4 SZC @BIS1(R2),@PSOUT ; PUT 1 SPA BACK
SOC @BIS2(R2),@PSOUT ; REMOVE 2 SPA
INC @SPOFF
JMP OUTPS
NEWRL5 INCT R2 ; GO TO NEXT BATTERY
CI R2,12
JNE NEWRL2
;
; TIME TO OUTPUT
; DONT TURN OFF THOSE THAT CCC TURNED OFF (STT)
; TURN OFF THOSE THAT ARE FLAGGED BY "PS"
; TURN ON THOSE THAN ARE FLAGGED BY "ES" (RESET EACH ORBIT)
;
OUTPS MOV @PSOUT,R1
SZC @STT,R1 ; DONT TURN OFF IF CCC OPENED
SOC @PS,R1 ; TURN OFF THOSE FLAGGED BY "PS"
SZC @ES,R1 ; TURN ON THOSE FLAGGED BY "ES"
LI R12,POUT+(POUTLSB*2)
LDCR R1,13
;
; TIME DELAY
;
TDLP MOV @TDLY,RO
TDLPL DEC RO
JNE TDLPL
;
; PULSE ROUTINE
; SHOULD PUT OUT PULSE EVERY SECOND SO NOT TO GET TIMEOUT
; ON ST HARDWARE. I.E., IF CC QUILTS, ST TEST SHUTS DOWN.
; A 60 US PULSE IS PUT OUT EVERY "PL" SOFTWARE CYCLES SO "TD"
; (TIME DELAY BETWEEN CYCLES) WILL HAVE AN EFFECT ALSO.
; THIS ALSO SENSES THE 15V SUPPLY AND STOPS PULSES IF IT FAILS. ALSO, IF THE AVERAGE OF THE SIX PLATE TEMPS
; EXCEEDS "TS", IT STOPS PULSES (CHAMBER FAIL HIGH TEMP)
; THIS ASSUMES THAT THE BATTERY HEATERS CAN KEEP THEM WARM
; IF THE CHAMBER FAILS LOW.
;
LI R12,DA1
TB V15
JNE OUTSAM
C @TAVG,@TS
JGT OUTSAM
DEC @PLC
JNE OUTSAM
MOV @PL, @PLC
LI R1, 10
SBO PULSE
TOL
DEC R1
JNE TOL
SBZ PULSE

; ; END OF LOOP ...... SO DO FOREVER
;
OUTSAM B SAMPLE
MB1 WORD 11B, 1100B, 110000B, 11000000B, 1100000000B,
       110000000000B
B1S2 WORD 01B, 0100B, 010000B, 01000000B, 0100000000B,
       010000000000B
B1S1 WORD 10B, 1000B, 100000B, 10000000B, 1000000000B,
       100000000000B
ZZZ EQU $

;
;
SECTION TASKRWM,ABSOLUTE
;
ORG RWM
;
WP1 BLOCK 32
WP2 BLOCK 32

;

CHL0 BLOCK 2 ; C0 EXAMINE
CHL1 BLOCK 2 ; C1
CHL2 BLOCK 2 ; ETC
CHL3 BLOCK 2
CHL4 BLOCK 2
CHL5 BLOCK 2
CHL6 BLOCK 2
CHL7 BLOCK 2
CHL8 BLOCK 2
CHL9 BLOCK 2
CHL10 BLOCK 2 ; CA
CHL11 BLOCK 2
CHL12 BLOCK 2
CHL13 BLOCK 2
CHL14 BLOCK 2
CHL15 BLOCK 2
PRV1 BLOCK 2 ; R1
PRV2 BLOCK 2 ; R2
PRV3 BLOCK 2 ; R3
APRV1 BLOCK 2 ; A1 EXAMINE AND SET THE REST
APRV2 BLOCK 2 ; A2
APRV3 BLOCK 2 ; A3
H1 BLOCK 2

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| L1   | BLOCK | 2 |
| H2   | BLOCK | 2 |
| L2   | BLOCK | 2 |
| H3   | BLOCK | 2 |
| L3   | BLOCK | 2 |
| H4   | BLOCK | 2 |
| L4   | BLOCK | 2 |
| H5   | BLOCK | 2 |
| L5   | BLOCK | 2 |
| H6   | BLOCK | 2 |
| L6   | BLOCK | 2 |
| UH   | BLOCK | 2 |
| UL   | BLOCK | 2 |
| LH   | BLOCK | 2 |
| LL   | BLOCK | 2 |
| P1   | BLOCK | 2 |
| P2   | BLOCK | 2 |
| P3   | BLOCK | 2 |
| DE   | BLOCK | 2 |
| TDLY | BLOCK | 2 |
| M1   | BLOCK | 2 |
| M2   | BLOCK | 2 |
| M3   | BLOCK | 2 |
| I1   | BLOCK | 2 |
| I2   | BLOCK | 2 |
| I3   | BLOCK | 2 |
| PSOUT| BLOCK | 2 |
| PS   | BLOCK | 2 |
| ES   | BLOCK | 2 |
| TR   | BLOCK | 2 |
| NS   | BLOCK | 2 |
| TRF  | BLOCK | 2 |
| DNF  | BLOCK | 2 |
| KI   | BLOCK | 2 |
| CCCT | BLOCK | 2 |
| STT  | BLOCK | 2 |
| SLTN | BLOCK | 2 |
| STTSLTN| BLOCK | 2 |
| SPOFF| BLOCK | 2 |
| TS   | BLOCK | 2 |
| PL   | BLOCK | 2 |
| PLC  | BLOCK | 2 |
| TAVG | BLOCK | 2 |
| ET   | BLOCK | 2 |
| ETC  | BLOCK | 2 |
| BTCC | BLOCK | 2 |
| NEWRF| BLOCK | 2 |
| PR   | BLOCK | 2 |
| EPC  | BLOCK | 2 |
| EPCC | BLOCK | 2 |
| LBCNT| BLOCK | 2 |
| EP   | BLOCK | 2 |

; TD

; FLAG TO DO POWER STEP ROUTINE

; WHICH STEP

; COUNTER INITIAL VALUE
D1 BLOCK 2 ; FIRST POWER DELTA (ADD)
D2 BLOCK 2 ; SECOND POWER DELTA (SUB)
D3 BLOCK 2 ; THIRD..ETC...
D4 BLOCK 2
D5 BLOCK 2
D6 BLOCK 2

; ;
VLB1 EQU CHL1
VLB2 EQU CHL2
VLB3 EQU CHL3
VB1 EQU CHL4
VB2 EQU CHL5
VB3 EQU CHL6
VB4 EQU CHL7
VB5 EQU CHL8
VB6 EQU CHL9
T1 EQU CHL10
T2 EQU CHL11
T3 EQU CHL12
T4 EQU CHL13
T5 EQU CHL14
T6 EQU CHL15

; ;
END START
APPROVAL

HUBBLE SPACE TELESCOPE SIX-BATTERY TEST BED

By J.A. Pajak, J.R. Bush, Jr., and J.R. Lanier, Jr.

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