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RoMPS CONCEPT REVIEW AUTOMATIC CONTROL OF SPACE ROBOT

M.E. DOBBS

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SpARC
Space Automation
& Robotics Center

ERIM P.O. Box 134001
Ann Arbor, MI 48113-4001

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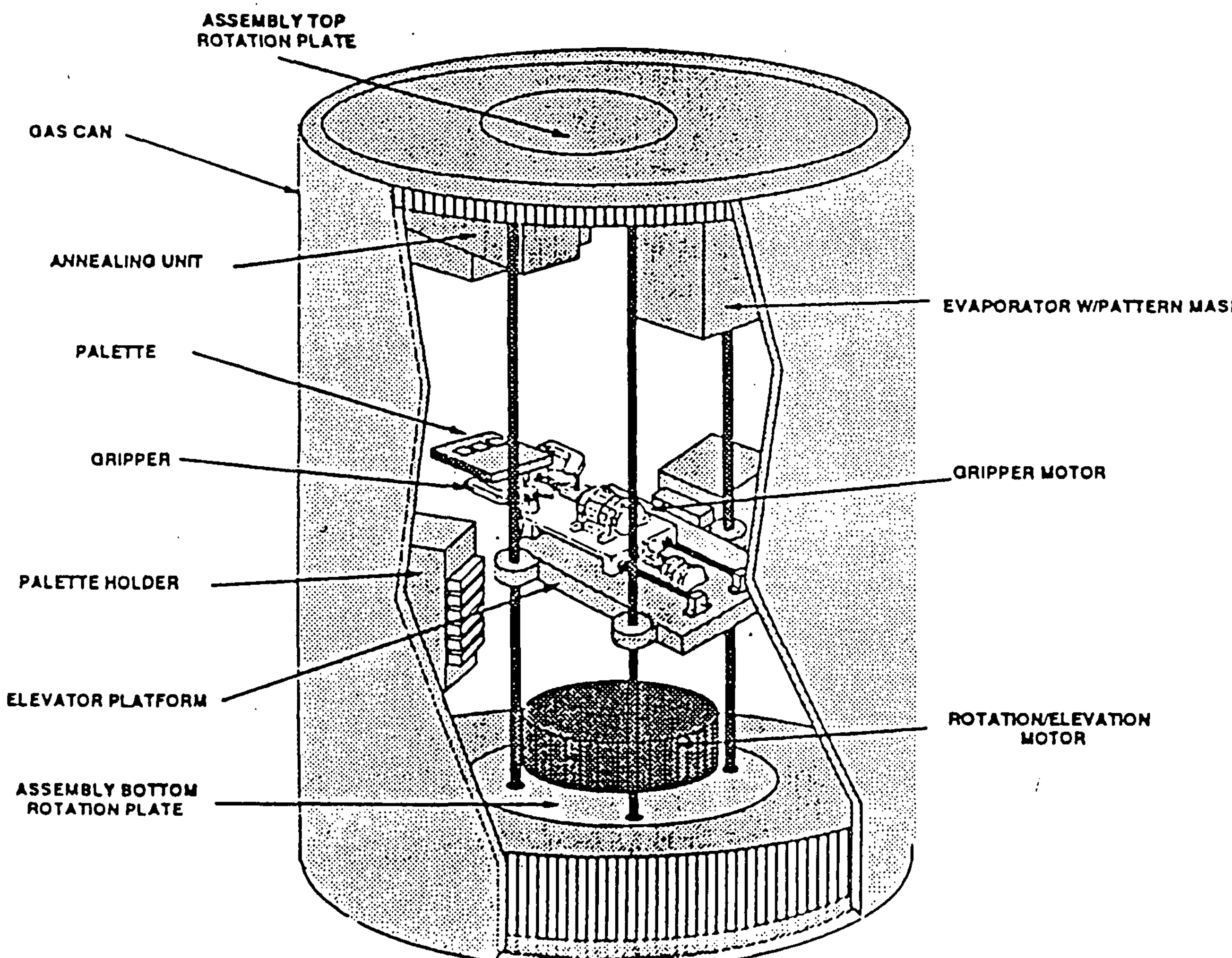
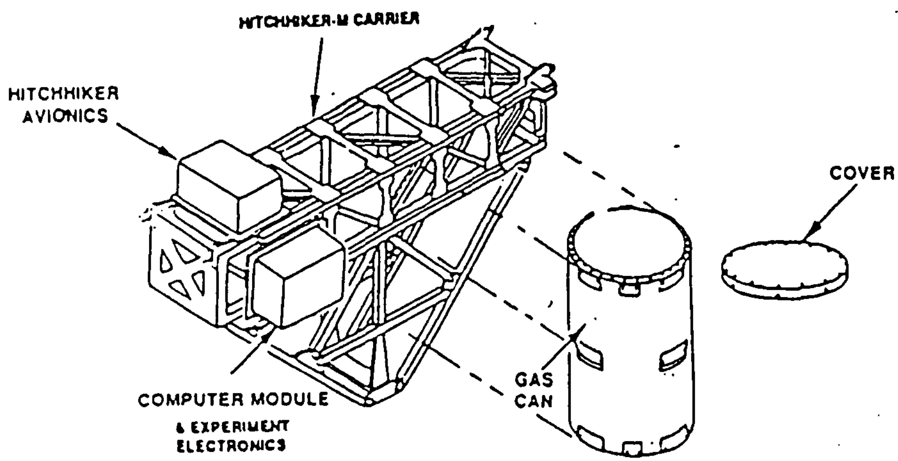
System Concept

GAS CAN CONCEPT LAYOUT

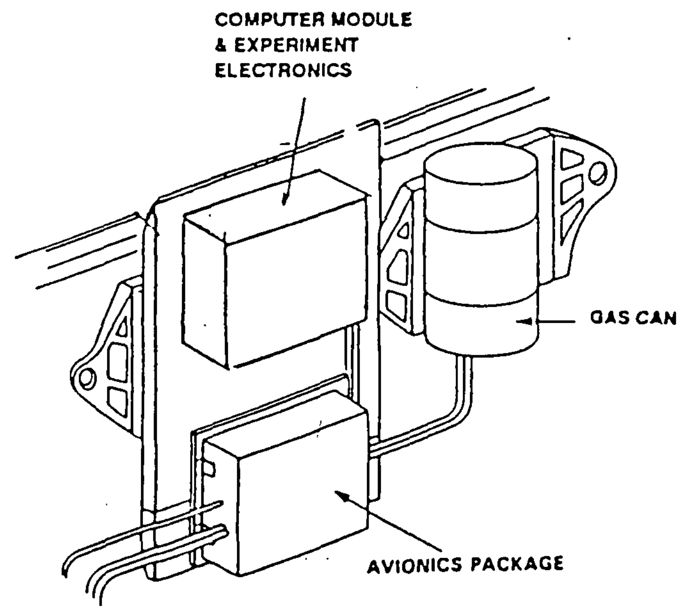


GSFC

CARRIER OPTIONS



HITCHHIKER-M



HITCHHIKER-G

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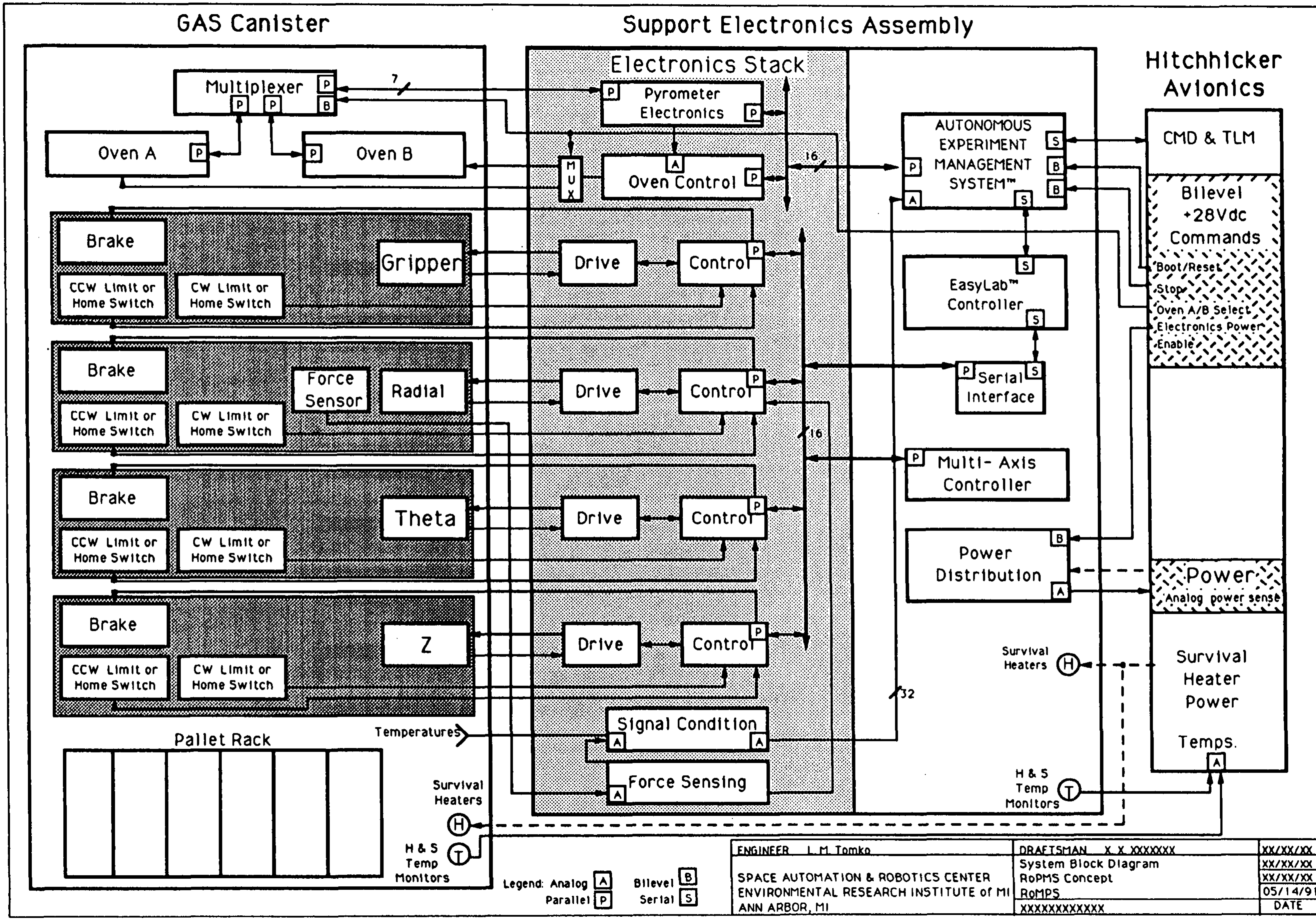

GAS Canister
Support Electronics Assembly
Electronics Stack
Hitchhicker Avionics
Multiplexer
Oven A
Oven B
Pyrometer Electronics
MUX
Oven Control
AUTONOMOUS EXPERIMENT MANAGEMENT SYSTEM™
CMD & TLM
Bilevel +28Vdc Commands
Boot/Reset
Stop
Oven A/B Select
Electronics Power Enable
Brake
CCW Limit or Home Switch
CW Limit or Home Switch
Gripper
Drive
Control
EasyLab™ Controller
Force Sensor
Radial
Serial Interface
Multi- Axis Controller
Theta
Power Distribution
Power
Analog power sense
Z
Survival Heaters
Survival Heater Power
Temps.
Signal Condition
Force Sensing
Temperatures
Pallet Rack
H & S Temp Monitors
7
16
32
Legend: Analog A Parallel P Bilevel B Serial S
ENGINEER L. M. Tomko
DRAFTSMAN X. X. XXXXXXX
SPACE AUTOMATION & ROBOTICS CENTER
ENVIRONMENTAL RESEARCH INSTITUTE of MI
ANN ARBOR, MI
System Block Diagram
RoPMS Concept
RoMPS
XXXXXXXXXXXX
XX/XX/XX
05/14/91
DATE

AUTONOMOUS EXPERIMENT MANAGEMENT SYSTEM

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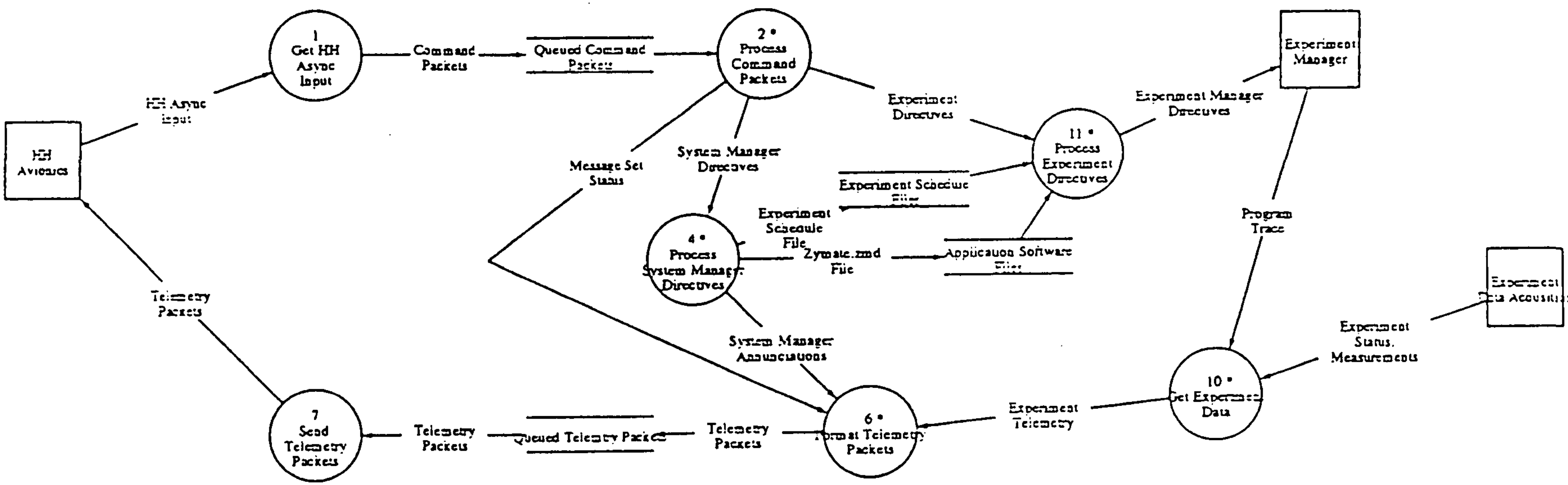

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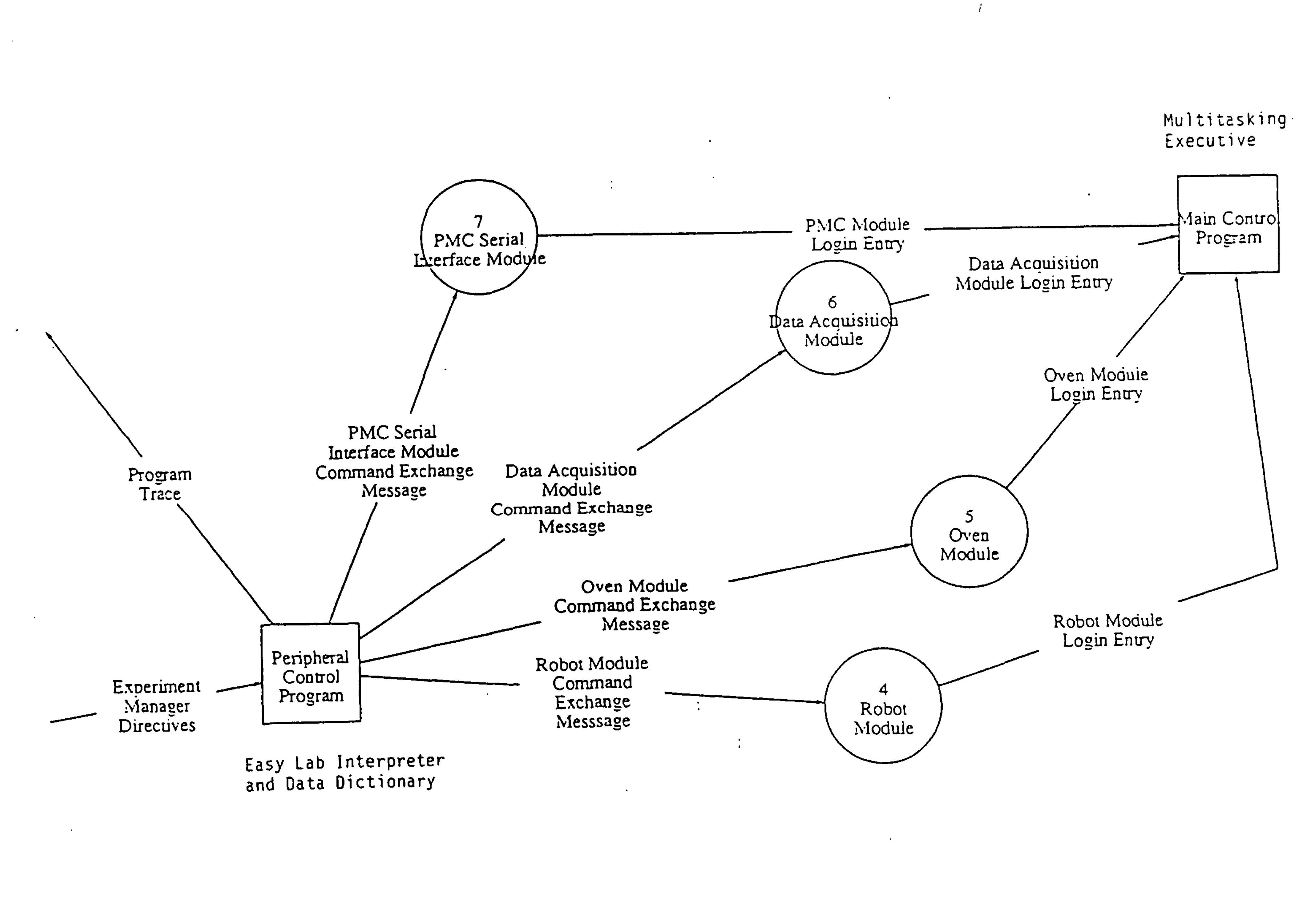
ZYMATE CONTROLLER



ROMPS INITIAL CONFIGURATION

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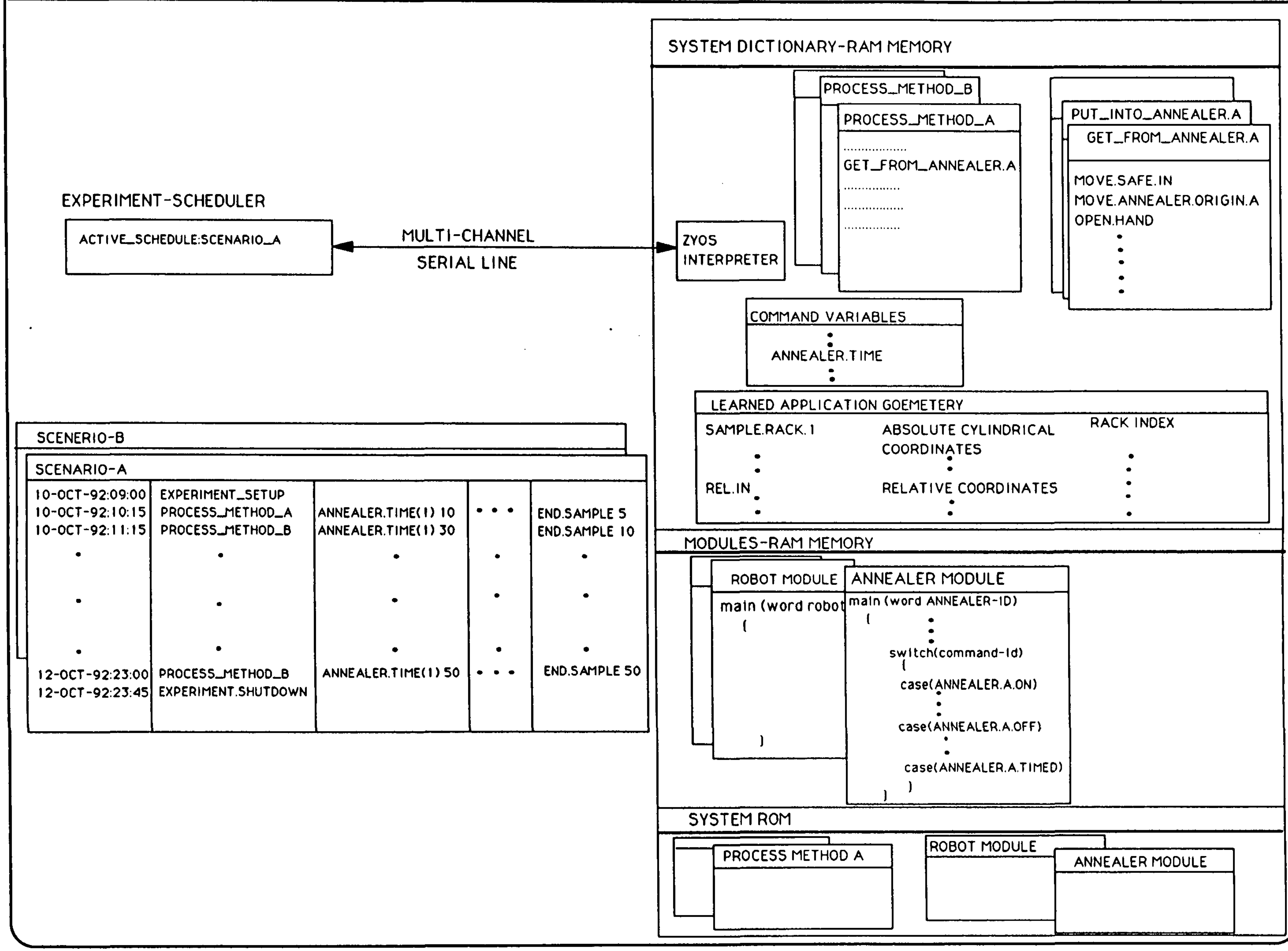
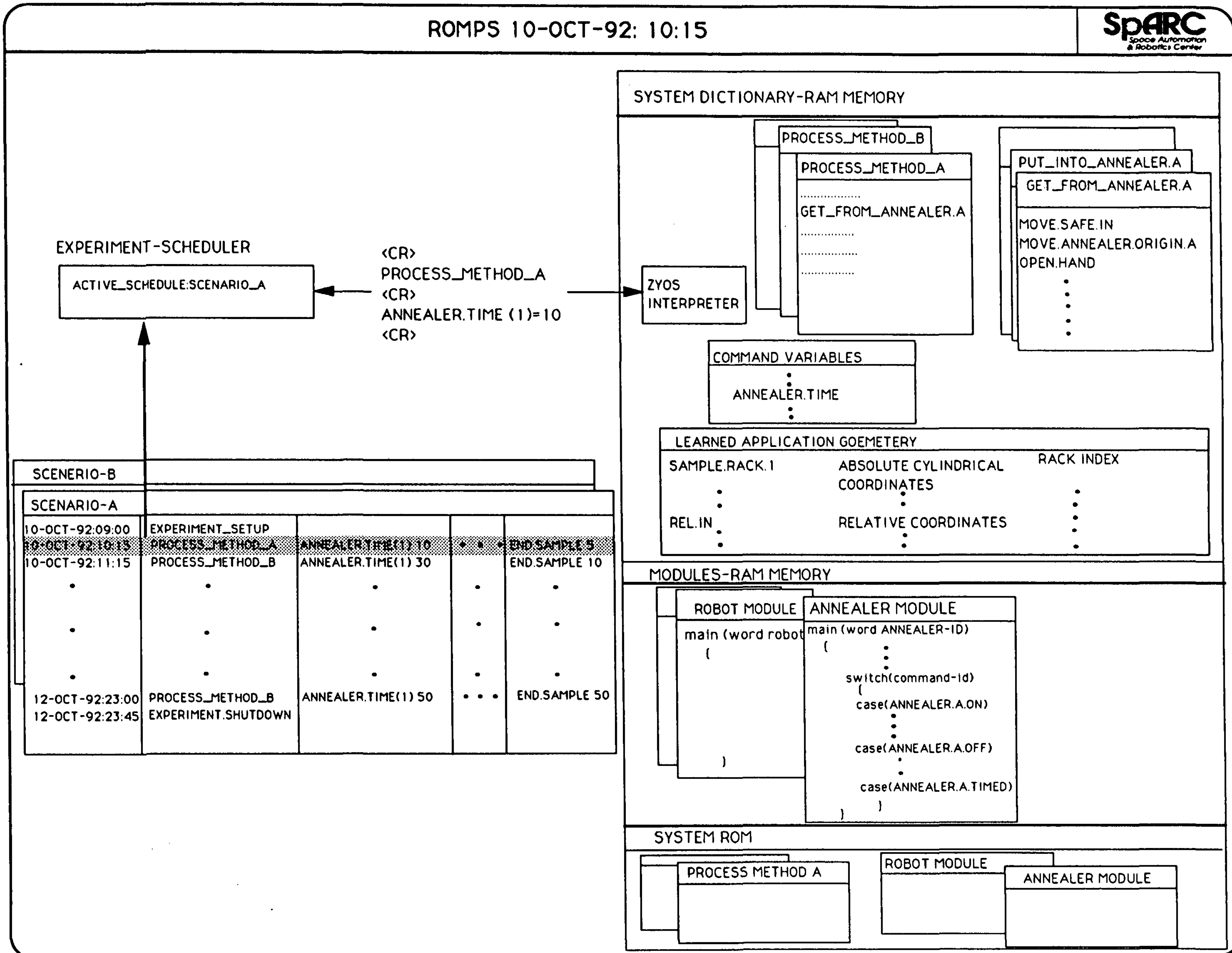
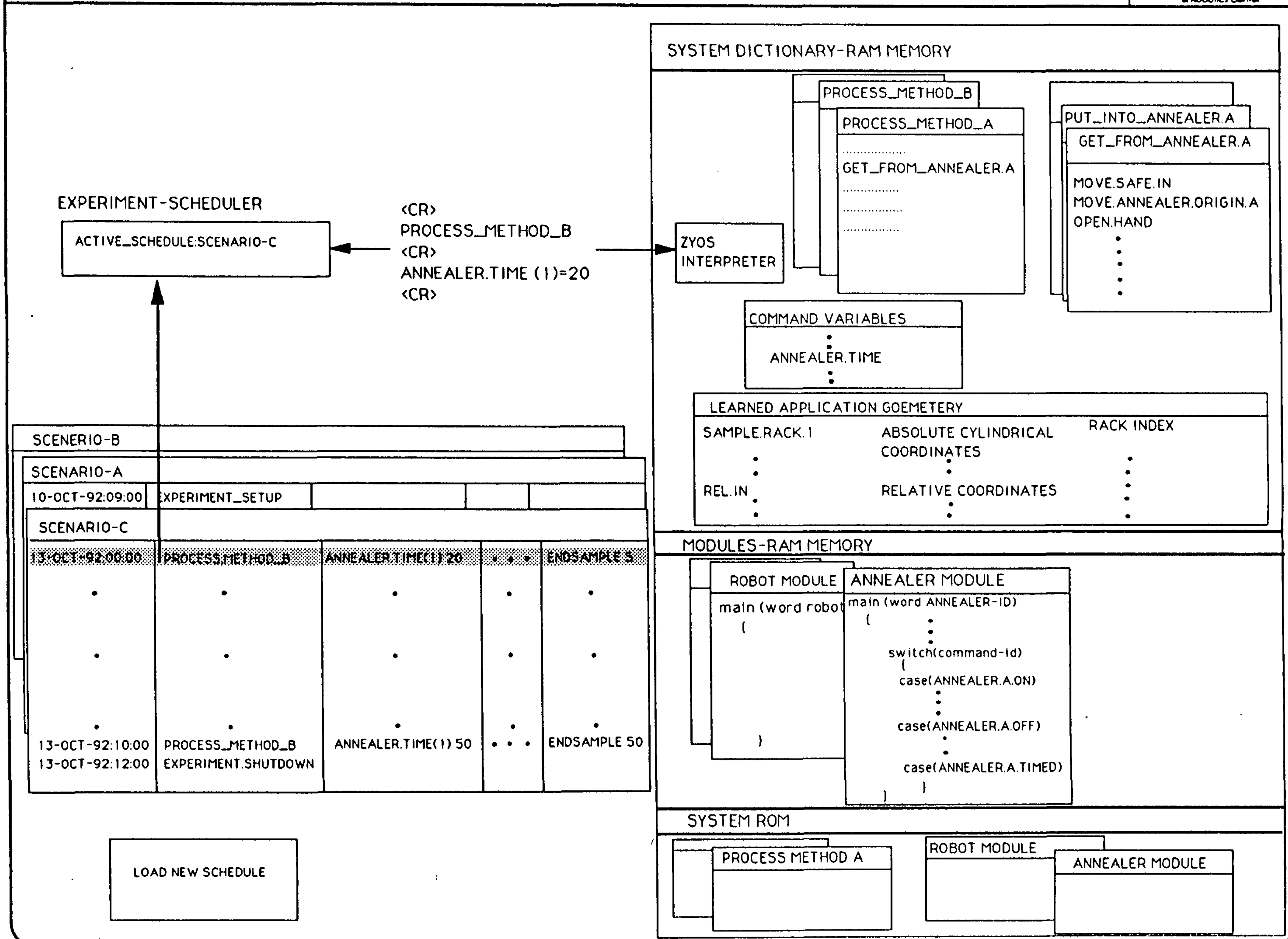


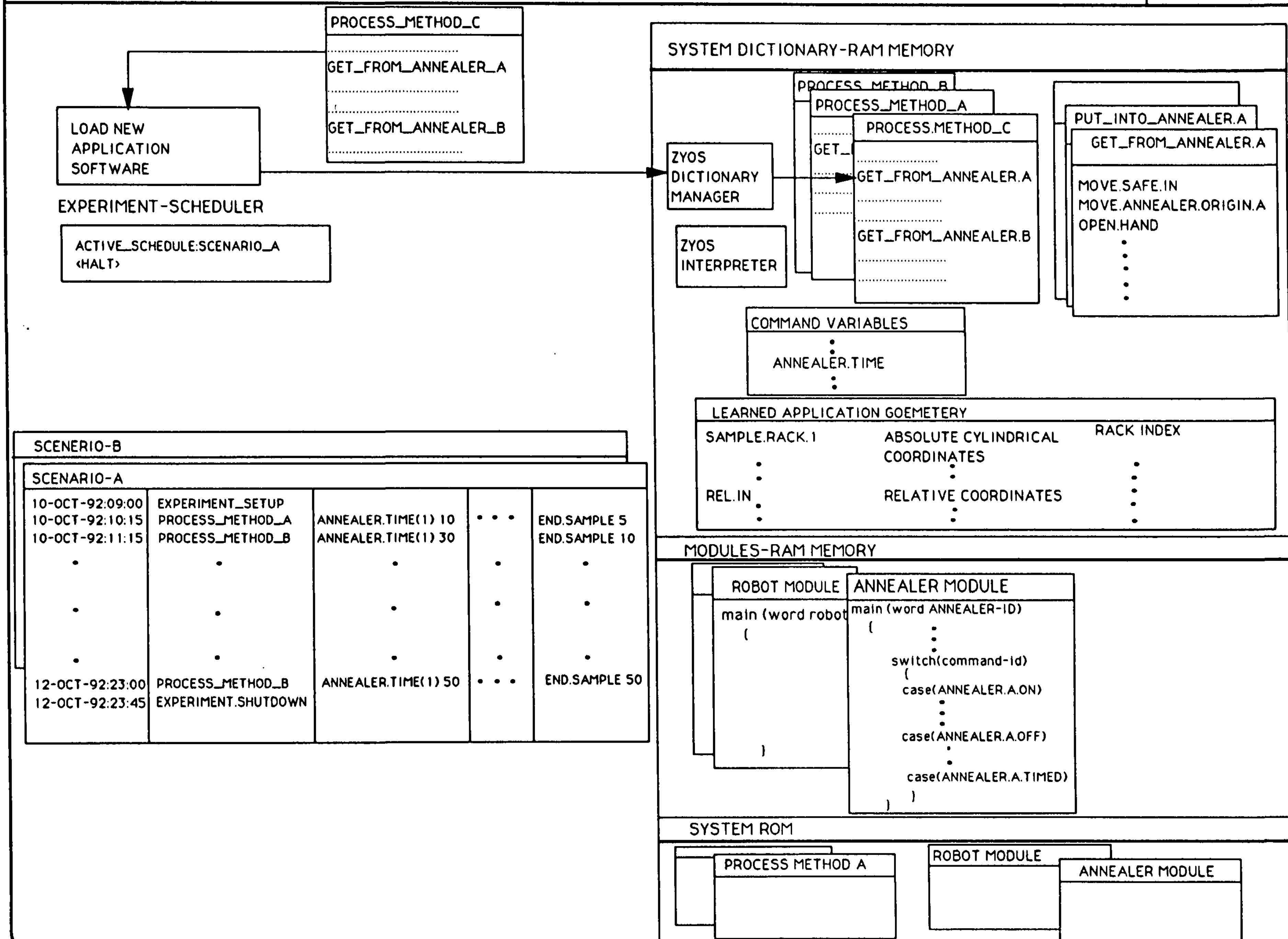


ROMPS 10-OCT-92: 10:15
SpARC Space Automation & Robotics Center
EXPERIMENT-SCHEDULER
ACTIVE_SCHEDULE:SCENARIO_A
<CR>
PROCESS_METHOD_A
<CR>
ANNEALER.TIME (1)=10
<CR>
SCENERIO-B
SCENARIO-A
10-OCT-92:09:00 EXPERIMENT_SETUP
10-OCT-92:10:15 PROCESS_METHOD_A ANNEALER.TIME(1) 10 • • • END.SAMPLE 5
10-OCT-92:11:15 PROCESS_METHOD_B ANNEALER.TIME(1) 30 END.SAMPLE 10
12-OCT-92:23:00 PROCESS_METHOD_B ANNEALER.TIME(1) 50 • • • END.SAMPLE 50
12-OCT-92:23:45 EXPERIMENT.SHUTDOWN
SYSTEM DICTIONARY-RAM MEMORY
ZYOS INTERPRETER
PROCESS_METHOD_B
PROCESS_METHOD_A
GET_FROM_ANNEALER.A
PUT_INTO_ANNEALER.A
GET_FROM_ANNEALER.A
MOVE.SAFE.IN
MOVE.ANNEALER.ORIGIN.A
OPEN.HAND
COMMAND VARIABLES
ANNEALER.TIME
LEARNED APPLICATION GOEMETERY
SAMPLE.RACK.1
ABSOLUTE CYLINDRICAL COORDINATES
RACK INDEX
REL.IN
RELATIVE COORDINATES
MODULES-RAM MEMORY
ROBOT MODULE
main (word robot
{
}
ANNEALER MODULE
main (word ANNEALER-ID)
{
switch(command-id)
{
case(ANNEALER.A.ON)
case(ANNEALER.A.OFF)
case(ANNEALER.A.TIMED)
}
}
SYSTEM ROM
PROCESS METHOD A
ROBOT MODULE
ANNEALER MODULE

SHUTTLE PROBLEM CAUSE POSTPONEMENT OF OCT-12 EXPERIMENT



EXPERIMENTERS DISCOVER ANOMALIES BETWEEN IDENTICAL SAMPLES PROCESSED IN OVEN A AND OVEN B: WANT LAST TWO PROCESS RUNS WITH NEW METHOD



ROBOT UNABLE TO GRAB SAMPLES FROM RACK
LOAD NEW APPLICATION GOEMETRY

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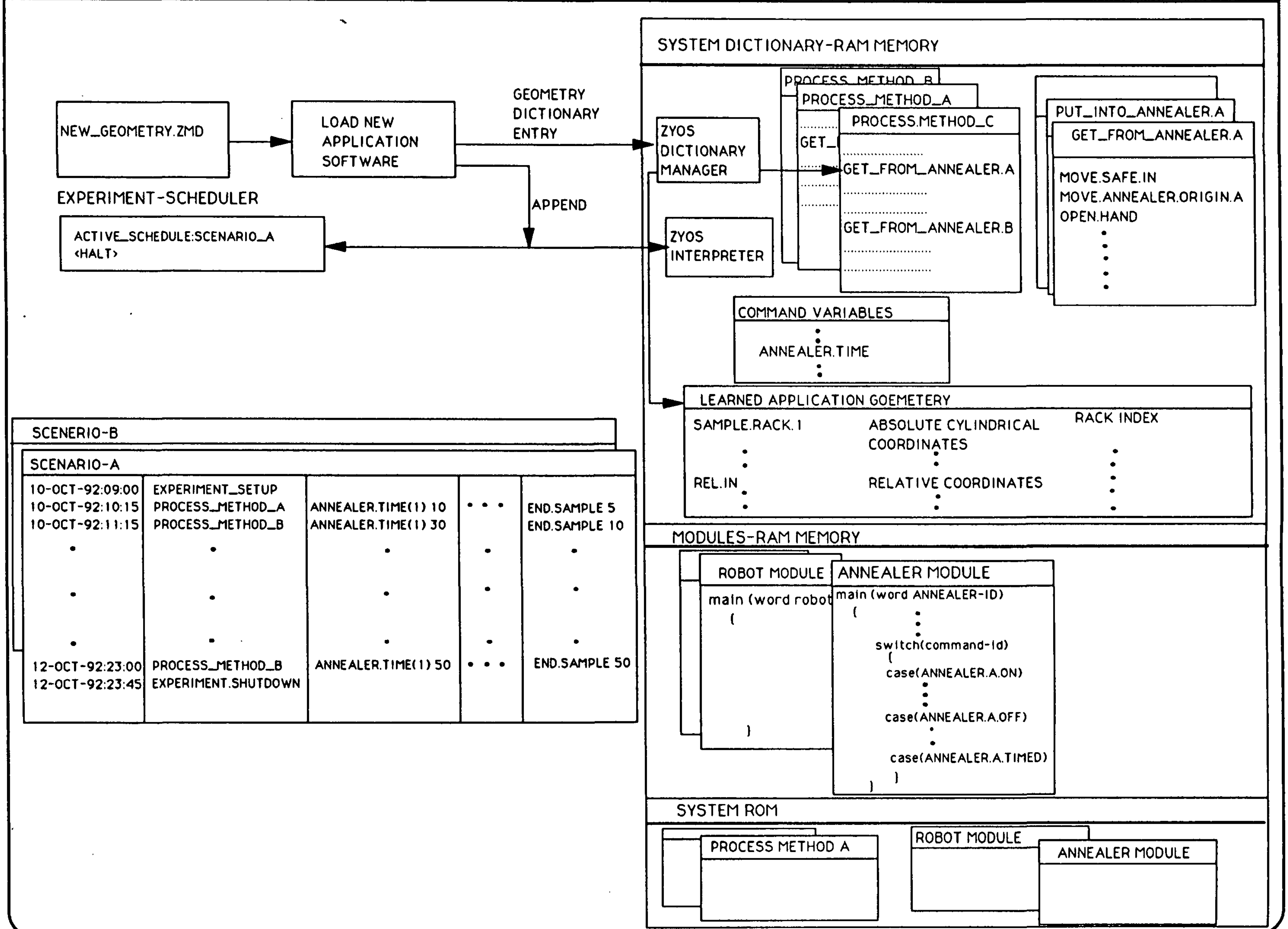
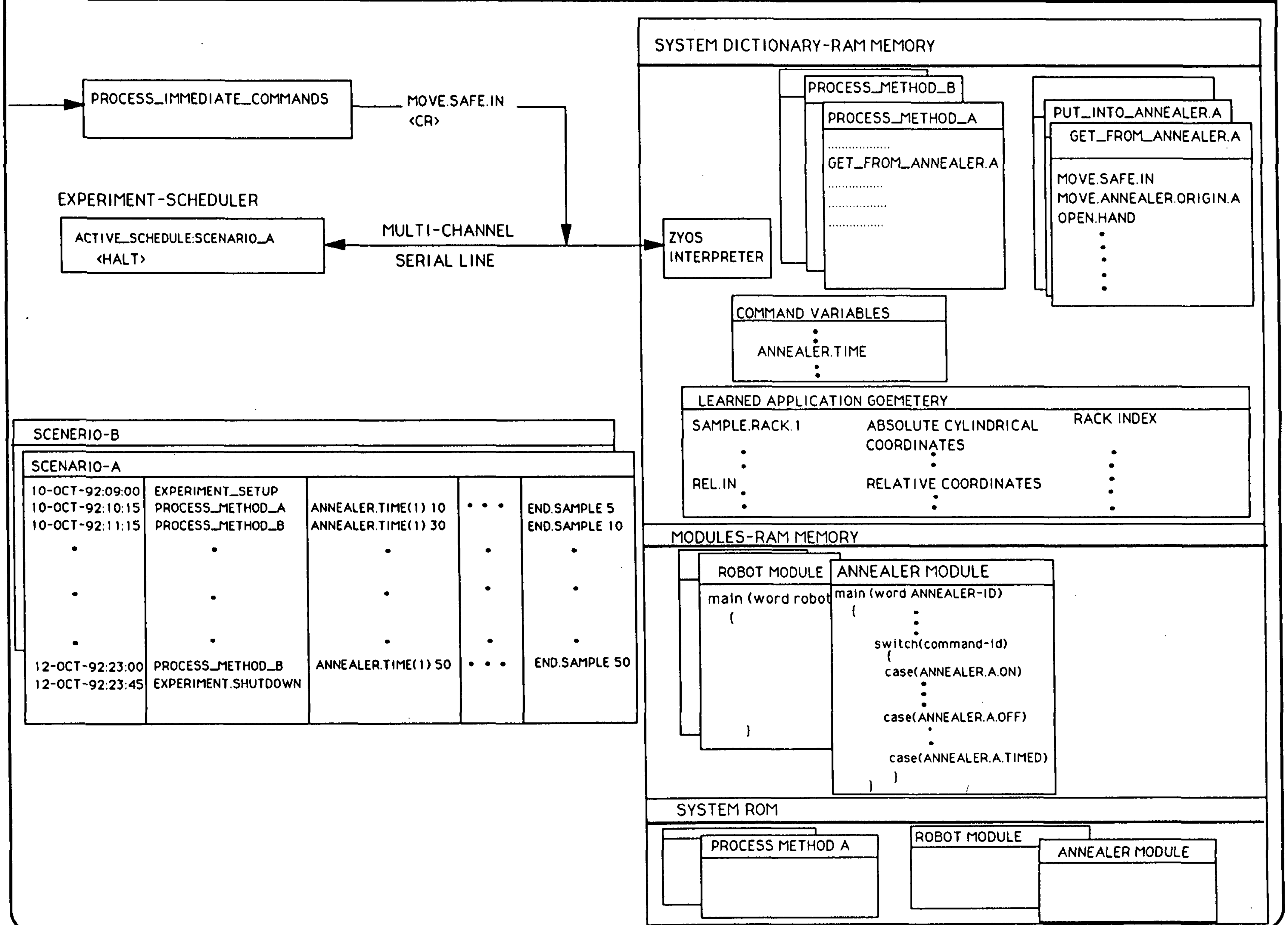


SINGLE STEP IMMEDIATE COMMAND MODE



```
- EasyLabsyLab program PROCESS_METHOD_A
- This procedure processes a samples START.SAMPLE to END.SAMPLE,
- using annealing oven a and the processing parameters contained in
- ANNEALER.TEMPS and ANNEALER.TIMES.

                - NOTE : WORKING.SAMPLE IS A LOCAL TYPE VARIABLE
                - THE START.SAMPLE IS ASSUMED TO BE SET BY THE CALLING
                - MODULE, THIS METHOD OF PARAMETER PASSING IS USED
                - THROUGHOUT THIS PROGRAM
WORKING.SAMPLE = START.SAMPLE

                - Get the sample to be processed
                - NOTE SAMPLE.RACK.1.INDEX IS USED BY THE ROBOT MODULE
                - TO DETERMINE THE SAMPLE WITHIN A RACK TO GET
SAMPLE.RACK.1.INDEX = WORKING.SAMPLE
GET.FROM.SAMPLE.RACK.1

                - put the sample in the annealer
PUT.INTO.ANNEALER.A

                - Set the temperature and time for the oven
                - and anneal the sample
ANNEALER.A.TEMPERATURE = ANNEALER.TEMPS(WORKING.SAMPLE)
ANNEALER.A.TIME = ANNEALER.TIMES(WORKING.SAMPLE)
ANNEALER.A.TIMED.RUN

                - Get the sample from the annealer
GET.FROM.ANNEALER.A

                - Put the sample into the inspection station
PUT.INTO.INSPECTER

                - Measure the sample
OBTAIN.SAMPLE.PROPERTIES

                - Put Sample back into rack
PUT.INTO.SAMPLE.RACK.1

                - Determine if we have processed all the samples
WORKING.SAMPLE = WORKING.SAMPLE.1
IF WORKING.SAMPLE <= END.SAMPLE THEN 10
```

```
May 12 19:48 1991  process_method_b.zy Page 1


- EasyLabsyLab program PROCESS_METHOD_A
- This procedure processes a samples START.SAMPLE to END.SAMPLE,
- using annealing oven b and the processing parameters contained in
- ANNEALER.TEMPS and ANNEALER.TIMES.

WORKING.SAMPLE = START.SAMPLE

                - Get the sample to be processed
SAMPLE.RACK.1.INDEX = WORKING.SAMPLE
GET.FROM.SAMPLE.RACK.1

                - put the sample in the annealer
PUT.INTO.ANNEALER.B

                - Set the temperature and time for the oven
                - and anneal the sample
ANNEALER.B.TEMPERATURE = ANNEALER.TEMPS(WORKING.SAMPLE)
ANNEALER.B.TIME = ANNEALER.TIMES(WORKING.SAMPLE)
ANNEALER.B.TIMED.RUN

                - Get the sample from the annealer
GET.FROM.ANNEALER.B

                - Put the sample into the inspection station
PUT.INTO.INSPECTER

                - Measure the sample
OBTAIN.SAMPLE.PROPERTIES

                - Put Sample back into rack
PUT.INTO.SAMPLE.RACK.1

                - Determine if we have processed all the samples
WORKING.SAMPLE = WORKING.SAMPLE.1
IF WORKING.SAMPLE <= END.SAMPLE THEN 10
```

```
- EasyLabsyLab program PROCESS_METHOD_C
- This procedure processes a samples START.SAMPLE to END.SAMPLE,
- using annealing oven a and the processing parameters contained in
- ANNEALER.TEMPS and ANNEALER.TIMES. It processes the sample a second
- time using the same processing parameters but using oven b.

                - This start the processing at the desired sample
WORKING.SAMPLE = START.SAMPLE

                - Get the sample to be processed
SAMPLE.RACK.1.INDEX = WORKING.SAMPLE
GET.FROM.SAMPLE.RACK.1

                - put the sample in the annealer
PUT.INTO.ANNEALER.A

                - Set the temperature and time for the oven
                - and anneal the sample
ANNEALER.A.TEMPERATURE = ANNEALER.TEMPS(WORKING.SAMPLE)
ANNEALER.A.TIME = ANNEALER.TIMES(WORKING.SAMPLE)
ANNEALER.A.TIMED.RUN

                - Get the sample from the annealer
GET.FROM.ANNEALER.A

                - Put the sample into the inspection station
PUT.INTO.INSPECTER

                - Measure the sample
OBTAIN.SAMPLE.PROPERTIES

                - put the sample in the annealer
PUT.INTO.ANNEALER.B

                - Set the temperature and time for the oven
                - and anneal the sample
ANNEALER.B.TEMPERATURE = ANNEALER.TEMPS(WORKING.SAMPLE)
ANNEALER.B.TIME = ANNEALER.TIMES(WORKING.SAMPLE)
ANNEALER.B.TIMED.RUN
```

May 12 19:43 1991 process_method_c.zy Page 2

```
                - Get the sample from the annealer
GET.FROM.ANNEALER.B

                - Put the sample into the inspection station
PUT.INTO.INSPECTER

                - Measure the sample
OBTAIN.SAMPLE.PROPERTIES

                - Put Sample back into rack
PUT.INTO.SAMPLE.RACK.1

                - Determine if we have processed all the samples
WORKING.SAMPLE = WORKING.SAMPLE.1
IF WORKING.SAMPLE <= END.SAMPLE THEN 10
```

Hitchhiker Interface Requirements

Hitchiker Avionics Interface Requirements
Summary

Bilevel Commands (+28V)
- bus A/B select
- oven enable
- processor restart
- system halt

Serial Command
- NONE

Asyncronous Uplink (RD)
- 1200 baud (1 start, 8 data, no parity, 1 stop)
- customer message - basic functions
  - operating system commands
  - experiment commands
- volume
  - TBD Bytes/Hour
- mission elapsed time (asyncronous or syncronous)

Asyncronous Downlink (SD)
- 1200 baud (1 start, 8 data, no parity, 1 stop)
- customer data - basic content
  - operating system status
  - experiment status
- volume
  - TBD Bytes/Hour

Medium Rate Downlink
- NONE

PCM Telemetry
- NONE

Analog Data
- Experiment Total Current

Temperature Data
- SEA Baseplate
- GAS Structure
- GAS Heatsink

IRIG-B MET
- None

1 Minute Pulse
- None

Hitchiker Avionics Interface Requirements
Telemetry Format
1 Second Frame

Mnemonic	Description	Type	Len	Range
SYNC	sync	byte	8	
SYNC	sync	byte	8	
SYNC	sync	byte	8	
ID	frame identifcation	byte	8	
SEC	sec	byte	8	0-59
MIN	min	byte	8	0-59
HOUR	hour	byte	8	0-11
UDAY	1's day	byte	8	0-9
TDAY	10's day	byte	8	0-3
	Manufacturing Control			
SLINE	schedule line number	byte	8	0-255
EXPID	experiment id	byte	8	0-255
ELINE	experiment line number	byte	8	0-255
SAMP	sample number	byte	8	0-255
	Manufacturing Process			
	pyrometer output	intg	16	
	sample temp	real	16	
	lamp intensity	real	16	
	lamp current	real	16	
	lamp voltage	real	16	
	Manufacturing Data			
	characterization output 1	real	16	
	characterization output 2	real	16	
	characterization output 3	real	16	
	characterization output 4	real	16	
	Robot Status			
	Z position	intg	16	
	Theta position	intg	16	
	Radial position	intg	16	
	Gripper position	intg	16	
	Radial force	real	16	
	Gripper force	real	16	
	Total Bytes			

Hitchiker Avionics Interface Requirements
Telemetry Format
1 Minute Frame

Mnemonic	Description	Type	Len	Range
SYNC	sync	byte	8	
SYNC	sync	byte	8	
SYNC	sync	byte	8	
ID	frame identifcation	byte	8	
	Manufacturing Calibration			
	pyrometer calibration	intg	16	
	pyrometer calibration	intg	16	
	pyrometer calibration	intg	16	
	pyrometer calibration	intg	16	
	Operating System			
OPSTAT	processor status	byte	16	
OSSTAT	software status	byte	16	
	Robot Controller			
CPSTAT	processor status	byte	16	
CSSTAT	software status	byte	16	
	Current Monitors			
ZMIMON	Z motor	real	8	0-tbd amp
TMIMON	Theta motor	real	8	0-tbd
RMIMON	Radial motor	real	8	0-tbd
GMIMON	Gripper motor	real	8	0-tbd
CPU1IMON	processor 1	real	8	0-1
CPU2IMON	processor 2	real	8	0-1
	Temperature Monitors - Support Electronics Assembly			
PWRTMP	power distribution	real	8	-20 +60 °C
CPU1TMP	processor 1	real	8	-20 +60
CPU2TMP	processor 2	real	8	-20 +60
	Temperature Monitors - Get Away Special Container			
BPTMP	baseplate	real	8	-20 +60
RADTMP	radiator	real	8	-20 +60
OV1TMP	lamp 1	real	8	-20 +60
OV2TMP	lamp 2	real	8	-20 +60
ROBTMP	robot	real	8	-20 +60

Total Bytes

Hitchiker Avionics Interface Requirements
Telemetry Format
Alternate 1 Second Frame

Mnemonic	Description	Type	Len	Range
SYNC	sync	byte	8	
SYNC	sync	byte	8	
SYNC	sync	byte	8	
ID	frame identifcation	byte	8	
	Operating System			
OPSTAT	processor status	byte	16	
OSSTAT	software status	byte	16	
	Robot Controller			
CPSTAT	processor status	byte	16	
CSSTAT	software status	byte	16	
	Data Field	byte	16	
	Total Bytes			

Hitchiker Avionics Interface Requirements
Asyncronous Command RD
Customer Message

- RoMPS payload command blocks will require one or more customer message packets.

  Embedded within the HH specified customer message format will be a customer specified, generated and on-orbit processed command block protocol.

- Contents of customer data in customer messages:

  customer protocol bytes
  ASCII Strings (high level experiment language) or Binary Data (processor load)
  terminator

PRELIMINARY

- User Interface Examples:

  The schedule might look like this

DAY	GMT	EXP
1	1300	01
1	1320	02
1	1900	05
2	2000	04

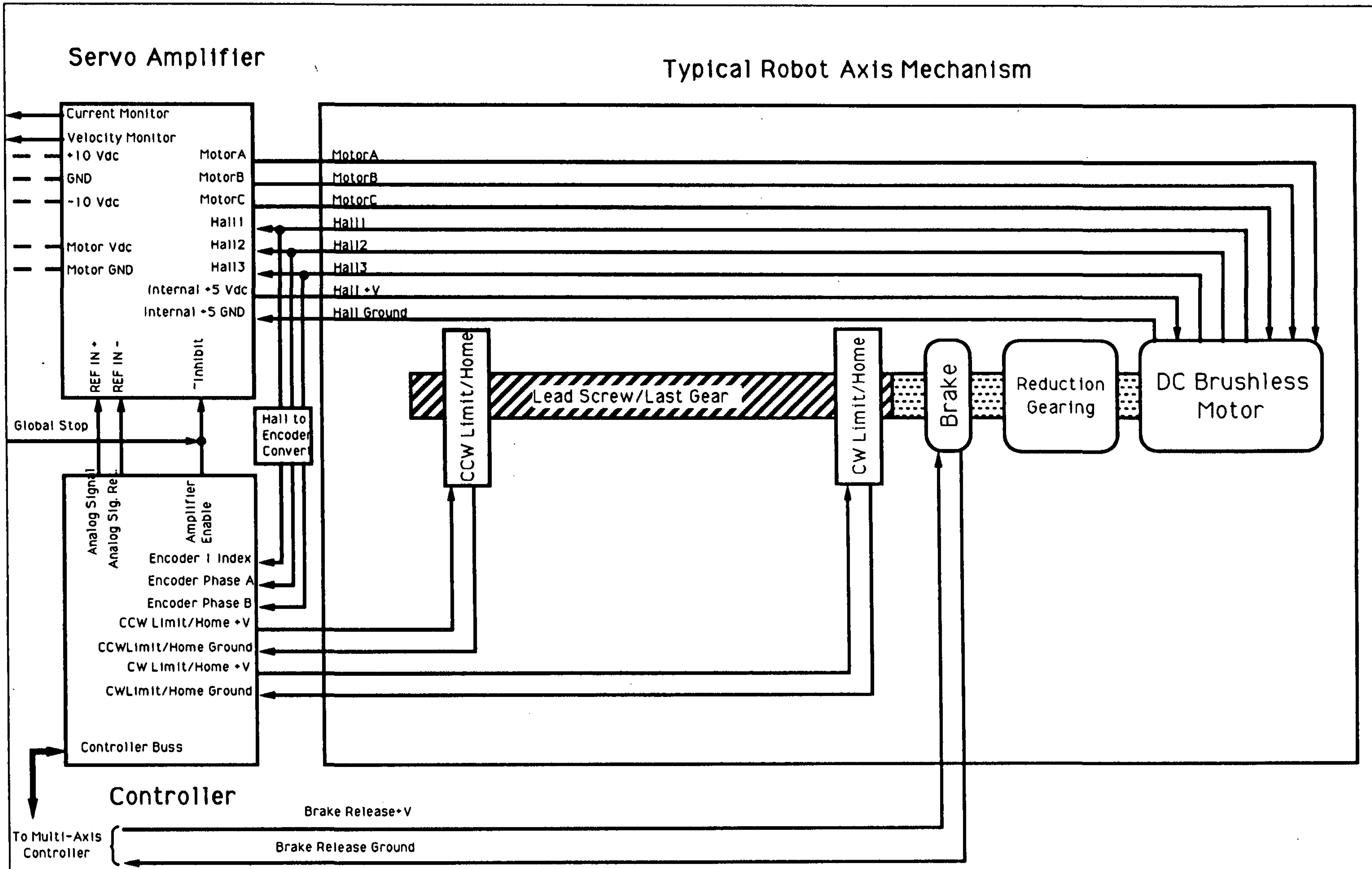
  The contents of Experiment 01 might look like this:

```
WHILE
        N>10 .and. N<=20
DO
        MOVE.SAMPLE.N.OVEN
        PROCESS.N.OVEN.NORMAL
END
ENDWHILE
```

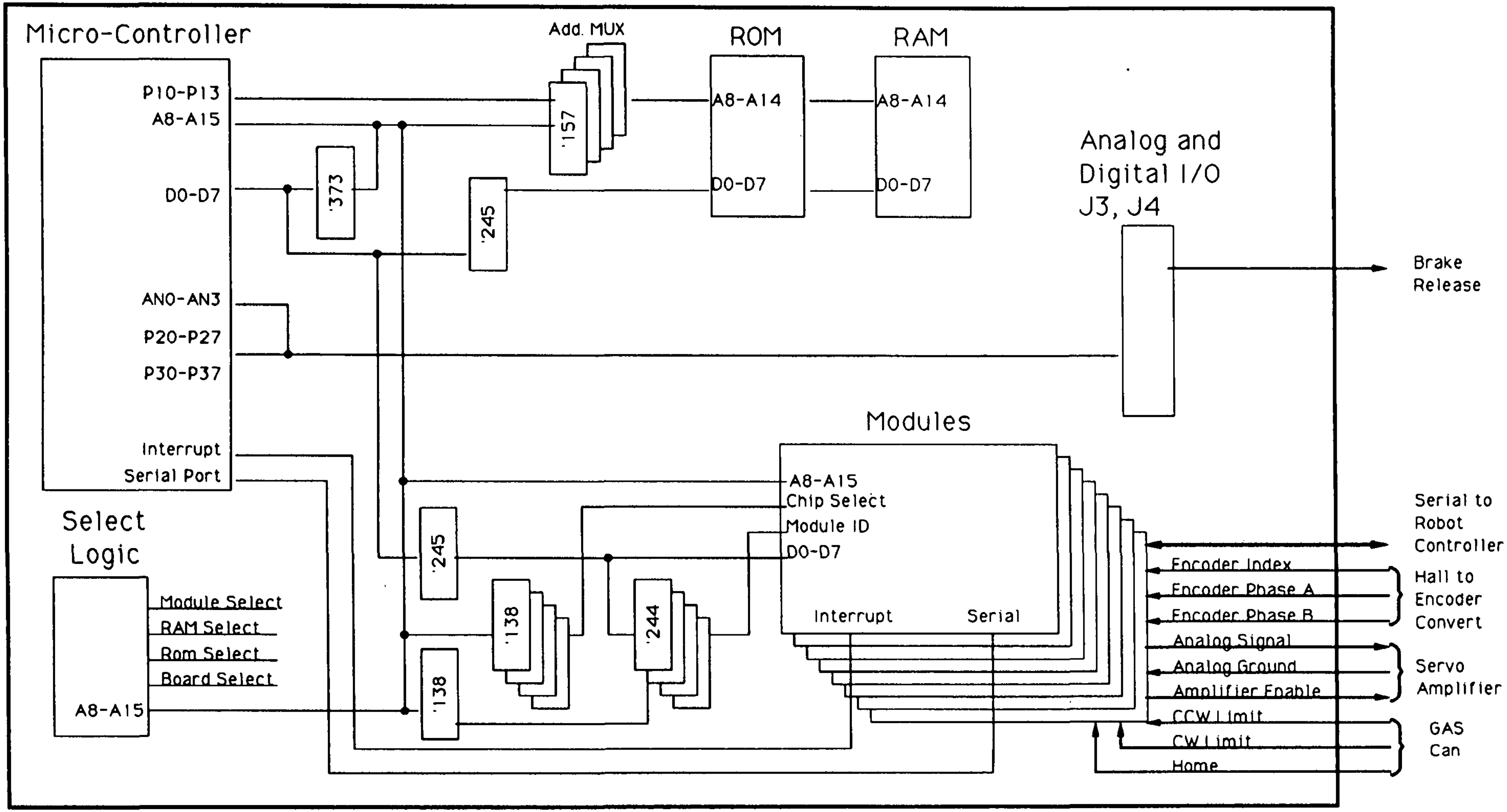
  However, for engineering purposes the language supports the following:

```
MOVE.AXIS.name.position
STEP.axis.dir.distance.rate
```

Robot Axis Control Concepts



ENGINEER L. M. Tomko	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
		XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER	Robot Mechanism Axis Block Diagram	XX/XX/XX
ENVIRONMENTAL RESEARCH INSTITUTE of MI	RoMPS	05/14/91
ANN ARBOR, MI	XXXXXXXXXXXX	DATE



ENGINEER M.E.Dobbs	DRAFTSMAN X X XXXXXXX	XX/XX/XX
	PMC Inc. Motion Controller	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER	Robot Mechanism Axis Block Diagram	XX/XX/XX
ENVIRONMENTAL RESEARCH INSTITUTE of MI	RoMPS	05/14/91
ANN ARBOR, MI	XXXXXXXXXXXX	DATE

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COMMAND SET SUMMARY

Parameter Setup Commands

DH	Define Home
DI	DIrection
DS	Deceleration Set
FF	Fall switch ofF
FN	Fall switch oN
FR	set derivative sampling period
IL	set Integration limit
JA	Jog Acceleration
JF	Jog swtich ofF
JN	Jog switch oN
JV	Jog Velocity
LF	Limit switch ofF
LM	Limit Mode
LN	Limit switch oN
PH	Set servo output PHase
RC	Reset Counter
RT	Reset seT
SA	Set Acceleration
SD	Set Derivative gain
SG	Set prop. Gain of motor
SI	Set Integral gain of DC servo or Set Initial pulse rate of stepper
SQ	Set torQue
SV	Set Velocity
VG	Set Velocity Gain

Motion Commands

AB	ABort
FE	Find Edge
FI	Find Index
GH	Go Home
GM	Gain Mode
GO	GO
HO	HOme
MA	Move Absolute
MF	Motor ofF
MN	Motor oN
MR	Move Relative
PM	Position Mode
QM	TorQue Mode
SE	Stop on Error
SM	Set Master
ST	STop
VM	Velocity Mode

Sequence Commands

IP	Interrupt on absolute Position
IR	Interrupt on Relative position
RP	RePeat
WA	Wait (time)
WE	Wait for Edge
WP	Wait for absolute Position
WR	Wait for Relative position
WS	Wait for Stop

Register Command

AA	Accumulator Add
AC	Accumulator Complement, blt wise
AE	Accumulator logical Exclusive or with *n*, bit wise
AI	Accumulator load Indirect
AL	Accumulator Load with constant *n*
AN	Accumulator logical aNd with *n*, bit wise
AO	Accumulator logical Or with *n*, bit wise
AR	copy Accumulator to Register *n*
AS	Accumulator Subtract
RB	Read Byte
RL	Read Long at absolute memory location *n* into accumulator
RW	Read Word at absolute memory location *n* into accumulator
SL	Shift Left -accumulator *n* bits
SR	Shlft Right accumulator *n* bits
TR	Tell contents of Register *n*
	Tell contents of accumulator (register O)
WB	Wrlte accumulator low Byte to absolute memory location *n*
WL	Write accumulator Long to absolute memory location *n*
WW	Write accumulator low Word to absolute memory location *n*

Learn Mode Commands

AP	Adjust Position
LI	Learn position Incrementing
LP	Learn Position
LT	Learn Target
MI	Move to point, Incrementing
MP	Move to Point

Reporting Commands

CC	Current Count
CS	Check Sum
HE	HElp
TA	Tell Analog to digital converter
TD	Tell Derivative qain
TF	Tell Following error
TG	Tell position Gain
TI	Tell Integral gain of DC servo or Tell Initial pulse rate of stepper
TL	Tell Integration Limit
TP	Tell Position
TS	Tell Status
TT	Tell Target
TV	Tell Velocity
VE	Tell VErsion

Macro Commands

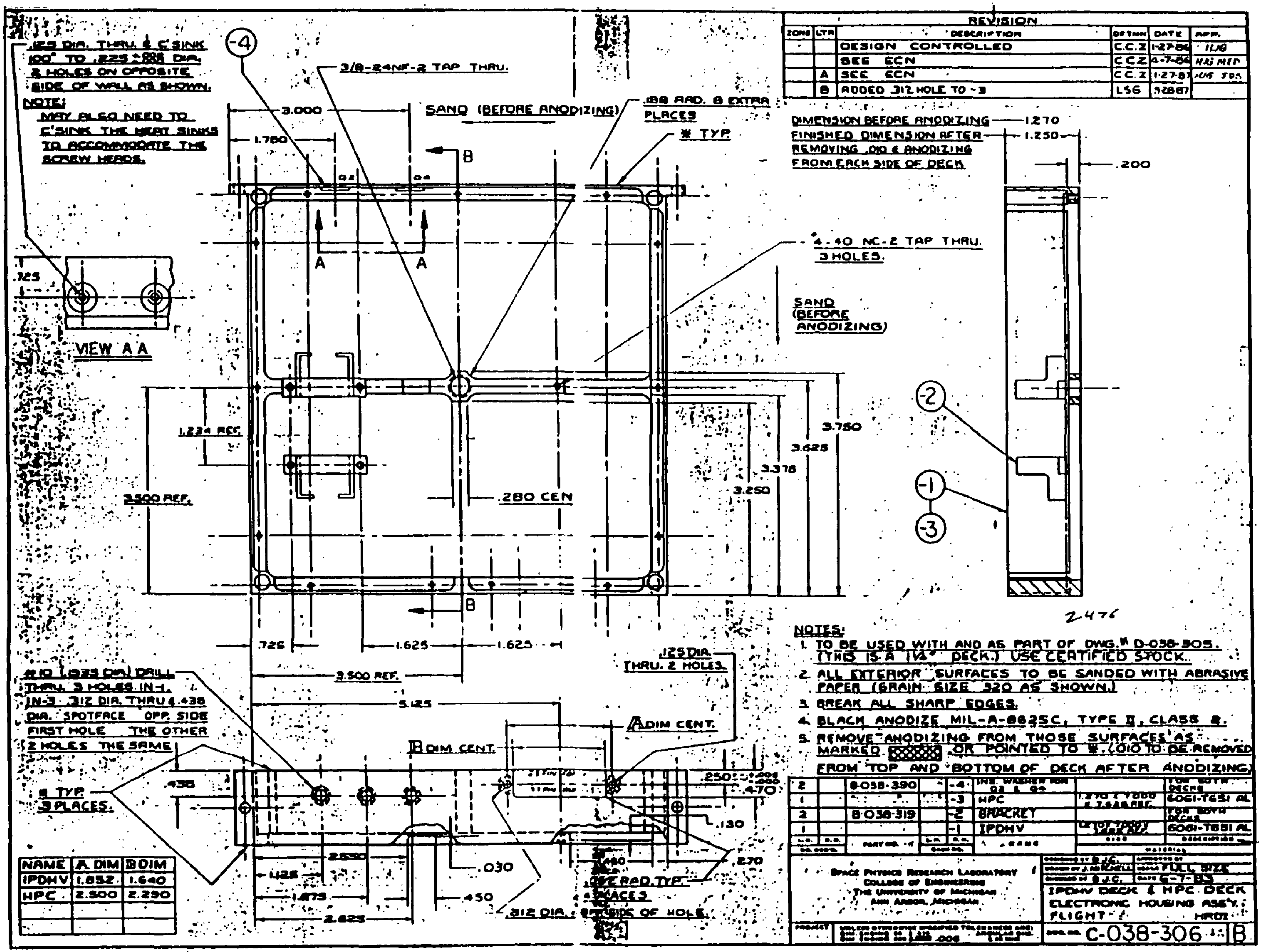
EM	Execute Macro
MC	Macro Command
MD	Macro Definition
RM	Reset Macros
TM	Tell Macros

Contouring Mode Commands

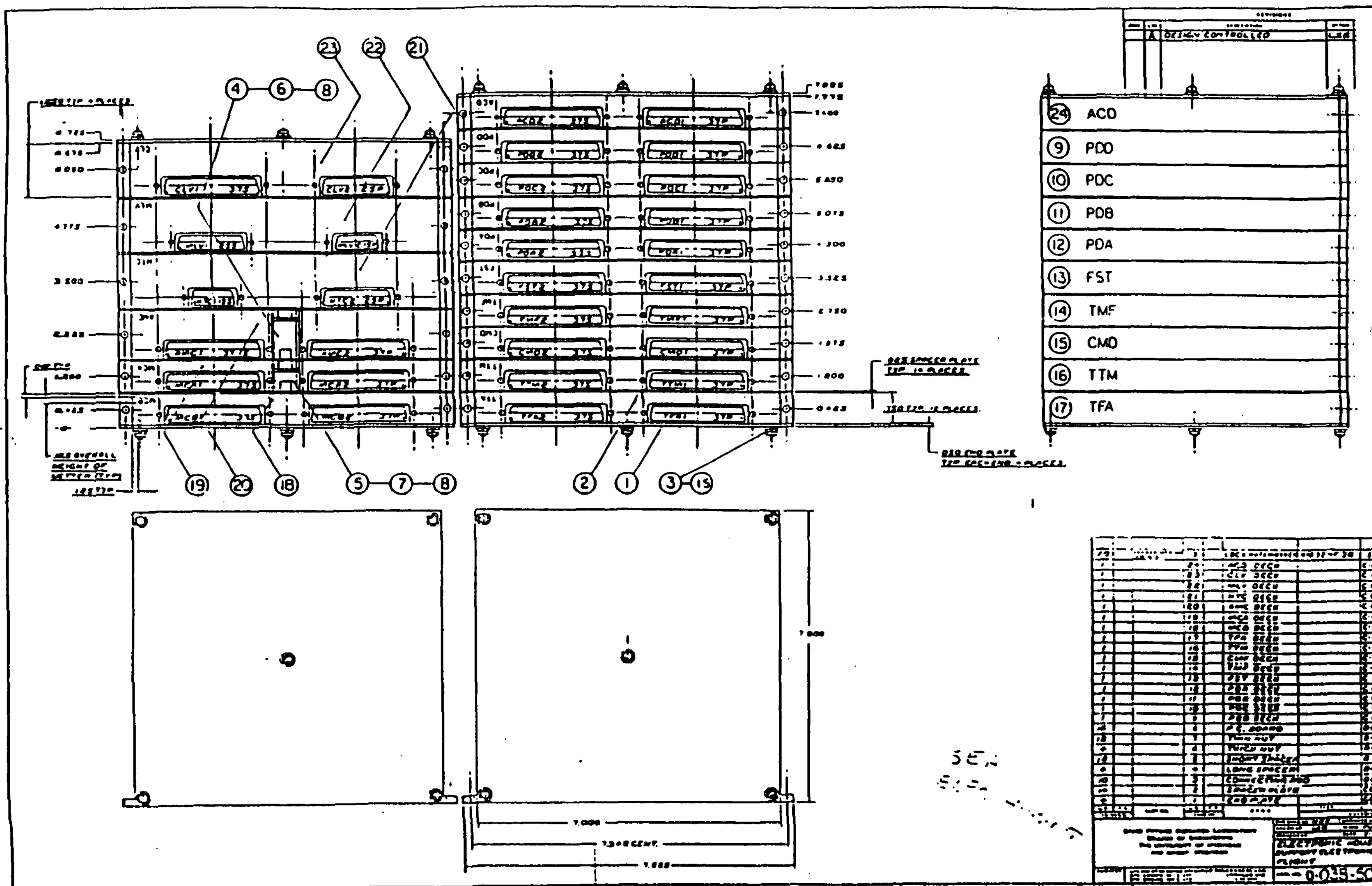
CM	Contouring Mode

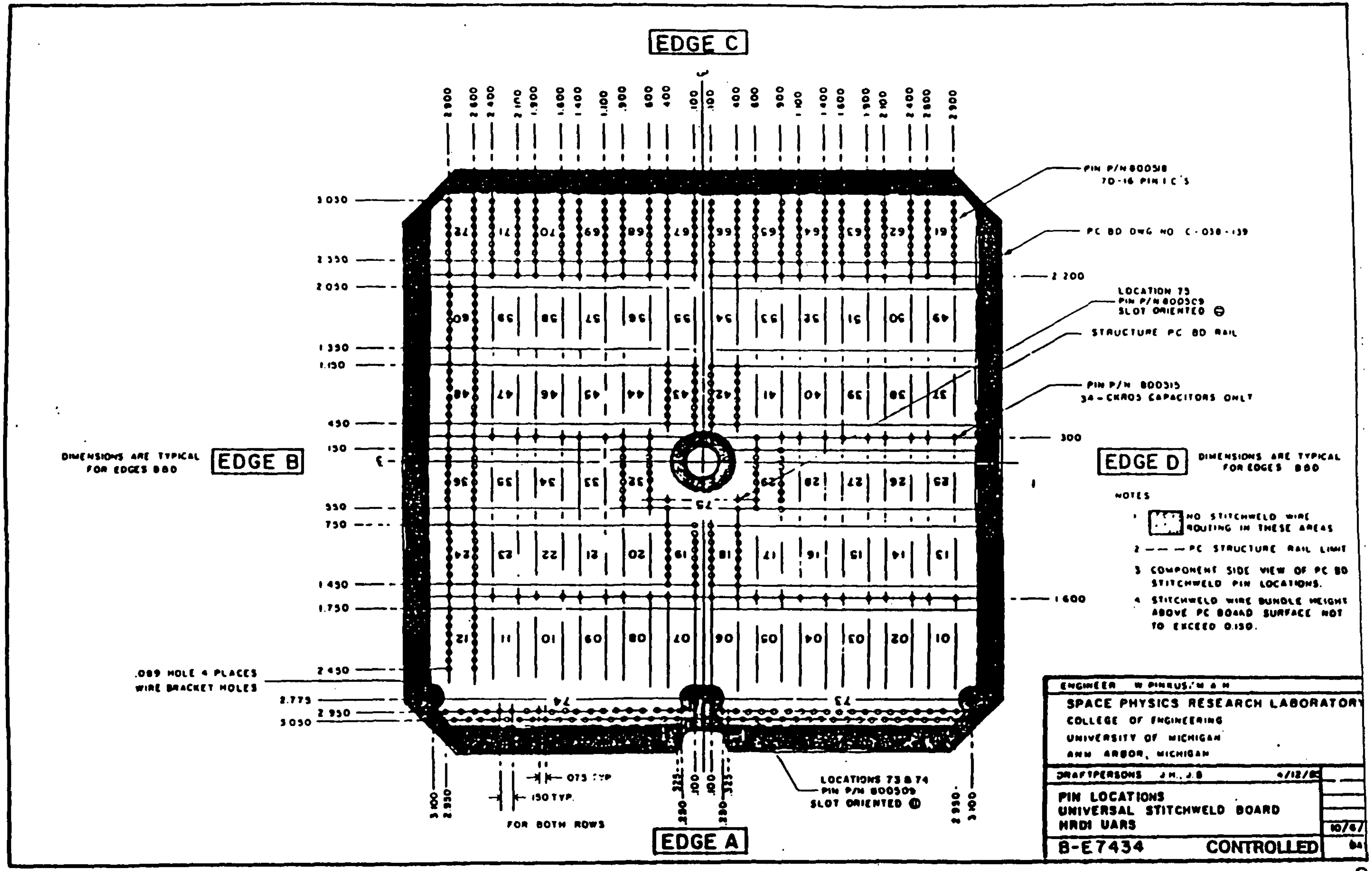
Miscellaneous Commands

BK	BreaK
DM	Decimal Mode
HM	Hexidecimal Mode
NO	No Operation
SB	Select Bank



REVISION
ZONE | LTR | DESCRIPTION | DFTMN | DATE | APP.
DESIGN CONTROLLED | C.C.Z | 1-27-86
SEE ECN | C.C.Z | 4-7-86
A | SEE ECN | C.C.Z | 1-27-87
B | ADDED .312 HOLE TO -3 | LSG
.125 DIA. THRU. & C'SINK 100° TO .225 DIA. 2 HOLES ON OPPOSITE SIDE OF WALL AS SHOWN.
NOTE: MAY ALSO NEED TO C'SINK THE HEAT SINKS TO ACCOMMODATE THE SCREW HEADS.
-4
3/8-24NF-2 TAP THRU.
3.000
1.780
SAND (BEFORE ANODIZING)
.188 RAD. 8 EXTRA PLACES
* TYP.
DIMENSION BEFORE ANODIZING 1.270
FINISHED DIMENSION AFTER REMOVING .010 & ANODIZING FROM EACH SIDE OF DECK 1.250
.200
4-40 NC-2 TAP THRU. 3 HOLES.
SAND (BEFORE ANODIZING)
VIEW A A
.725
1.234 REF.
3.500 REF.
.280 CEN
3.750
3.625
3.376
3.250
-2
-1
-3
.725
1.625
1.625
3.500 REF.
5.125
.125 DIA. THRU. 2 HOLES.
#10 (.1935 DIA) DRILL THRU 3 HOLES IN -1. IN -3 .312 DIA. THRU & .438 DIA. SPOTFACE OPP. SIDE FIRST HOLE THE OTHER 2 HOLES THE SAME
A DIM CENT.
B DIM CENT.
.438
.250
.470
.130
.030
.270
.062 RAD. TYP. 4 PLACES
.450
.312 DIA. OPP. SIDE OF HOLE
1.125
2.625
8 TYP. 3 PLACES.
NAME | A DIM | B DIM
IPDHV | 1.852 | 1.640
HPC | 2.500 | 2.290
NOTES:
1. TO BE USED WITH AND AS PART OF DWG. # D-038-305. (THIS IS A 1¼" DECK.) USE CERTIFIED STOCK.
2. ALL EXTERIOR SURFACES TO BE SANDED WITH ABRASIVE PAPER (GRAIN SIZE 320 AS SHOWN.)
3. BREAK ALL SHARP EDGES.
4. BLACK ANODIZE MIL-A-8625C, TYPE II, CLASS 2.
5. REMOVE ANODIZING FROM THOSE SURFACES AS MARKED OR POINTED TO *. (.010 TO BE REMOVED FROM TOP AND BOTTOM OF DECK AFTER ANODIZING)
2 | B-038-390 | -4 | INS. WASHER FOR
1 | -3 | HPC | 6061-T651 AL
2 | B-038-319 | -2 | BRACKET
1 | -1 | IPDHV | 6061-T651 AL
SPACE PHYSICS RESEARCH LABORATORY
COLLEGE OF ENGINEERING
THE UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN
FULL SIZE
IPDHV DECK & HPC DECK
ELECTRONIC HOUSING ASS'Y.
FLIGHT
C-038-306
B


24 ACO
9 PDO
10 PDC
11 PDB
12 PDA
13 FST
14 TMF
15 CMD
16 TTM
17 TFA
DESIGN CONTROLLED
7.000

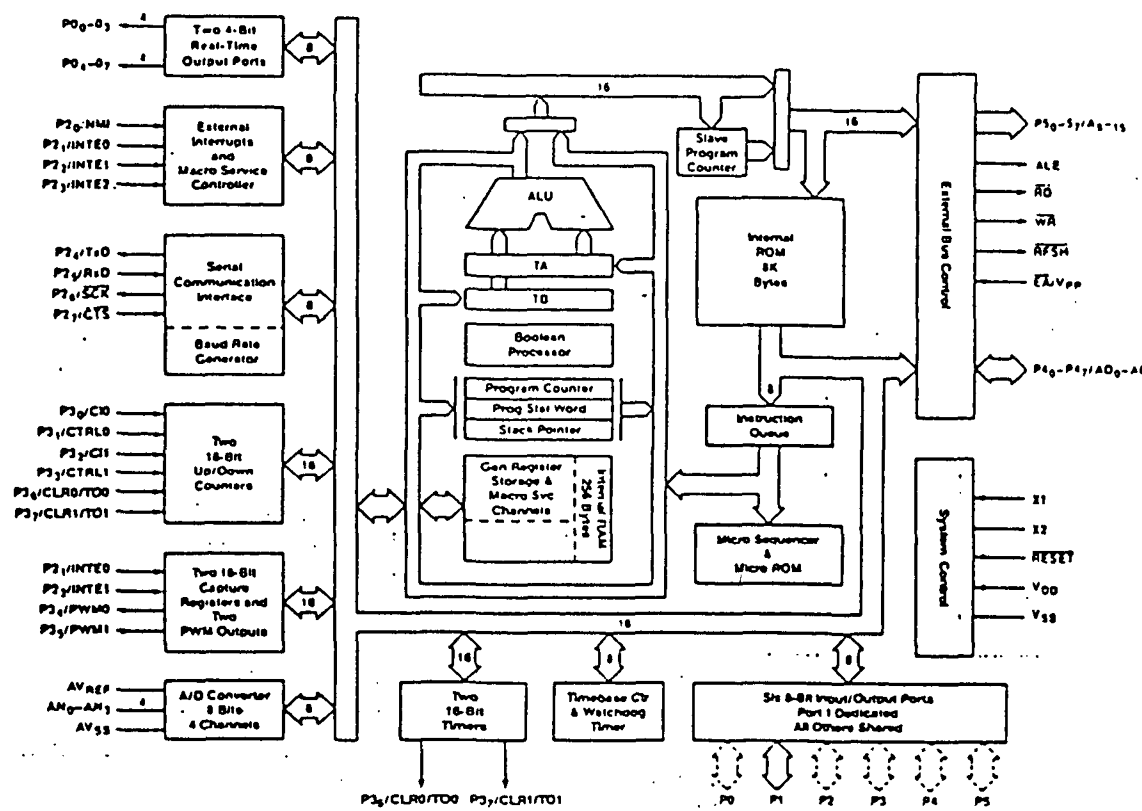

EDGE C
EDGE B
EDGE D
EDGE A
PIN P/N 800518 TO-16 PIN I C'S
PC BD DWG NO C-038-139
LOCATION 75 PIN P/N 800309 SLOT ORIENTED
STRUCTURE PC BD RAIL
PIN P/N 800315 34-CKR05 CAPACITORS ONLY
DIMENSIONS ARE TYPICAL FOR EDGES B&D
DIMENSIONS ARE TYPICAL FOR EDGES B&D
NOTES
1 NO STITCHWELD WIRE ROUTING IN THESE AREAS
2 PC STRUCTURE RAIL LIMIT
3 COMPONENT SIDE VIEW OF PC BD STITCHWELD PIN LOCATIONS.
4 STITCHWELD WIRE BUNDLE HEIGHT ABOVE PC BOARD SURFACE NOT TO EXCEED 0.130.
.089 HOLE 4 PLACES WIRE BRACKET HOLES
.075 TYP
.150 TYP.
FOR BOTH ROWS
LOCATIONS 73 & 74 PIN P/N 800509 SLOT ORIENTED
ENGINEER W PINKUS
SPACE PHYSICS RESEARCH LABORATORY
COLLEGE OF ENGINEERING
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN
DRAFTPERSONS J.H., J.B
PIN LOCATIONS
UNIVERSAL STITCHWELD BOARD
HRDI UARS
B-E7434
CONTROLLED

NEC µPD7831xA 16-Bit Single-chip Microcomputer for Real-Time Control

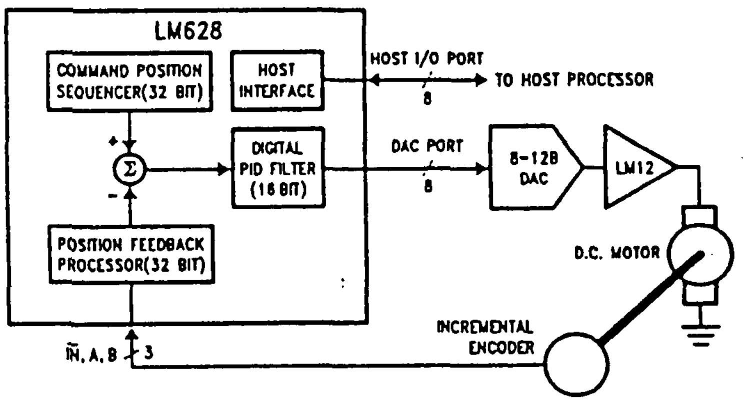
Features

- Complete single-chip microcomputer
  - 16-bit ALU
  - 8K ROM (µPD78312A only)
  - 256 bytes RAM
  - 1-bit and 8-bit logic
- Instruction prefetch queue
- 16-bit unsigned multiply and divide
- String instructions
- Memory expansion
  - 8085A bus-compatible
  - Total 64K address space
- Large I/O capacity: up to 32 I/O port lines
- Extensive timer/counter system
  - Two 16-bit up/down counters
  - Quadrature counting
  - Two 16-bit timers
  - Free-running counter with two 16-bit capture registers
  - Pulse-width modulated outputs
  - Timebase counter
- Four-channel 8-bit A/D converter
- Two 4-bit real-time output ports
- Two nonmaskable interrupts
- Eight hardware priority interrupt levels
- Macroservice facility for interrupts gives the effect of eight DMA channels
- Bidirectional serial port
  - Either UART or interface mode
  - Dedicated baud rate generator
- Watchdog timer
- Refresh output for pseudostatic RAM
- Programmable HALT and STOP modes
- One-byte call instruction
- On-chip clock generator
- CMOS silicon gate technology
- +5-volt power supply

Block Diagram



ENGINEER M.F.Dobbs	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	NEC uPD7831xA 16-bit microcontroller	XX/XX/XX
	Robot Mechanism Axis Block Diagram	XX/XX/XX
	RoMPS	05/14/91
	XXXXXXXXXXXX	DATE



TL/H/9219-1

FIGURE 1. Typical System Block Diagram

Features

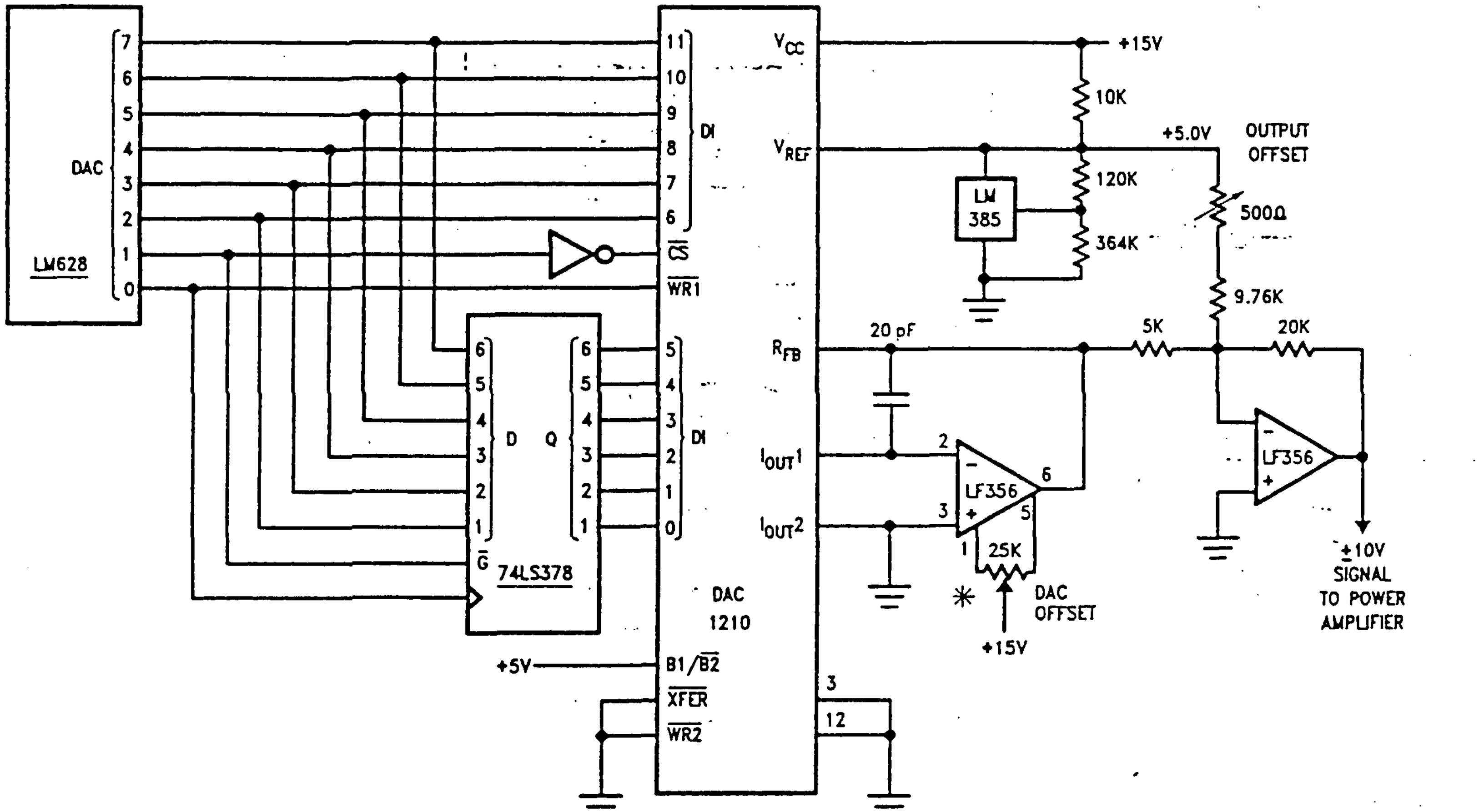
- 32-bit position, velocity, and acceleration registers
- Programmable digital PID filter with 16-bit coefficients
- Programmable derivative sampling interval
- 8- or 12-bit DAC output data (LM628)
- 8-bit sign-magnitude PWM output data (LM629)
- Internal trapezoidal velocity profile generator
- Velocity, target position, and filter parameters may be changed during motion
- Position and velocity modes of operation
- Real-time programmable host interrupts
- 8-bit parallel asynchronous host interface
- Quadrature incremental encoder interface with index pulse input

ENGINEER M.E.Dobbs	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER	LM628629 Motion Controller IC (MC100 system):	XX/XX/XX
ENVIRONMENTAL RESEARCH INSTITUTE of MI	Robot Mechanism Axis Block Diagram	XX/XX/XX
ANN ARBOR, MI	RoMPS	05/14/91
	XXXXXXXXXXXX	DATE

TABLE I. System Specifications Summary

Position Range	−1,073,741,824 to 1,073,741,823 counts
Velocity Range	0 to 1,073,741,823/2^{16} counts/sample; ie, 0 to 16,383 counts/sample, with a resolution of 1/2^{16} counts/sample
Acceleration Range	0 to 1,073,741,823/2^{16} counts/sample/sample; ie, 0 to 16,383 counts/sample/sample, with a resolution of 1/2^{16} counts/sample/sample
Motor Drive Output	LM628: 8-bit parallel output to DAC, or 12-bit multiplexed output to DAC LM629: 8-bit PWM sign/magnitude signals
Operating Modes	Position and Velocity
Feedback Device	Incremental Encoder (quadrature signals; support for index pulse)
Control Algorithm	Proportional Integral Derivative (PID) (plus programmable integration limit)
Sample Intervals	Derivative Term: Programmable from 2048/f_{CLK} to (2048 * 256)/f_{CLK} in steps of 2048/f_{CLK} (256 to 65,536 μs for an 8.0 MHz clock). Proportional and Integral: 2048/f_{CLK}

ENGINEER M.E.Dobbs	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
	LM628 Spec Summary	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER	Robot Mechanism Axis Block Diagram	XX/XX/XX
ENVIRONMENTAL RESEARCH INSTITUTE of MI	RoMPS	05/14/91
ANN ARBOR, MI	XXXXXXXXXXXX	DATE



*DAC offset must be adjusted to minimize DAC linearity and monotonicity errors. See text.

FIGURE 14. Interfacing a 12-Bit DAC and LM628

ENGINEER M.E.Dobbs	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
	LM628 Analog Application	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER	Robot Mechanism Axis Block Diagram	XX/XX/XX
ENVIRONMENTAL RESEARCH INSTITUTE of MI	RoMPS	05/14/91
ANN ARBOR, MI	XXXXXXXXXXXX	DATE

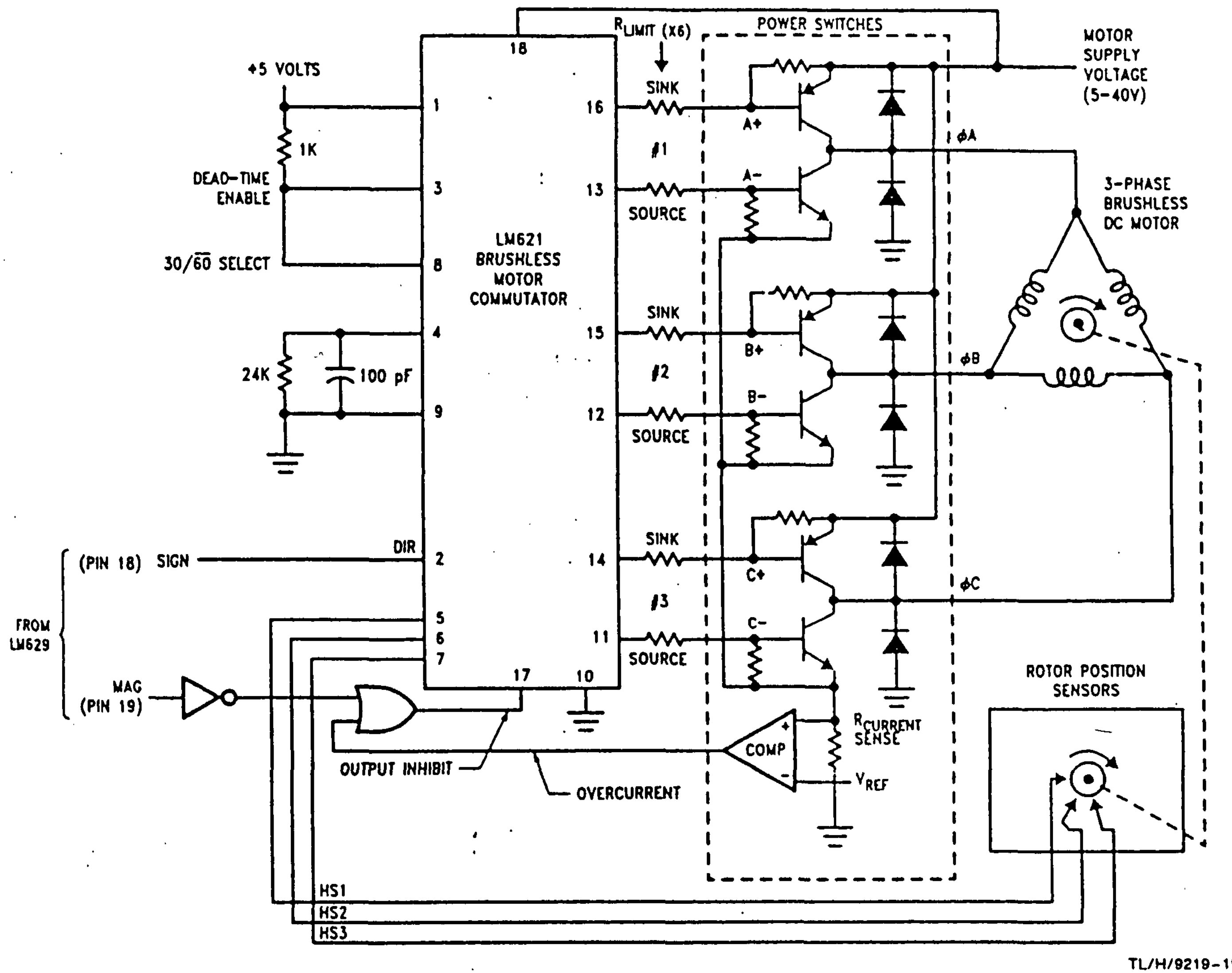
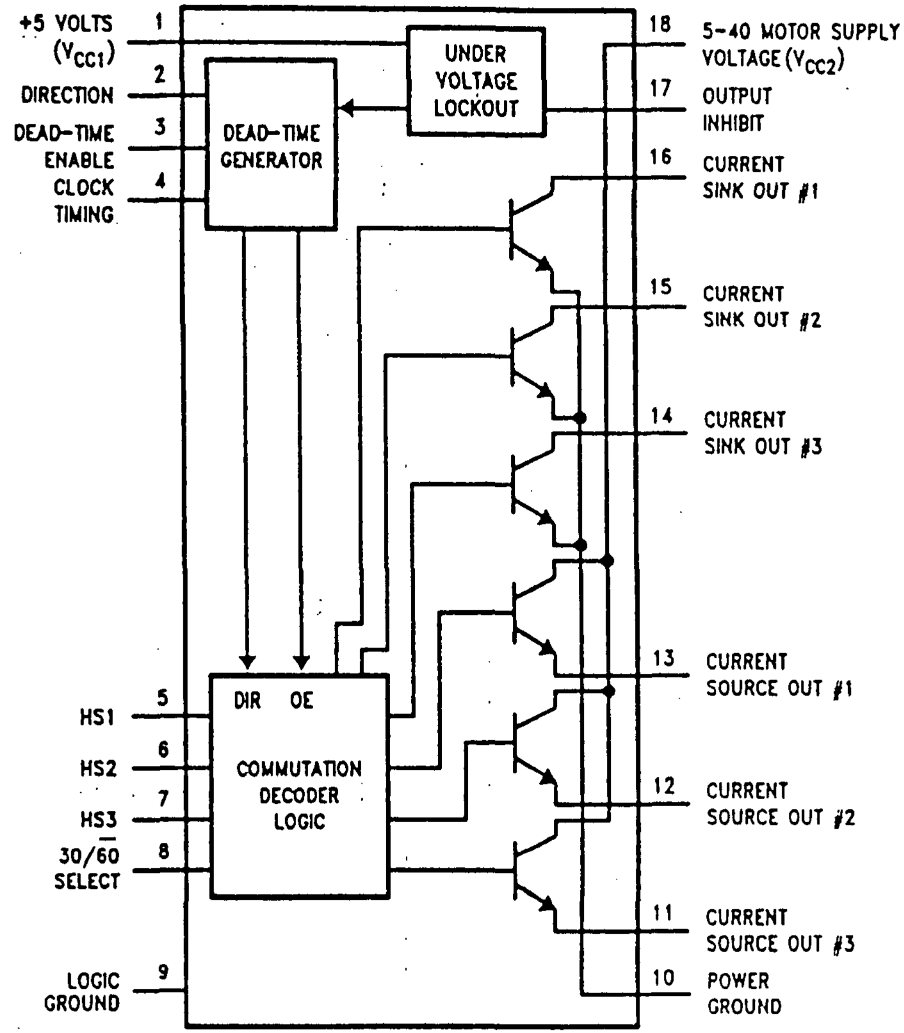


FIGURE 17. PWM Drive for Brushless Motors

ENGINEER M.E.Dobbs	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	LM629 PWM Application	XX/XX/XX
	Robot Mechanism Axis Block Diagram	XX/XX/XX
	RoMPS	05/14/91
	XXXXXXXXXXXX	DATE

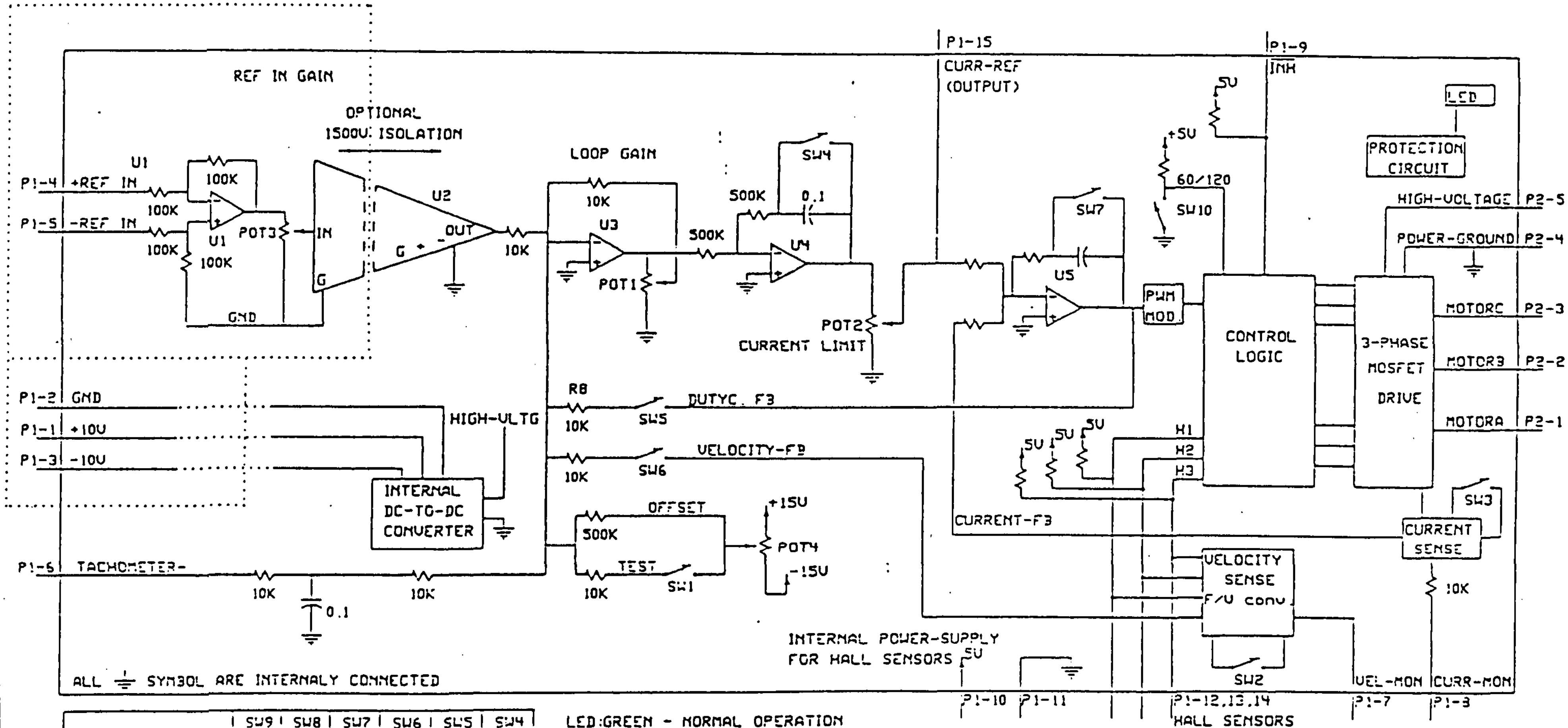
Connection Diagram



TL/H/8879-1

Order Number LM621N
See NS Package Number N18A

ENGINEER M.E.Dobbs	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
	LM621 Brushless Motor Drive IC	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER	Robot Mechanism Axis Block Diagram	XX/XX/XX
ENVIRONMENTAL RESEARCH INSTITUTE of MI	RoMPS	05/14/91
ANN ARBOR, MI	XXXXXXXXXXX	DATE



	SW9	SW8	SW7	SW6	SW5	SW4
CURRENT MODE	ON	ON	OFF	OFF	OFF	ON
VELOCITY MODE	OFF	OFF	ON	ON	OFF	*
OPEN LOOP CONTR	ON	ON	OFF	OFF	ON	*

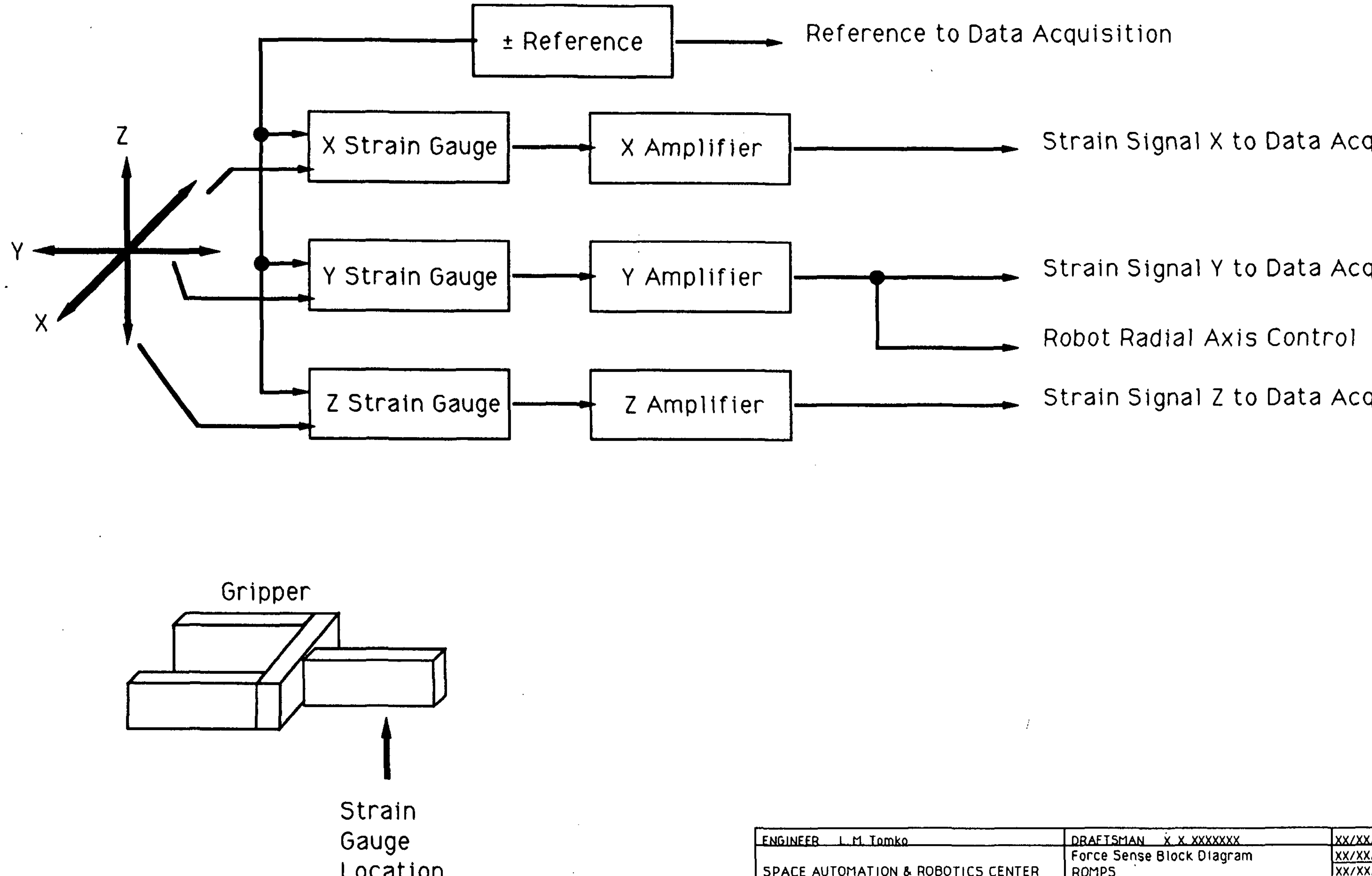
* - DEPENDS ON LOOP COMPENSATION

LED: GREEN - NORMAL OPERATION
RED - FAULT

SW1: ON - POT1 TEST INPUT
OFF - POT1 OFFSET ADJUSTMENT

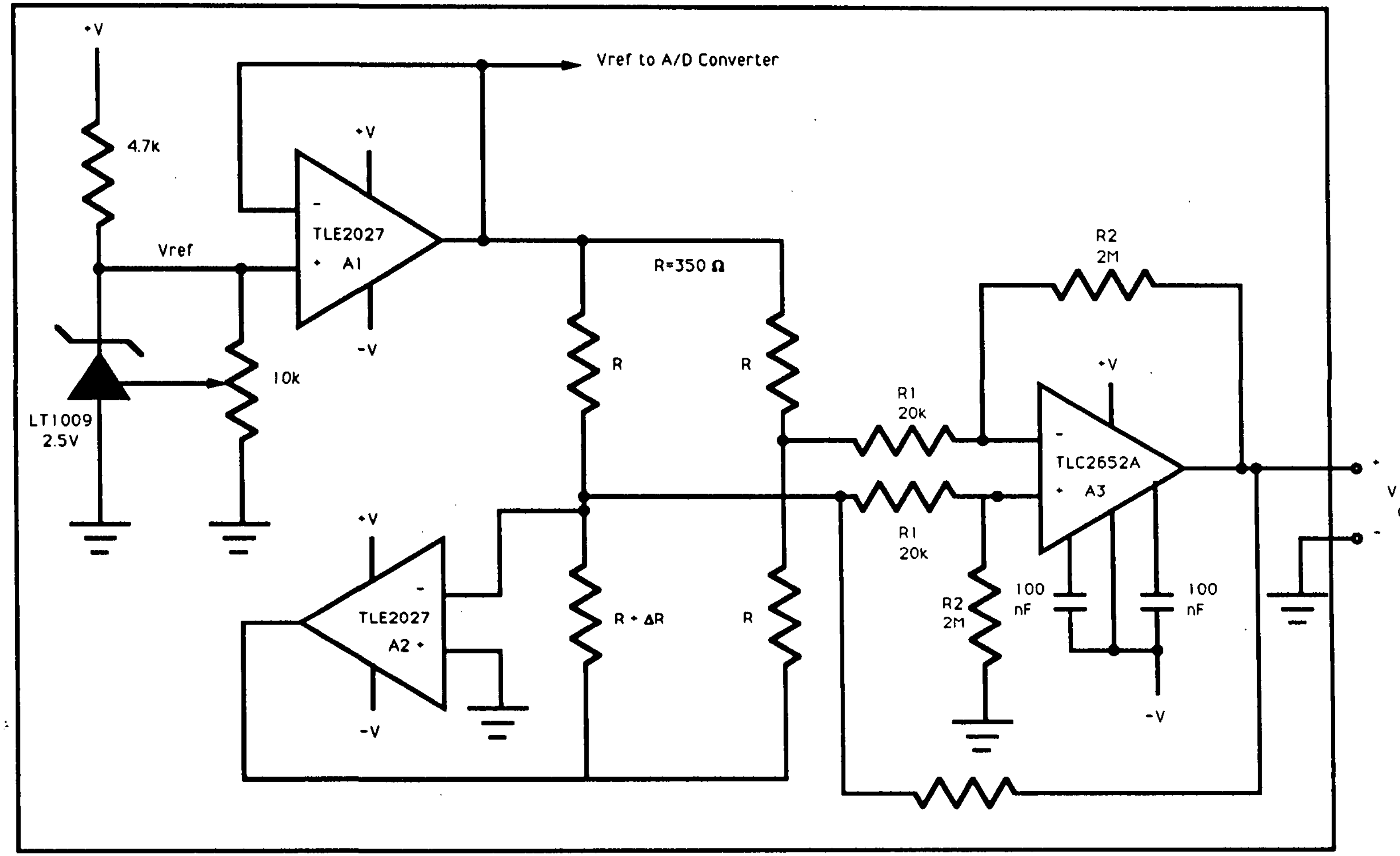
SW10: ON - 120 DEGREE PHASING
OFF - 60 DEGREE PHASING

ENGINEER M.E. Dobbs	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
	AMC Inc. Servo Apmlifier	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER	Robot Mechanism Axis Block Diagram	XX/XX/XX
ENVIRONMENTAL RESEARCH INSTITUTE of MI	RoMPS	05/14/91
ANN ARBOR, MI	XXXXXXXXXXXX	DATE



ENGINEER L. M. Tomko	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
	Force Sense Block Diagram	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER	ROMPS	XX/XX/XX
ENVIRONMENTAL RESEARCH INSTITUTE of MI	XXXXXXXXXXXX	05/14/91
ANN ARBOR, MI		DATE

Typical Robot Axis Strain Gauge Amplifier



Very Linear, low noise strain gauge circuit.

The four strain gauge elements (R) and the amplifiers A1 and A2 form a bridge network. The differential connection between the bridge network and amplifier A3 virtually eliminates the offset errors in A1 and A2. Positive feedback through Rx makes the effective input impedance of A3 greater than 1MΩ. The high impedance is used to reduce amplifier loading effects on the bridge circuit. The effects of both input offset and positive feedback resistance are described by the formulas below.

Effect of Rx: $Vo = +1/2 * R2/R1 * \Delta R/R * Vref(1 - Ra/2R1)^{-1}$, $Ra = \begin{cases} -R \text{ Without } Rx \\ \Delta R \text{ Using } Rx = R2 \end{cases}$

Effect of Vio: $Vo = +1/2 * R2/R1 * \Delta R/R * [Vref + Vio(A1) + Vio(A2)] + [1 + R2/R1]\, Vio(A3)$

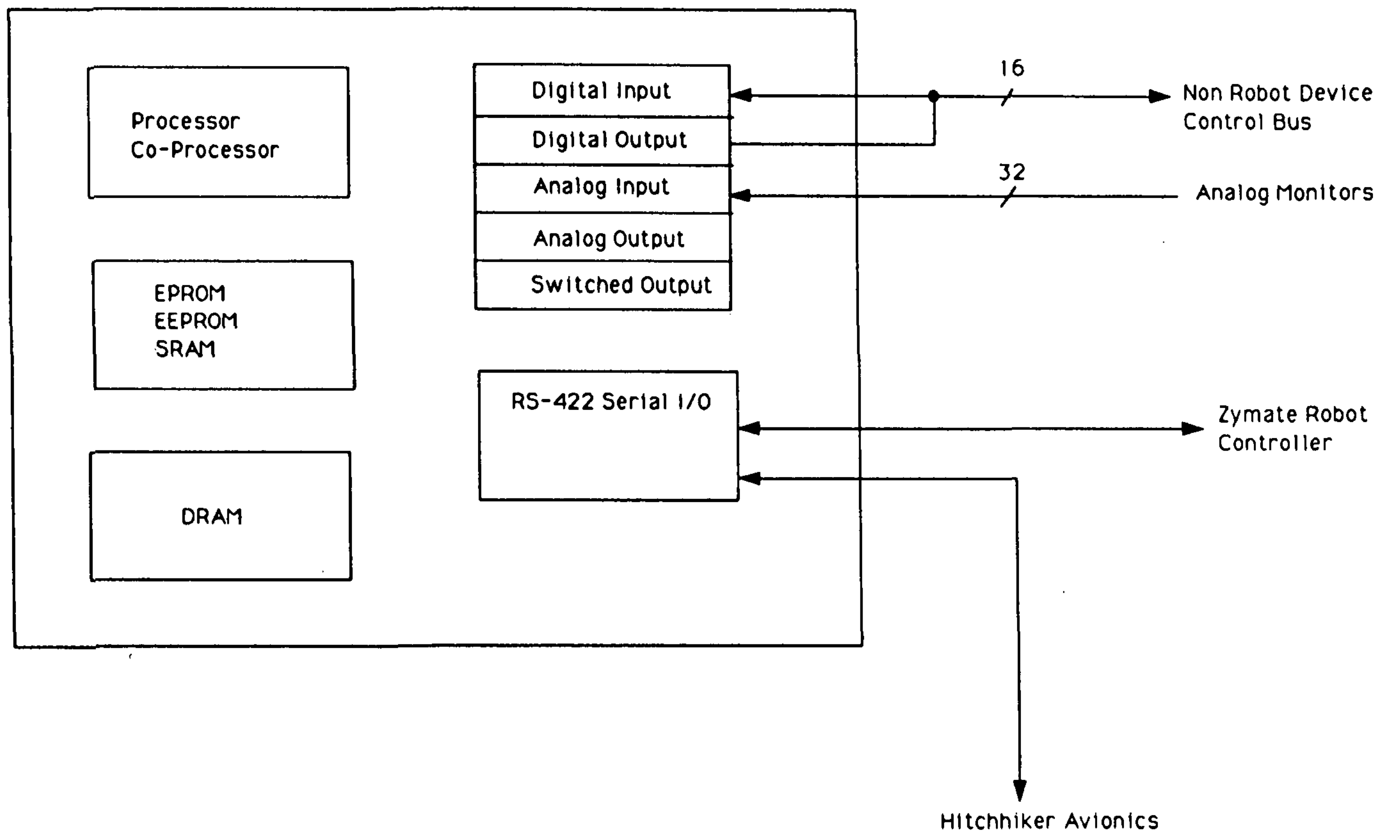
ENGINEER L. M. Tomko	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Force Sensing Amplifier-Typical Force Sensing Block Diagram RoMPS XXXXXXXXXXXX	XX/XX/XX XX/XX/XX 05/14/91 DATE

Autonomous Experiment Managment System

Zymate Robot Controller

Southwest SC-4 Computer

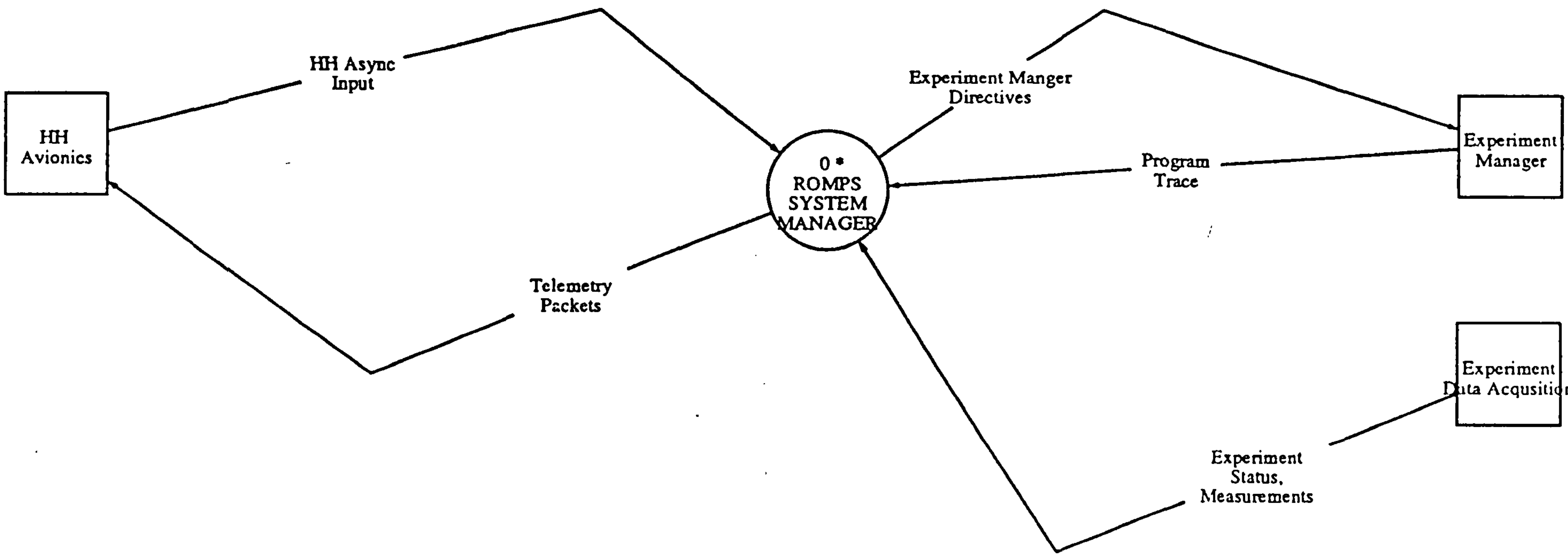
AUTONOMOUS CONTROLLER



ENGINEER M.E.Dobbs	DRAFTSMAN X. X. XXXXXX	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Autonomous Experiment System Manager Block Diagram RoPMS	XX/XX/XX XX/XX/XX 05/14/91
	XXXXXXXXXXXX	DATE

SpARC Space Automation & Robotics Center

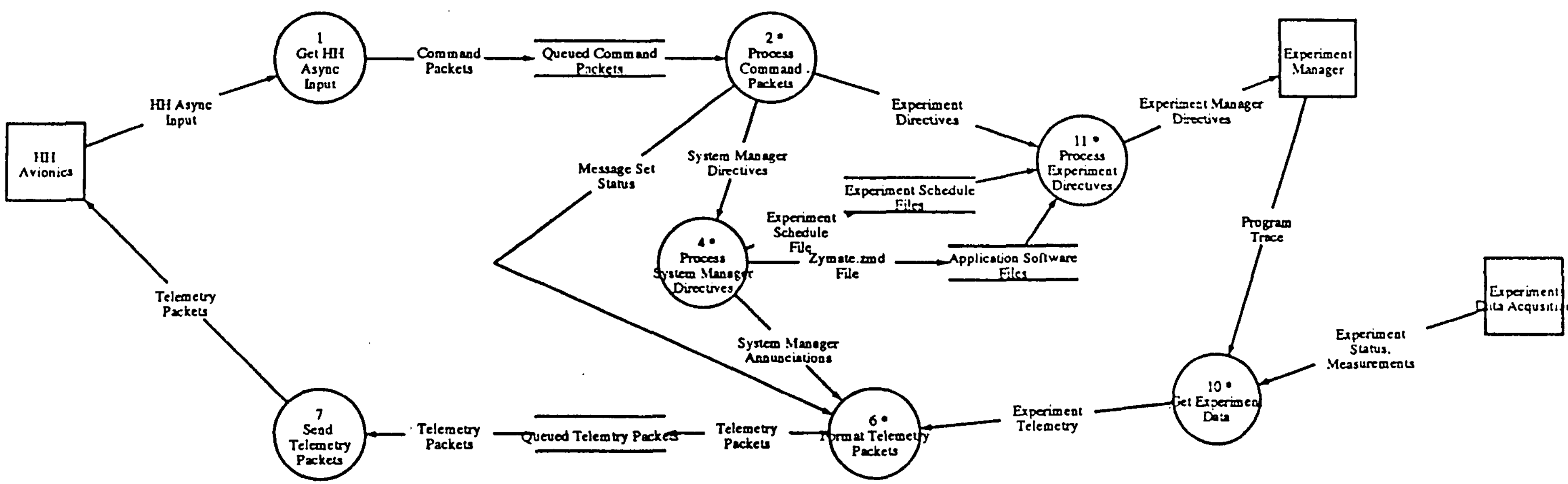
romps: level top



Level 0

SpARC Space Automation & Robotics Center

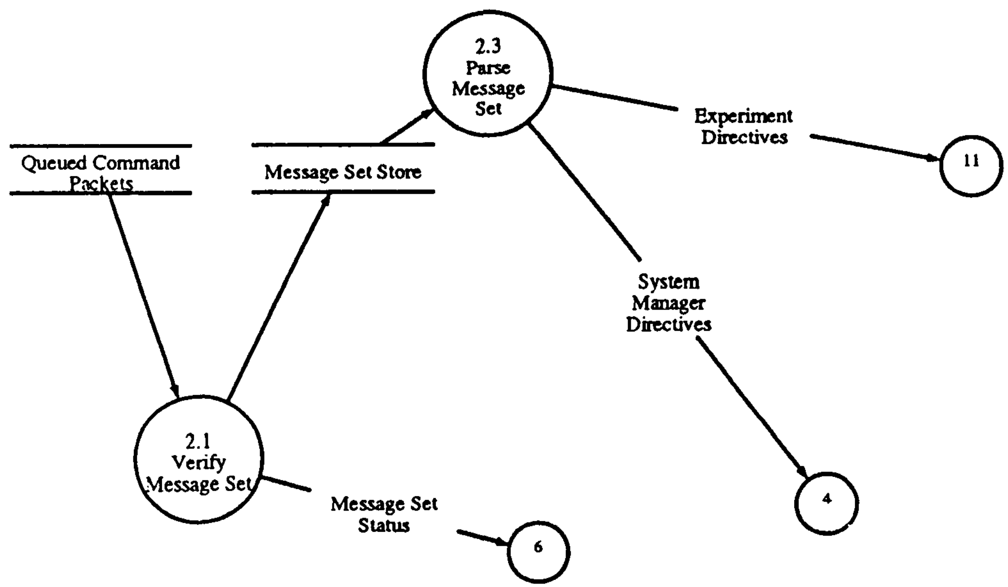
romps: level 0



SpARC 051491/ME1.0

SpARC Space Automation & Robotics Center

romps: level 2



SpARC 051491/ME1.0

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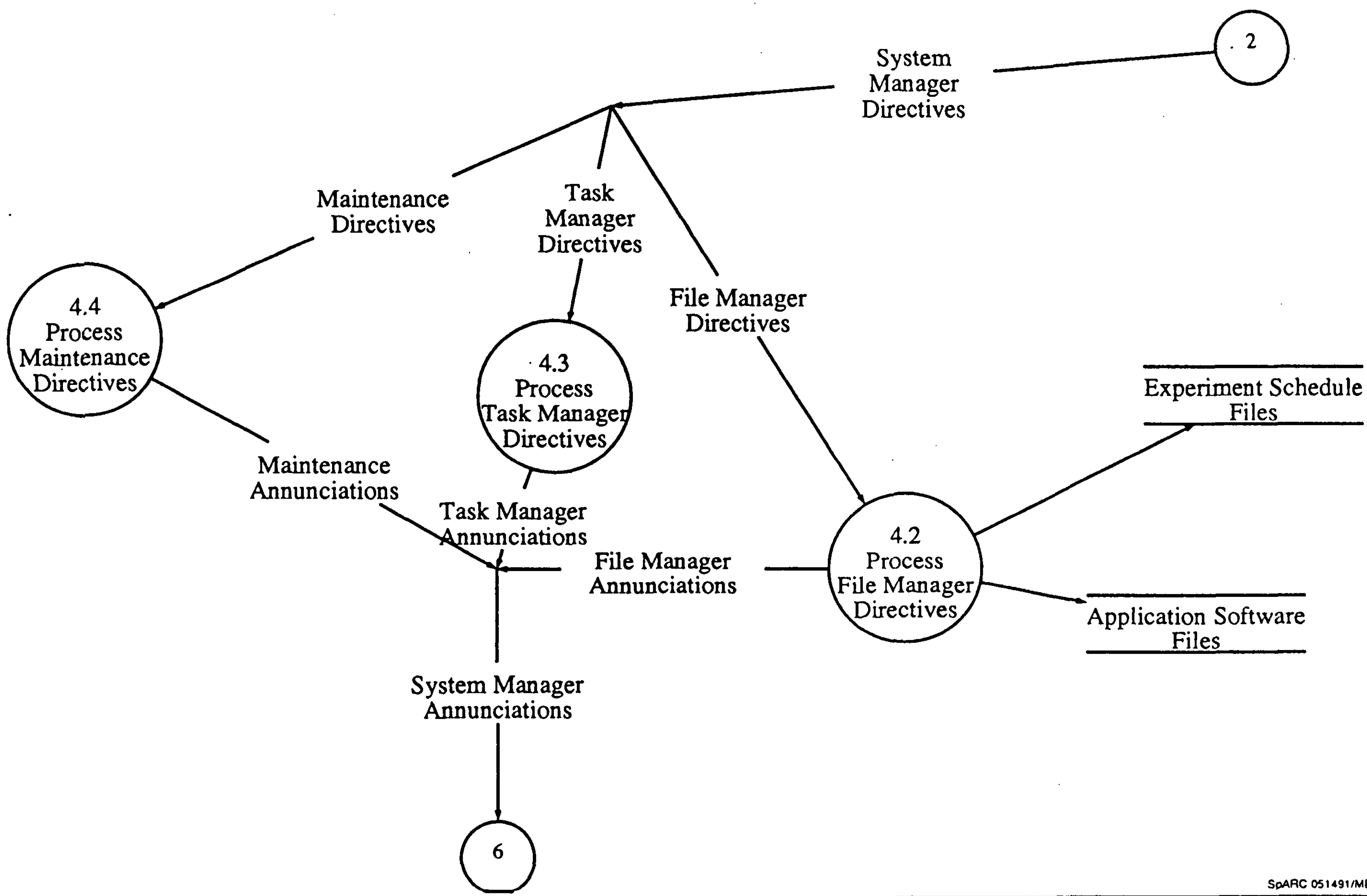
Format Telemetry Packet

SpARC Space Automation & Robotics Center

romps: level 4



SpARC 051491/ME1.0

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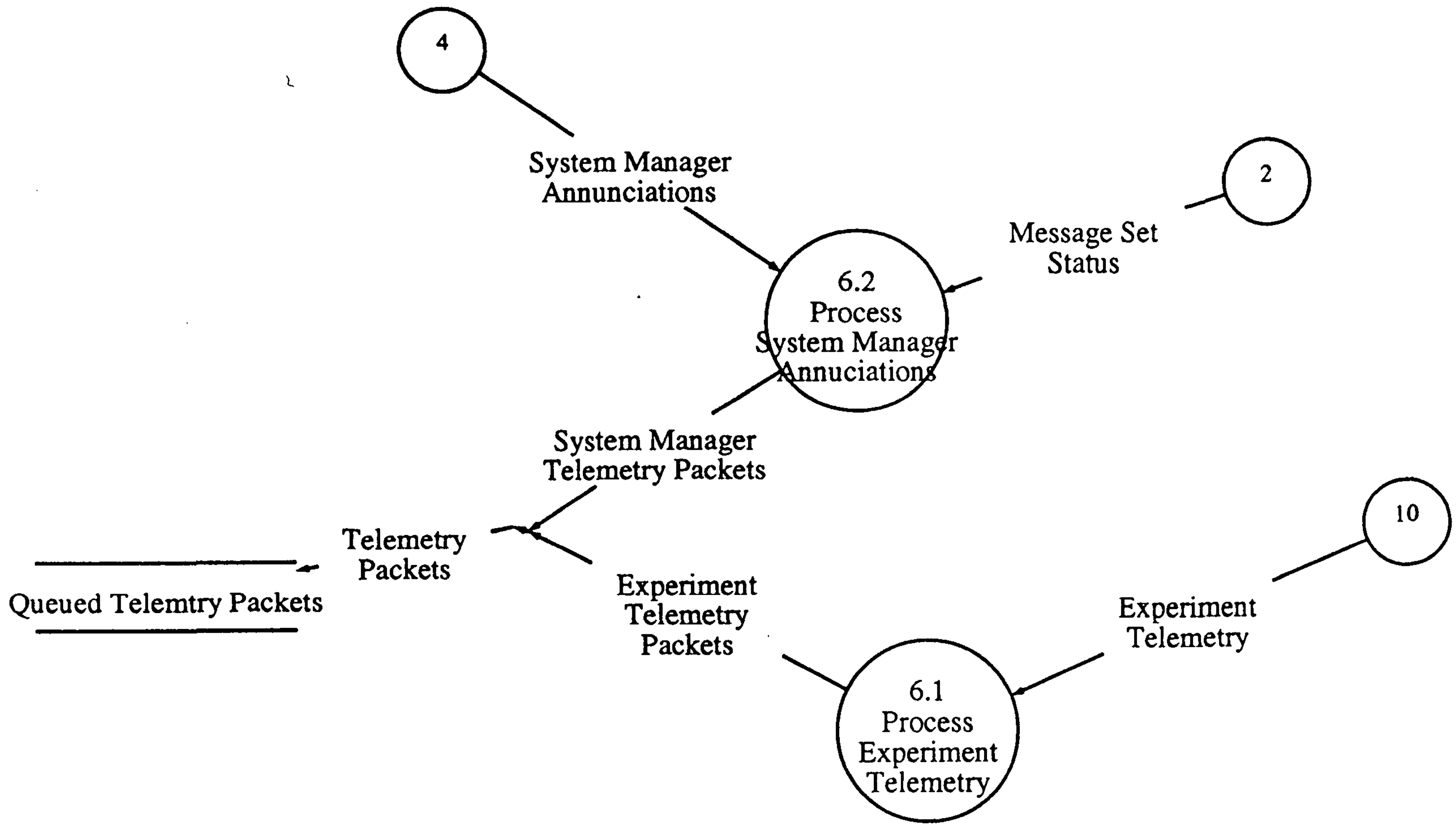
Get Experiment Data

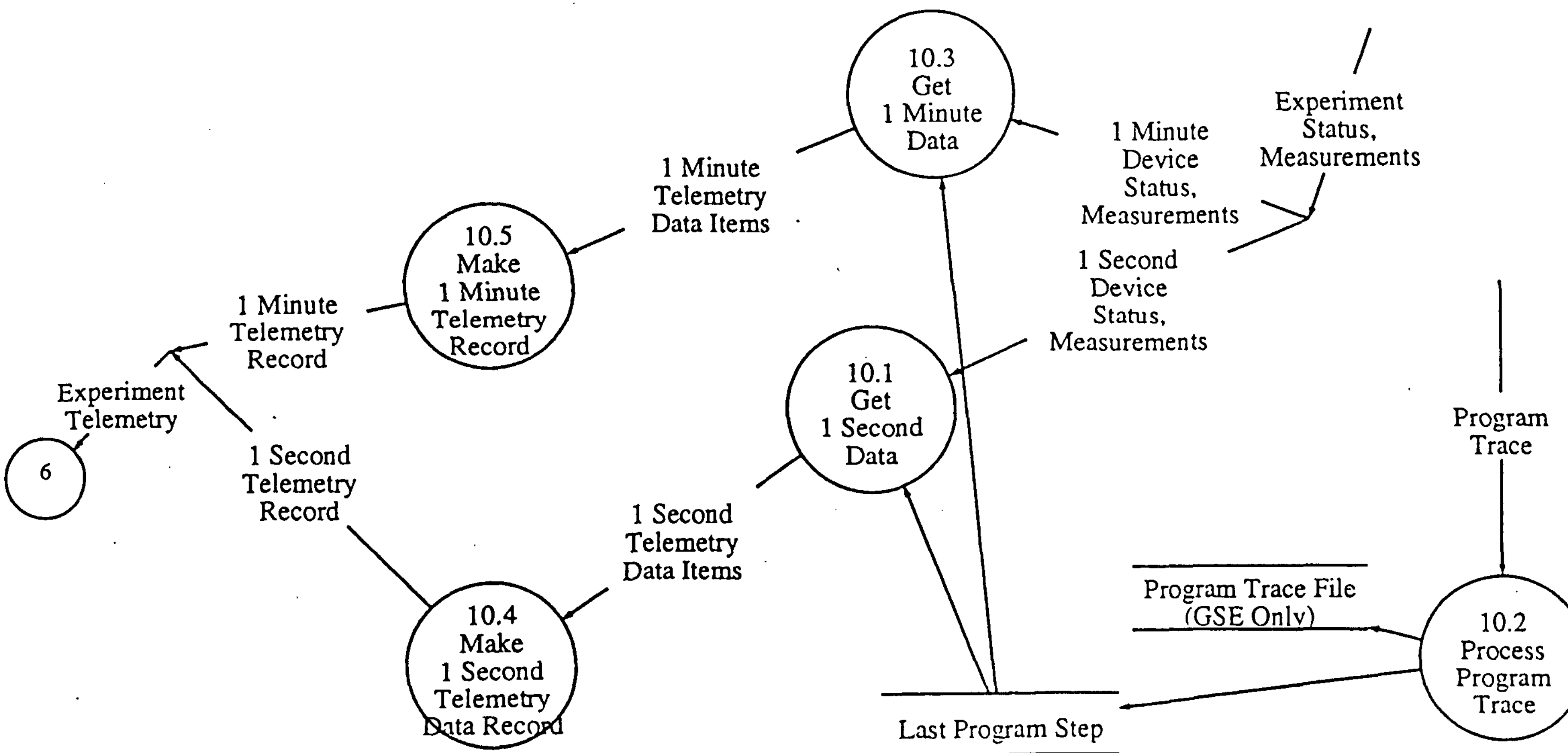
romps: level 6



Process Experiment Data

SpARC Space Automation & Robotics Center

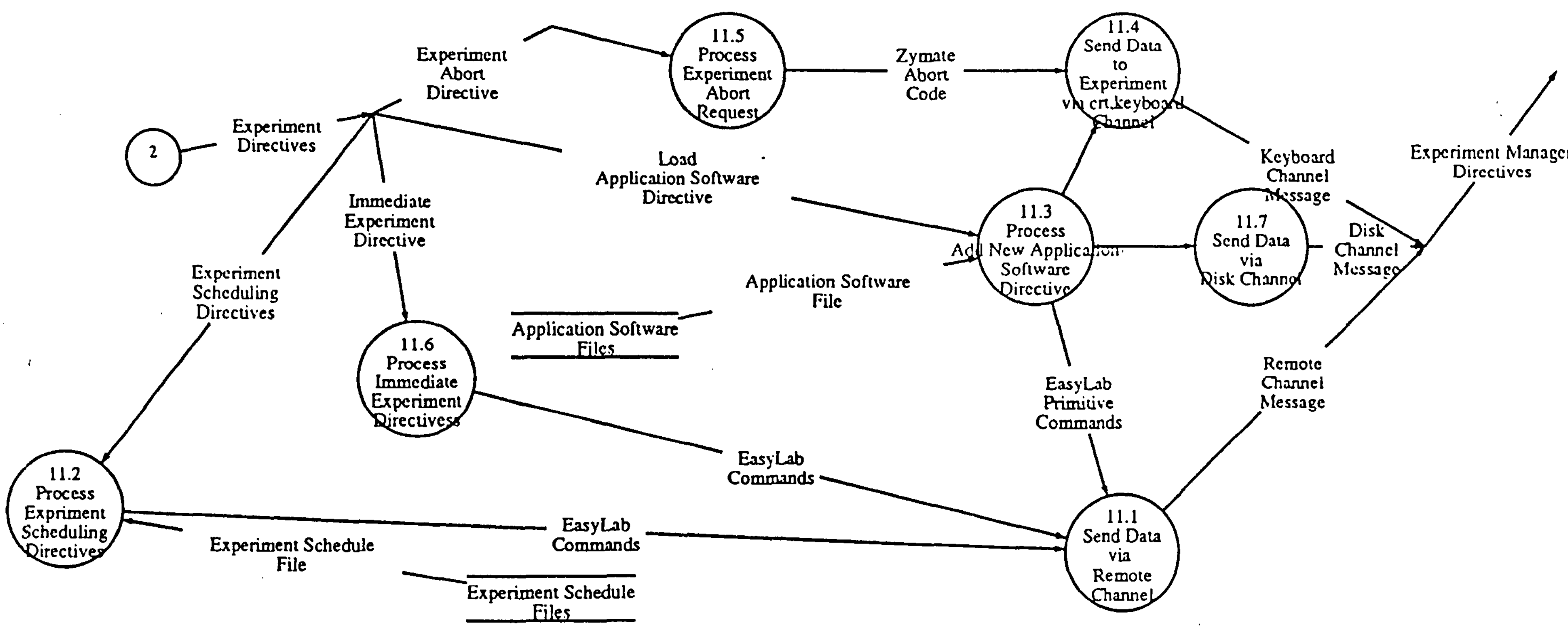
romps: level 10



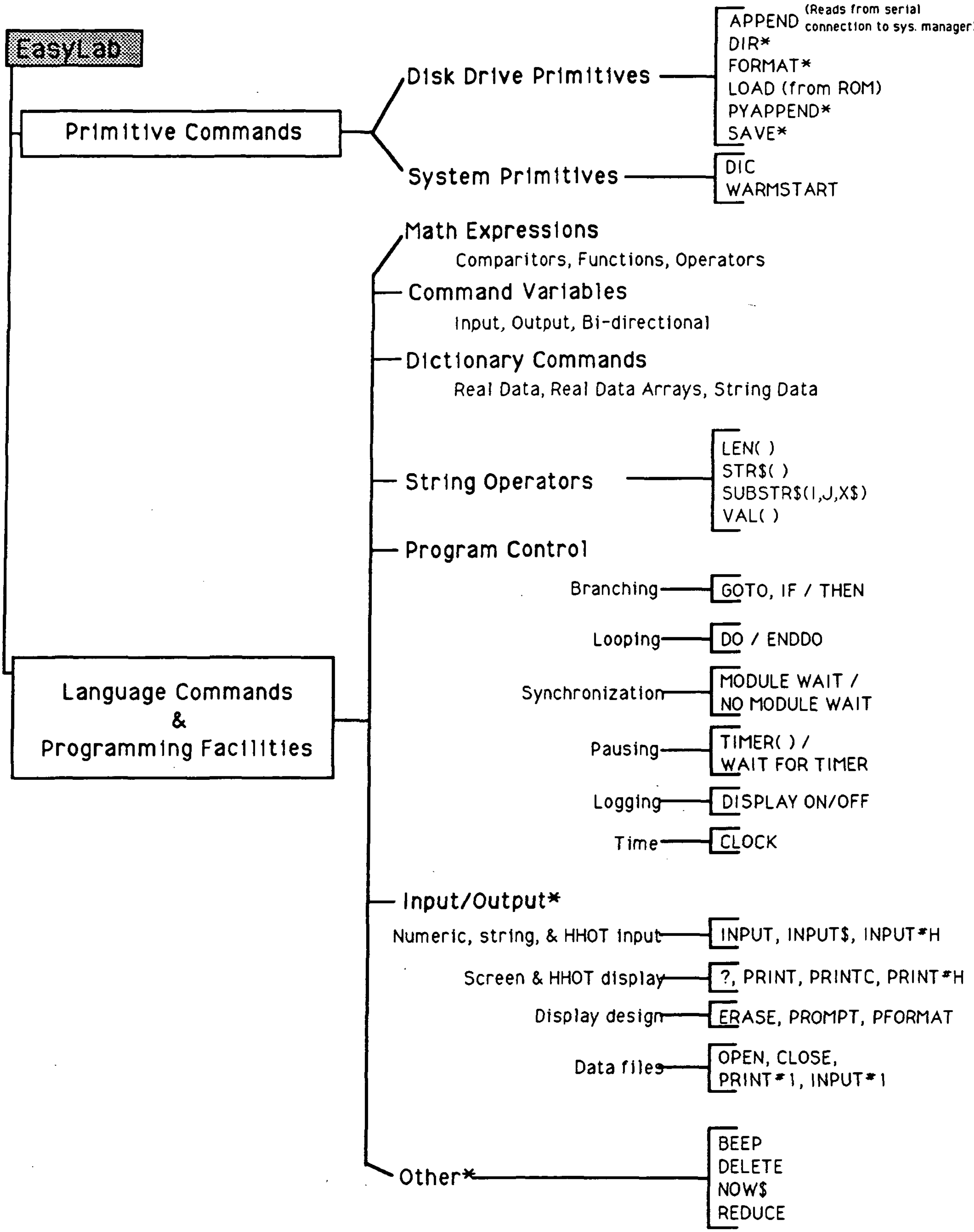
Process System Directives

SpARC Space Automation & Robotics Center

romps: level 11



EasyLab™ Command Structure



*Not supported in SC-4 port.

SpARC 051491/MC1.0

IMPLEMENTATION OPTIONS FOR THE ROBOT MOVEMENT
EasyLab™ Language Interface.

PUT.INTO.ANNEALER

```
MOVE.IN.SAFE
MOVE.ANNEALER
MOVE.BELOW.ANNEALER
MOVE.UP.INTO.ANNEALER
```

This implementation uses a set of "learned" absolute and relative positions. This method is supported and available in the current EasyLab™.
NOTE : As these positions are stored in the system data dictionary their values can be modified.

```
S:ALL.SPEED = 1.0
S:THETA= SAFE.RADIAL
S:RADIAL = ANNEALER.RADIAL
S:Z= ANNEALER.HEIGHT
S:THETA = S:THETA +
            ANNEALER.THETA
S:HEIGHT = UP.TO.ALLEALER
```

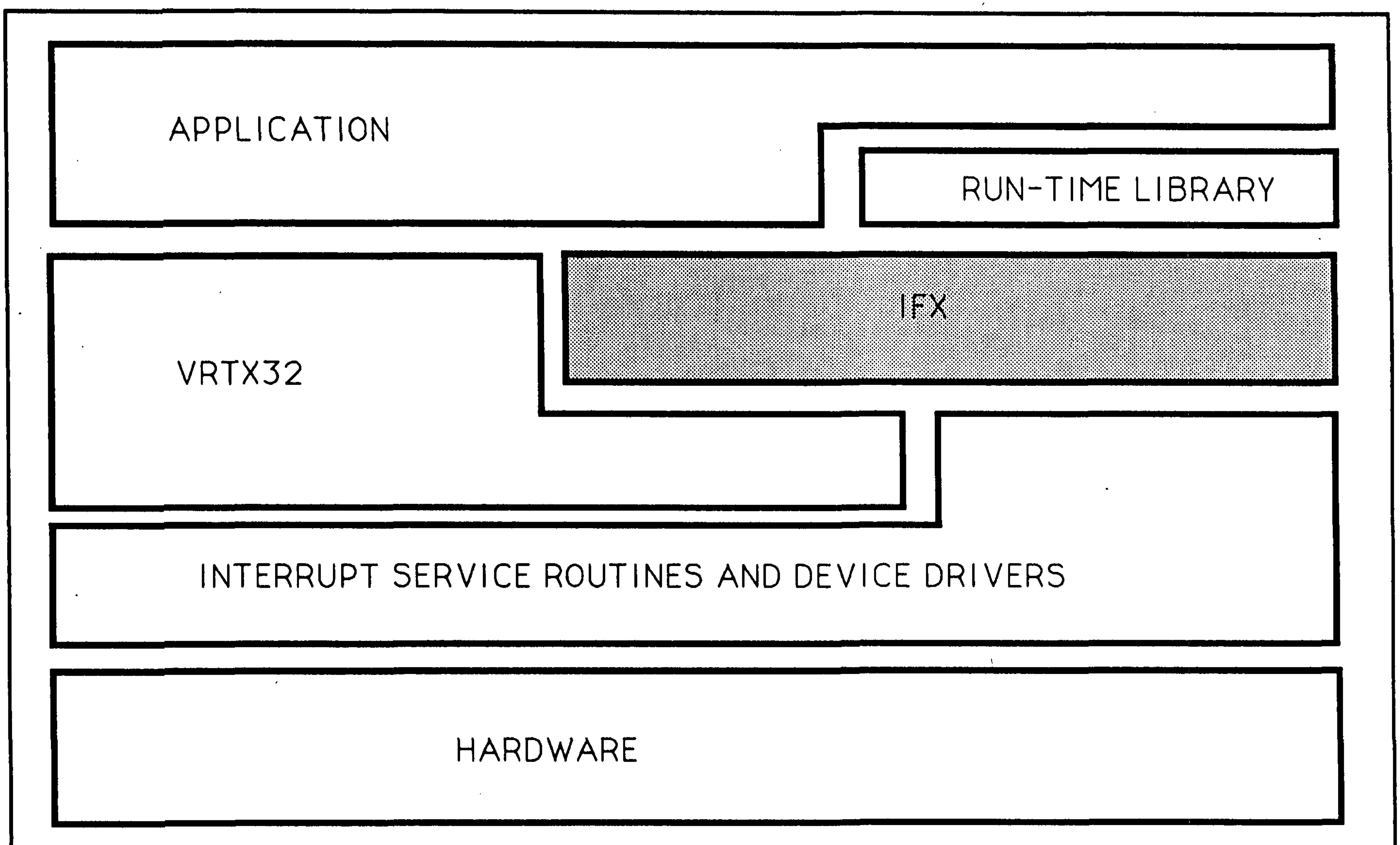
This implementation uses EasyLab™ Command Variables. Assignment to these variables causes the variable state to change and an action to occur. Again, this is still a method used and supported by EasyLab™.

```
S:ALL.SPEED = 1.0
S:THETA= SAFE
MOVE.THETA
S:RADIAL = ANNEALER.RADIAL
S:Z= ANNEALER.HEIGHT
MOVE.ALL
S:THETA = S:THETA +
            ANNEALER.THETA
MOVE.THETA
S:HEIGHT = UP.TO.ANNEALER
MOVE.HEIGHT
```

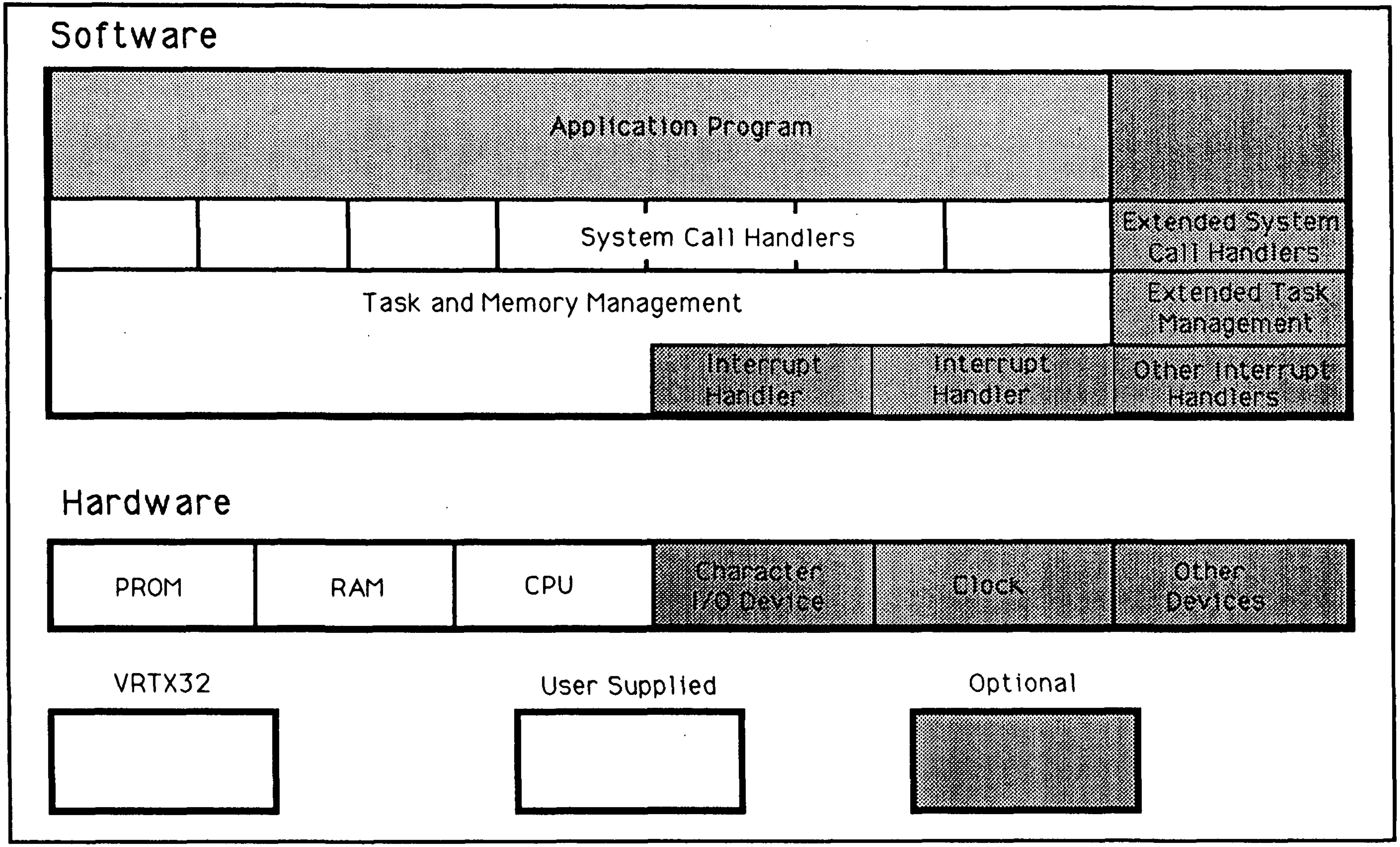
This implementation uses command variables in a different manner than the current EasyLab™ robot movement language.
Command variables do not cause the robot movement to occur.
Instead, movement is initiated by a simple command which uses the previously set variable states as its inputs. This implementation would be easy to accomplish with the current EasyLab™ interpreter.

```
MOVE "THETA" , ALL.SPEED,
          SAFE.THETA
MOVE "RADIAL", ALL.SPEED,
          ANNEALER.RADIAL
MOVE "Z", ALL.SPEED,
          ANNEALER.HEIGHT
MOVE.REL "THETA", ALL.SPEED
          BELOW.ANNEALER
MOVE.REL "THETA" ,ALL.SPEED,
          UP.ANNEALER
```

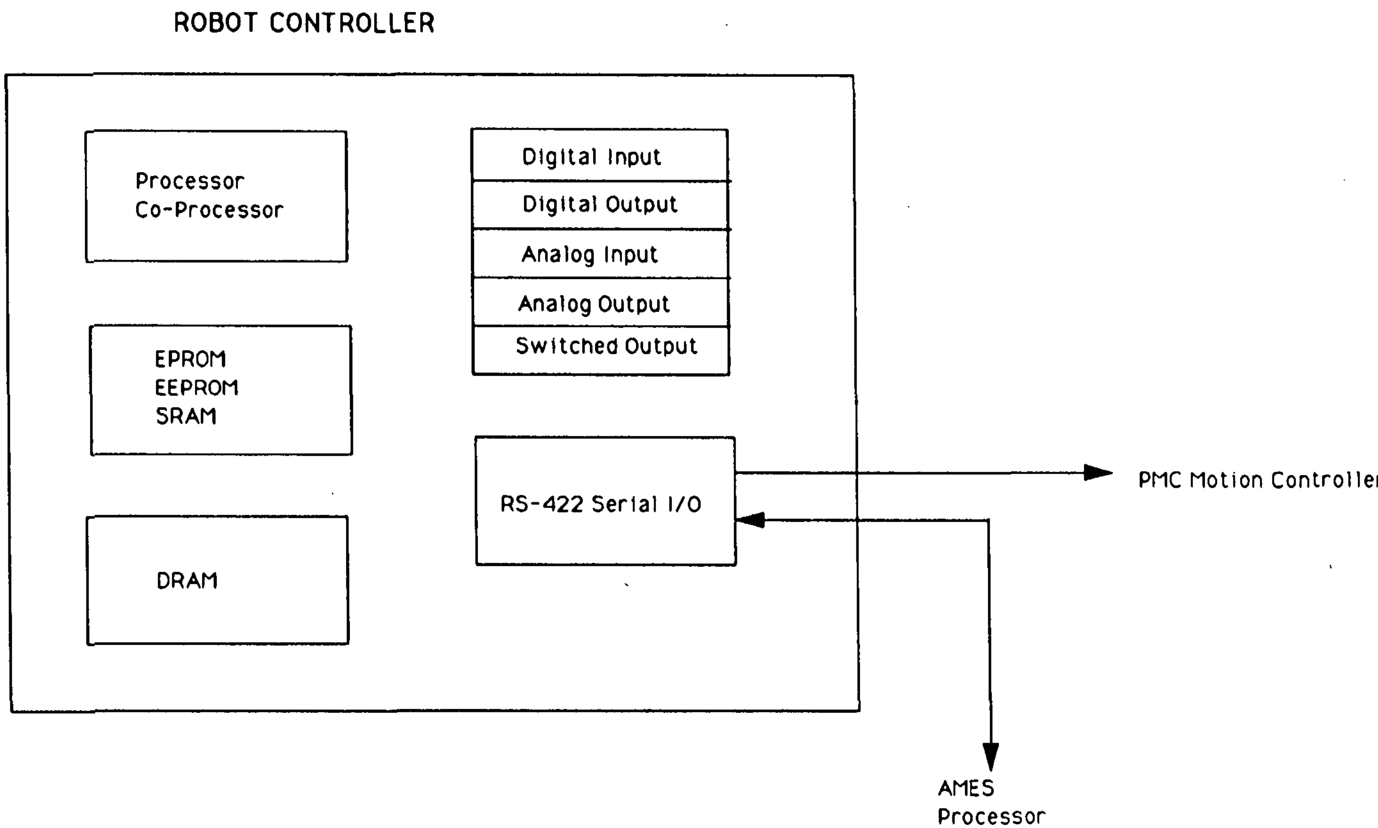
This implementation uses a currently unavailable zymate interpreter ability, parameter passing. There are no plans for this to be implemented in the port to the SC-4 system.



ENGINEER M.E Dobbs	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	VRTX Multi-Tasking Real-Time System	XX/XX/XX
	AESM Data Flow Diagrams	XX/XX/XX
	RoMPS	05/14/91
	XXXXXXXXXXXX	DATE

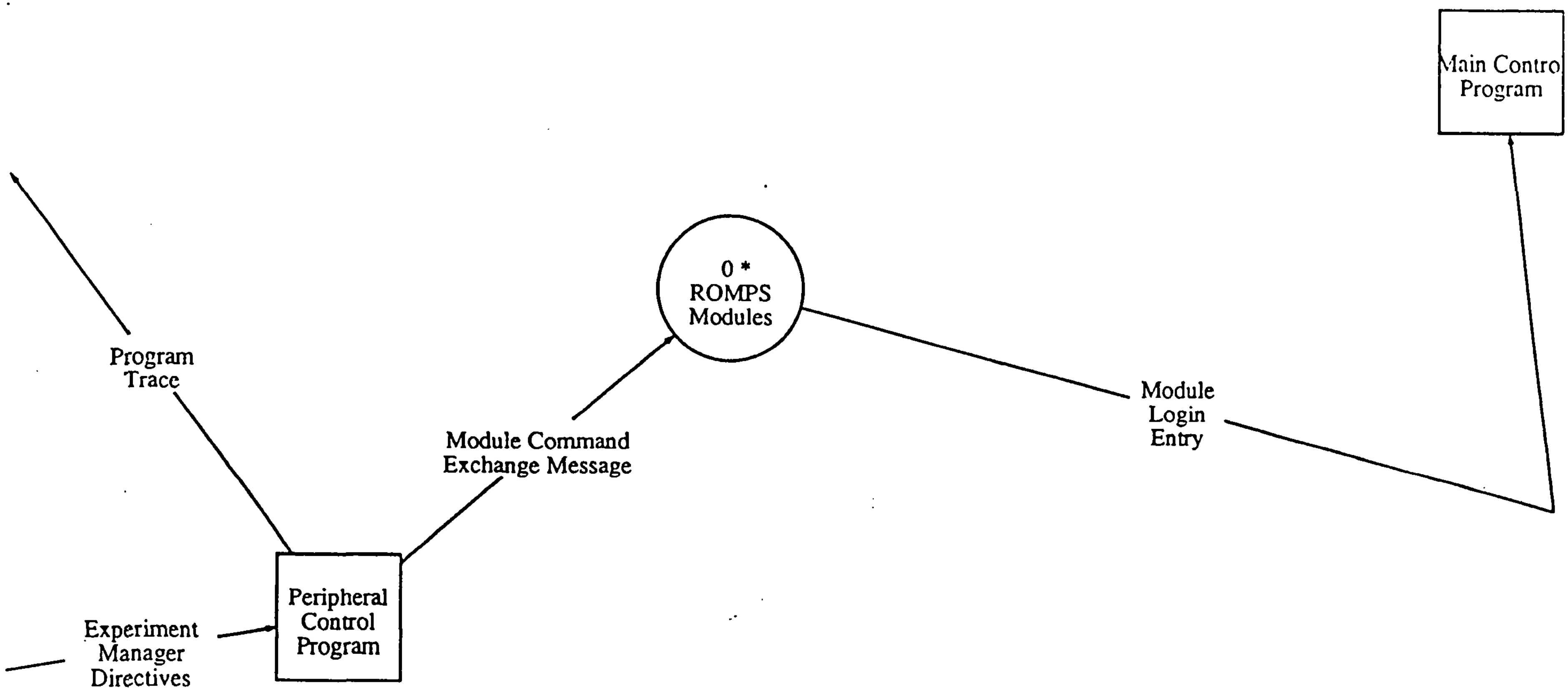


ENGINEER M.E.Dobbs	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	VRTX Multi-Tasking Real-Time Kernel	XX/XX/XX
	AESM Data Flow Diagrams	XX/XX/XX
	RoMPS	05/14/91
	XXXXXXXXXXXX	DATE



ENGINEER X. X. XXXXXXX	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
		XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER	Zymate Robot Controller Block Diagram	XX/XX/XX
ENVIRONMENTAL RESEARCH INSTITUTE of MI	RoMPS	05/14/91
ANN ARBOR, MI	XXXXXXXXXXXX	DATE

zymate: level top



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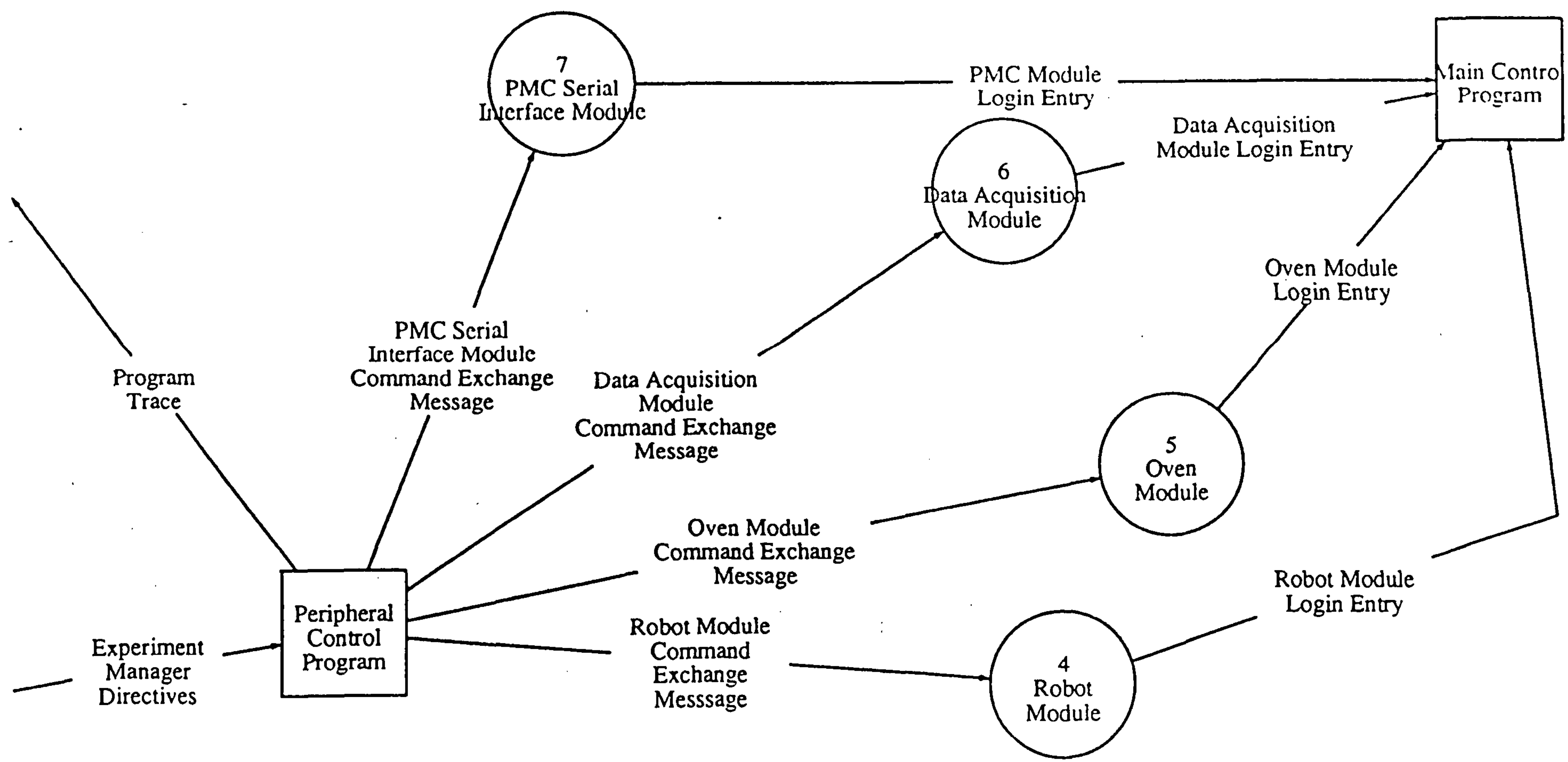
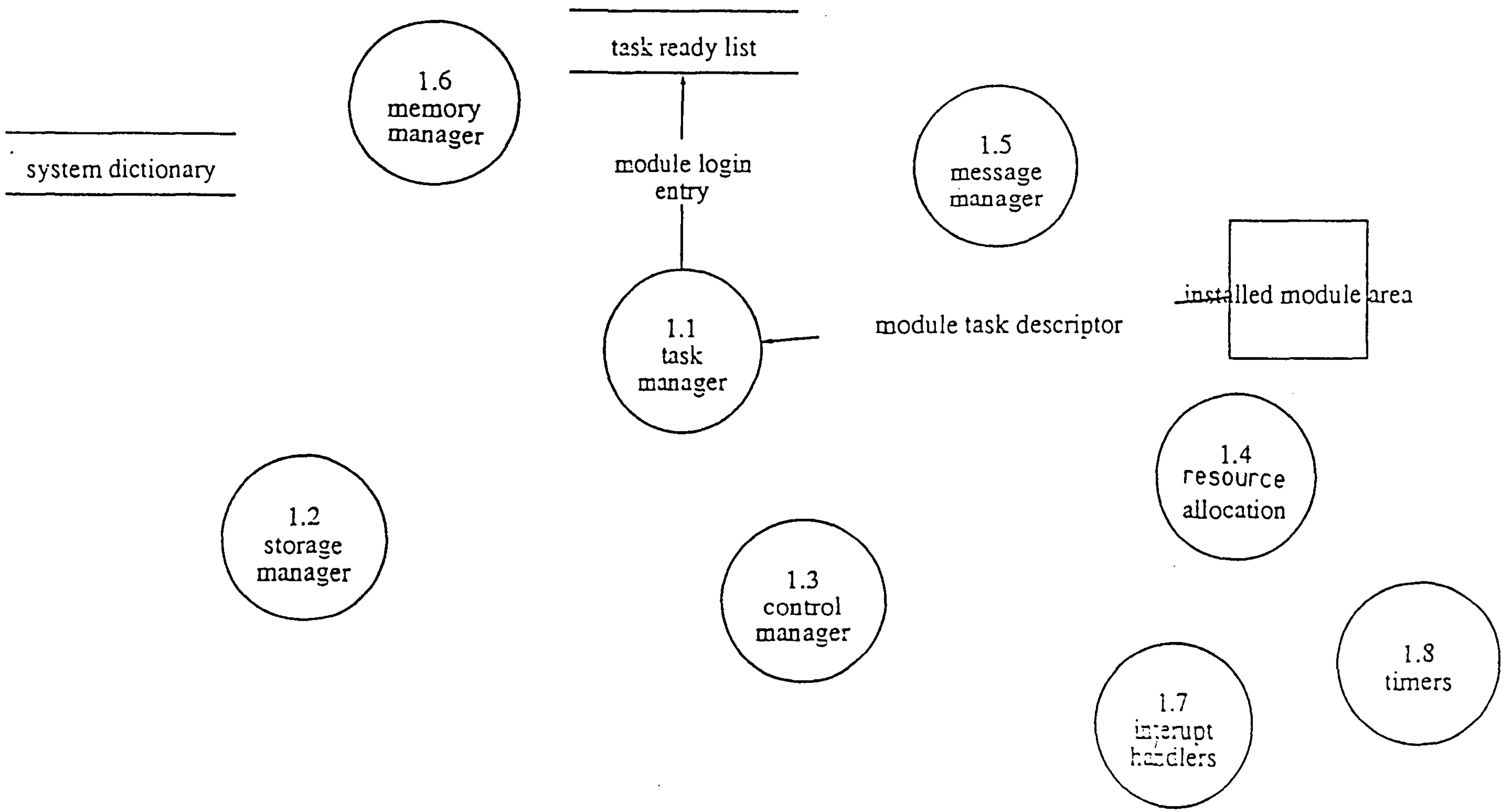
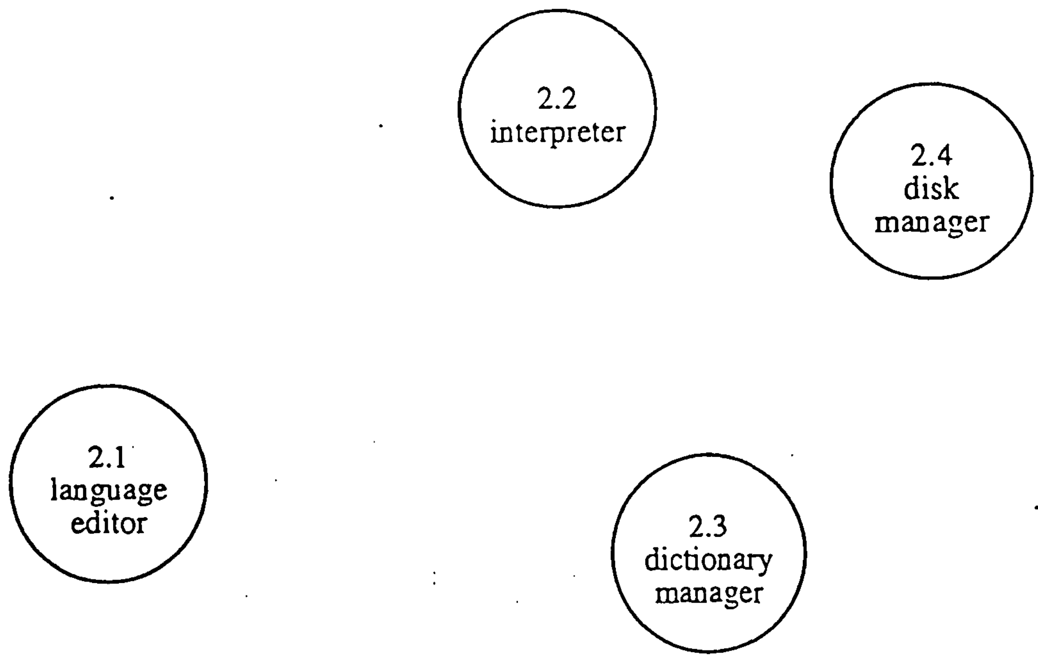


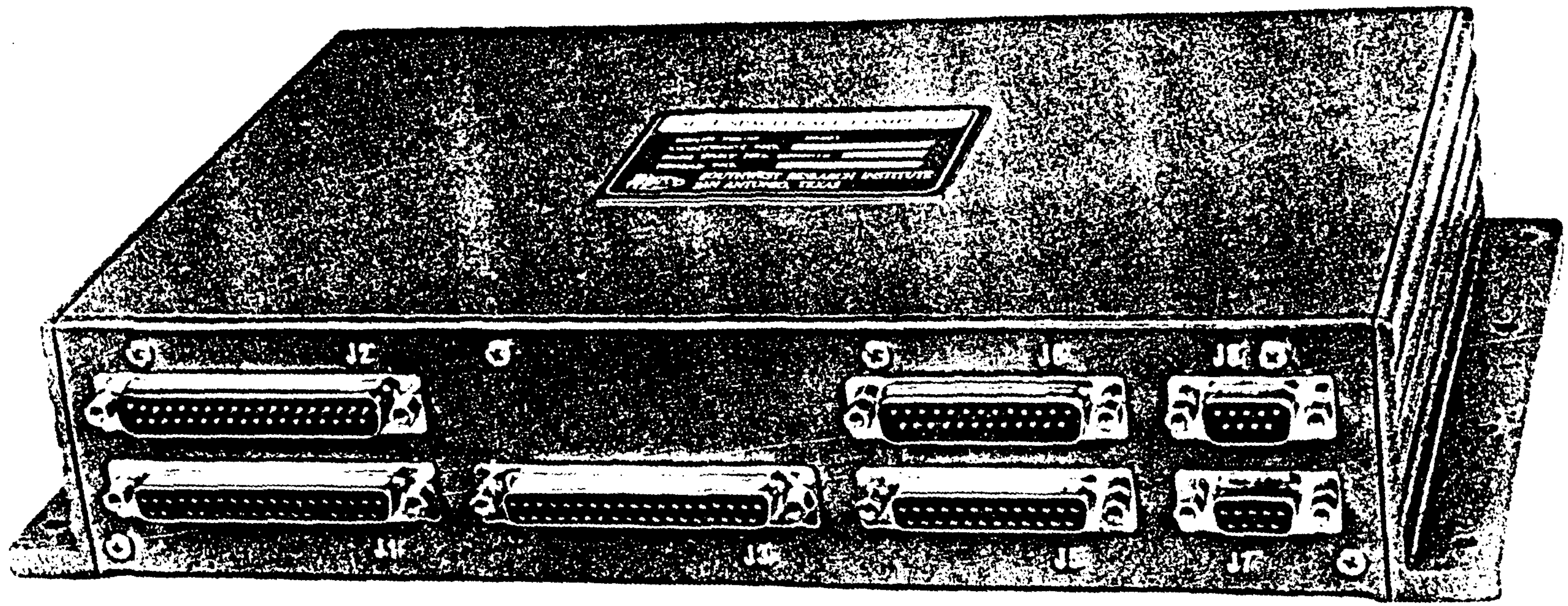
SpARC Space Automation & Robotics Center

ZYMATE MAIN CONTROL PROGRAM



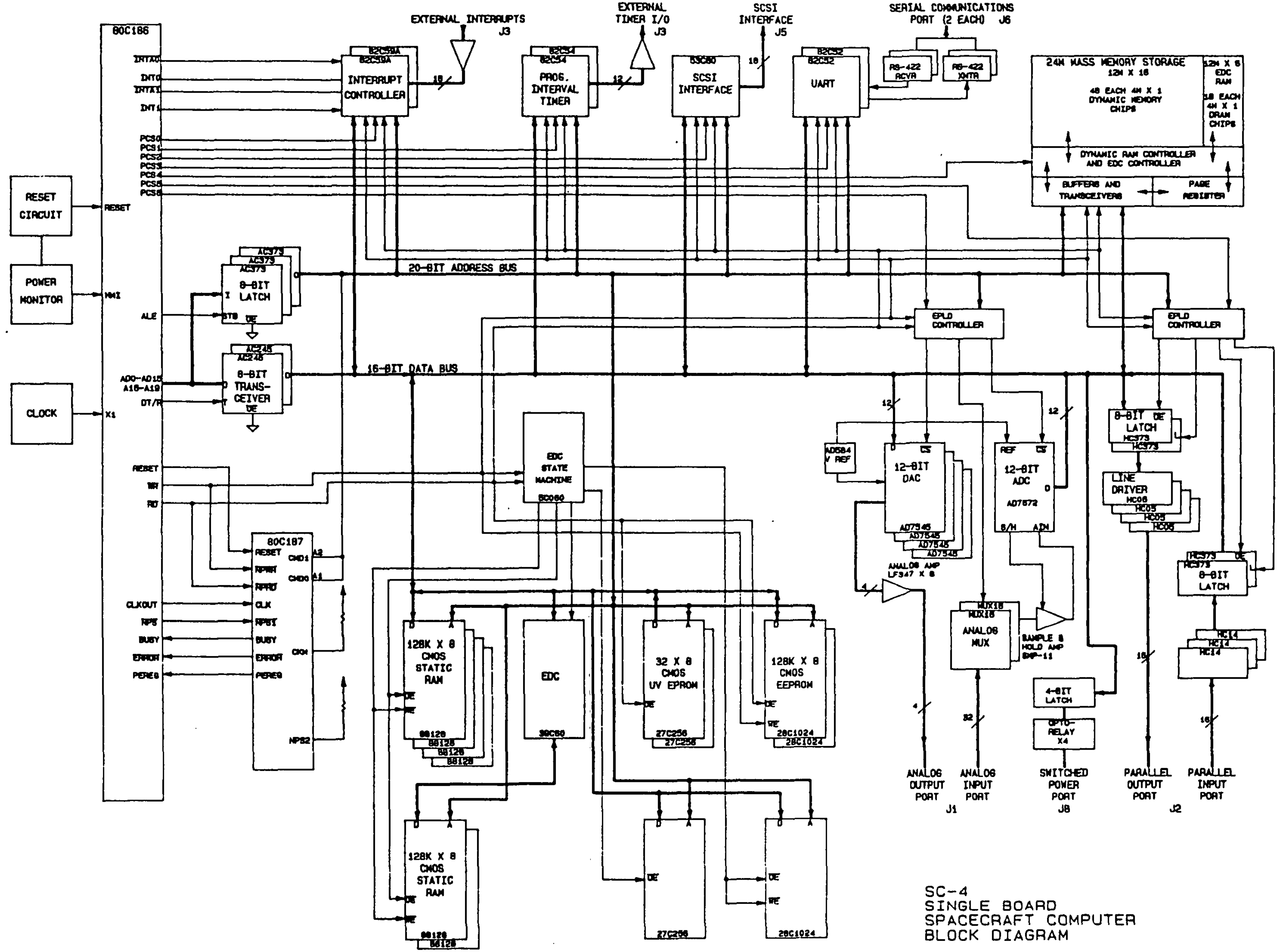
ZYMATE PERIPHERAL
CONTROL PROGRAM




J2

Preliminary Specification
SC-4 Single Board Spacecraft Computer

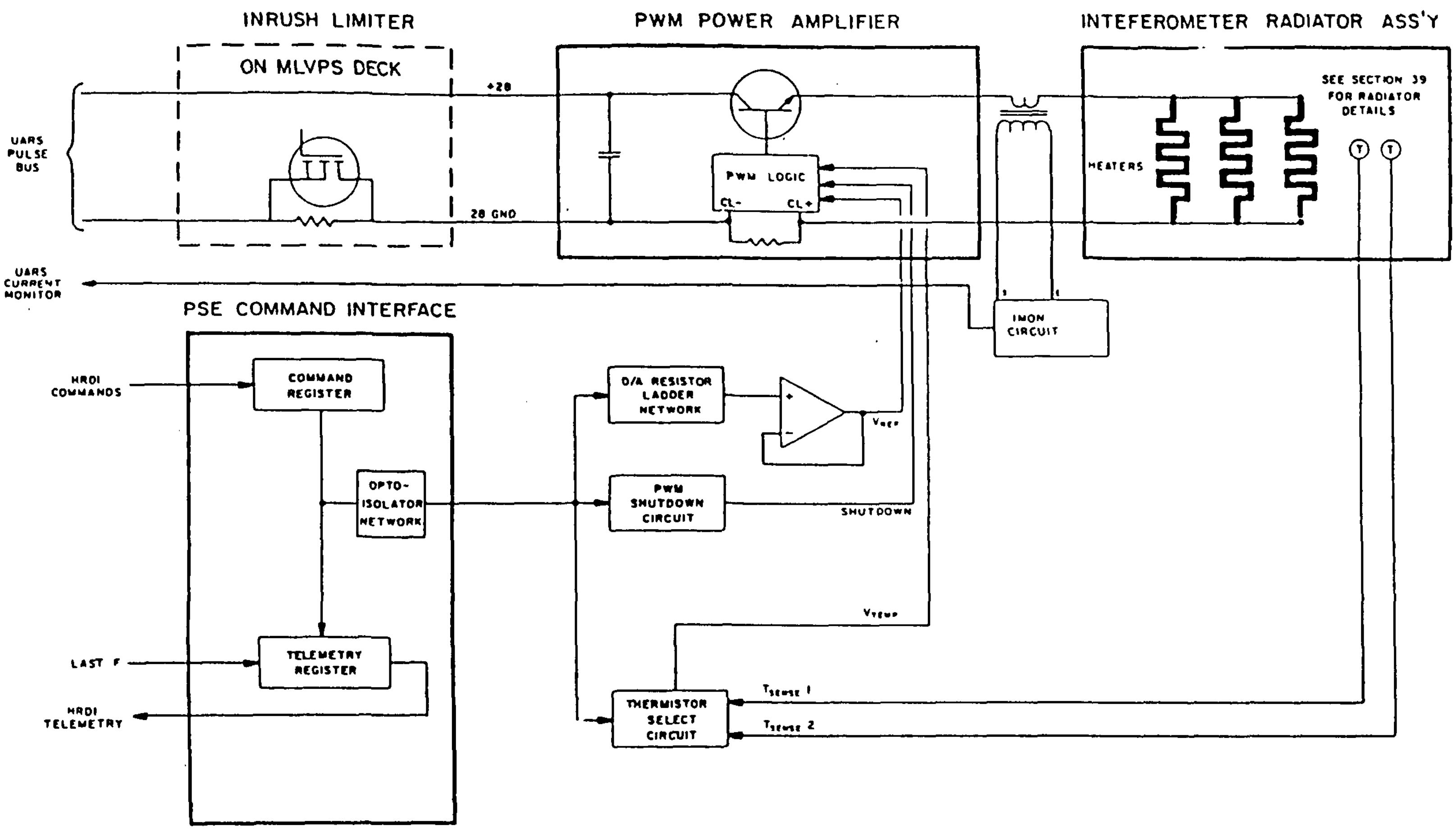
Central Processor	80C186/80C187 16 Bit
Clock Frequency	10 MHz
Operating System	MS-DOS and VRTX Compatible
Onboard Memory	
RAM	512K Bytes w/EDC
EEPROM	256K Bytes
UVPROM	64K Bytes
Hardware Vectored Interrupts	16 User Configurable
Timer/Event Counters	6, Software Configurable, 120 ns Granularity
Input/Output Capability	
Parallel I/O	16 Input, 16 Output
Analog Input	32 Differential Channels, 12-bit Resolution,
Analog Output	4 Channels
RS-422 Serial I/O	2 Channels
SCSI Interface	1 Port
Mass Storage	24M Bytes, Read/Write Non-volatile
Expansion	Internal Daughterboard Connector
Size	7 X 12 X 2.25 in
Weight	5 Lb (Approximate)
Power	28v @ 5w (Approximate)



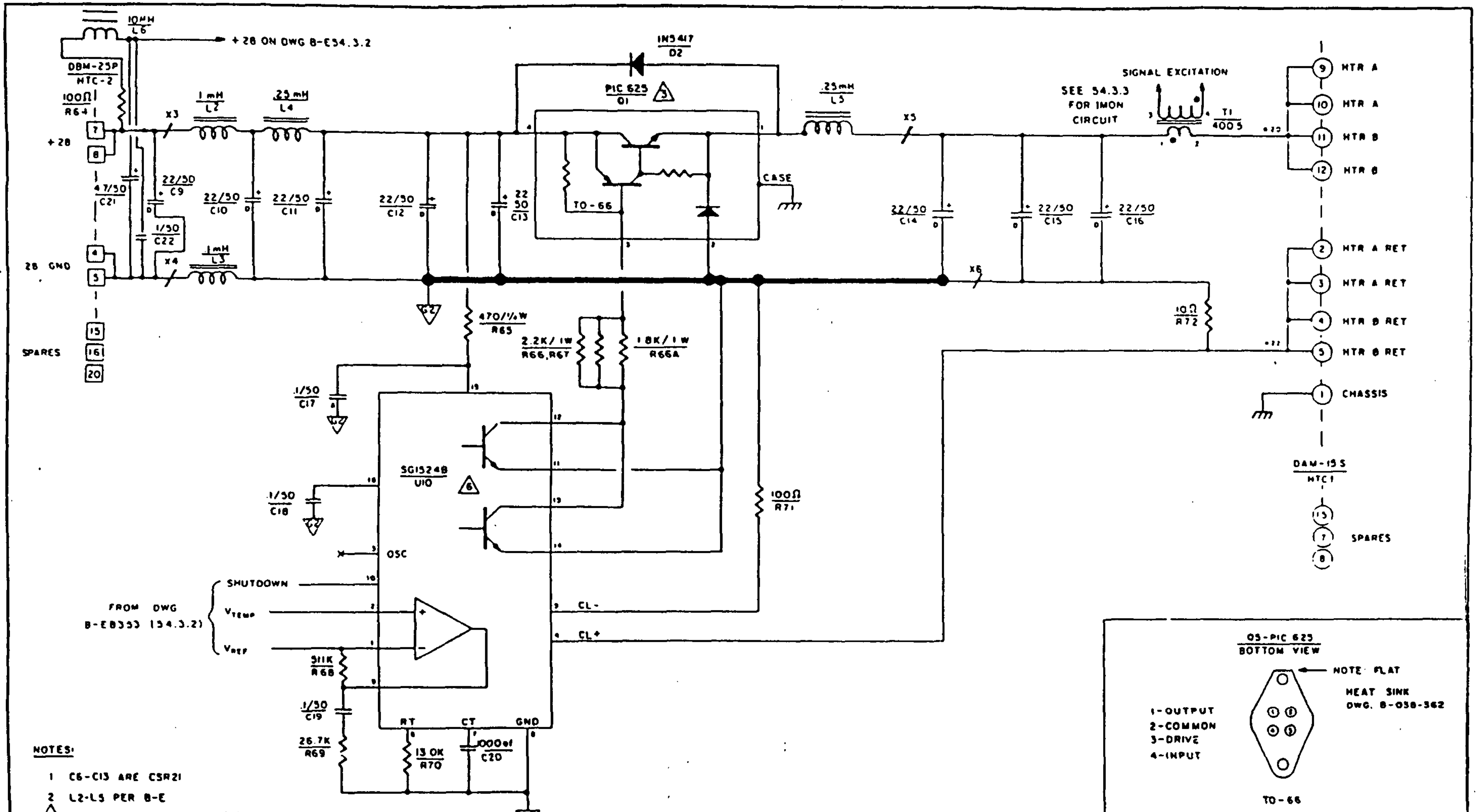
SC-4
SINGLE BOARD
SPACECRAFT COMPUTER
BLOCK DIAGRAM

Oven Control

Housekeeping Data



ENGINEER J. STEVENS	DRAFTER EGJ REK 4/9/8?	
SPACE PHYSICS RESEARCH LABORATORY COLLEGE OF ENGINEERING UNIVERSITY OF MICHIGAN ANN ARBOR, MICHIGAN	IF THERMAL CONTROLLER BLOCK DIAGRAM HRDI UARS PSE	2/1/89 7/15/88
	B-E8033 CONTROLLED	DATE



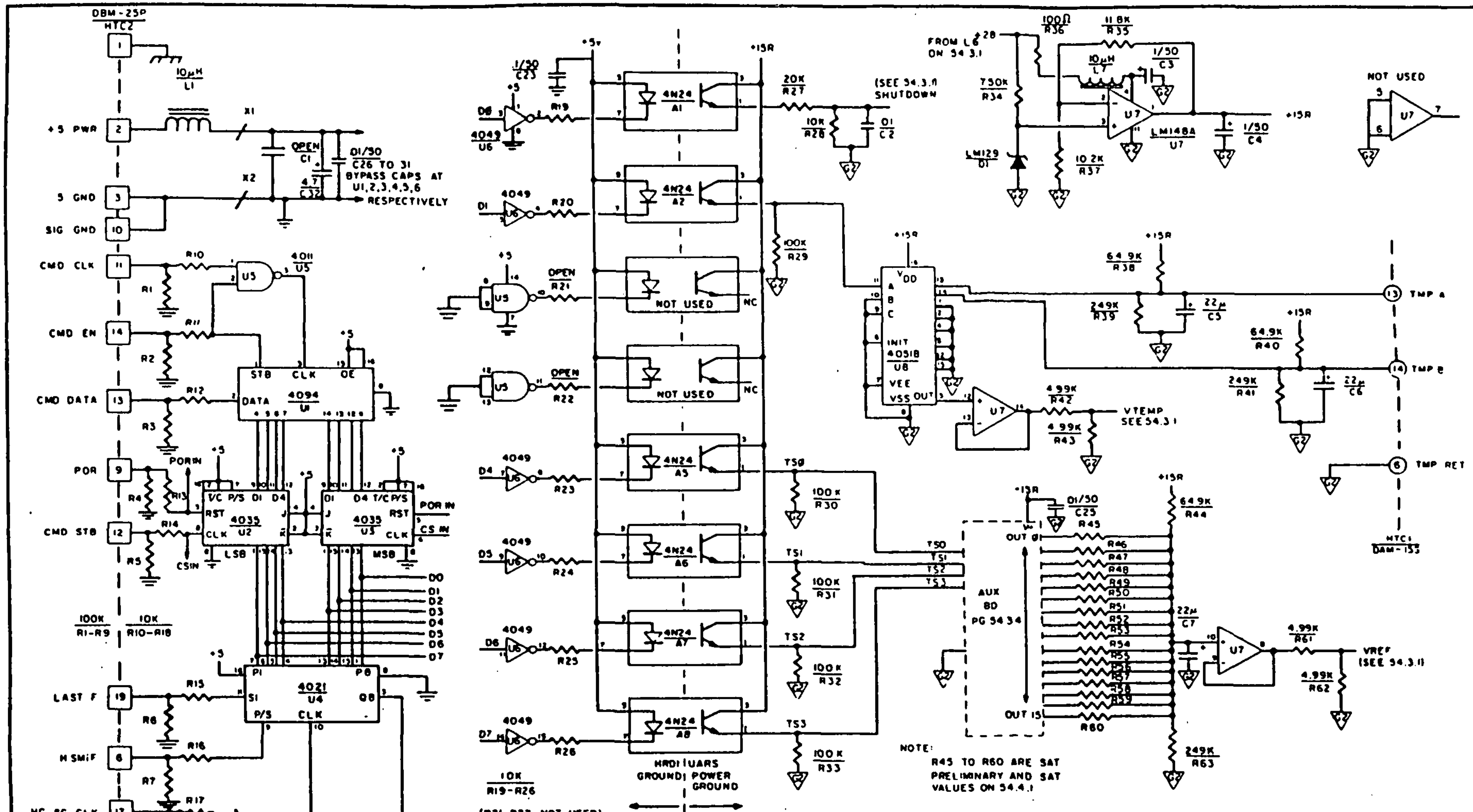
NOTES:

1 C6-C13 ARE CSR21
2 L2-L5 PER B-E
3 HEAT SINK REQUIRED, DWG. B-038-362
4 X3, X4, X5, X6 ARE FERRITE BEADS
5 SAT
6 HEAT SINK REQUIRED, DWG. A-038-

ENGINEER J.STEVENS D.BOPRIE	DRAFTER EGJ 4/22/'87	
SPACE PHYSICS RESEARCH LABORATORY COLLEGE OF ENGINEERING UNIVERSITY OF MICHIGAN ANN ARBOR, MICHIGAN	PWM DRIVER HTC HRDI UARS PSE	11/10/88 7/15/88
	B-E8035 CONTROLLED	DATE

LAST USED R 04/72 C 8/22 D2 Q1 L 2/6

[redacted]

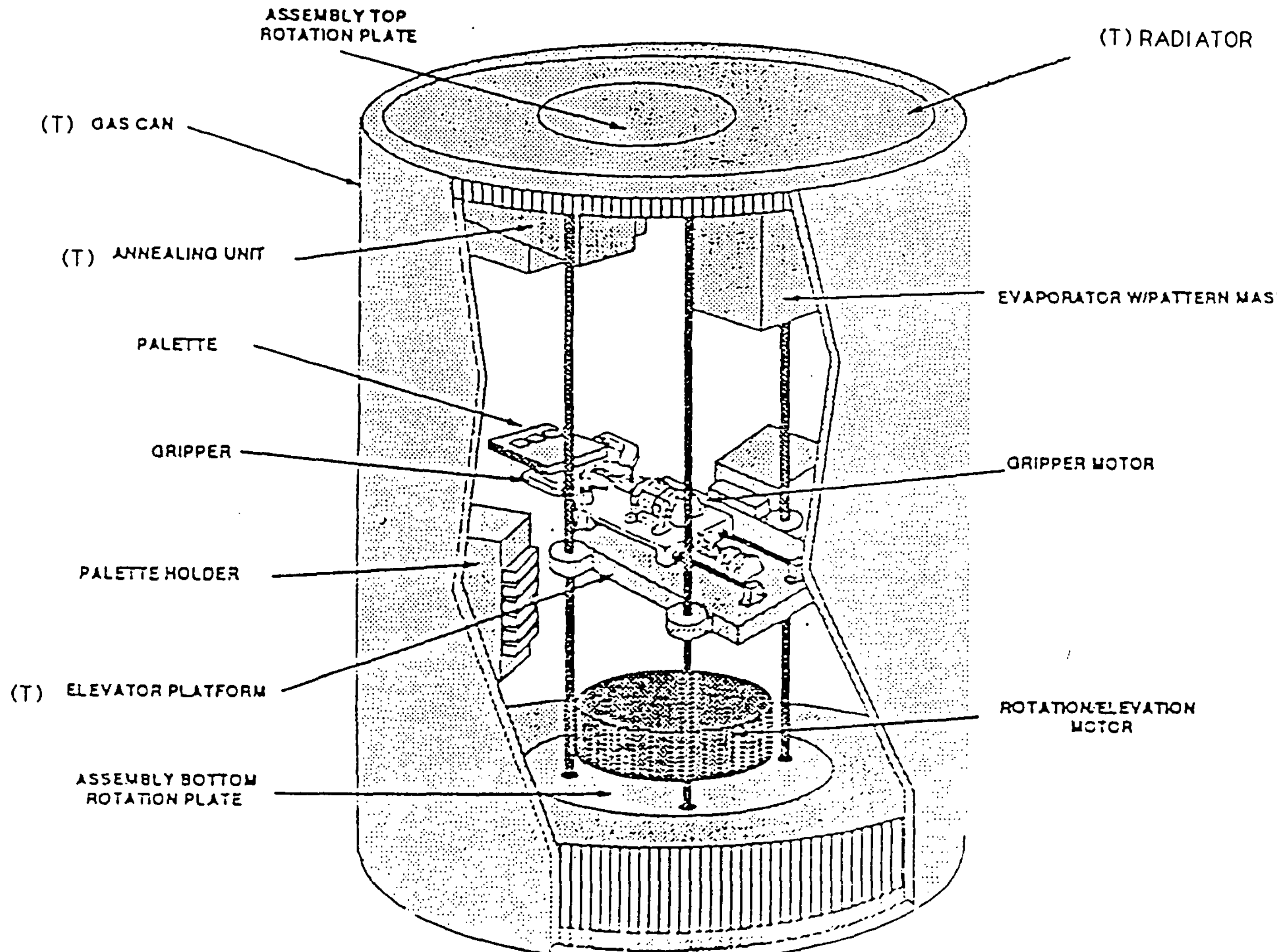


ENGINEER J STEVENS D.BOPRIE	DRAFTSMAN M.F. 3/8/88	
SPACE PHYSICS RESEARCH LABORATORY COLLEGE OF ENGINEERING UNIVERSITY OF MICHIGAN ANN ARBOR, MICHIGAN	PSE INTERFACE HTC HRDI UARS PSE	6/27/89 2/1/89 7/15/88
	B-E8353 CONTROLLED	DATE

LAST USED R1 R63 C1 C7 D1 A8 U9

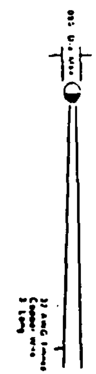
[redacted]

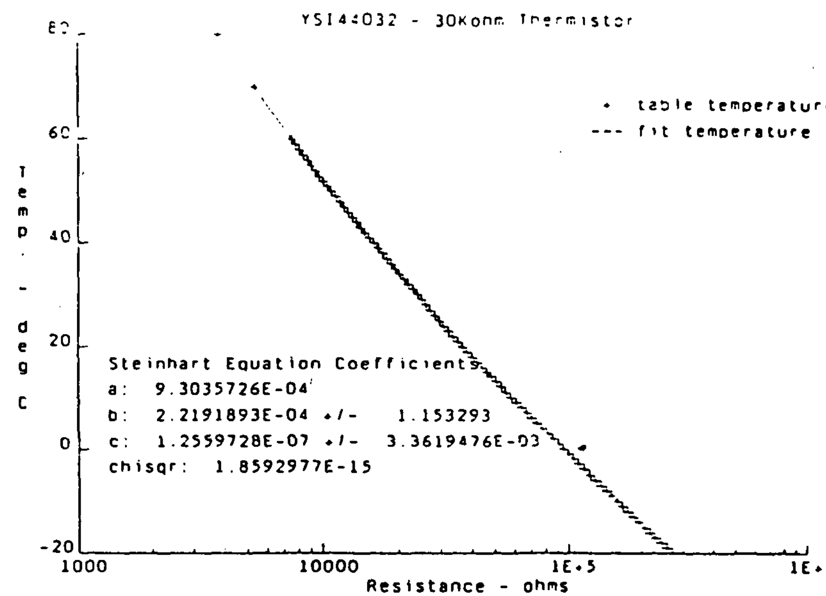
GAS CAN CONCEPT LAYOUT



RESISTANCE VERSUS TEMPERATURE — 40° to + 100°

TEMP°C	RES	TEMP°C	RES	TEMP°C	RES	TEMP°C	RES	TEMP°C	RES
−40	884.6K	−10	158.0K	+20	37.30K	+50	10.97K	+80	3843
39	830.9K	9	150.0K	21	35.70K	51	10.57K	81	3720
38	780.8K	8	142.4K	22	34.17K	52	10.18K	82	3602
37	733.9K	7	135.2K	23	32.71K	53	9807	83	3489
36	690.7K	6	128.5K	24	31.32K	54	9450	84	3379
35	649.3K	5	122.1K	25	30.00K	55	9109	85	3273
34	611.0K	4	116.0K	26	28.74K	56	8781	86	3172
33	575.2K	3	110.3K	27	27.54K	57	8467	87	3073
32	541.7K	2	104.9K	28	26.40K	58	8166	88	2979
31	510.4K	−1	99.80K	29	25.31K	59	7876	89	2887
−30	481.0K	0	94.98K	+30	24.27K	+60	7599	+90	2799
29	453.5K	+1	90.41K	31	23.28K	61	7332	91	2714
28	427.7K	2	86.09K	32	22.33K	62	7076	92	2632
27	403.5K	3	81.99K	33	21.43K	63	6830	93	2552
26	380.9K	4	78.11K	34	20.57K	64	6594	94	2476
25	359.6K	5	74.44K	35	19.74K	65	6367	95	2402
24	339.6K	6	70.96K	36	18.96K	66	6149	96	2331
23	320.9K	7	67.66K	37	18.21K	67	5940	97	2262
22	303.3K	8	64.53K	38	17.49K	68	5738	98	2195
21	286.7K	9	61.56K	39	16.80K	69	5545	99	2131
−20	271.2K	+10	58.75K	+40	16.15K	+70	5359	+100	2069
19	256.5K	11	56.07K	41	15.52K	71	5180		
18	242.8K	12	53.54K	42	14.92K	72	5007		
17	229.8K	13	51.13K	43	14.35K	73	4842		
16	217.6K	14	48.84K	44	13.80K	74	4682		
15	206.2K	15	46.67K	45	13.28K	75	4529		
14	195.4K	16	44.60K	46	12.77K	76	4381		
13	185.2K	17	42.64K	47	12.29K	77	4239		
12	175.6K	18	40.77K	48	11.83K	78	4102		
11	166.6K	19	38.99K	49	11.39K	79	3970		



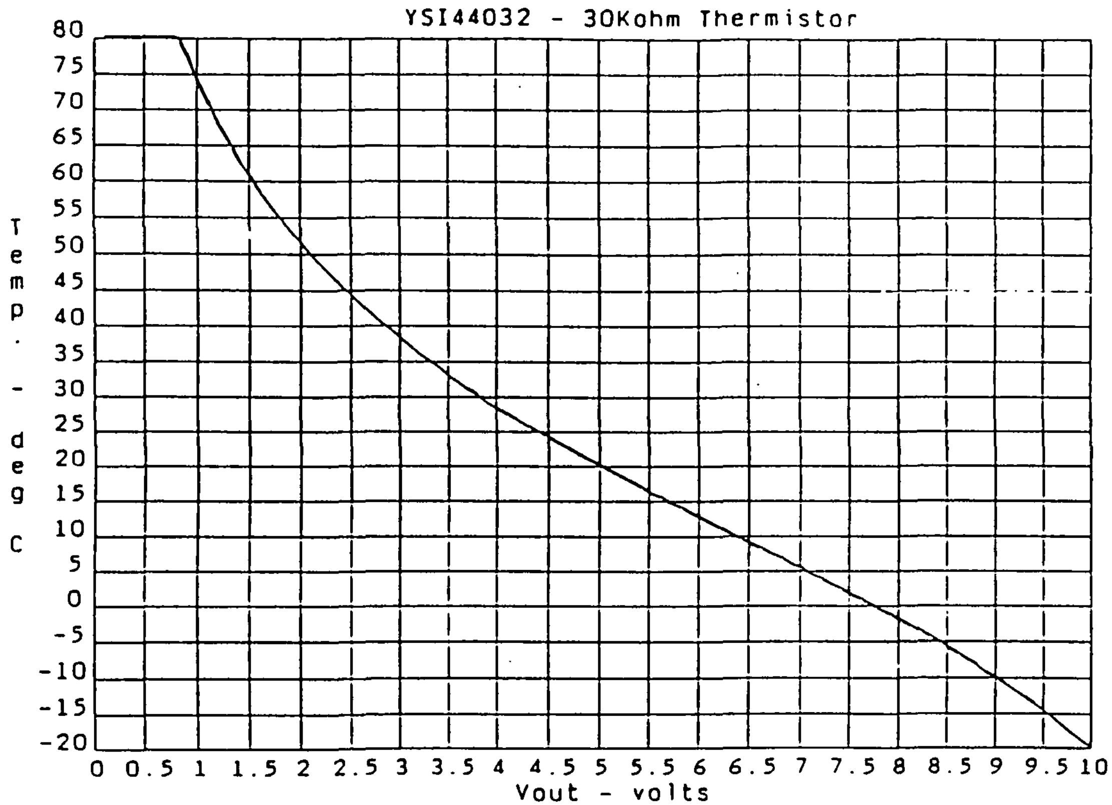


ENGINEER M.DOBBS	DRAFTSMAN M.F. 6/10/87
SPACE PHYSICS RESEARCH LABORATORY COLLEGE OF ENGINEERING UNIVERSITY OF MICHIGAN ANN ARBOR, MICHIGAN	TEMPERATURE ALGORITHMS 2 OF 2 INTERFEROMETER HOUSEKEEPING HRDI UARS
	B-E8154 CONTROLLED

6/10/87
DATE

LAST USED R C D L

[redacted]

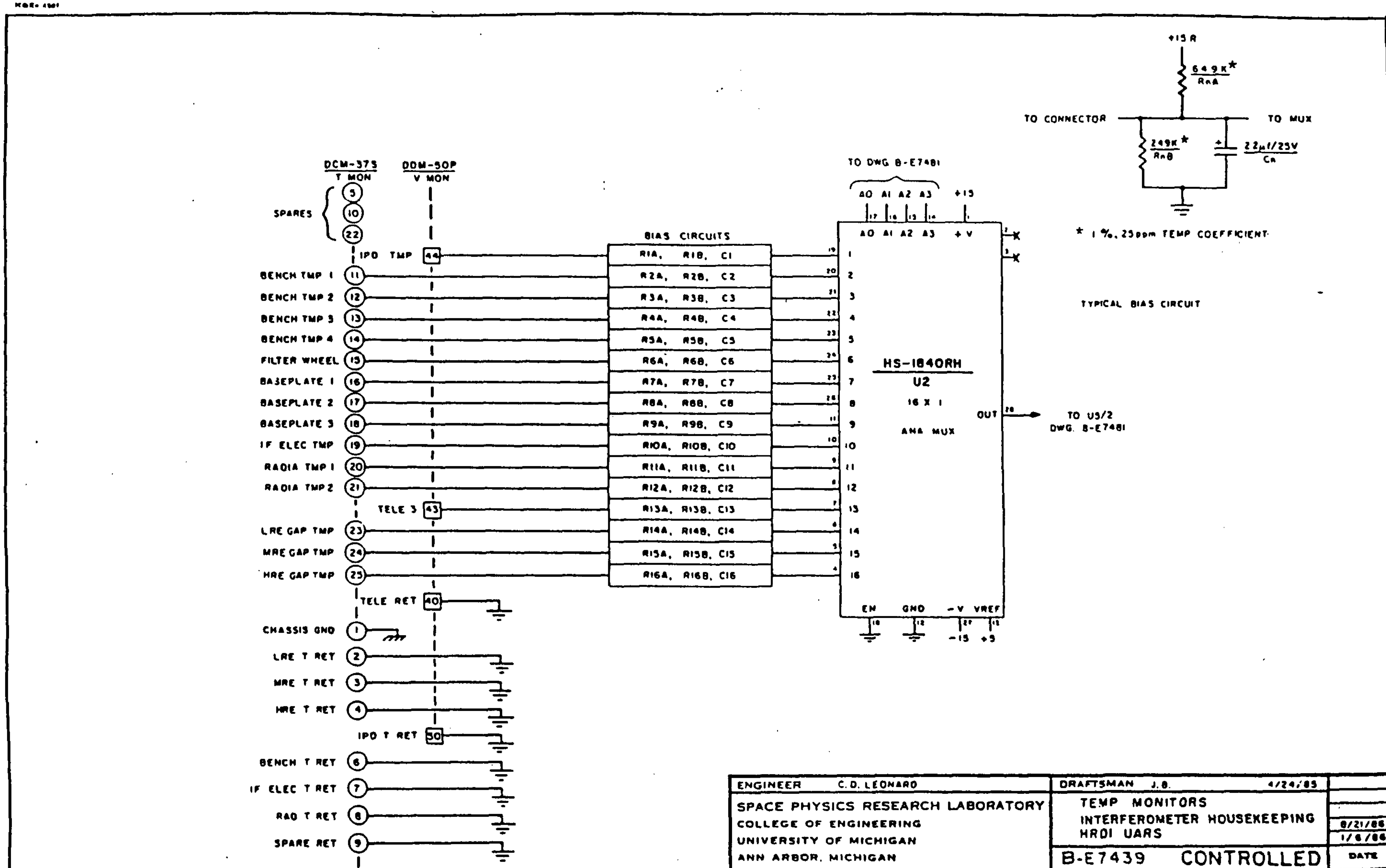


ENGINEER M DOBBS	DRAFTSMAN MF 6/30/87	
SPACE PHYSICS RESEARCH LABORATORY COLLEGE OF ENGINEERING UNIVERSITY OF MICHIGAN ANN ARBOR, MICHIGAN	TEMPERATURE CALIBRATION CURVE INTERFEROMETER HOUSEKEEPING HRDI UARS	8/10/87
	B-E 8204 CONTROLLED	DATE

LAST USED R C D L

[redacted]

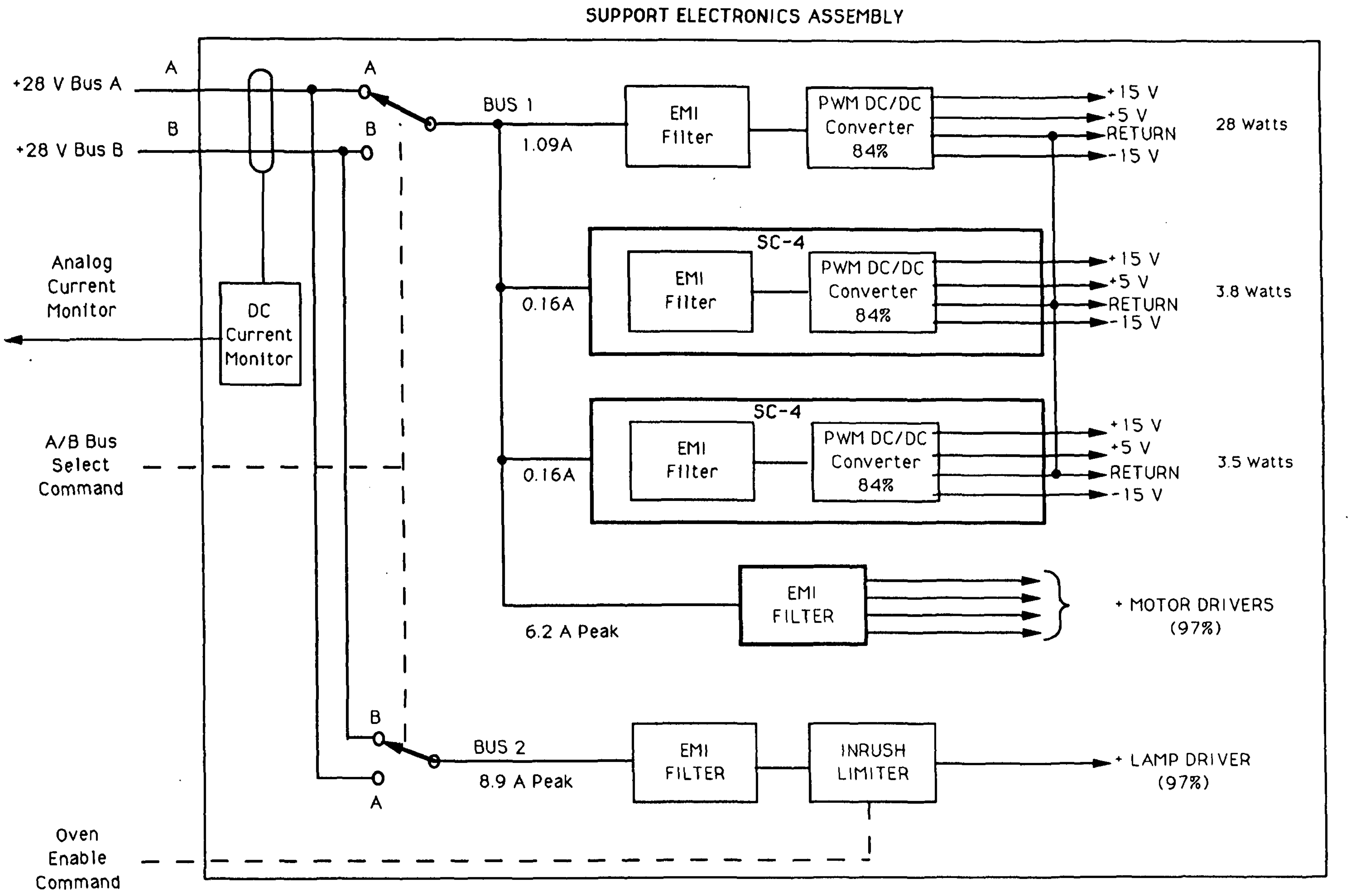
[redacted]



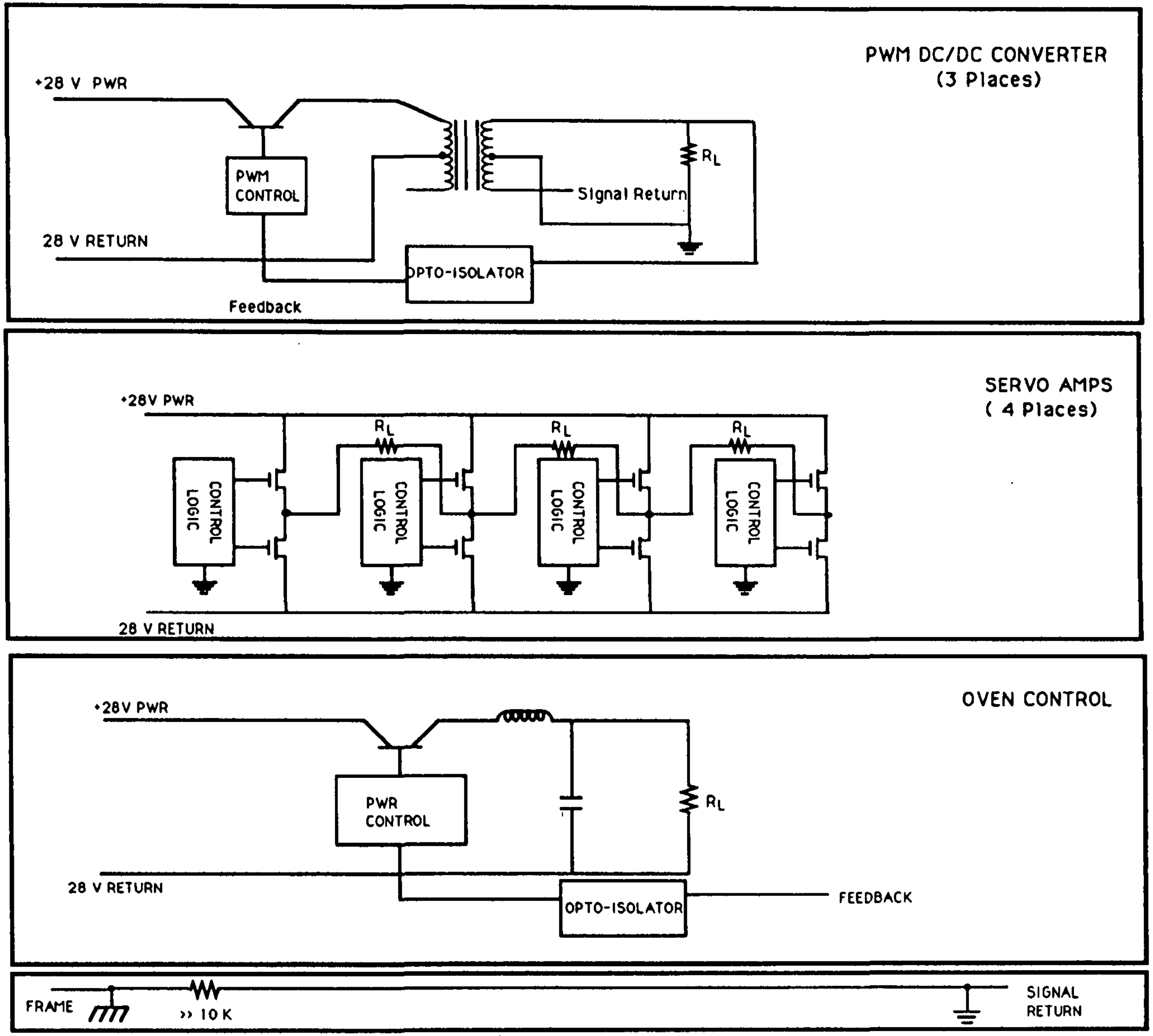
LAST USED R16 C16 D L

[redacted]

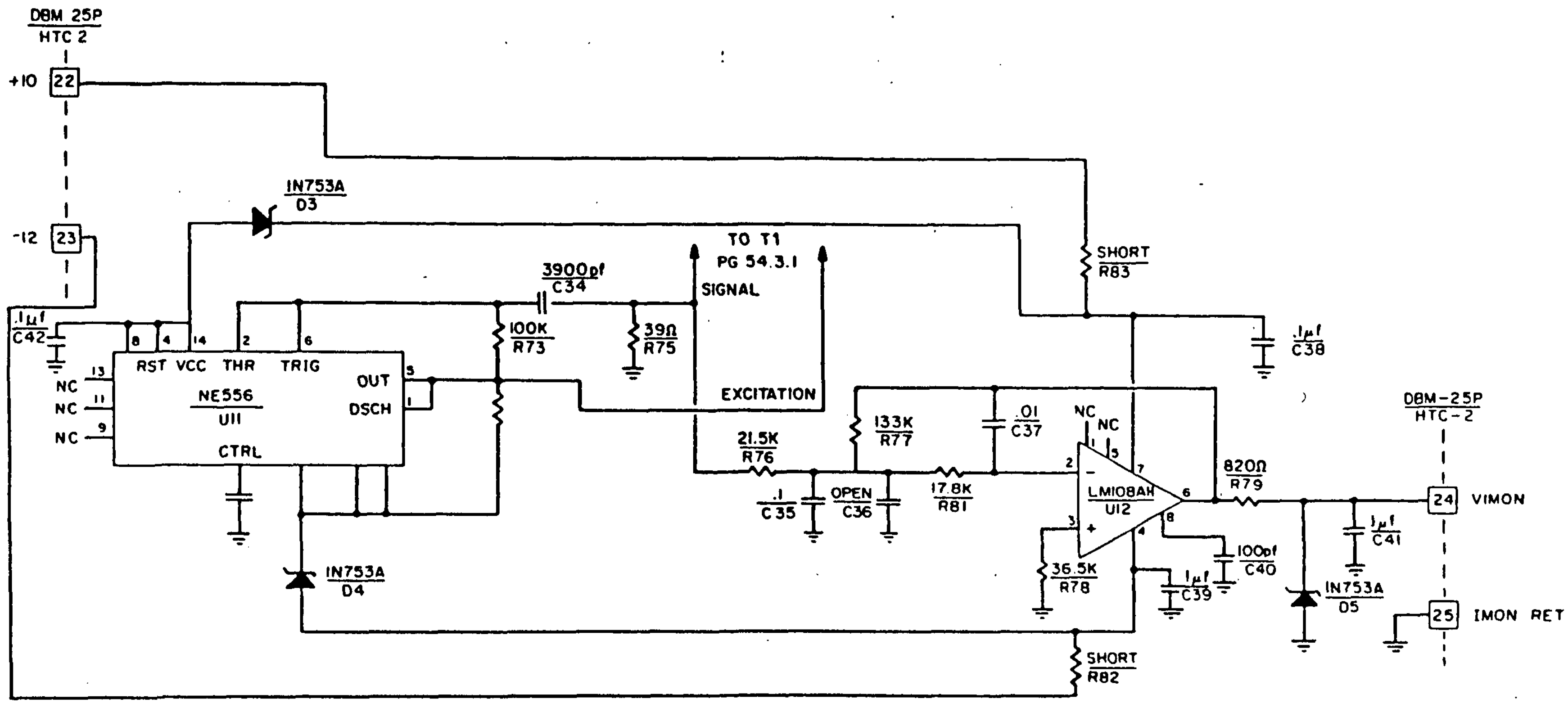
Power Distribution



ENGINEER M. E. Dobbs	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
		XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER	Power Distribution Block Diagram	XX/XX/XX
ENVIRONMENTAL RESEARCH INSTITUTE of MI	ROMPS	05/14/91
ANN ARBOR, MI	XXXXXXXXXXXX	DATE



ENGINEER L. M. Tomko	DRAFTSMAN X. X. XXXXXXX	XX/XX/XX
SPACE AUTOMATION & ROBOTICS CENTER	Grounding Diagram	XX/XX/XX
ENVIRONMENTAL RESEARCH INSTITUTE of MI	Power Distribution Block Diagram	XX/XX/XX
ANN ARBOR, MI	RoMPS	05/14/91
	XXXXXXXXXXXX	DATE



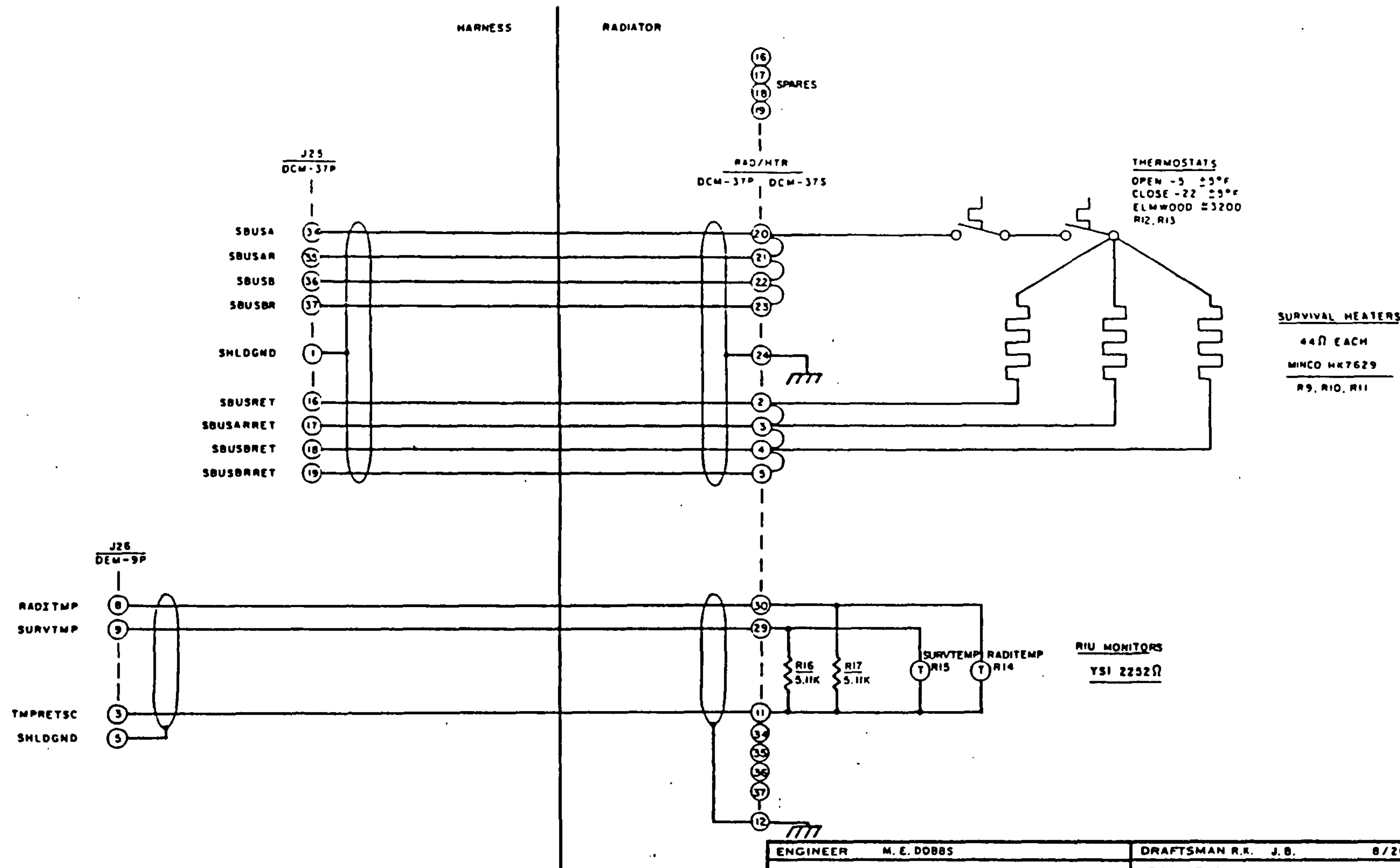
NOTE:

1) NE556 VCC@ 10-6.2=3.8
GND@ -12+6.2=5.8
9.6 TOTAL

ENGINEER J. STEVENS D. BOPRIE	DRAFTSMAN R.K. 6/15/88
SPACE PHYSICS RESEARCH LABORATORY COLLEGE OF ENGINEERING UNIVERSITY OF MICHIGAN ANN ARBOR, MICHIGAN	IMON HTC HRDI UARS
	B-E8376 CONTROLLED

2/1/89
7/15/88
DATE

LAST USED R C D L



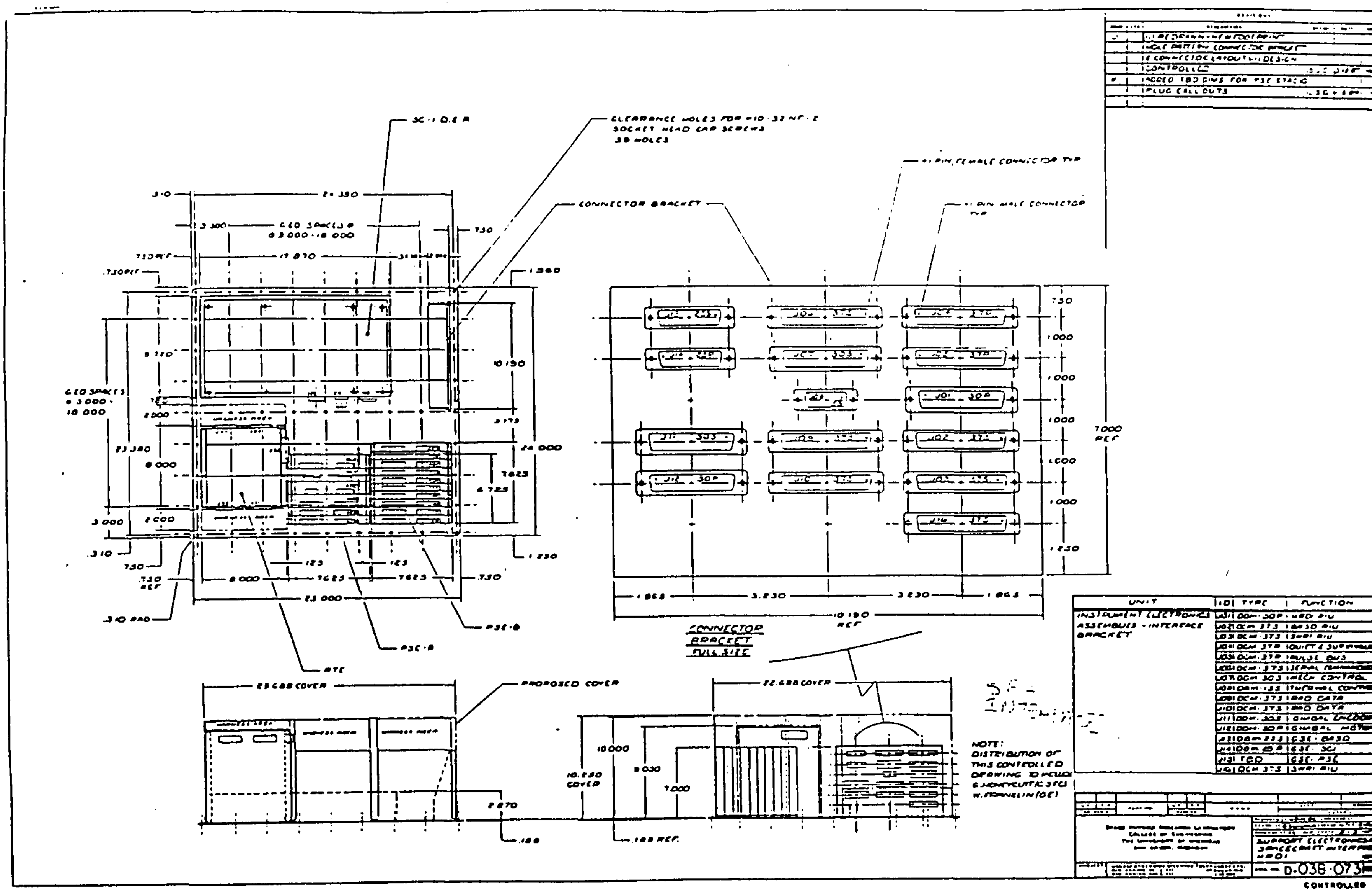
ENGINEER M. E. DOBBS	DRAFTSMAN R.K. J.B. 8/26/87
SPACE PHYSICS RESEARCH LABORATORY COLLEGE OF ENGINEERING UNIVERSITY OF MICHIGAN ANN ARBOR, MICHIGAN	RADIATOR WIRING INTERFEROMETER HRDI UARS PAGE 2 OF 2
	B-E8272 CONTROLLED

7/15/88
7/6/88
5/27/88
DATE

K&E 10 1193 2/88 1140F

LAST USED R C D L

Space Physics Research Laboratory
Packaging Conventions



UNIT	ID	TYPE	FUNCTION
INSTRUMENT ELECTRONICS ASSEMBLIES - INTERFACE BRACKET	J01	DCM-30P	HRD RIU
	J02	DCM-37S	BASD RIU
	J03	DCM-37S	SWRI RIU
	J04	DCM-37P	QUIET & SUP[illegible]
	J05	DCM-37P	PULSE BUS
	J06	DCM-37S	SERIAL COMMAND
	J07	DCM-3CS	MECH CONTROL
	J08	DAM-15S	THERMAL CONTROL
	J09	DCM-37S	RAD DATA
	J10	DCM-37S	RAD DATA
	J11	DDM-50S	GIMBAL ENCODER
	J12	DDM-50P	GIMBAL MOTOR
	J13	DDM-25S	GSE-DASD
	J14	DDM-50P	GSE-SCI
	J15	TBD	GSE-PSE
	J16	DCM-37S	SWRI RIU