NASA-CR-191613

M-61-CR
p. 257

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ROMPS CRITICAL DESIGN REVIEW
Volume I–Hardware

(NASA-CR-191613) ROMPS CRITICAL DESIGN REVIEW. VOLUME 1: HARDWARE (ERIM) 257 p

N93-16673

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M.E. DOBBS

DECEMBER 1992

Prepared for:

NASA Goddard Space Flight Center
Space Technology Division
Greenbelt, MD 20771

Contract No. NAG 5-1517

SpARC
Space Automation
& Robotics Center

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

SpARC
Space Automation & Robotics Center

Environmental Research Institute of Michigan

7 December 1992

NASA Goddard Space Flight Center
Mr. Lloyd Purves, Code 714.2
Greenbelt Road
Greenbelt MD 20771

Dear Lloyd:

Enclosed is the CDR package, revised per instructions. It is a little long in page count, but several of the pages can be done quickly. Others are required to address the PDR review team questions. Finally, new material is included to address mechanical, structural, thermal design and analysis, and harnessing.

The CDR review, plus our support at the review, completes the CDR deliverable. A second package containing the detailed hardware, software, mechanical and thermal material will be delivered shortly per the requirements of the grant.

The team looks forward to a succesfull review and the beginning of the ECS program.

Very Truly,

Michael E. Dobbs
Principal Investigator

cc: Gloria R. Blanchard, GSFC Code 286.1

SpARC ROMPS BACKUP INDEX

10:15AM 12/4/1992

PRESENTATION ORDER

page	sec.pg	in CDI	dwg#	title	type	comments	section	status
165	0			**Control System Detailed Design**	COVER	UPDATE		N
INTRO								
166	1.01	x	422	Operational Concept	DWG	UPDATE		Done
167	1.02	x	MED/2	Control System Requirements	BUL	UPDATE		
168	1.03	x	MED/3	Control System Requirements	BUL	UPDATE		
SYSTEM OVERVIEW								
173	2.01	x	536	Flight and Ground Software Component Distribution	DFD	UPDATE		Done
193	2.02		544	Payload Software Distribution/Operations	WPX	UPDATE		Done
194	2.03	x	542	Payload Software Interfaces/Platforms	WPX	UPDATE		Done
	2.04		809	ROMPS Control Sysytem Power-On Resets			B	Done
	2.05			ROMPS Telemetry List 7.1			B	Done
	2.06			ROMPS CMDs List v.6 extended			B	Done
SERVO								
	3.01	x	803	Nominal Operation of XP Servo	WPX	NEW		Done
	3.02	x	440	System Block Diagram				
220	3.03		421	XP System Distribution	DWG	UPDATE	B	Done
	3.04		812	Summary Table of Original XP Servo Commands and Replies			B	Done
	3.05		811	Summary Table of New XP Servo Commands and Replies			B	Done
201	3.06		805	XP Servo Move Command Sequence	DIA	NEW	B	Done
	3.07		906	XP Servo Communication Protocol	DIA	UPDATE	B	Done
	3.08	x	801	XP Servo Code Outline Chart	DIA	NEW		Done
	3.09		802	XP Servo Code Outline Chart page 2	DIA	NEW	B	Done
	3.10		807	Axis Sequencer State Machine	DIA	NEW	B	Done
	3.11			Calling Chart of XPC main() page 1			B	Done
	3.12			Calling Chart of XPC main() page 2			B	Done
	3.13			Calling Chart of XPC do_servos			B	Done
	3.14			Calling Chart of XPC azimuth()			B	Done
	3.15			Calling Chart of XPC elevation()			B	Done
	3.16			Calling Chart of XPC radial()			B	Done
	3.17			Calling Chart of XPC gripper()			B	Done
	3.18			Calling Chart of XPC checkcomm() page 1			B	Done
	3.19			Calling Chart of XPC checkcomm() page 2			B	Done
	3.20		804	Servo PID Algorithm	DIA	NEW		Done
	3.21		806	XP Servo and Subsystems Fault Handling Summary	TBL	NEW		Done
	3.22	x		XP Firmware Performance Margin/Memory Map				
	3.23			XP Firmware Performance Margin				
	3.24		541	XP Servo Memory Map	MAP	NEW	B	Done
TESTBED & SIMULATION RESULTS								
	4.01	x	813	Axis Data Summary	TBL	NEW		N
	4.02	x	800	Testbed Phase II Preliminary Results	WPX	NEW		Done
SYSTEM V CONTROLLER								
	5.01	x	924	Nominal Operation of the Zymate System V Controller		DONE		Done
	5.02	x	923	Top Level DFD Zymates System V Controller Software		DONE		Done
	5.03	x	905	EasyLab Remote Control Interface		UPDATE		Done
	5.04	x		System V Easylab Software Performance/Margin				
	5.05		531	System V Controller Memory Map			B	N
ROBOT MODULE								
	6.01	x	915	Nominal Operation of the ROMPS Robot Module		DONE		Done
	6.02	x	914	Robot Module DFD		DONE		Done
	6.03		419	Motor/Zymark			B	Done
	6.04		913	Summary Table of Original Robot Module EasyLab Command Variables		DONE	B	Done
	6.05		912	Summary Table of New Robot Module EasyLab Command Variables		DONE	B	Done
	6.06	x	700	Command Variable Processing example Flow Chart of Absolute Move		Started		Done
	6.07	x	702	EasyLab Program PUT.INTO.RACK Processing Flowchart				Done
	6.08		707	Robot Module Software Fault Handling Summary		Started		Done
	6.09		705	EasyLab Program GET.FROM.RACK Processing Flowchart		Started	B	Done
	6.10		703	EasyLab Program PUT.INTO.FURNACE Processing Flowchart		Started	B	Done
	6.11		706	EasyLab Program GET.FROM.FURNACE Processing Flowchart		Started	B	Done
	6.12		704	EasyLab Program LAUNCH.LOCK Processing Flowchart		Started	B	Done
FURNACE MODULE								
	7.01	x	911	Nominal Operation of the ROMPS Furnace Module		DONE		Done

	7.02 x	910	Furnace Module DFD		DONE		Done
	7.03	416	Oven/Zymark			B	Done
	7.04 x	701	Furnace Module Time/Temperature Chart				
	7.05	706	Furnace Module Software Fault Handling Summary				Done
	7.06	909	Summary Table of Furnace Module EasyLab Command Variables		DONE	B	Done

SCL EXPERIMENT SUPERVISOR

	8.01 x	921	Nominal Operation of the SCL Experiment Supervisor		NEW		N
	8.02 x	900	Top Level DFD SCL Experiment Supervisor Software		UPDATE		
	8.03 x	523	HH Bilevel Commands Packet Protocol		UPDATE		Done
	8.04 x	524	ROMPS SCL Command Packet Protocol		UPDATE		Done
	8.05 x	526	ROMPS DownLink Protocol		UPDATE		Done
	8.06 x	917	SCL Runtime Engine DFD	DFD	NEW		Done
	8.07 x	920	SCL Real Time Database Records Summary		NEW		Done
	8.08 x	916	SCL Project Scripts, Rules, and Commands Summary		NEW		Done
	8.09	534	SCL Versus EasyLab Command Processing Functions			B	Done
	8.10 x		SCL Software Performance/Margin w/ Memory Map				
	8.11		SCL Software Performance/Margin				
206	8.12	532	Experiment Supervisor Memory Map	MAP	UPDATE	B	N
	8.13		RoMPS CPU Loading WS				
	8.14		ARD Task Chart				

SCL SCRIPT SAMPLE PROCESSING CONTROL

202	9.01 x	922	SCL Script Automated Sample Processing Overview	DIA	UPDATE		Done
	9.02	906	Nominal Operation of the SCL APC and SPC Scripts		NEW	B	Done
204	9.03	907	SPC (Single Processing Cycle) Script	TXT	UPDATE	B	Done

SCL EXPERIMENT SUPERVISOR FAULT HANDLING

	10.01 x	918	Rule Based Shutdown of APC Script				Done
	10.02 x	925	Rule Based Health and Saftey Monitoring				Done
	10.03	919	SCL Experiment Supervisor Fault Handling Summary				Done

BLOCK DIAGRAMS

218	11.01 x	814	Connection Diagram (foldout)	DWG	UPDATE		Done
	11.02 x	436	XPC Board Block Diagram				
	11.03 x	437	XPP Board Block Diagram				
	11.04 x	434	ENC Board Block Diagram				
	11.05 x	433	STP Board Block Diagram				
	11.06 x	435	MUX Board Block Diagram				

HITCHHIKER INTERFACES

	12.01 x		RoMPS Hicthhiker/System Controller Interfaces				
	12.02		RoMPS Hicthhiker/System Controller Serial Compatibility				Done

BATTERY SYSTEM

	13.01 x		Encoder and Computer Battery Data				
	13.02		Encoder Battery Data				Done
	13.03		Computer Battery Data				
	13.04 x	632	Encoder Battery Circuit Schematic			B	Done
	13.05 x	636	Battery Box Circuit Schematic			B	

WATCHDOG TIMERS

	14.01 x		RoMPS Reset and Watchdog Timer Siganls Diagram				
	14.02		Notes for RoMPS Reset and Watchdog Timer Siganls Diagram				
	14.03	633	Watchdog Timer Circuit Schematic				

MECHANICAL/THERMAL

	15.01 x		Board Outlines SC1 & SC2				
233	15.02		Board Outlines - SC1	DWG	UPDATE		Done
233	15.03		Board Outlines - SC2	DWG	UPDATE		Done
231	15.04 x	MED/29	Control System Design - Weight & Power Summary	TBL	UPDATE		
	15.05		RoMPS Weight and Power Summary v.4				
	15.06		Individual Board Power Estimates				
	15.07	250	Electronics Layout 1 of 3		NEW		Done
	15.08	250	Electronics Layout 2 of 3		NEW		Done
	15.09	250	Electronics Layout 3 of 3		NEW		Done
	15.10 x	257	Experiment Layout w/ CG				
	15.11 x	438	Inter-box Wiring Harness Diagram				
	15.12	260	Electronics Harness Routing				
	15.13	251	Battery Box Assembly		NEW		Done
	15.14 x		Payload Controller		NEW		Done
	15.15 x	256	Instrument Plate/Adapter Plate				
	15.16	254	Adapter Plate			B	

	15.17	256	Computer P.C. Spacer			B	
	15.18	255	Battery Box Spacer			B	
232	15.19 x		SWRI Control Computer	photo			Done
	15.20 x		Thermal Design		NEW		Done
	15.21 x		Temperature Predictions		NEW		Done
	15.22		Control System Temp Requirements and Power Dissipation			B	
	15.23		Control System Thermal Design			B	
	15.24		Control System Thermostats and Heaters			B	
	15.25		Control System Thermal Analysis, Surface Model			B	
	15.26		Control System Thermal Analysis, Math Model			B	
	15.27 x		Control System Transient Response, Earth View, On		NEW		Done
	15.28		Control System Transient Response, Moderately Cold Case, On			B	
	15.29		Control System Transient Response, Cold Case, On			B	
	15.30		Control System Transient Response, Hot Case, On			B	
	15.31		Control System Transient Response, Earth View, Off			B	
	15.32		Control System Transient Response, Moderately Cold Case, Off			B	
	15.33		Control System Transient Response, Cold Case, Off			B	
	15.34 x	439	Heaters Block Diagram				
	15.35 x		Control System Mechanical Design		NEW		Done
	15.36		Control System Structural Analysis			B	
	15.37		Payload Controller Random Vibration			B	
	15.38 x		Control System Stress Analysis		NEW		Done

FAULT CONDITIONS & RECOVERY

229	16.01	MED/?	Control System Design - Single Event Upset Considerations	BUL	UPDATE		
230	16.02 x	810	Fault Conditions and Responses (Paul's long chart)	TBL	UPDATE		

SUMMARY

	17.01 x	MED/32	Status of Control System Nov92		UPDATE	N	
	17.02 x		Development Plan			N	

OPERATIONS

181	18.01	509	Ground Operations - Issuing HH Bilevel Commands	WPX			
182	18.02	510	Ground Operations - Issuing HH Serial Commands	WPX			
183	18.03	514	Experiment Parameters	PIX	UPDATE		
184	18.04	513	Modification of Experiment Processing Parameters	WPX			
185	18.05	516	Processing Schedule	PIX			
186	18.06	515	Creating a Processing Schedule	WPX			
187	18.07	511	Ground Operations - Uploading SCL Scripts and Rules...	WPX	delete		
188	18.08	512	...cont'd	WPX	delete		
189	18.09	517	Operational Concept - GAS Can 2	DWG	UPDATE		
190	18.10	523	Command Uplink Protocols - Bilevel CMD Packet	DIA			
191	18.11	524	Command Uplink Protocols - SCL CMD Packet	DIA			
192	18.12	525	Command Uplink Protocols - SCL Uplink Packet	DIA			
195	18.13	521	What is Spacecraft Command Language (SCL)?	WPX			
196	18.14	522	SCL Experiment Supervisor - Top Level DFD	DFD			
197	18.15	526	Telemetry Downlink Protocols - SCL 1 sec, 30 sec & Async	DIA			

SCHEMATICS

19.01	600	Schematic XPC Board	sheet 1 of 1	B	Done
19.02	639	Schematic XPP Board	sheet 1 of 4	B	Done
19.03	640	Schematic XPP Board	sheet 2 of 4	B	Done
19.04	641	Schematic XPP Board	sheet 3 of 4	B	Done
19.05	642	Schematic XPP Board	sheet 4 of 4	B	Done
19.06	605	Schematic STP Board	sheet 1 of 5	B	Done
19.07	606	Schematic STP Board	sheet 2 of 5	B	Done
19.08	607	Schematic STP Board	sheet 3 of 5	B	Done
19.09	608	Schematic STP Board	sheet 4 of 5	B	Done
19.10	609	Schematic STP Board	sheet 5 of 5	B	Done
19.11	620	Schematic ENC Board	sheet 1 of 5	B	Done
19.12	621	Schematic ENC Board	sheet 2 of 5	B	Done
19.13	622	Schematic ENC Board	sheet 3 of 5	B	Done
19.14	623	Schematic ENC Board	sheet 4 of 5	B	Done
19.15	624	Schematic ENC Board	sheet 5 of 5	B	Done
19.16	632	Schematic WDT Board	sheet 1 of 2	B	Done
19.17	633	Schematic WDT Board	sheet 2 of 2	B	Done
19.18	635	Schematic MUX Board	sheet 1 of 3	B	Done
19.19	636	Schematic MUX Board	sheet 2 of 3	B	Done
19.20	637	Schematic MUX Board	sheet 3 of 3	B	Done
19.21	638	Schematic BAT Box	sheet 1 of 1	B	Done

Memos and Misc Summary Sheets

20.01	MED/?	Memo on Batteries	B	Done
20.02		XP Servo LED Control	B	Done

LEGEND: M = marked-up or sketched; S = started; D = done; N = needs revision

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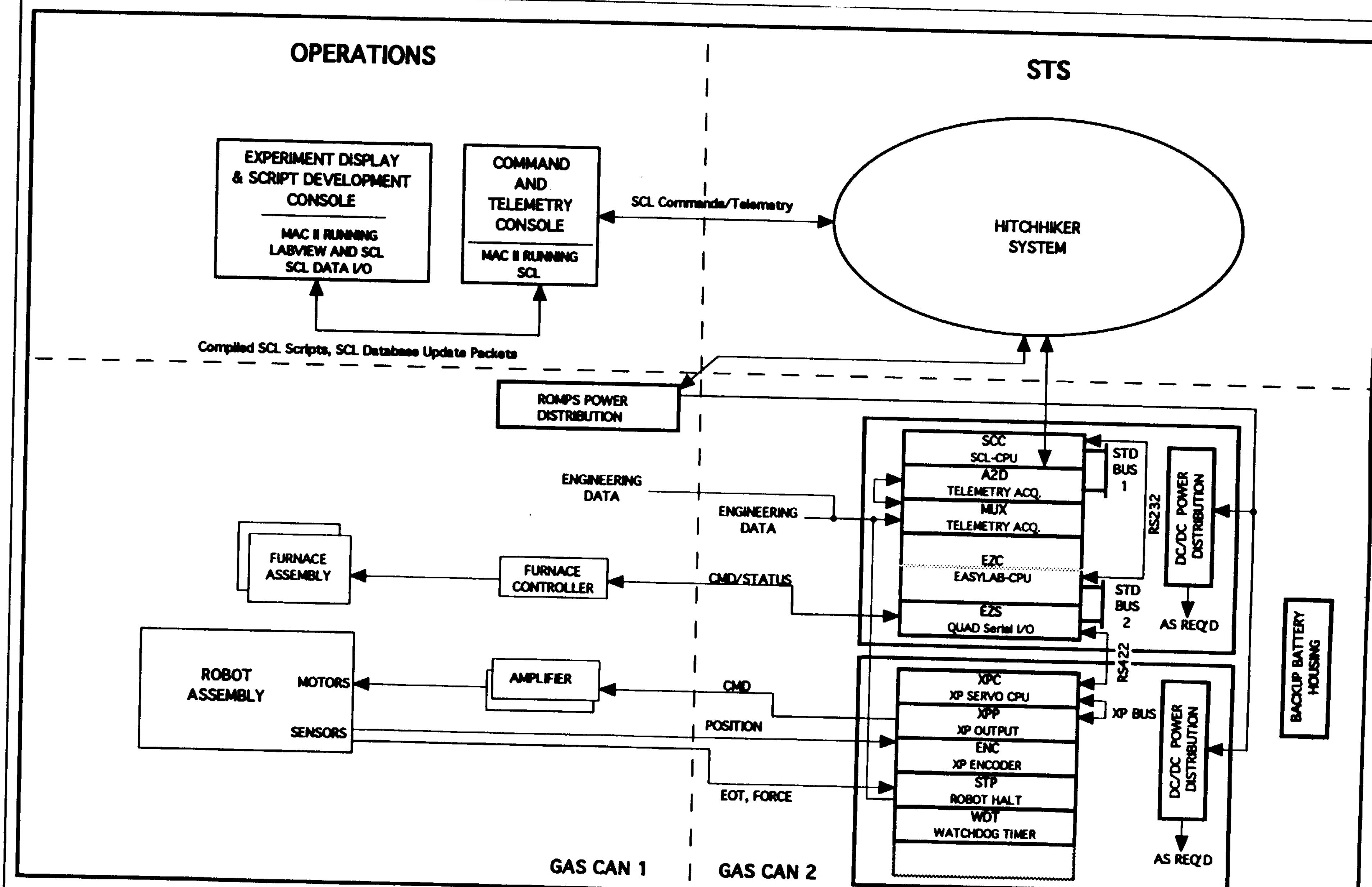
RoMPS

INTRO



ENGINEER M. E. Dobbs	DRAFTSMAN	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	RoMPS OPERATIONAL CONCEPT RoMPS 010-422	12/2/92 4/6/92 1/9/92 DATE

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CONTROL SYSTEM REQUIREMENTS

CARRIER	NSTS HITCHHIKER, 1/2 HEIGHT GAS ENCLOSURE, SEALED
POWER	+28 ±4 VDC UNREGULATED, DC ISOLATION
COMMAND	RS422, 1200 BAUD, ASYNCHRONOUS, LIMITED THRUPUT
	4 DISCRETE COMMANDS FOR ENABLES/DISABLES & PROCESSOR BOOT
TELEMETRY	RS422, 1200 BAUD, ASYNCHRONOUS, ~100 C/S MAX. THRUPUT

GENERAL

- AUTOMATIC EXECUTION OF EXPERIMENT
- MANUAL CONTROL OF ALL FUNCTIONS
- FAIL-SAFE OPERATION
- POWER-FAIL RECOVERY
- TELEMETRY - 1 SEC ENGINEERING, 30 SEC ENGINEERING, 3 SEC^{-1} DIAGNOSTICS
- EXPERIMENT SCHEDULE & PROCESS SCRIPT MODIFICATION & UPLOAD
- TELEMETRY LOGGING, DISPLAY, PLAYBACK
- MANUAL COMMANDING

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ROBOT
CONTROL SYSTEM REQUIREMENTS

4 DOF MATERIAL HANDLING ROBOT

- ±0.005" (14BIT) POSITION RESOLUTION & ACCURACY
- 200 SEC^{-1} LOOP SAMPLE RATE
- INCREMENTAL & HALL POSITION ENCODERS
- END-OF-TRAVEL DETECTION
- FORCE LIMIT DETECTION
- ±10VFS CONTROL OUTPUT TO MOTOR DRIVERS
- DISCRETE OUTPUTS - POWER-TO-RELEASE BRAKE, DRIVER ENABLE
- TELEMETRY - POSITION, EOT, FORCE, MOTOR V & I, TEMPS, MISC. STATUS

MATERIAL RESEARCH FURNACE

- UP TO 7 TEMPERATURE/TIME PLATEAUS
- SERIAL COMMAND & DISCRETE ENABLE TO FURNACE CONTROLLER
- TELEMETRY - SETPOINT, LAMP V&I, REF TEMP, MISC. STATUS

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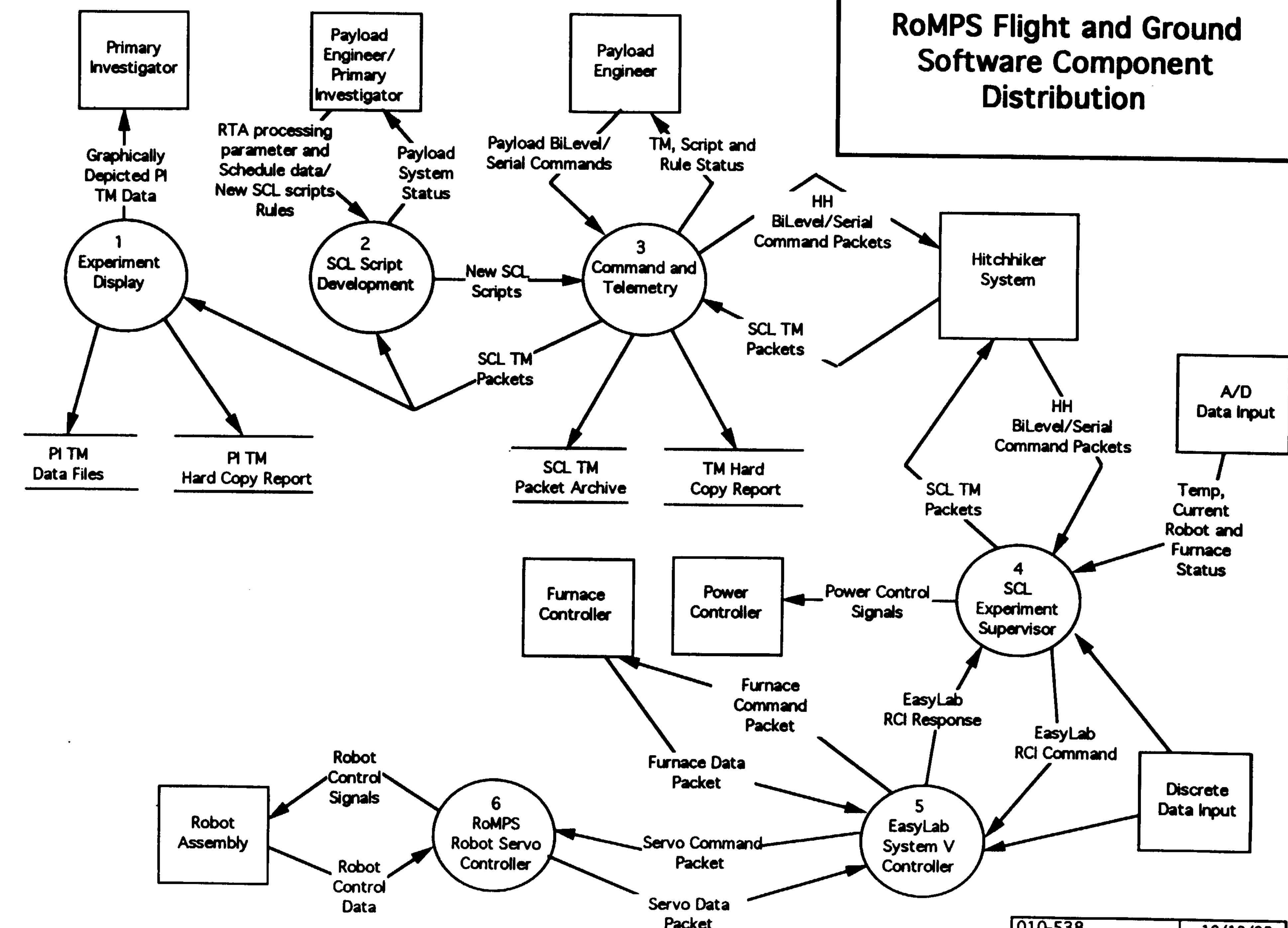
RoMPS

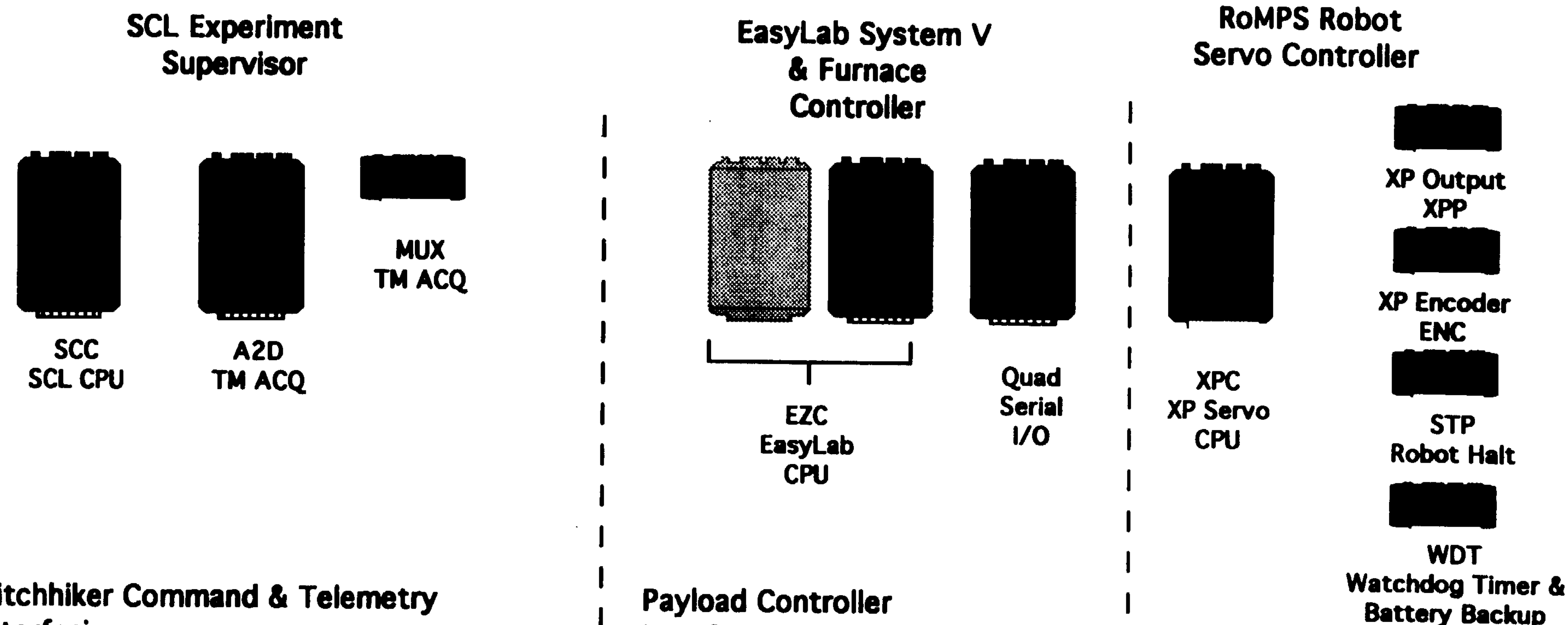
SYSTEM OVERVIEW

RoMPS Flight and Ground Software Component Distribution



010-538 10/13/92

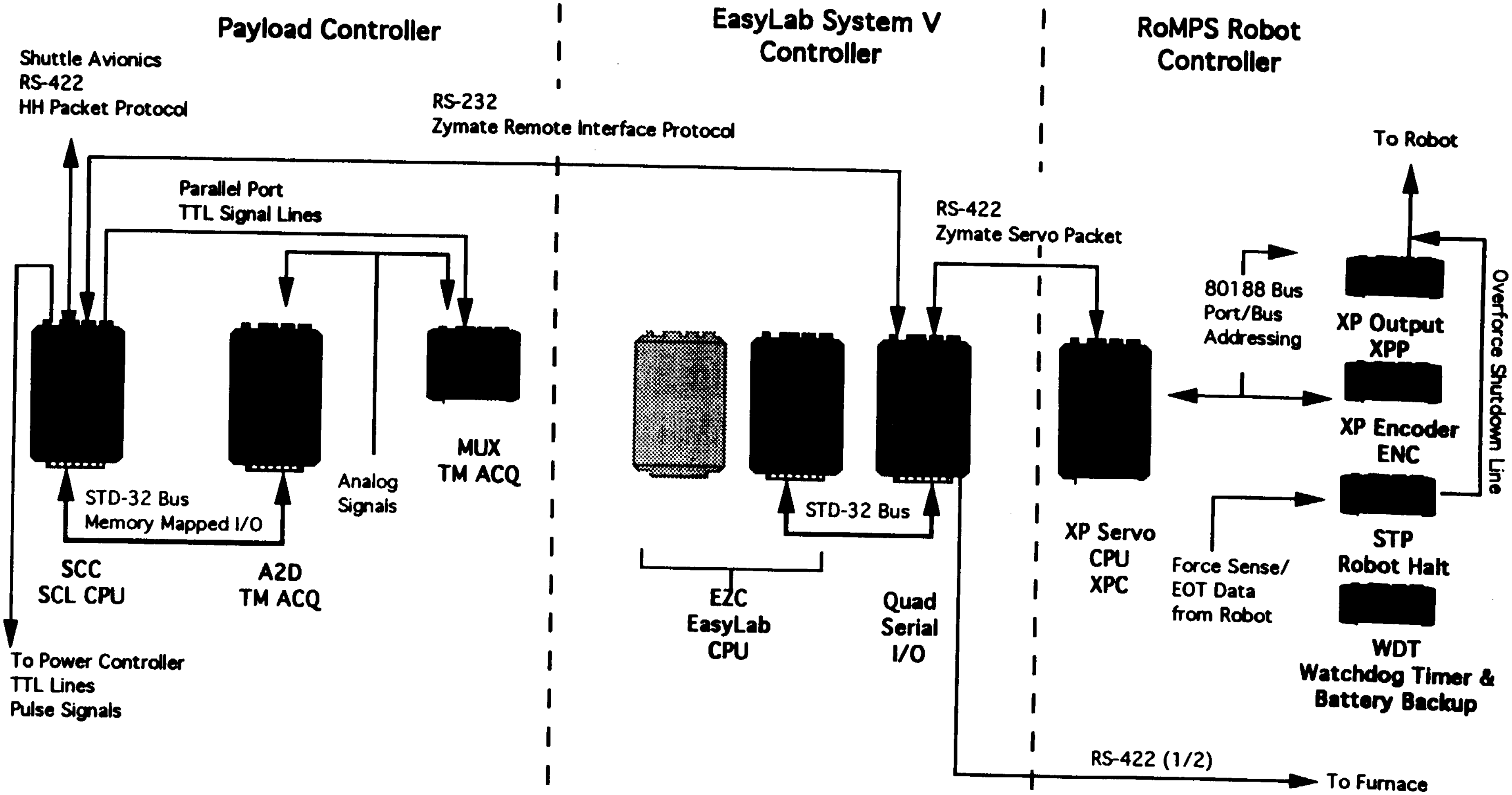
RoMPS Payload Software Distribution/Operations



SCL Experiment Supervisor	EasyLab System V & Furnace Controller	RoMPS Robot Servo Controller
Hitchhiker Command & Telemetry Interfacing	Payload Controller Interfacing	Robot Servo Serial Command Interface with EZC
Telemetry Acquisition and Monitoring	High Level Robot Interfacing and Control	Robot Servo Control Algorithm Execution
Zymate System V Interfacing	High Level Furnace Interfacing and Control	Robot Position Sensing
Power Controller pulse command generation	Robot & Furnace Controller Interfacing	
RTA Processing Control	Furnace Set Point Commands	
System Error Recovery		

010-544 | 11/9/92

RoMPS Payload Software Interfaces/Platforms



Payload Controller	EasyLab System V Controller	RoMPS Robot Controller
Platform : Ziatech 89CT01 (286)	Platform : ProLog 7872-01 (386)	Platform : 80c188 Single Board
Operating System : SCL/VRTX	Operating System : Zymate ZYOS	Operating System : None
Task Management : Priority level, ISR driven multitasking	Task Management : Resource, ISR driven multitasking	Task Management : Single Operating Task

RoMPS Control System
Power-On Resets

Subsystem	State	Behavior
SCC Processor	Processor is restarted by WDT and by its own POC circuit.	Software resumes processing where it left off when power failed.
EZC Processor	Processor is restarted by WDT and by its own POC circuit.	Software is initialized, stored programs are retained, but any operations not completed before power loss are aborted.
XPC Processor	Processor is restarted by its own POC circuit.	Software is initialized, any operations not completed before power loss are aborted.
FRN Processor	Processor is restarted by its own POC circuit.	Software is initialized, any operations not completed before power loss are aborted.
Motor Selects	XP POC resets the PIAs to the high output state, forcing Select lines low.	All motors are de-selected.
Brake Drives	XP POC resets the PIAs to the high output state, forcing all brake lines to engaged state.	All brakes are engaged.
Motor Voltages	XP POC resets the PIAs to the high output state, disconnecting reference voltage to output DACs.	All motor control voltages are zero.
Axis Encoders	Encoders and counters are battery-backed, so they continue tracking position through power cycles.	No effect from power cycle.
Battery Relay	Battery relay is magnetic latching type, does not change with power cycles.	Battery remains on or off, as previously commanded.
Furnace Enable	EZC RS422 RTS line goes low on reset.	Furnace is disabled.
System Power Enable/Disable	System Power relay is magnetic latching type, does not change with power cycles.	No effect from power cycle. (Is this how it should be?)
Power Bus A/B	Power Bus A/B relay is magnetic latching type, does not change with power cycles.	No effect from power cycle.
Furnace A/B Select	SCC POC resets the output lines to the high output state, selecting Furnace A.	Furnace A is selected until a switch to B is commanded.
Motor Drive A/B Select	SCC POC resets the output lines to the high output state, selecting Motor Driver A.	Motor Driver A is selected until a switch to B is commanded.

12/2/92
REV
NOT FINAL

file RoMPS Telemetry List 7

version 11/5/92gw 11/12/92gw 11/16/92gw 11/18/92g11/25/92gw
11/30/92gw 12/2/92gw

For comments explanation see RoMPS TM List Comments Page

Unless Serial
All discrete source=parallel
All analog source=ADC/Mux set

RoMPS 1 Second TM list

Function	Data Item	Data Point Source	FS Range User	FS Accur %	FS Range Raw	Length Bytes	No.Pts Item	TM Req. Byt/Pac	Data Type	Source Mux/ Port	Source Chan	Source A2D Chan	Comments
Header	Sync	n/a	constant value			1.000	1	1.000	byte	n/a	n/a	n/a	
	1 Sec ID	n/a	constant value			1.000	1	1.000	byte	n/a	n/a	n/a	
	Size	n/a	constant value			1.000	1	1.000	byte	n/a	n/a	n/a	
	Data Aquire Time	GMT Time	hh24:MM:SS			3.000	1	3.000	BCD	n/a	n/a	n/a	
Command Verification	Num Good Packets RCV	SCL Database	0–32,762			2.000	1	2.000	byte	n/a	n/a	n/a	
	Num Bad Packets RCV	SCL Database	0–32,762			2.000	1	2.000	byte	n/a	n/a	n/a	
APC Parameters	Time 1	SCL Database	SS:1-32,762			2.000	1	2.000	Word	n/a	n/a	n/a	
	Time 2	SCL Database	SS:1-32,762			2.000	1	2.000	Word	n/a	n/a	n/a	
	Time 3	SCL Database	SS:1-32,762			2.000	1	2.000	Word	n/a	n/a	n/a	
	Time 4	SCL Database	SS:1-32,762			2.000	1	2.000	Word	n/a	n/a	n/a	
	Time 5	SCL Database	SS:1-32,762			2.000	1	2.000	Word	n/a	n/a	n/a	
	Time 6	SCL Database	SS:1-32,762			2.000	1	2.000	Word	n/a	n/a	n/a	
	Time 7	SCL Database	SS:1-32,762			2.000	1	2.000	Word	n/a	n/a	n/a	
	Setpoint 1	SCL Database	350 - 1450 c			2.000	1	2.000	Word	n/a	n/a	n/a	
	Setpoint 2	SCL Database	350 - 1450 c			2.000	1	2.000	Word	n/a	n/a	n/a	
	Setpoint 3	SCL Database	350 - 1450 c			2.000	1	2.000	Word	n/a	n/a	n/a	
	Setpoint 4	SCL Database	350 - 1450 c			2.000	1	2.000	Word	n/a	n/a	n/a	
	Setpoint 5	SCL Database	350 - 1450 c			2.000	1	2.000	Word	n/a	n/a	n/a	
	Setpoint 6	SCL Database	350 - 1450 c			2.000	1	2.000	Word	n/a	n/a	n/a	
	Setpoint 7	SCL Database	350 - 1450 c			2.000	1	2.000	Word	n/a	n/a	n/a	
	Rack	SCL Database	1–6			2.000	1	2.000	Word	n/a	n/a	n/a	
	Rack Index	SCL Database	1-no. of pallets			1.000	1	1.000	Byte	n/a	n/a	n/a	
	Min Cooling Time	SCL Database	ss:1-32,762			1.000	1	1.000	Byte	n/a	n/a	n/a	
	Max Coolong Time	SCL Database	ss:1-32,762			2.000	1	2.000	Byte	n/a	n/a	n/a	
	Min Cooling Temp	SCL Database	0–1450° c			2.000	1	2.000	Byte	n/a	n/a	n/a	
	Schedule ID	SCL Database	1-255			2.000	1	2.000	Byte	n/a	n/a	n/a	
	Parameters ID	SCL Database	1-255			1.000	1	1.000	Byte	n/a	n/a	n/a	
	Schedule Index	SCL Database	1-255			1.000	1	1.000	Byte	n/a	n/a	n/a	
						1.000	1	1.000	Byte	n/a	n/a	n/a	
TM Status	Num Error Packets	SCL Database	1–32,762			2.000	1	2.000	Byte	n/a	n/a	n/a	
	Num Message Packets	SCL Database	1–32,762			2.000	1	2.000	Byte	n/a	n/a	n/a	
	Num 1 and 30 Log Pacl	SCL Database	1–32,762			2.000	1	2.000	Byte	n/a	n/a	n/a	
Processing Status	Sample ID	SCL Database	1-144			1.000	1	1.000	Byte	n/a	n/a	n/a	
	Process Step	SCL Database	1-255			1.000	1	1.000	Byte	n/a	n/a	n/a	
	Processing Status	SCL Database	Encoded Value			1.000	1	1.000	Byte	n/a	n/a	n/a	

EOT Status	Elevation Top EOT	STP	bi-level		0.125	1	0.125	bit field	P1	1	–	
	Elevation Bottom EOT	STP	bi-level		0.125	1	0.125	bit field	P1	2	–	
	Azimuth CW EOT	STP	bi-level		0.125	1	0.125	bit field	P1	3	–	
	Azimuth CCW EOT	STP	bi-level		0.125	1	0.125	bit field	P1	4	–	
	Radial In EOT	STP	bi-level		0.125	1	0.125	bit field	P1	5	–	
	Radial Out EOT	STP	bi-level		0.125	1	0.125	bit field	P1	6	–	
	Gripper Open EOT	STP	bi-level		0.125	1	0.125	bit field	P1	7	–	
	Gripper Closed EOT	STP	bi-level		0.125	1	0.125	bit field	P1	8	–	
	Furnace Set Point	SCL	SCL variable	tbd	2.000	1	2.000	int	n/a	n/a	n/a	
	Sample In Place	SCL	derived	tbd	1.000	1	1.000	byte	n/a	n/a	n/a	
Furn Driver Status	Furn Ctrl Enable Status	Furnace	bi-level		0.125	1	0.125	bit field	P2	1	–	
	Furn A/B Relay Status	Furnace	bi-level		0.125	1	0.125	bit field	P2	2	–	NO WIRE
	Furn WD Timer Status	Furnace	bi-level		0.125	1	0.125	bit field	P2	3	–	
Motor Driver Status	Gen Mtr Drv ENA Status	RBT	bi-level		0.125	1	0.125	bit field	P2	4	–	
	Elevation Enable Status	XP/Easylab	bi-level		0.125	1	0.125	bit field	P2	5	–	
	Azimuth Enable Status	XP/Easylab	bi-level		0.125	1	0.125	bit field	P2	6	–	
	Radial Enable Status	XP/Easylab	bi-level		0.125	1	0.125	bit field	P2	7	–	
	Gripper Enable Status	XP/Easylab	bi-level		0.125	1	0.125	bit field	P2	8	–	
System Status	SCC WD Timer Status	WDT	bi-level		0.125	1	0.125	bit field	P3	1	–	
	EZC WD Timer Status	WDT	bi-level		0.125	1	0.125	bit field	P3	2	–	
	XP WD Timer Status	WDT	bi-level		0.125	1	0.125	bit field	P3	3	–	
	WD Ena/Dis Status	WDT	bi-level		0.125	1	0.125	bit field	P3	4	–	
	Bus A/B Relay Status	WDT	bi-level		0.125	1	0.125	bit field	P3	5	–	
	Sys Enable Relay Status	RBT	bi-level		0.125	1	0.125	bit field	P3	6	–	
	Battery Relay Status	WDT	bi-level		0.125	1	0.125	bit field	P3	7	–	
	Mtr Drv A/B Relay Statu	RBT	bi-level		0.125	1	0.125	bit field	P3	8	–	
OvF and Brake Status	Elevation OvF Status	STP	bi-level		0.125	1	0.125	bit field	P4	1	–	
	Radial OvF Status	STP	bi-level		0.125	1	0.125	bit field	P4	2	–	
	L. Grip OvF Status	STP	bi-level		0.125	1	0.125	bit field	P4	3	–	
	R. Grip OvF Status	STP	bi-level		0.125	1	0.125	bit field	P4	4	–	
	Elevation Brake Status	STP	bi-level		0.125	1	0.125	bit field	P4	5	–	
	Azimuth Brake Status	STP	bi-level		0.125	1	0.125	bit field	P4	6	–	
	Radial Brake Status	STP	bi-level		0.125	1	0.125	bit field	P4	7	–	
	UNASSIGNED		n/a		0.125	1	0.125	bit field	P4	8	–	
Command Byte 1	Furnace A/B Select	SCL	Bi-level		0.125	1	0.125	bit field	P5	1	–	
	Stop	SCL	Bi-level		0.125	1	0.125	bit field	P5	2	–	
	Power Bus A Select	SCL	Bi-level/P		0.125	1	0.125	bit field	P5	3	–	
	Power Bus B Select	SCL	Bi-level/P		0.125	1	0.125	bit field	P5	4	–	
	Mtr Drv Enable/Disable	SCL	Bi-level		0.125	1	0.125	bit field	P5	5	–	
	Motor Driver A/B Select	SCL	Bi-level		0.125	1	0.125	bit field	P5	6	–	
	Open Battery Relay	SCL	Bi-level/P		0.125	1	0.125	bit field	P5	7	–	
	Close Battery Relay	SCL	Bi-level/P		0.125	1	0.125	bit field	P5	8	–	

Command Byte 2	WD Timer Strobe	SCL	Bi-level			0.125	1	0.125	bit field	P6	1	–	
	Reset XPC	SCL	Bi-level			0.125	1	0.125	bit field	P6	2	–	
	Furn Reset/WD Disable	SCL	Bi-level/P			0.125	1	0.125	bit field	P6	3	–	
	UNASSIGNED	SCL	n/a			0.125	1	0.125	bit field	P6	4	–	
	Mux Address 0	SCL	Bi-level			0.125	1	0.125	bit field	P6	5	–	
	Mux Address 1	SCL	Bi-level			0.125	1	0.125	bit field	P6	6	–	
	Mux Address 2	SCL	Bi-level			0.125	1	0.125	bit field	P6	7	–	
	Mux Address 3	SCL	Bi-level			0.125	1	0.125	bit field	P6	8	–	
Furnace 1 Sec Multiplexer TM	UNASSIGNED		n/a			0.000	0	0.000	int	U1	1	1	
	Furn Lamp Voltage	Furnace	0-26V	< 1%	tbd	1.000	1	1.000	int	U1	2	1	
	Furn Lamp Current	Furnace	0-12A	< 1%	tbd	2.000	1	2.000	int	U1	3	1	
	UNASSIGNED		n/a			0.000	0	0.000	int	U1	4	1	
	Cal Sample Temp #1	Furnace	350–1450° c	1.00%	tbd	1.000	1	1.000	int	U1	5	1	TC Polyn
	Cal Sample Temp #2	Furnace	350–1450° c	1.00%	tbd	1.000	1	1.000	int	U1	6	1	TC Polyn
	Furn Rel Temp #1	Furnace	tbd	1.00%	tbd	1.000	1	1.000	int	U1	7	1	
	Furn Rel Temp #2	Furnace	tbd	1.00%	tbd	1.000	1	1.000	int	U1	8	1	
Motor 1 Sec Multiplexer TM	Elevation Ctrl Sig Lvl	XPP	±10V	tbd	±10V	2.000	1	2.000	int	U2	1	2	
	Azimuth Ctrl Sig Lvl	XPP	±10V	tbd	±10V	2.000	1	2.000	int	U2	2	2	
	Radial Ctrl Sig Lvl	XPP	±10V	tbd	±10V	2.000	1	2.000	int	U2	3	2	
	Gripper Ctrl Sig Lvl	XPP	±10V	tbd	±10V	2.000	1	2.000	int	U2	4	2	
	Elevation Position	ENC	0-10V	tbd	0-10V	2.000	1	2.000	int	U2	5	2	
	Azimuth Position	ENC	0-10V	tbd	0-10V	2.000	1	2.000	int	U2	6	2	
	Radial Position	ENC	0-10V	tbd	0-10V	2.000	1	2.000	int	U2	7	2	
	Gripper Position	ENC	0-10V	tbd	0-10V	2.000	1	2.000	int	U2	8	2	
	Elevation Frc Measurem	RBT	±10 lbs	tbd	±10V	2.000	1	2.000	int	U2	9	2	
	Radial Frc Measurement	RBT	±10 lbs	tbd	±10V	2.000	1	2.000	int	U2	10	2	
	R. Grip Frc Measuremen	RBT	±32 lbs	tbd	±10V	2.000	1	2.000	int	U2	11	2	
	L. Grip Frc Measuremen	RBT	±32 lbs	tbd	±10V	2.000	1	2.000	int	U2	12	2	
	Elevation Motor Temp	RBT	–20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U2	13	2	YSI Polyn
	Azimuth Motor Temp	RBT	–20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U2	14	2	YSI Polyn
	Radial Motor Temp	RBT	–20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U2	15	2	YSI Polyn
	Gripper Motor Temp	RBT	–20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U2	16	2	YSI Polyn
Motor 1 Sec TM	Motor Current	RBT	0-5A	1.00%	0-10V	1.000	1	1.000	int	–	–	5	ITE Polyn
	Motor Velocity	RBT	±7000 rpm	1.00%	tbd	1.000	1	1.000	int	–	–	6	Omnirel Polyn
	Check Sum	Der By TM Output	0-255			2.000	1	2.000	int	n/a	n/a	n/a	
	Total Number Bytes Per Packet							106.000					
	Packet Rate							1.000					
	Average Telemetry Rate							106.000					
	Requested Telemetry Allocation							100.000					

Function

RoMPS 30 Second TM list

Data Item	Data Point Source	FS Range User	FS Accur %	FS Range Raw	Length Bytes	No.Pts Item	TM Req. Byt/Pac	Data Type	Source Mux/ Port	Source Chan	Source A2D Chan	Comments
Sync	n/a	constant value			1.000	1	1.000	Byte	n/a	n/a	n/a	
30 Sec ID	n/a	constant value			1.000	1	1.000	Byte	n/a	n/a	n/a	
Size	n/a	constant value			1.000	1	1.000	Byte	n/a	n/a	n/a	
Data Acquire Time	AMS Clock	32 bit range	.1 mil sec		4.000	1	4.000	BCD	n/a	n/a	n/a	
Power Bus Voltage	MUX	0-32V	tbd	tbd	1.000	1	1.000	int	U4	1	3	
Sys Cntrl Temp #1	MUX	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U4	2	3	YSI poyln
Sys Cntrl Temp #2	MUX	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U4	3	3	YSI poyln
Sys Cntrl Ref V #1	MUX	tbd	tbd	tbd	1.000	1	1.000	int	U4	4	3	
Sys Cntrl Ref V #2	MUX	tbd	tbd	tbd	1.000	1	1.000	int	U4	5	3	
Motor Driver Temp	RBT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U4	6	3	ITE Polyn
Motor Driver Box Temp	RBT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U4	7	3	YSI poyln
Ref Voltage #3	RBT	0-15V	tbd	tbd	1.000	1	1.000	int	U4	8	3	
Furn Cntrl Box Temp	Furnace	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U4	9	3	YSI poyln
Ref Voltage #1	Furnace	0-15V	tbd	tbd	1.000	1	1.000	int	U4	10	3	TO BE ASSIGNED
Ref Voltage #2	Furnace	0-5V	tbd	tbd	1.000	1	1.000	int	U4	11	3	TO BE ASSIGNED
Isothermal Blk Temp	Furnace	0-10V	1.00%	tbd	1.000	1	1.000	int	U4	12	3	RTD polyn
Furn Str TC Temp #1	Furnace	tbd	tbd	tbd	1.000	1	1.000	int	U4	13	3	TC polyn
Furn Str TC Temp #2	Furnace	tbd	tbd	tbd	1.000	1	1.000	int	U4	14	3	TC polyn
Furn Str TC Temp #3	Furnace	tbd	tbd	tbd	1.000	1	1.000	int	U4	15	3	TC polyn
Furn Str Temp #1	Furnace	tbd	tbd	tbd	1.000	1	1.000	int	U4	16	3	
Furn Str Temp #2	Furnace	tbd	tbd	tbd	1.000	1	1.000	int	U5	1	4	
Furn Str Temp #3	Furnace	tbd	tbd	tbd	1.000	1	1.000	int	U5	2	4	
Furn Str Temp #4	Furnace	tbd	tbd	tbd	1.000	1	1.000	int	U5	3	4	
Furn Str Temp #5	Furnace	tbd	tbd	tbd	1.000	1	1.000	int	U5	4	4	
Power Cntrl Box Temp	RBT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U5	5	4	YSI poyln
Pallet Rack Temp #1	RBT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U5	6	4	YSI poyln
Pallet Rack Temp #2	RBT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U5	7	4	YSI poyln
Pallet Rack Temp #3	RBT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U5	8	4	YSI poyln
Pallet Rack Temp #4	RBT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U5	9	4	YSI poyln
Pallet Rack Temp #5	RBT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U5	10	4	YSI poyln
GAS #1 Rad Temp #1	RBT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U5	11	4	YSI poyln
GAS #1 Rad Temp #2	RBT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U5	12	4	YSI poyln
GAS #1 Rad Temp #3	RBT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U5	13	4	YSI poyln
GAS #1 Base Temp #1	RBT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U5	14	4	YSI poyln
GAS #1 Base Temp #2	RBT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U5	15	4	YSI poyln
Battery Temp	BAT	-20 to 80° c	1.00%	0-10V	1.000	1	1.000	int	U5	16	4	YSI poyln
Check Sum	Derived By TM O	0- 255			2.000	1	2.000	int	n/a	n/a	n/a	exclusive or of all packet byte
Total Number Bytes Per Packet							41.000					
Packet Rate							30.000					
Average Telemetry Rate							1.367					
Requested Telemetry Allocation							100.000					

RoMPS Ayenchronous Query Reponse TM List

Function	Data Item	Data Point Source	FS Range User	FS Accur %	FS Range Raw	Length Bytes	No.Pts Item	TM Req. Byt/Pac	Data Type	Source Mux/ Port	Source Chan	Source A2D Chan	Comments
Header	Synch	n/a	constant value			2.000	1	2.000	int		–	–	Hard Coded Synch pattern
	Query ID	n/a	constant value			2.000	1	2.000	int		–	–	stamped by TM Output task
	Data Acquire Time	AMS Clock	32 bit range	.1 mil sec		4.000	1	4.000	BCD				
Length	String Length	SCL Database	0-32,762			2.000	1	2.000	word				
Response	Query Response	SCL Database	String			100.0	1	100.000	string				
	Check Sum	Derived By TM O	0- 255			2.000	1	2.000	int				exclusive or of all packet byte
	Total Number Bytes Per Packet							112.000					
	Packet Rate							asynchronous					
	Average Telemetry Rate							n/a					
	Requested Telemetry Allocation							n/a					

Example of Query Reponse String

Header, String Length, "Furn Ctrl Status = 0", Checksum
Header, String Length, "Furn Ctrl Self Check Results = 0", Checksum
Header, String Length, "Furn Ctrl Prop Gain = 0", Checksum
Header, String Length, "Furn Ctrl Int Gain = 0", Checksum
Header, String Length, "Furn Ctrl Diff Gain = 0", Checksum
Header, String Length, "Furn Ctrl Loop Time = 0", Checksum
Header, String Length, "Furn Ctrl Status = 0", Checksum
Header, String Length, "Furn Ctrl Status = 0", Checksum
Header, String Length, "Furn Ctrl Status = 0", Checksum
ect.....

RoMPS 0.333 Second Robot TM list

Function	Data Item	Data Point Source	FS Range User	FS Accur %	FS Range Raw	Length Bytes	No.Pts Item	TM Req. Byt/Pac	Data Type	Source: Mux/ Port	Source: Chan	Source: A2D Chan	Comments
Header	0.333 Sec Sync	n/a	constant value			1.000	1	1.000	Byte	n/a	n/a	n/a	
	0.333 Sec ID	n/a	constant value			1.000	1	1.000	Byte	n/a	n/a	n/a	
	Data Acquire Time	AMS Clock	32 bit range	.1 mil sec		4.000	1	4.000	BCD	n/a	n/a	n/a	
EOT Status	Elevation Top EOT	STP	bi-level			0.125	1	0.125	bit field	P1	1	–	
	Elevation Bottom EOT	STP	bi-level			0.125	1	0.125	bit field	P1	2	–	
	Azimuth CW EOT	STP	bi-level			0.125	1	0.125	bit field	P1	3	–	
	Azimuth CCW EOT	STP	bi-level			0.125	1	0.125	bit field	P1	4	–	
	Radial In EOT	STP	bi-level			0.125	1	0.125	bit field	P1	5	–	
	Radial Out EOT	STP	bi-level			0.125	1	0.125	bit field	P1	6	–	
	Gripper Open EOT	STP	bi-level			0.125	1	0.125	bit field	P1	7	–	
	Gripper Closed EOT	STP	bi-level			0.125	1	0.125	bit field	P1	8	–	
OvF and Brake Status	Elevation OvF Status	STP	bi-level			0.125	1	0.125	bit field	P4	1	–	
	Radial OvF Status	STP	bi-level			0.125	1	0.125	bit field	P4	2	–	
	L. Grip OvF Status	STP	bi-level			0.125	1	0.125	bit field	P4	3	–	
	R. Grip OvF Status	STP	bi-level			0.125	1	0.125	bit field	P4	4	–	
	Elevation Brake Status	STP	bi-level			0.125	1	0.125	bit field	P4	5	–	
	Azimuth Brake Status	STP	bi-level			0.125	1	0.125	bit field	P4	6	–	
	Radial Brake Status	STP	bi-level			0.125	1	0.125	bit field	P4	7	–	
	UNASSIGNED		n/a			0.125	1	0.125	bit field	P4	8	–	
Motor 1 Sec Multiplexer TM	Elevation Ctrl Sig Lvl	XPP	±10V	tbd	±10V	2.000	1	2.000	int	U2	1	2	
	Azimuth Ctrl Sig Lvl	XPP	±10V	tbd	±10V	2.000	1	2.000	int	U2	2	2	
	Radial Ctrl Sig Lvl	XPP	±10V	tbd	±10V	2.000	1	2.000	int	U2	3	2	
	Gripper Ctrl Sig Lvl	XPP	±10V	tbd	±10V	2.000	1	2.000	int	U2	4	2	
	Elevation Position	ENC	0-10V	tbd	0-10V	2.000	1	2.000	int	U2	5	2	
	Azimuth Position	ENC	0-10V	tbd	0-10V	2.000	1	2.000	int	U2	6	2	
	Radial Position	ENC	0-10V	tbd	0-10V	2.000	1	2.000	int	U2	7	2	
	Gripper Position	ENC	0-10V	tbd	0-10V	2.000	1	2.000	int	U2	8	2	
	Elevation Frc Measurem	FBT	±10 lbs	1.00%	±10V	1.000	1	1.000	int	U2	9	2	
	Radial Frc Measurement	FBT	±10 lbs	1.00%	±10V	1.000	1	1.000	int	U2	10	2	
	R. Grip Frc Measuremen	FBT	±32 lbs	1.00%	±10V	1.000	1	1.000	int	U2	11	2	
	L. Grip Frc Measuremen	FBT	±32 lbs	1.00%	±10V	1.000	1	1.000	int	U2	12	2	
Motor 1 Sec TM	Motor Current	FBT	0-5A	1.00%	0-10V	2.000	1	2.000	int	–	–	5	ITE Polyn
	Check Sum	Derived By TM Ot	0- 255			2.000	1	2.000	int	n/a	n/a	n/a	exclusive or of all packet byte
	Total Number Bytes Per Packet							32.000					
	Packet Rate							0.333					
	Average Telemetry Rate							96.000					
	Requested Telemetry Allocation							100.000					

RoMPS 0.25 Second Furnace TM list

Function	Data Item	Data Point Source	FS Range User	FS Accur %	FS Range Raw	Length Bytes	No.Pts Item	TM Req. Byt/Pac	Data Type	Source: Mux/ Port	Source: Chan	Source: A2D Chan	Comments
Header	0.25 Sec Sync	n/a	constant value			1.000	1	1.000	Byte	n/a	n/a	n/a	
	0.25 Sec ID	n/a	constant value			1.000	1	1.000	Byte	n/a	n/a	n/a	
	Data Acquire Time	AMS Clock	32 bit range	.1 mil sec		4.000	1	4.000	BCD	n/a	n/a	n/a	
Furnace 1 Sec Multiplexer TM	UNASSIGNED		n/a	n/a	n/a	0.000	0	0.000	int	U1	1	1	
	Furn Lamp Voltage	Furnace	0-26V	1.00%	tbd	2.000	1	2.000	int	U1	2	1	
	Furn Lamp Current	Furnace	0-12A	1.00%	tbd	2.000	1	2.000	int	U1	3	1	
	UNASSIGNED		n/a	n/a	n/a	0.000	0	0.000	int	U1	4	1	
	Cal Sample Temp #1	Furnace	350–1450° c	1.00%	tbd	1.000	1	1.000	int	U1	5	1	TC polyn
	Cal Sample Temp #2	Furnace	350–1450° c	1.00%	tbd	1.000	1	1.000	int	U1	6	1	TC polyn
	Furn Rel Temp #1	Furnace	tbd	1.00%	tbd	1.000	1	1.000	int	U1	7	1	
	Furn Rel Temp #2	Furnace	tbd	1.00%	tbd	1.000	1	1.000	int	U1	8	1	
	Furnace Set Point	SCL	SCL variable	tbd		2.000	1	2.000	int	n/a	n/a	n/a	
	Check Sum	Derived By TM Ct	0- 255			2.000	1	2.000	int	n/a	n/a	n/a	exclusive or of all packet byte
	Total Number Bytes Per Packet							18.000					
	Packet Rate							0.250					
	Average Telemetry Rate							72.000					
	Requested Telemetry Allocation							100.000					

RoMPS Telemetry List Comments and Notes

Comment	Description
TC polyn	
ITE polyn	
Omnirel polyn	
YSI polyn	
RTD polyn	

RoMPS Commands List

User Accessable	Command	Code Type	HH	SCC	EZC	XPC	FRN	RBT	Origin	Port ID	Destination	Port ID
x	Furnace A/B Select	Level	S	>			D		SCC	P5-1	power control	
x		Interrupt	S	>	D				SCC	P5-2	EZC	
x	Power Bus A Select	Discrete/p	S	>				D	SCC	P5-3	power control	
x	Power Bus B Select	Discrete/p	S	>				D	SCC	P5-4	power control	
x	General Motor Drivers Enable/Disable	Discrete	S	>				D	SCC	P5-5	motor control	
x	Motor Driver A/B Select	Discrete	S	>				D	SCC	P5-6	motor control	
x	Open Battery Relay	Discrete/p	S	>		D			SCC	P5-7	WDT	
x	Close Battery Relay	Discrete/p	S	>		D			SCC	P5-8	WDT	
	WD Timer Strobe	Discrete		S		D			SCC	P6-1	WDT	
	XPC Reset	Discrete		S		D			SCC	P6-2	XPC	
x	Furnace Reset/WD Disable	Discrete/p		S			D		SCC	P6-3	furn control	
	Unassigned									P6-4		
	Mux Address 0	Discrete		SD					SCC	P6-5	MUX	
	Mux Address 1	Discrete		SD					SCC	P6-6	MUX	
	Mux Address 2	Discrete		SD					SCC	P6-7	MUX	
	Mux Address 3	Discrete		SD					SCC	P6-8	MUX	
x	HH Enable System Power	HH Discrete/p	S					D	HH	BLCMD1	WDT	
x	HH Disable System Power	HH Discrete/p	S					D	HH	BLCMD2	WDT	
x	HH Reset All Processors	HH Discrete/p	S	D	D	D	D		HH	BLCMD3	WDT	
x	HH Disable All WD Timers	HH Discrete/p	S	D	D	D	D		HH	BLCMD4	WDT	
x	Execute Script		S	D					SCL	n/a	SCL	
x	Stop Sample Processing		S	D					SCL	n/a	SCL	
x	Inquire Status		S	D					SCL	n/a	SCL	
x	Begin Downlinking TM		S	D					SCL	n/a	SCL	
x	Stop Downlinging TM		S	D					SCL	n/a	SCL	
	Select Elevation Motor Driver	Discrete				S		D	XP	U2/5	motor control	
	Select Azimuth Motor Driver	Discrete				S		D	XP	U2/7	motor control	
	Select Radial Motor Driver	Discrete				S		D	XP	U2/6	motor control	
	Select Gripper Motor Driver	Discrete				S		D	XP	U2/4	motor control	
x	Elevation Axis Move		S	>	>	D			SCL	Serial	EasyLab/XP	
x	Azimuth Axis Move		S	>	>	D			SCL	Serial	EasyLab/XP	
x	Radial Axis Move		S	>	>	D			SCL	Serial	EasyLab/XP	

x	Gripper Axis Move			S	>	>	D			SCL	Serial	EasyLab/XP
	Engage/Disengage Elevation Brake		Discrete				S		D	XP	U2/5	ROBOT
	Engage/Disengage Azimuth Brake		Discrete				S		D	XP	U2/7	ROBOT
	Engage/Disengage Radial Brake		Discrete				S		D	XP	U2/6	ROBOT
x	Enable/Disable Elevation EOT Hardware		Discrete	S	>	>	D			SCL	U1/23	STP
x	Enable/Disable Azimuth EOT Hardware		Discrete	S	>	>	D			SCL	U1/25	STP
x	Enable/Disable Radial EOT Hardware		Discrete	S	>	>	D			SCL	U1/24	STP
x	Enable/Disable Gripper EOT Hardware		Discrete	S	>	>	D			SCL	U1/22	STP
x	Enable/Disable Elevation OverForce		Discrete	S	>	>	D			SCL	U1/21	FRC
x	Enable/Disable Radial OverForce		Discrete	S	>	>	D			SCL	U1/20	FRC
x	Enable/Disable Gripper Left OverForce		Discrete	S	>	>	D			SCL	U1/18	FRC
x	Enable/Disable Gripper Right OverForce		Discrete	S	>	>	D			SCL	U1/19	FRC
x	Elevation OvF Software Threshold			S	D					SCL	n/a	SCL
x	Radial OvF Software Threshold			S	D					SCL	n/a	SCL
x	Gripper Left OvF Software Threshold			S	D					SCL	n/a	SCL
x	Gripper Right OvF Software Threshold			S	D					SCL	n/a	SCL
x	Elevation Velocity Anomaly Threshold		?	S	>	>	D			SCL	Serial	EasyLab/XP
x	Azimuth Velocity Anomaly Threshold		?	S	>	>	D			SCL	Serial	EasyLab/XP
x	Radial Velocity Anomaly Threshold		?	S	>	>	D			SCL	Serial	EasyLab/XP
x	Gripper Velocity Anomaly Threshold		?	S	>	>	D			SCL	Serial	EasyLab/XP
x	Enable/Disable Furnace Controller		Discrete	S	>	>		D		SCL	Serial RTS	furn control
x	Inquire Status	06H		S	>	>		D		SCL	Serial	furn control
x	Set Furnace Power Level	01H		S	>	>		D		SCL	Serial	furn control
x	Set Furnace Temperature	02H		S	>	>		D		SCL	Serial	furn control
x	Set Furnace PID Factors	03H		S	>	>		D		SCL	Serial	furn control
x	Override Overtemp Protection	04H		S	>	>		D		SCL	Serial	furn control
x	Override OvTemp Cmd Clear	05H		S	>	>		D		SCL	Serial	furn control
x	Set Elevation PID Factors	13H		S	>	>	D			SCL	Serial	EasyLab/XP
x	Set Azimuth PID Factors	23H		S	>	>	D			SCL	Serial	EasyLab/XP
x	Set Radial PID Factors	33H		S	>	>	D			SCL	Serial	EasyLab/XP
x	Set Gripper PID Factors	43H		S	>	>	D			SCL	Serial	EasyLab/XP
x	Read Elevation PID Factors	14H		S	>	>	D			SCL	Serial	EasyLab/XP
x	Read Azimuth PID Factors	24H		S	>	>	D			SCL	Serial	EasyLab/XP
x	Read Radial PID Factors	34H		S	>	>	D			SCL	Serial	EasyLab/XP

x	Read Gripper PID Factors	44H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Re-Zero Elevation Axis Counter	12H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Re-Zero Azimuth Axis Counter	22H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Re-Zero Radial Axis Counter	32H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Re-Zero Gripper Axis Counter	42H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Auto-Zero Elevation Axis Position & Counte	12H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Auto-Zero Azimuth Axis Position & Counter	22H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Auto-Zero Radial Axis Position & Counter	32H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Auto-Zero Gripper Axis Position & Counter	42H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Read Limit Status (EOT, OVF, Stall)	51H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Read Arm Max Speeds	52H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Read Hand Max Speed	53H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Set Limit Overrides (EOT, OVF)	54H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Read Limit Overrides (EOT, OVF)	55H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Read Hand Position	75H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Read Hand Move Status	76H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Set Hand Max Speed	78H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Read Arm Move Status	63H	S	>	>	D		SCL	Serial	EasyLab/XP
	Stop Robot	64H			S	D		EZC	Serial	EasyLab/XP
x	Read Arm Position	65H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Set Arm Max Speeds	68H	S	>	>	D		SCL	Serial	EasyLab/XP
x	Enter Debug Mode	6DH	S	>	>	D		SCL	Serial	EasyLab/XP

NOTE: All other XP commands are not available.
ARM = Elevation + Azimuth + Radial
HAND = Gripper
S = Source D = Destination

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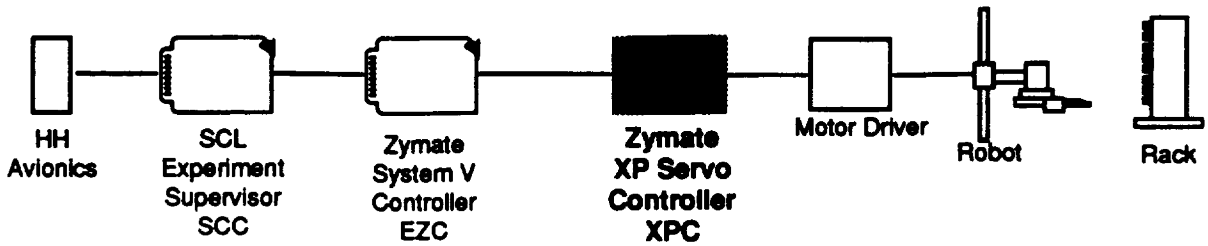
RoMPS

SERVO

Nominal Operation of the ROMPS XP Servo



Upon Reset

1) XP Servo Controller System Startup

- System Hardware (timers, UART, LEDs, etc.) is initialized and assocciated and Interupt Service Routines are installed
- Servo Control and Processing Control Data Structures are intiallized

2) Ready XP Servo Controller System for Main Processing Loop

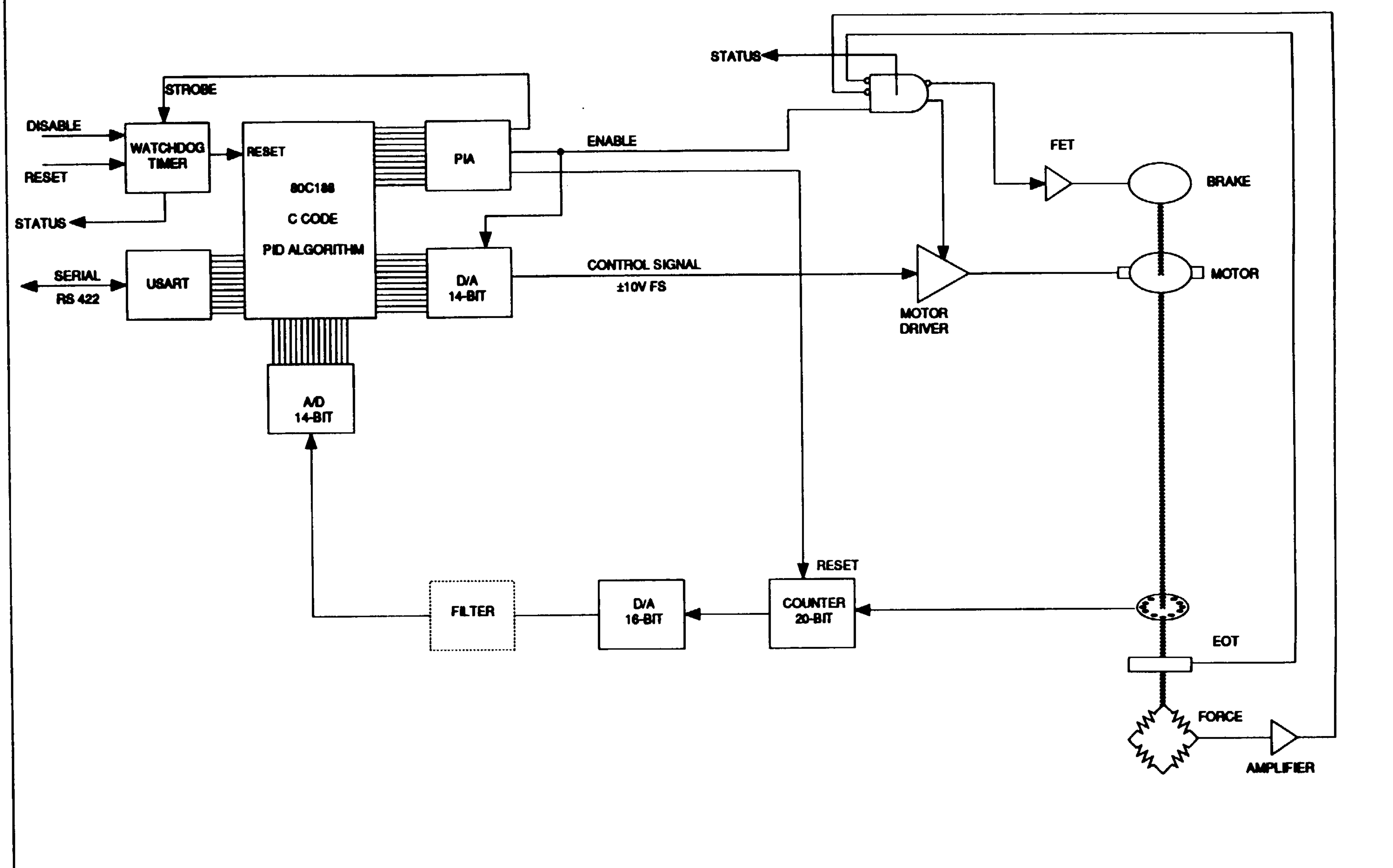
- Inhibit the D/As used for Axis Position Control
- Kick the Watch Dog Timer
- Execute Servo Contol Algorithm 5 times to "Prime" the Servo Control intermediary data structures
- Set all Axis Control Target Positions to Current Position
- Set all Axis Control Speeds to Zero
- Initiallize the Communication Structures used to communicate with the System V Controller
- Uninhibit the D/As used for Axis Control

3) Begin Main Servo Processing Loop

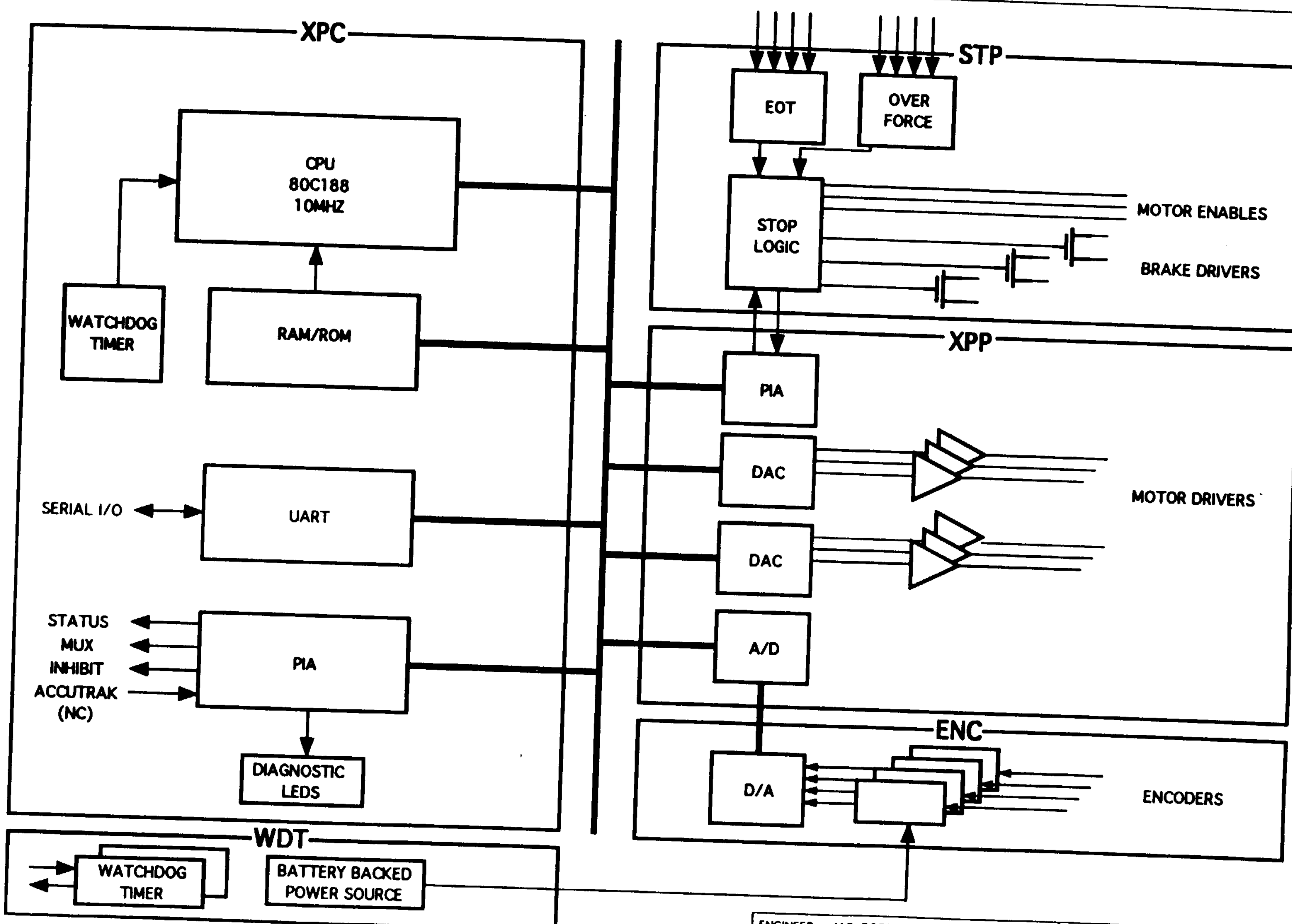
Loop Forever

- Set the 5 millisecond Main Processing Loop Timer
- Execute the Servo Algorithm for Base and Gripper Axis
- Output the computed Control Voltages to the D/A used for Axis Control
- Kick Watch Dog Timer High
- Update the System Diagnostic LEDs
- Get/Process XP Servo Commands from the Zymate System V Controller
  see XP Servo Command Tables
- Wait for the remainder of 5 millisecond Main Processing Loop Timer
  - Kick Watch Dog Timer Low

End Loop



ENGINEER M.E. DOBBS	DRAFTSMAN G. WASSICK	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Block Diagram Servo System RoMPS 010-440	12/07/92 DATE



ENGINEER M.E. DOBBS	DRAFTSMAN G. WASSICK
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	XP System Distribution RoMPS 010-421
	11/30/92 DATE

Summary Table of Original XP Servo Commands and Replies

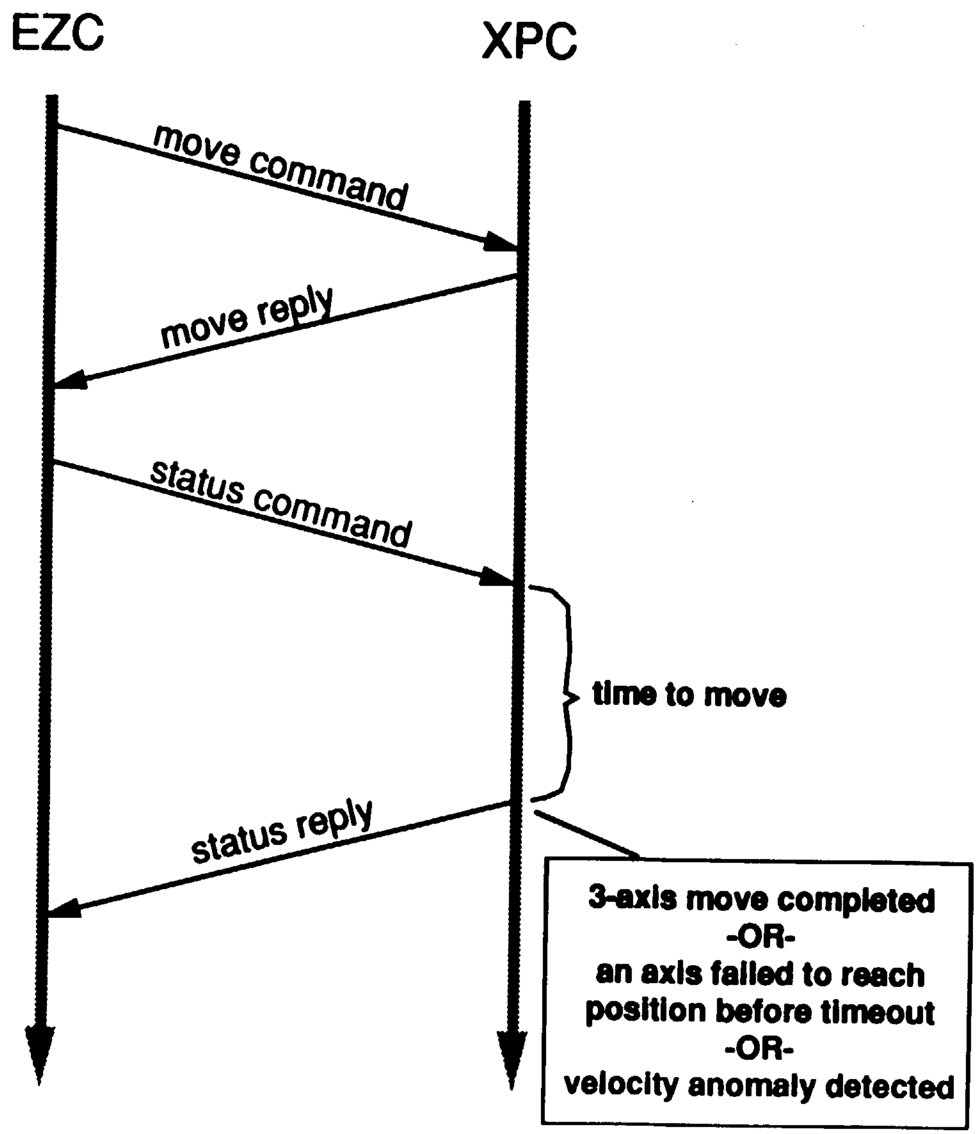
ID	NAME	CMD DATA BYTES	REPLY DATA BYTES
HAND COMMANDS (GRIPPER)			
71H	MOVE HAND TO POSITION	6	0
75H	READ PRESENT HAND POSITION	0	6
76H	READ HAND MOVE STATUS	0	1
77H	n.a.	0	4
78H	SET HAND MAX SPEED (and ACCELERATION)	6	0
79H	n.a.	1	0
7AH	n.a.	1	0
7BH	n.a.	1	0
7EH	(SET HAND CALIBRATION DATA)	12	0
7FH	(READ HAND CALIBRATION DATA)	0	12
ARM COMMANDS (ELEVATION, AZIMUTH, RADIAL)			
61H	MOVE ARM TO POSITION	6	0
63H	READ ARM MOVE STATUS (- TRANSITION POSITION)	0	1
64H	STOP ROBOT	1	0
65H	READ PRESENT ARM POSITION	0	6
66H	n.a.	0	1
67H	n.a.	0	4
68H	SET ARM MAX SPEED (and ACCELERATION and TRANSITIONS)	9	0
69H	n.a.	1	0
6AH	n.a.	1	0
6BH	n.a.	1	0
6DH	ENTER DEBUG MODE	2	0
6EH	(SET ARM CALIBRATION DATA)	12	0
6FH	(READ ARM CALIBRATION DATA)	0	12

Summary Table of New XP Servo Commands and Replies

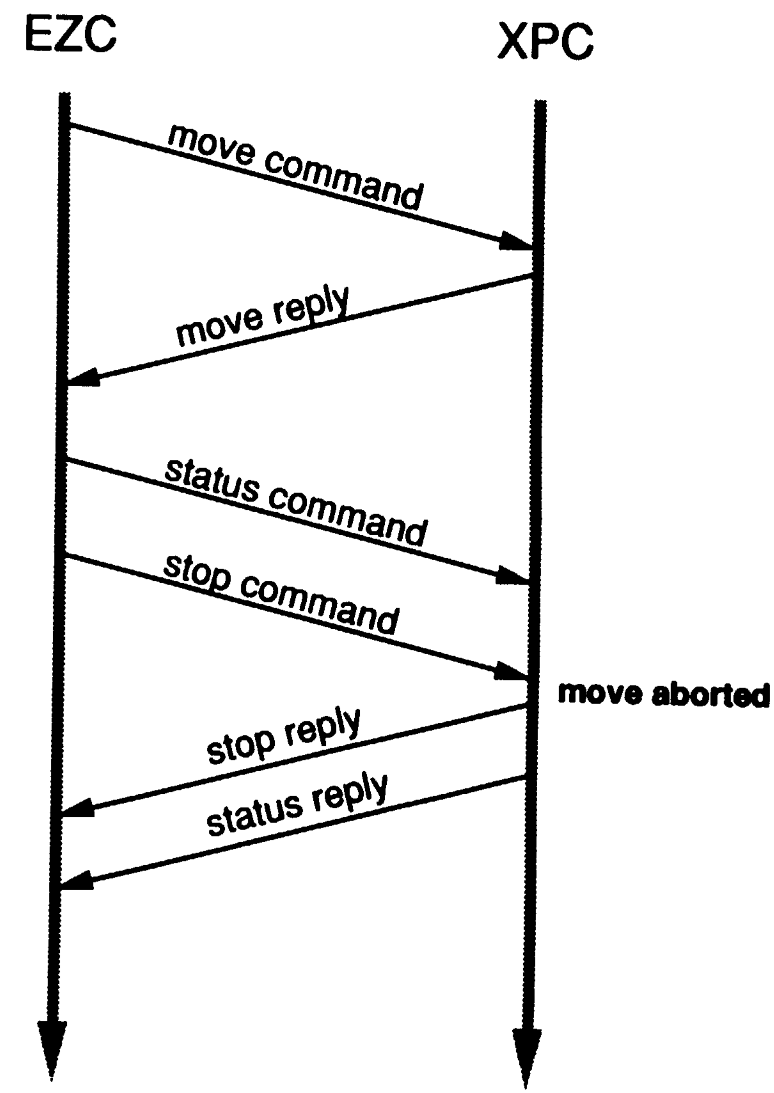
ID	NAME	CMD DATA BYTES	REPLY DATA BYTES
NEW ROMPS COMMANDS			
11H	ZERO ELEVATION AXIS	0	0
12H	AUTO-ZERO ELEVATION AXIS	0	0
13H	SET PID FACTORS FOR ELEVATION	10	0
14H	READ PID FACTORS FOR ELEVATION	0	10
21H	ZERO AZIMUTH AXIS	0	0
22H	AUTO-ZERO AZIMUTH AXIS	0	0
23H	SET PID FACTORS FOR AZIMUTH	10	0
24H	READ PID FACTORS FOR AZIMUTH	0	10
31H	ZERO RADIAL AXIS	0	0
32H	AUTO-ZERO RADIAL AXIS	0	0
33H	SET PID FACTORS FOR RADIAL	10	0
34H	READ PID FACTORS FOR RADIAL	0	10
41H	ZERO GRIPPER AXIS	0	0
42H	AUTO-ZERO GRIPPER AXIS	0	0
43H	SET PID FACTORS FOR GRIPPER	10	0
44H	READ PID FACTORS FOR GRIPPER	0	10
51H	READ LIMIT STATUS (EOT, OVF, Stall)	0	3
52H	READ ARM MAX SPEEDS	0	6
53H	READ HAND MAX SPEED	0	6
54H	SET LIMIT OVERRIDES (EOT, OVF)	1	0
55H	READ LIMIT OVERRIDES (EOT, OVF)	0	1

XP Servo Move Command Sequence

Normal Move

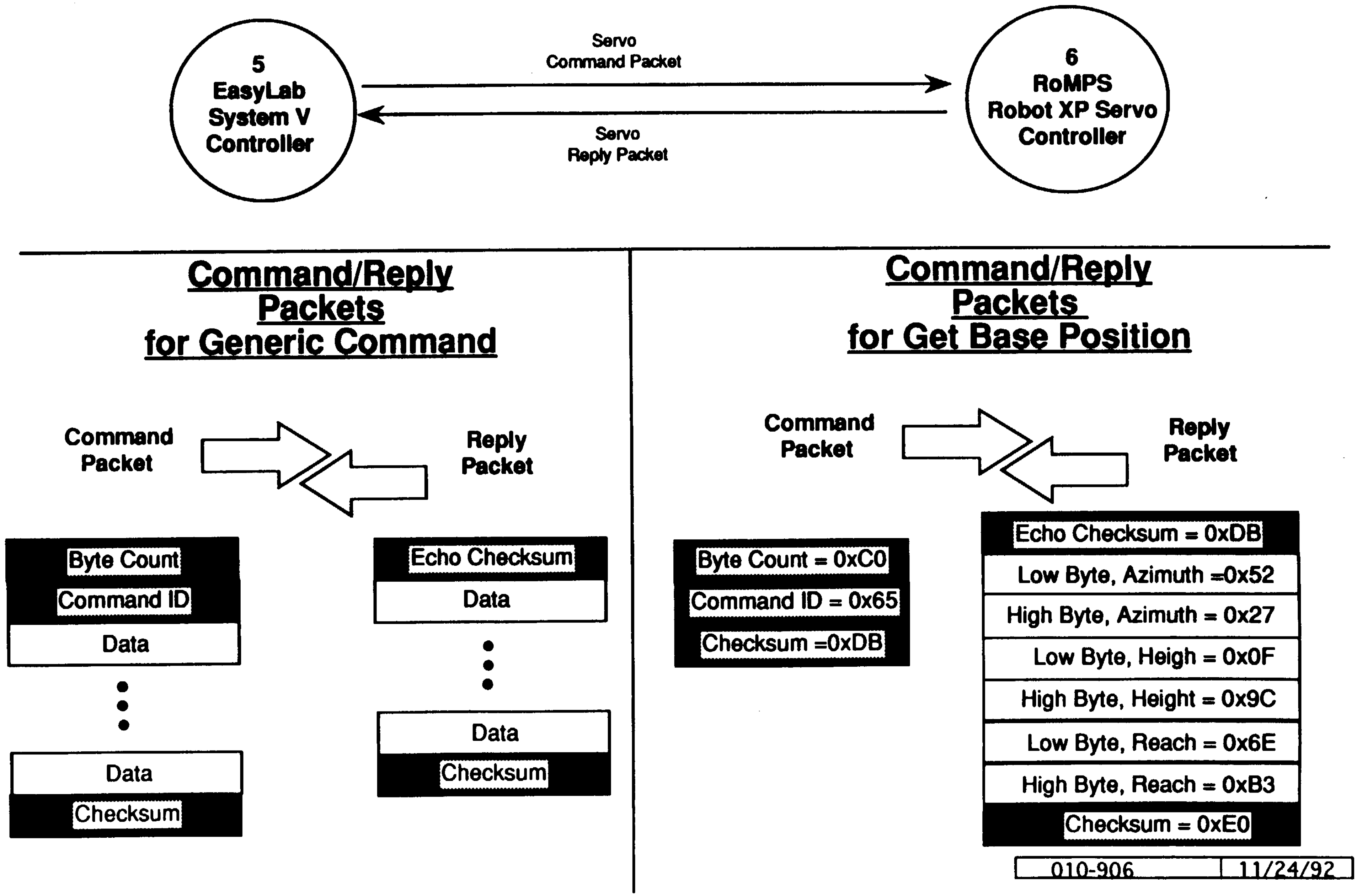


Effect of STOP Command

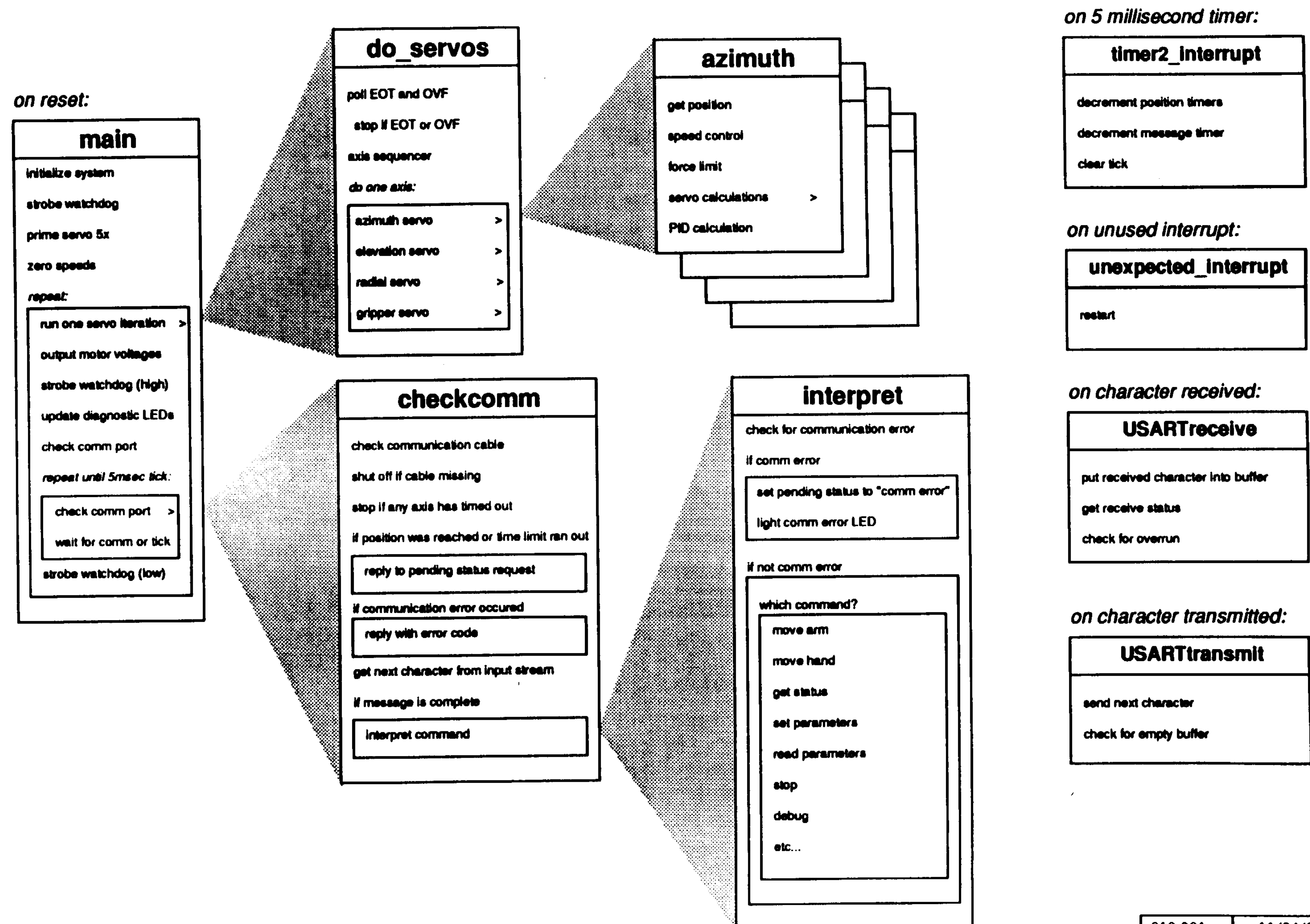


010-805	11/24/92

ROMPS
XP Robot Servo Controller
Communication Protocol



RoMPS XPC Servo Code Outline Chart



11/5/92 GD

010-801 | 11/24/92

servo calculations

if in velocity phase

- adjust proportional gain for inertia
- reset integral

if in position phase

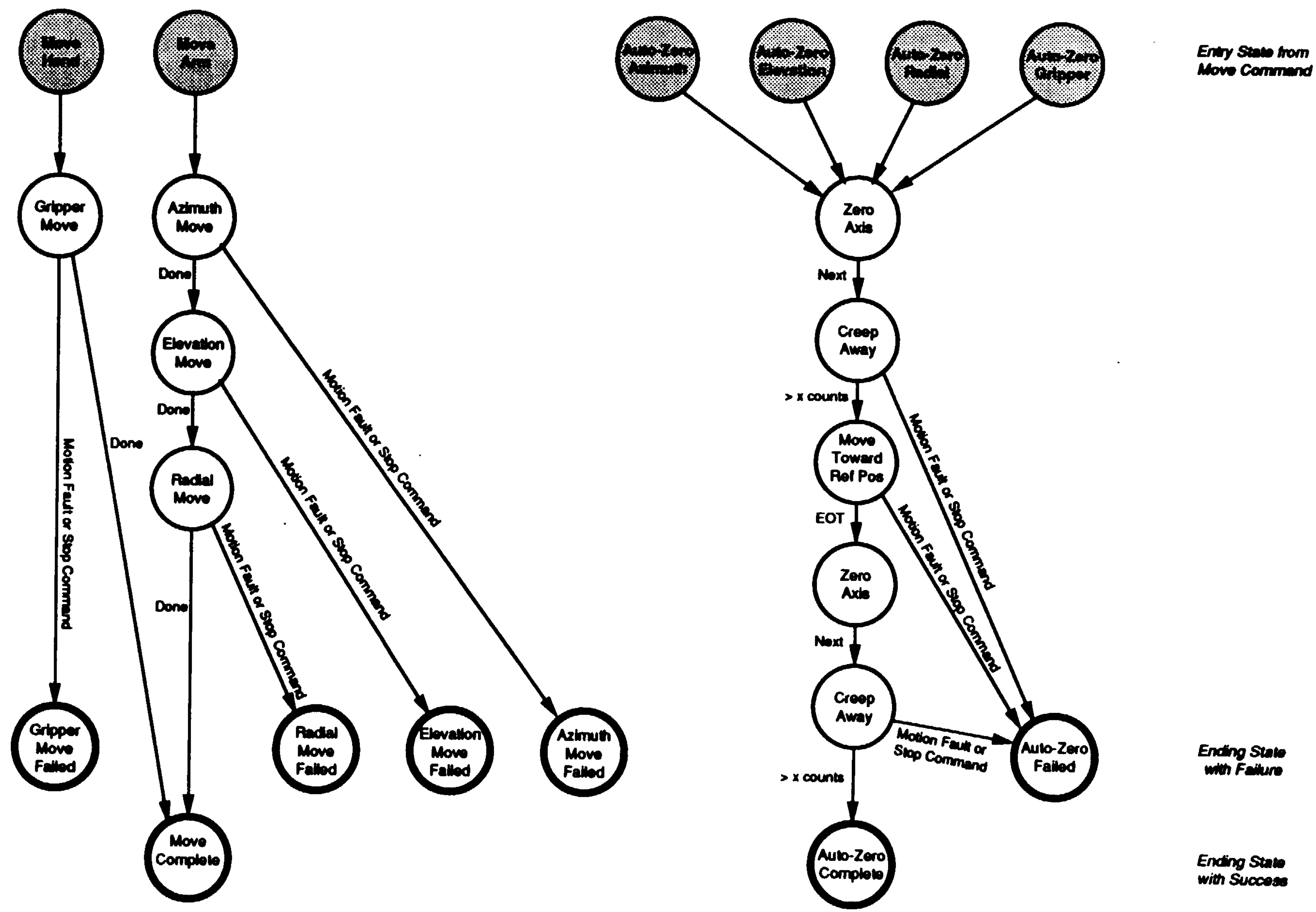
- if error is within target window
  and servo is not stopped
  - set status to "in position"
  - step integral
  - tweak proportional gain
  - microtune integral

PID calculation

voltage = P*(error) + I + D*(speed)

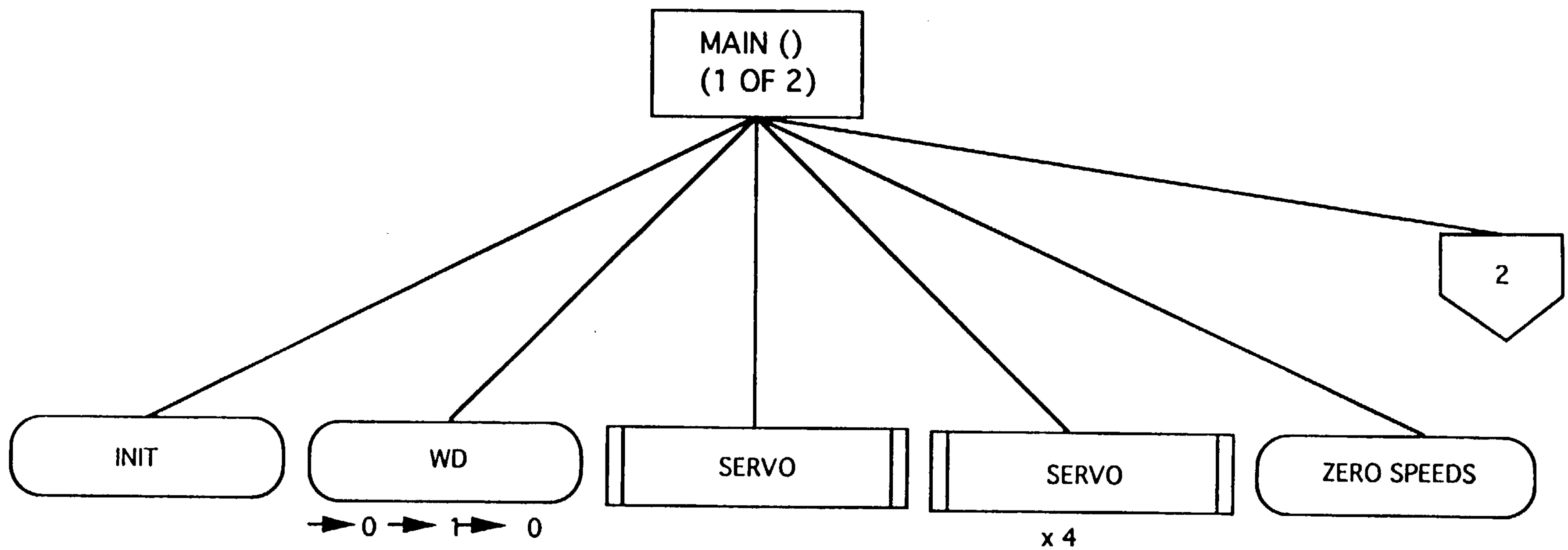
limit voltage to range

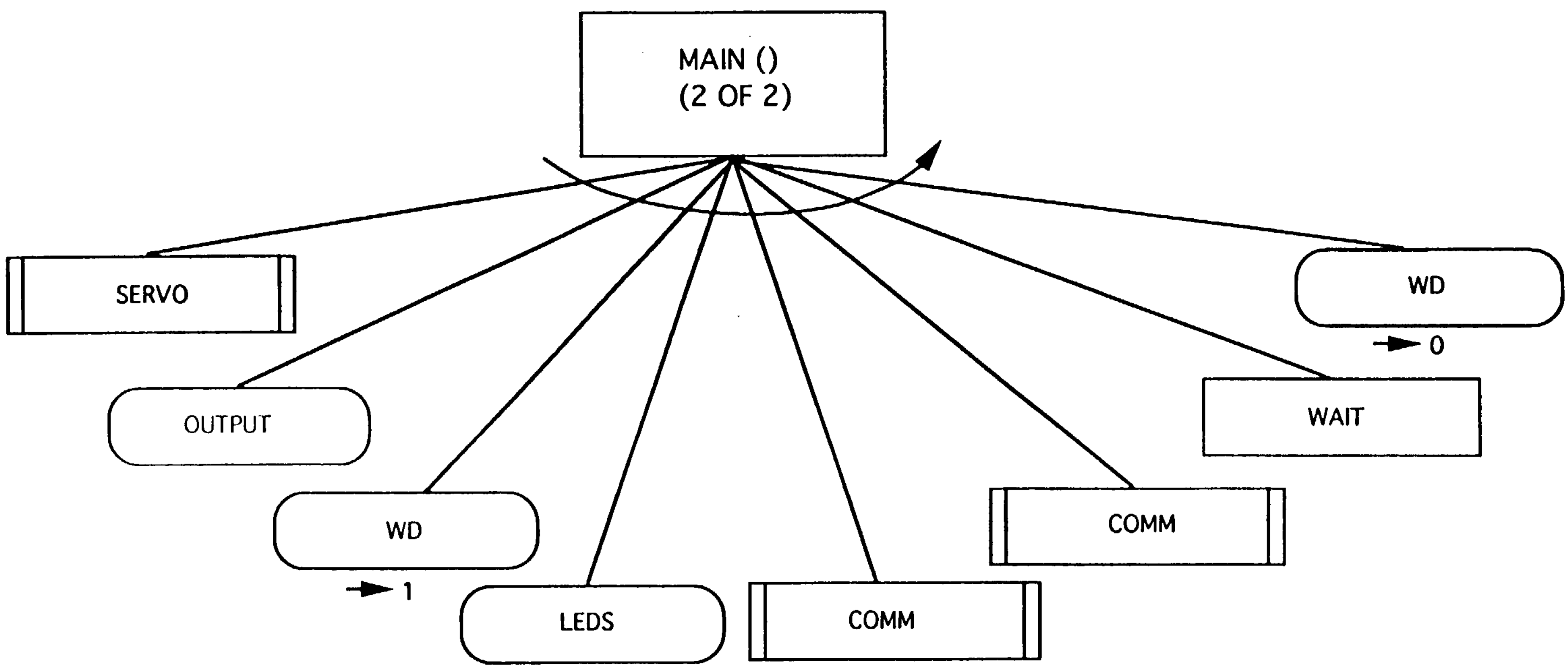
Axis Sequencer State Machine



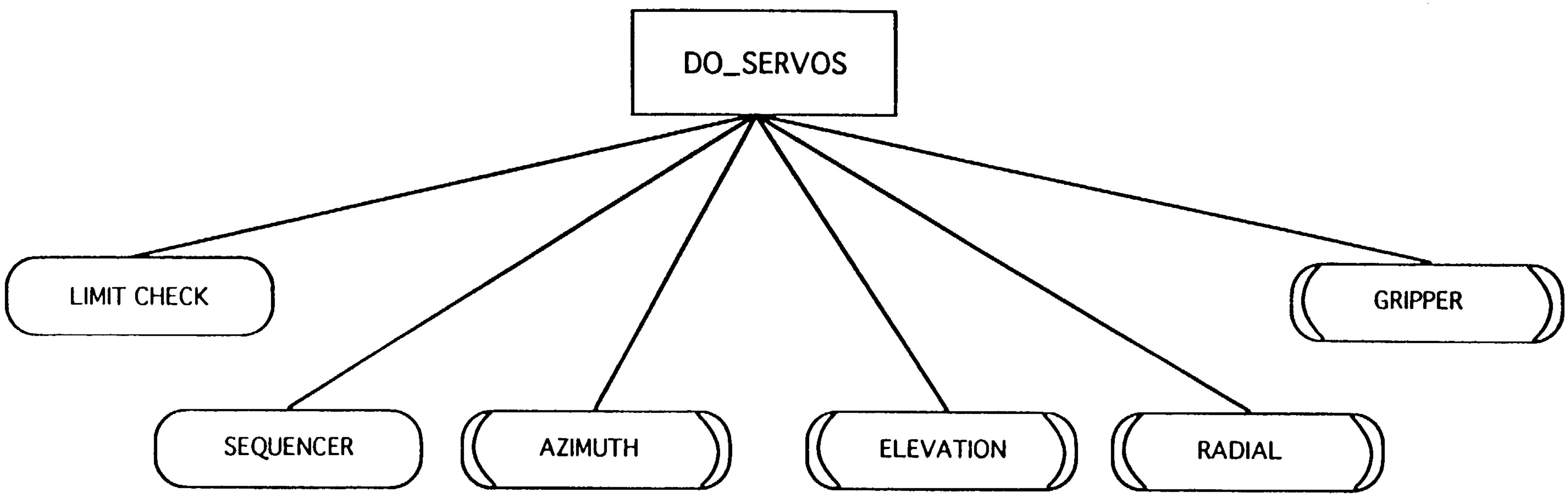
NOTE: Motion Faults include: EOT, OVF, Move Timeout, and Stall.

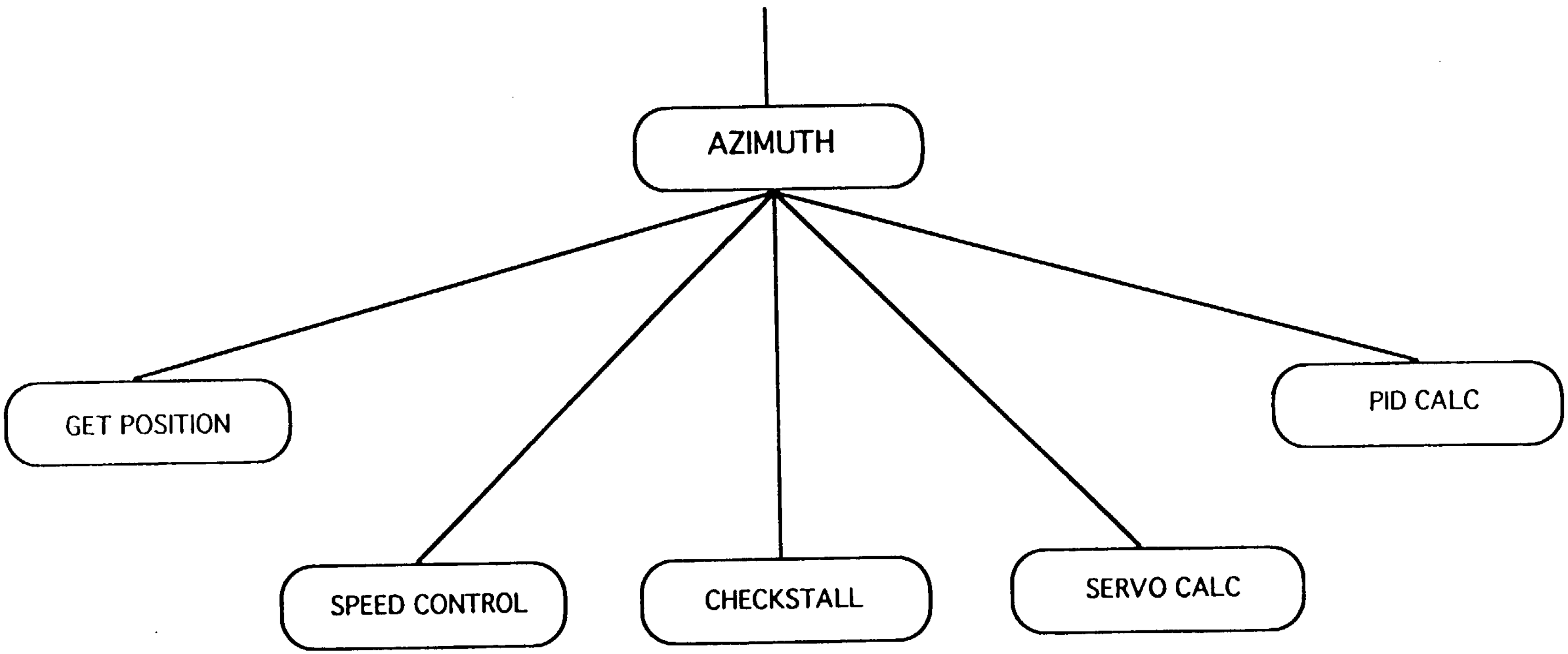
010-807	11/24/92

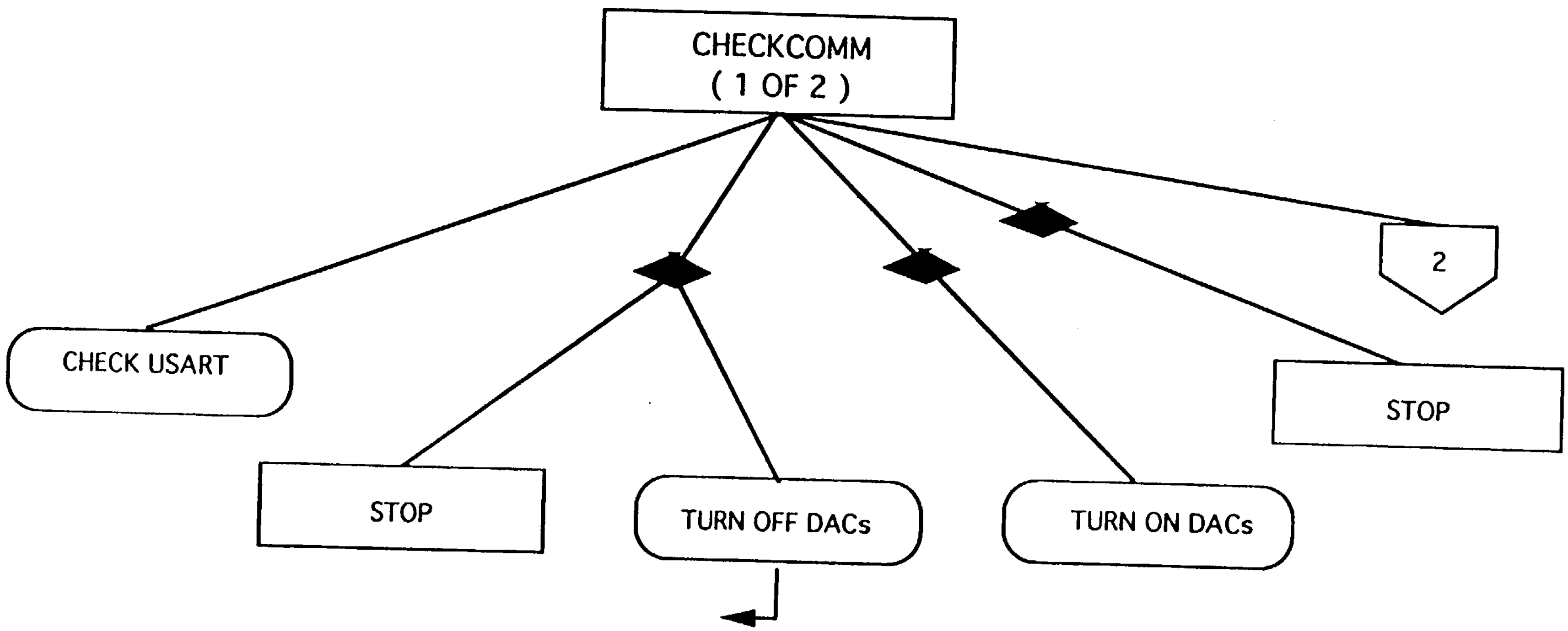

MAIN ()
(1 OF 2)
2
INIT
WD
0
1
0
SERVO
SERVO
x 4
ZERO SPEEDS

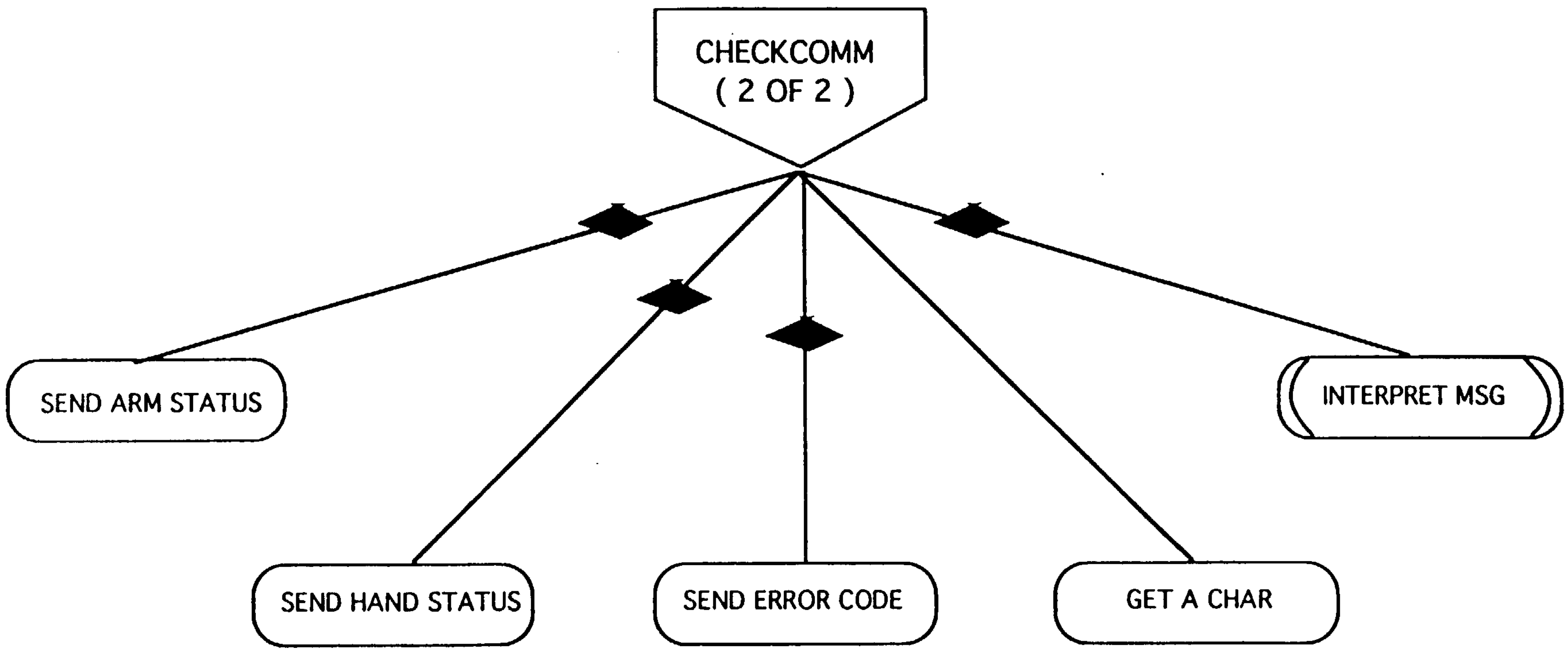


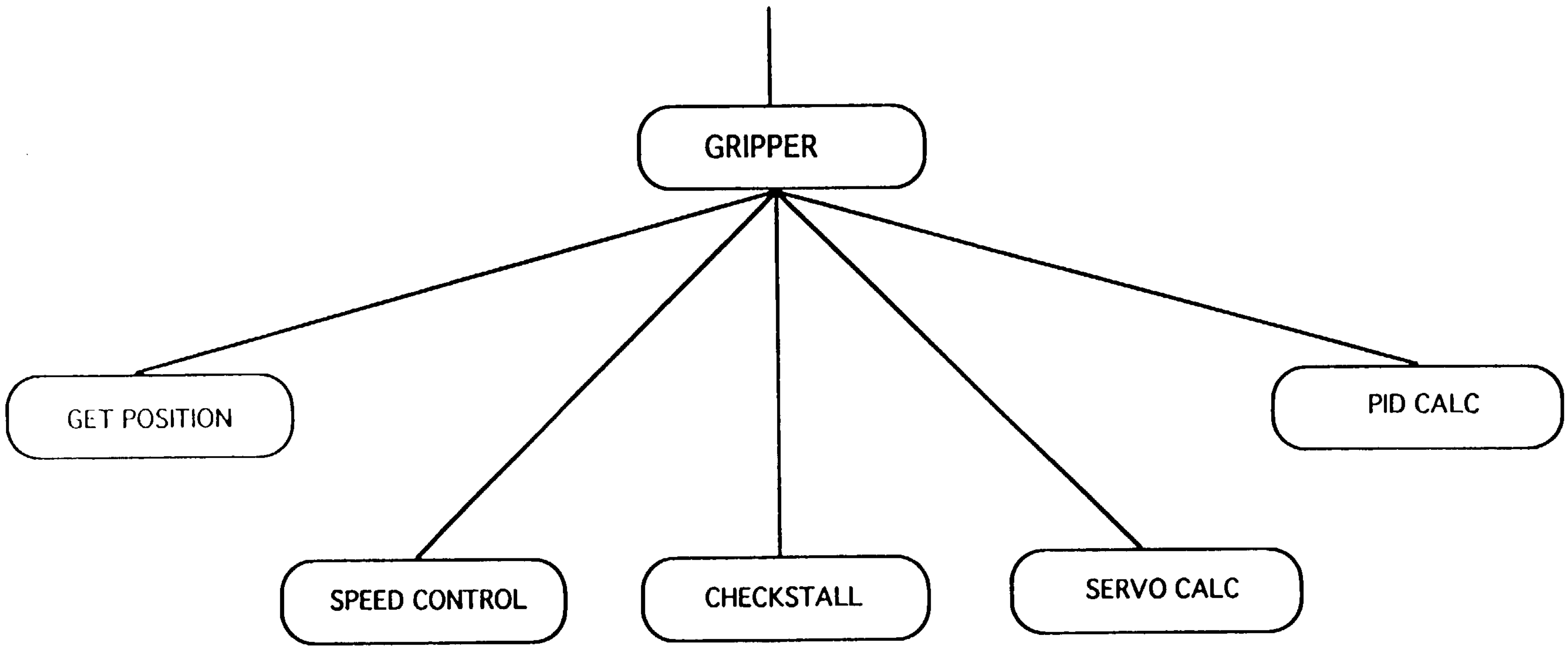
MAIN ()
(2 OF 2)
SERVO
OUTPUT
WD
1
LEDS
COMM
COMM
WAIT
WD
0

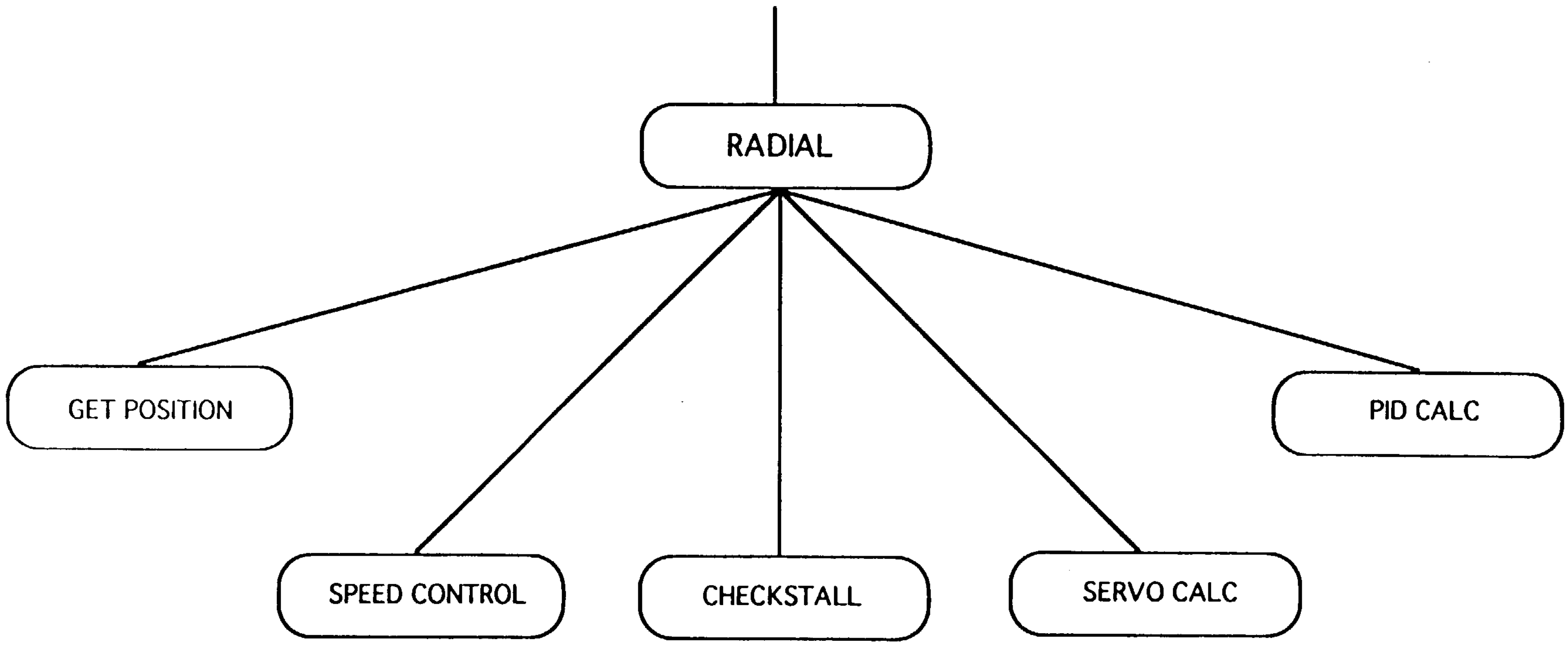

DO_SERVOS
LIMIT CHECK
SEQUENCER
AZIMUTH
ELEVATION
RADIAL
GRIPPER

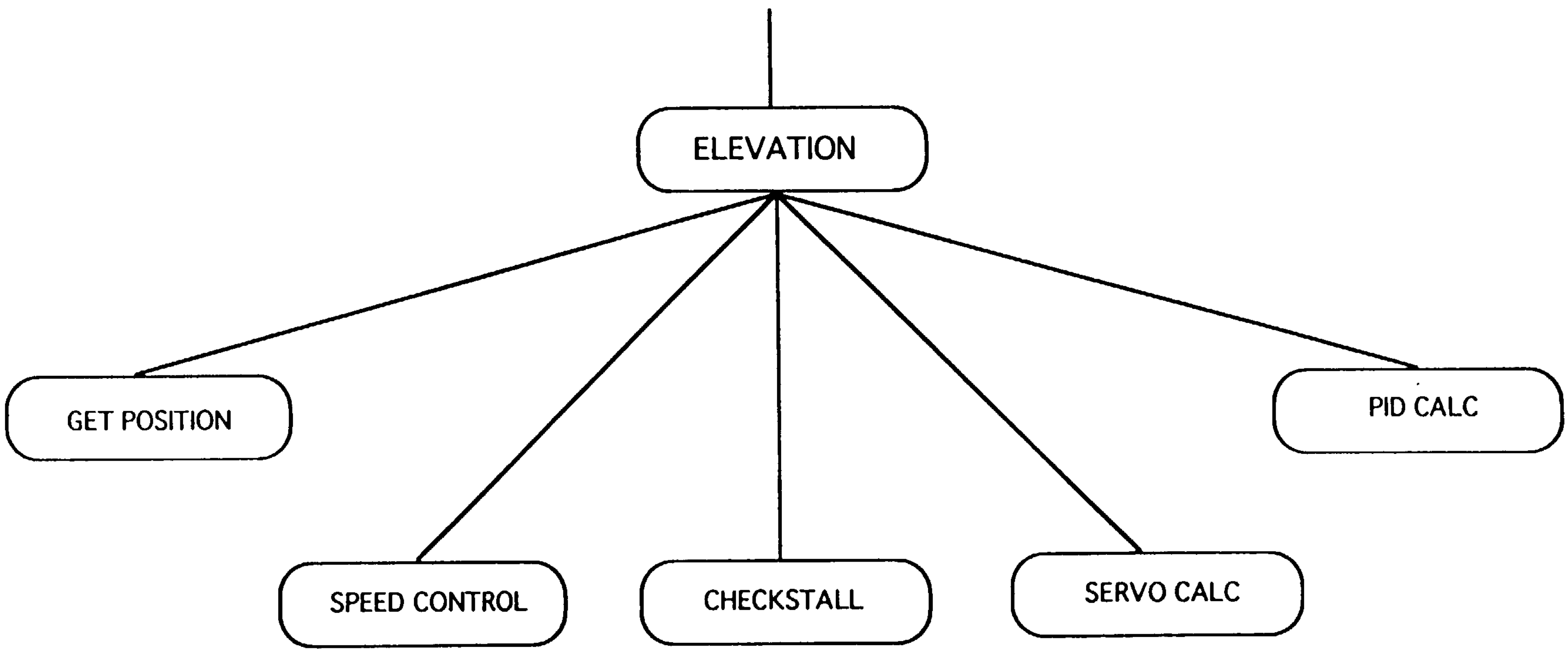

AZIMUTH
GET POSITION
SPEED CONTROL
CHECKSTALL
SERVO CALC
PID CALC


CHECKCOMM
(1 OF 2)
CHECK USART
STOP
TURN OFF DACs
TURN ON DACs
STOP
2

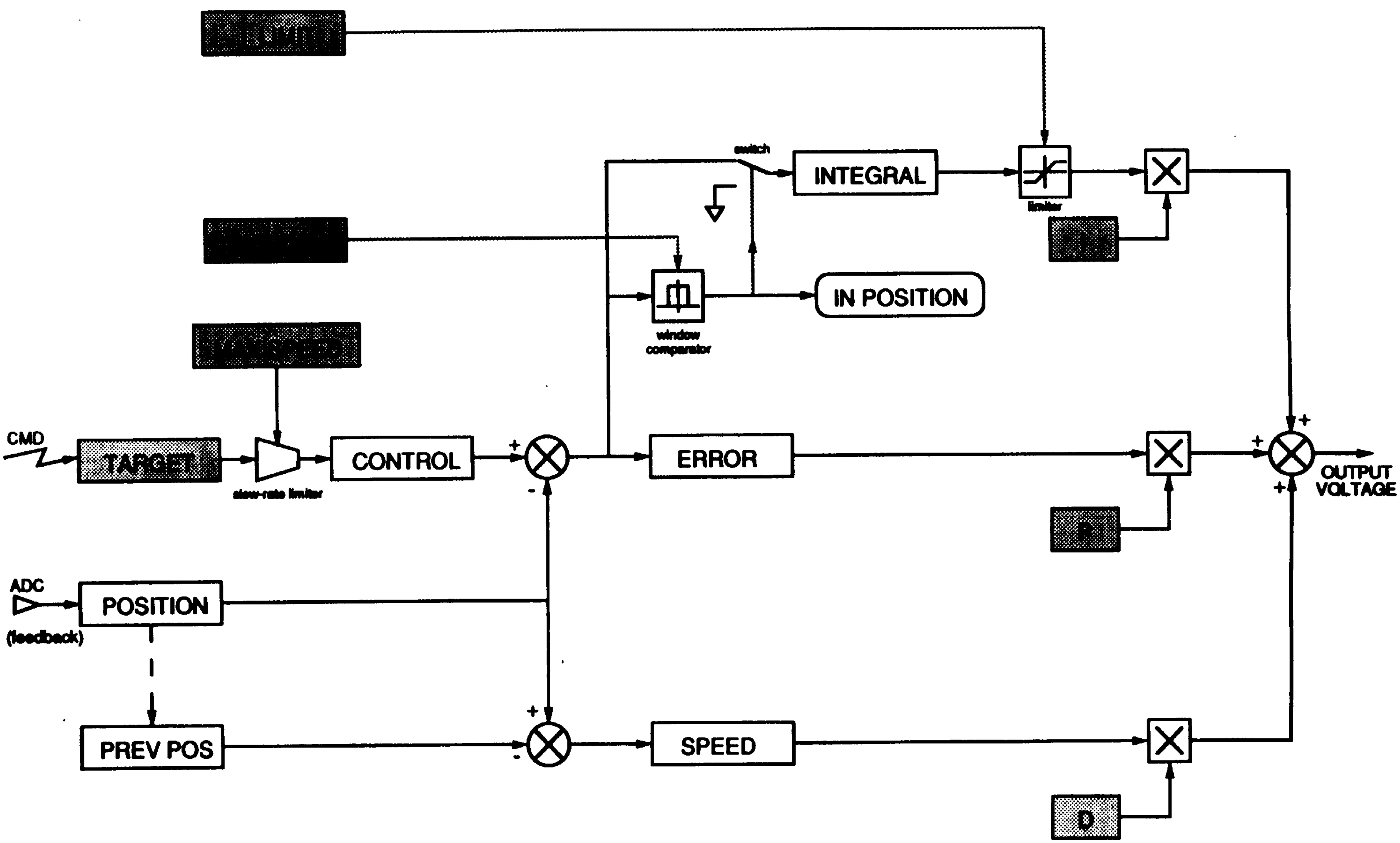

CHECKCOMM
(2 OF 2)
SEND ARM STATUS
SEND HAND STATUS
SEND ERROR CODE
GET A CHAR
INTERPRET MSG


GRIPPER
GET POSITION
SPEED CONTROL
CHECKSTALL
SERVO CALC
PID CALC


RADIAL
GET POSITION
SPEED CONTROL
CHECKSTALL
SERVO CALC
PID CALC


ELEVATION
GET POSITION
SPEED CONTROL
CHECKSTALL
SERVO CALC
PID CALC

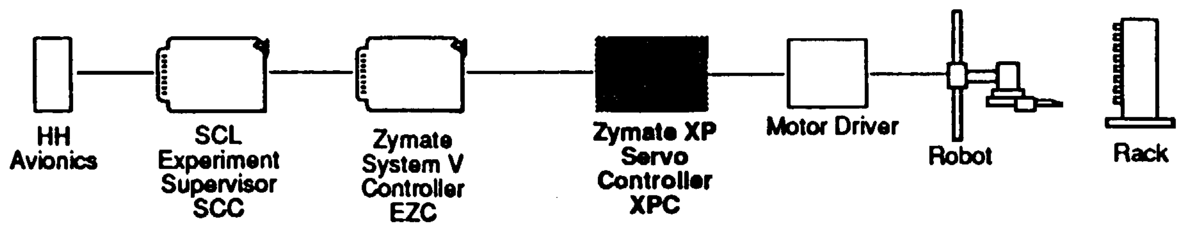
RoMPS Servo PID Algorithm



XP Servo and Subsystems Fault Handling Summary

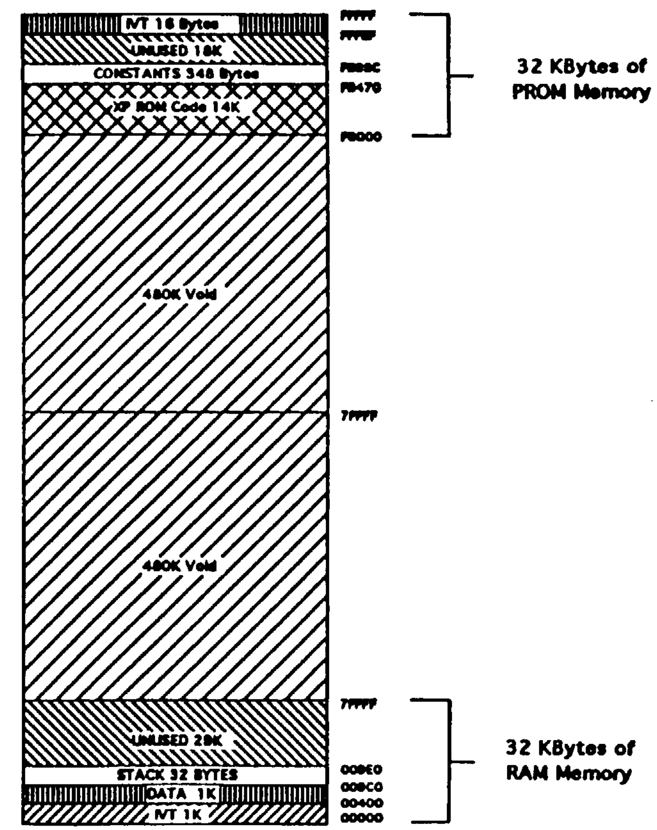
Fault Condition	Fault Detection	Fault Response
End of Travel Limit	STP logic latches EOT event, XPC software polls EOT status.	STP stops motor, XPC aborts current move and reports error status.
Overforce	STP threshold comparator latches OVF event, XPC software polls OVF status.	STP stops motor, XPC aborts current move and reports error status.
Move Timeout	XPC servo checks progress of move against countdown timer	XPC software aborts current move and reports error status.
Move Velocity Anomaly (Stall)	XPC servo monitors velocity of move over time	XPC software aborts current move and reports error status.
Strain Gauge Open	STP OVF status fails to reset	STP OVF latches can be overridden in case of strain gauge failure.
Serial Cable Missing	XPC software checks USART DTR status.	XPC software shuts off outputs to motor drive, aborts any move command, and resets USART.
USART Communication Failure	XPC software checks for parity, overrun, framing, and buffer full errors	XPC returns diagnostic error code via serial interface to EZC
Communication Protocol Failure	XPC software checks packet checksum, interbyte timing, and command format.	XPC returns diagnostic error code via serial interface to EZC
Power Loss	WDT circuit detects loss of power. Brakes are energize-to-release type.	WDT circuit provides uninterrupted battery-backed power to encoder circuits. Brakes are engaged.
Power Up	XPC reset circuit detects power up.	XPC reset circuit restarts processor and resets outputs to safe states.
Single Event Processor Upset	XPC watchdog timer detects loss of periodic watchdog strobes.	XPC watchdog timer restarts processor and resets outputs to safe states.

XP FIRMWARE PERFORMANCE MARGIN



XP Firmware	BB Measured 6DOF	ROMPS Estimate 1DOF
Communication I/O	interrupt basis .8 msec worst case	interrupt basis .8 msec worst case
State Machine	0	.1 msec
PID Loop	1.6 msec complex code 6 axis 5 msec loop	.27 msec simpler code 1 axis 5 msec loop
Accutrack Interrupts	.1 msec est	0
CPU Margin	2X	4.3X

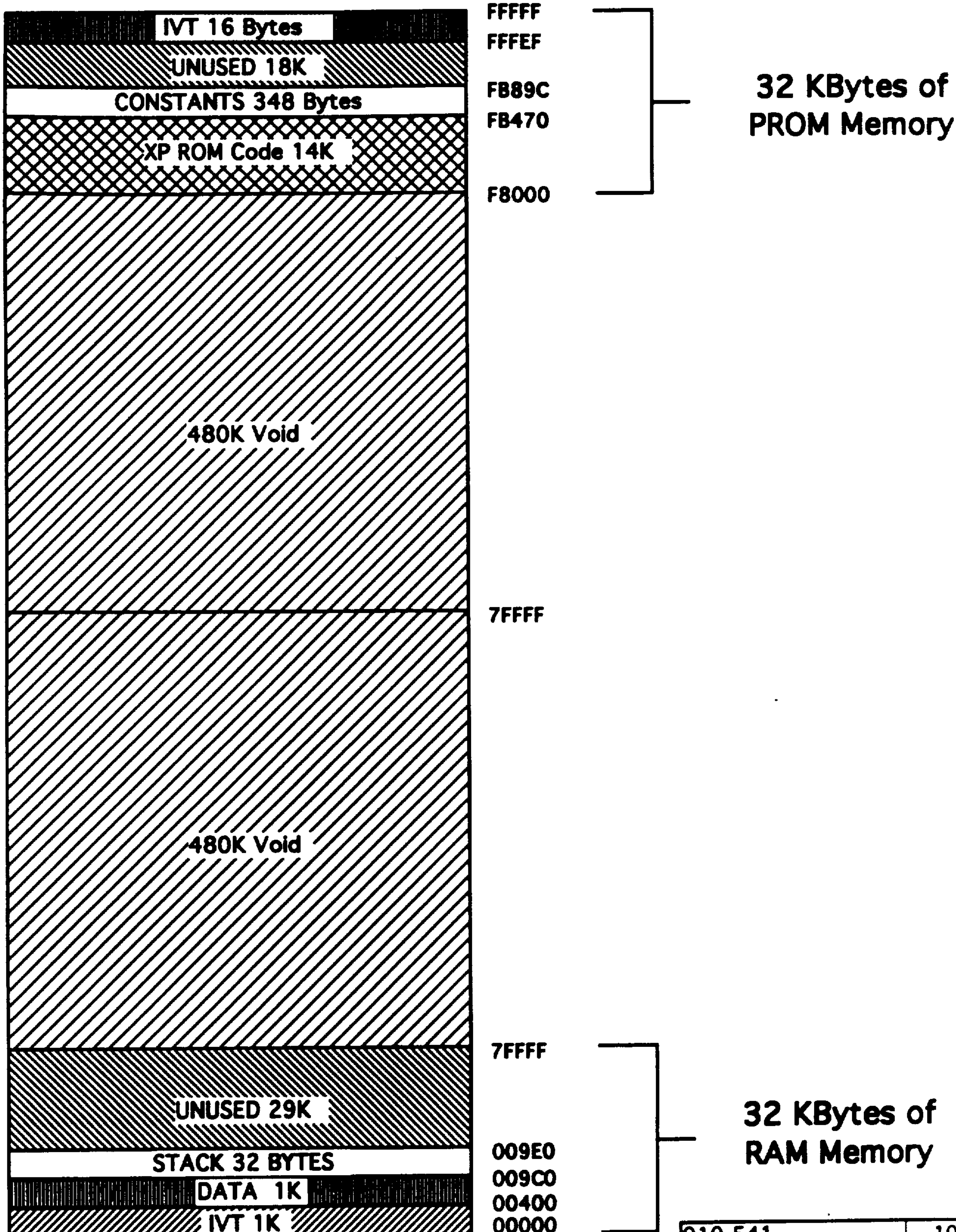
Memory Map



XP FIRMWARE PERFORMANCE/MARGIN

XP Firmware	BB Measured 6DOF	RoMPS Estimate 1DOF
Communication I/O	interrupt basis	interrupt basis
State Machine	0	???
PID Loop	=X complex code 6 axis 5 msec loop	=X/6x#lessthan1 simpler code 1 axis 5 msec loop
Accutrack Interrupts		0
CPU Margin	???	???

RoMPS Zymark XP Servo Controller Memory Map



010-541 10/15/92

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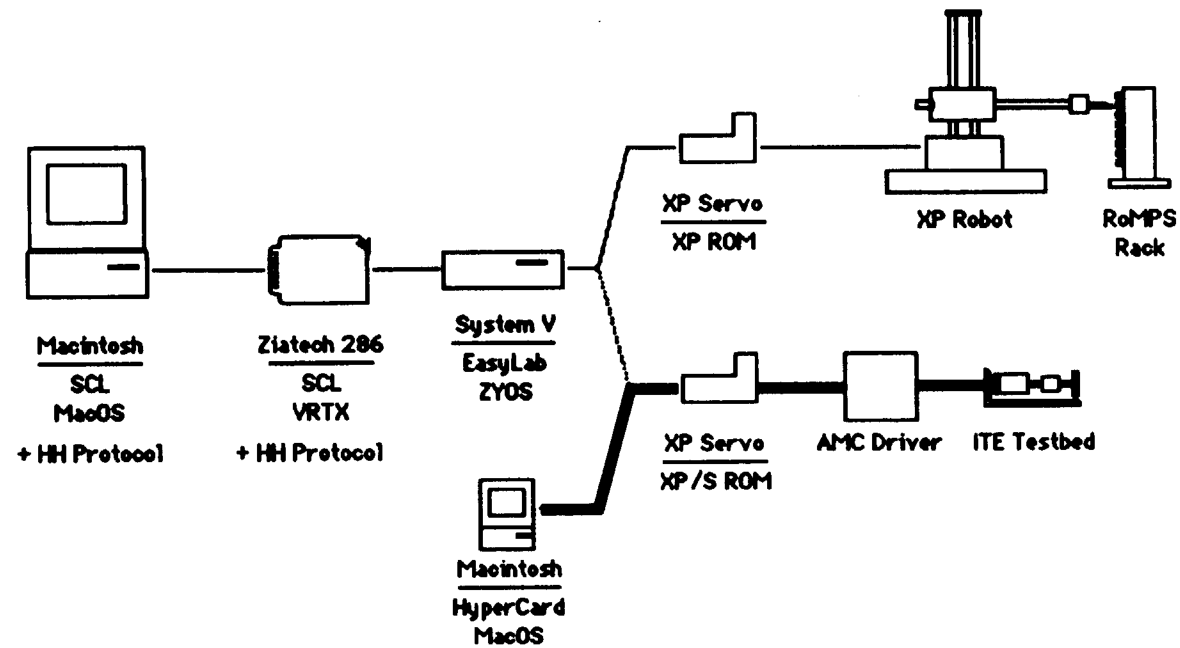
RoMPS

TESTBED AND SIMULATION RESULTS

HoMPS Axis Data Summary

	Elevation	Azimuth	Radial	Gripper	Testbed
Full Scale Travel	18"	44"	4.0"	0.7" (each side)	..
Resolution at End Effector	.004"	.005"	.004"	.004" (each side)	.0156 rev = 5.6°
Gear (effector/motor)	.079"/rev	.280"/rev	.00390"/rev	.00126"/rev	1
Revolutions Full Scale at Motor	227.9 rev	160 rev	1016 rev	560 rev	512 rev
Revolutions Resolution at Motor	.050 rev	.0182 rev	1.016 rev	3.2 rev	
Encoder Pitch at Motor	500 lines/rev	500 lines/rev	.495 lines/rev	3 lines/rev	256 lines/rev
Encoder Pitch at End Effector	6329 lines/inch	1786 lines/inch	127 lines/inch	2381 lines/inch	256 lines/rev
Decoder Gain	4 steps/line	4 steps/line	4 steps/line	4 steps/line	4
Full Scale Counts	455,700 steps	320,000 steps	2,012 steps	6,720 steps	..
Counter Size	19 bits = 524,288	19 bits = 524,288	11 bits = 2,048	13 bits = 8,192	19 bits = 524,288
Counter Steps for Resolution	101.6 steps	36.36 steps	2.012 steps	38.4 steps	
DAC Voltage at Full Scale	8.692V FS	6.104V	9.823V	8.203V	10.000V
Voltage for Resolution	1.93 mV	.694 mV	9.82 mV	46 mV	
A/D Count Range	14,241 counts	10,001 counts	16,093 counts	13,440 counts	16384
Motor Model #	RBEH 01502	RBEH 01201	RBEH 00401	RBE 00700	RBEH 00704
No Load Speed	1300 RPM	2500	14100	6500	2500
Moment of Inertia	.005 oz-in-sec2	0.0013	0.000027	0.00013	0.00045
Torque Constant	15.1 oz-in/√W	7.4	1.13	2.5	8.6
Motor Resistance	2.5 ohm	2.9	3.9	3.7	2.1
Motor Viscous Damping	.0017 oz-in/RPM	0.00035	0.0000124	0.000069	0.00032
Motor Hysteresis Drag Torque	2.44 oz-in	0.92	0.12	0.26	1.1
Motor Cogging Torque	3.6 oz-in	2.2	0.5	0.9	2.8
Gear Efficiency	0.9	0.6	0.5	0.21	..
Total Inertia	0.00706 oz-in-sec2	0.004	0.0000324	0.000425	.013 est
Total Viscous Friction	.0162 oz-in-sec	0.0033	0.000118	0.00066	.004 est
Total Coulomb Friction	10.34 oz-in	10.72	1.3	4.96	3.5 est
Accuracy Required (at motor)	±.05 rev	±.0145 rev	±1.00 rev	±3.2 rev	±.1 rev
Torque Required	9.24 oz-in	5.6	0.54	0.75	..
Speed Required	650 RPM	1250	7000	3250	1250

RoMPS Testbed Phase II



XP COMMERCIAL TESTBED PHASE A RESULTS

PARAMETER	TESTBED	ELEV	AZIM	RAD	GRIP
FULL SCALE TRAVEL [REV'S]	512	228	160	1016	560
RESOLUTION [%FS]	$8.2\ 10^{-3}$ [14-bit $=6.1\ 10^{-3}$	$2.2\ 10^{-2}$	$1.2\ 10^{-2}$	$1.0\ 10^{-1}$	$5.7\ 10^{-1}$
MAX VELOCITY [REV SEC^{-1}]	20 [MOTOR LIMIT]	10.8	20.8	117	54.2
SETTLE / DAMPING	CRITICAL				

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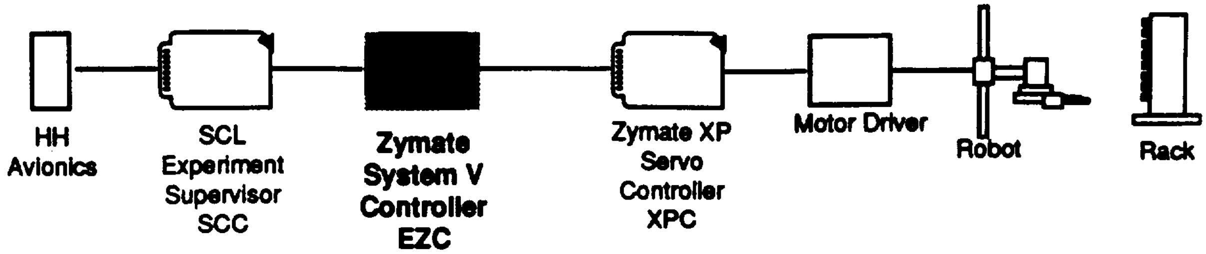
SYSTEM V
CONTROLLER

Nominal Operation of the Zymate System V Controller



UPON RESET

1) Zymate Operating System (ZYOS) Startup

- System Hardware (timers, disk drives, etc.) is initialized and assocciated and Interupt Service Routines initiallized
- Memory, Task and Message Manager structures inittiallized
- Language Editor, EasyLab Interpreter, Disk Manager and Data Dictionary Manager structures initiallized

2) Load the ROMPS Application Data Dictionary

- Read from ROM (flight) or disk (ground development) the AutoLoad System File Containing the ROMPS EasyLab programs, Robot PyTechnology, Furnace PyTechnology, Launch Rack PyTechnology

3) ZYOS Starts Task Dispatching

- The Robot and Furnace Module Tasks in turn become the active task, execute their module initialization code, then return to the task ready list to await for a command at their exchange
- Watchdog Timer Task begins execution

4) EasyLab Interpreter Executes Startup EasyLab Program

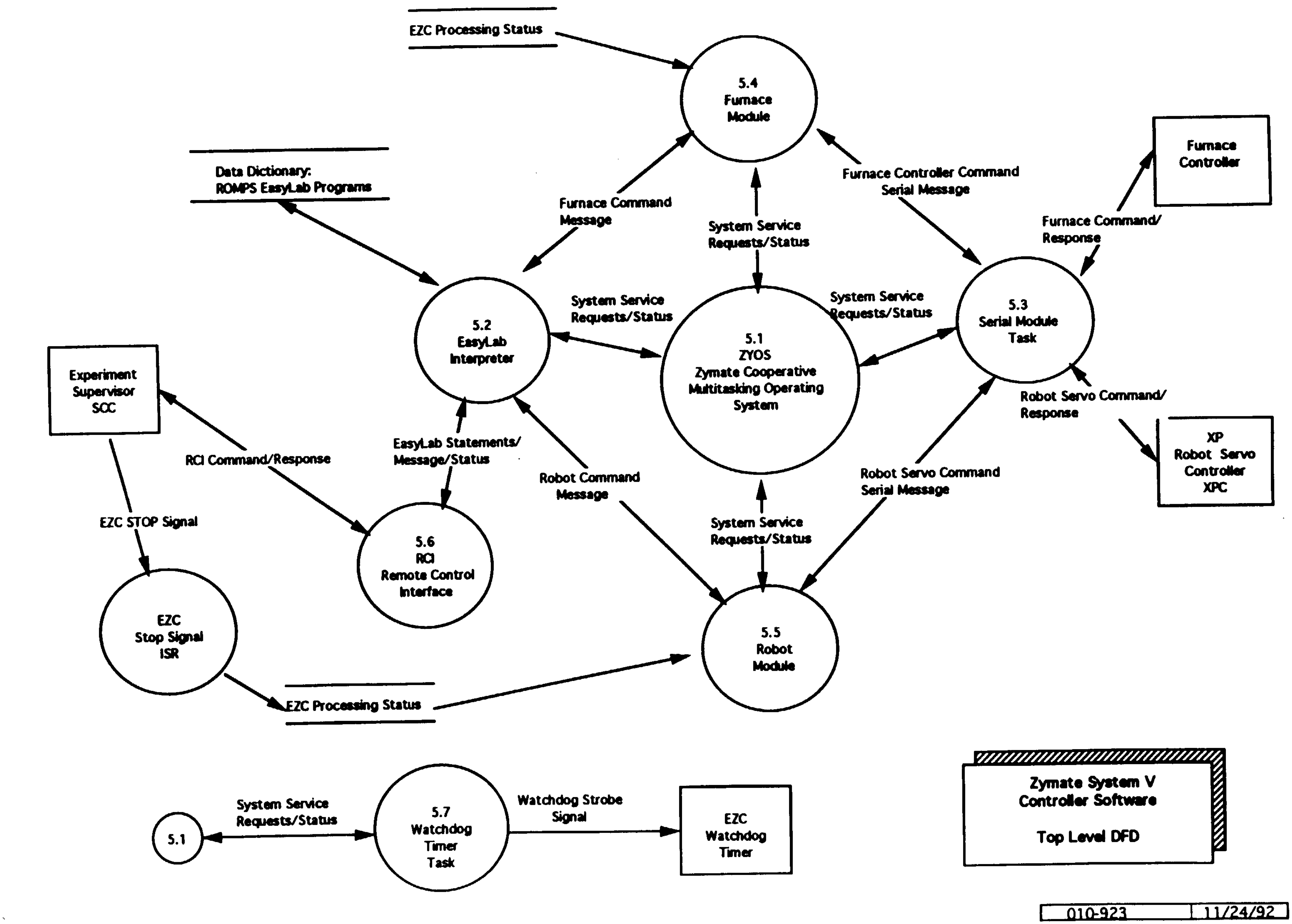
- The EasyLab Intrepeter exectutes the ROMPS startup script AUTOSTART, which executes the command to put the system into Remote Control Mode

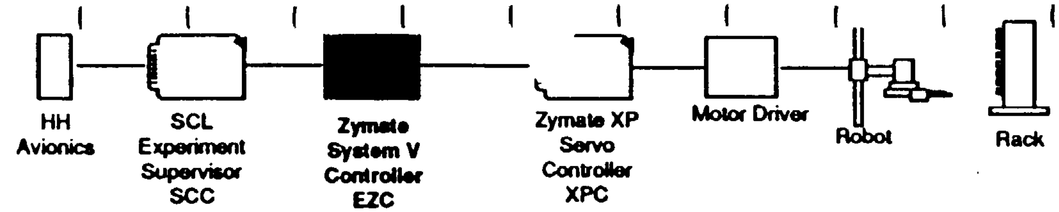
5) System Begins Normal EasyLab Processing

Loop Forever

- Remote Control Interface Task waits to get a EasyLab Command to pass to Interpreter
- EasyLab Interpreter gets commands from RCI processing EasyLab Programs and forwarding Robot and Furnace Module Commands to their respective tasks
- Robot and Furnace Module process any commands sent to them, issuing commands themselves to the XP Robot Servo and the Furnace Controller

End Loop

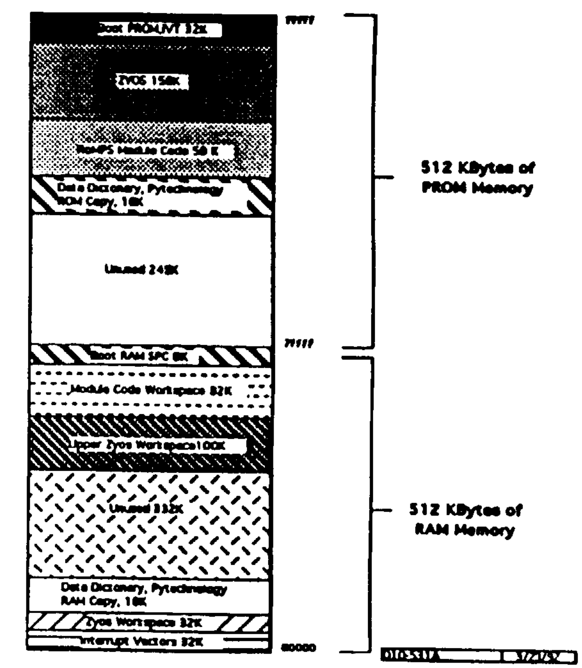

EZC Processing Status
5.4
Furnace
Module
Data Dictionary:
ROMPS EasyLab Programs
Furnace Command
Message
System Service
Requests/Status
Furnace Controller Command
Serial Message
Furnace
Controller
Furnace Command/
Response
5.2
EasyLab
Interpreter
System Service
Requests/Status
5.1
ZYOS
Zymate Cooperative
Multitasking Operating
System
System Service
Requests/Status
5.3
Serial Module
Task
Experiment
Supervisor
SCC
Robot Servo Command/
Response
XP
Robot Servo
Controller
XPC
RCI Command/Response
EasyLab Statements/
Message/Status
Robot Command
Message
Robot Servo Command
Serial Message
EZC STOP Signal
5.6
RCI
Remote Control
Interface
System Service
Requests/Status
5.5
Robot
Module
EZC
Stop Signal
ISR
EZC Processing Status
5.1
System Service
Requests/Status
5.7
Watchdog
Timer
Task
Watchdog Strobe
Signal
EZC
Watchdog
Timer
Zymate System V
Controller Software
Top Level DFD
010-923
11/24/92



SYSTEM V EASYLAB SOFTWARE PERFORMANCE/MARGIN

EZC Experiment Controller	Commercial CPU 80188	RoMPS CPU 80386
# lines of EasyLab for "move sample to rack"	20	20
EZC Interpreter Thruput in lines-per-second	10 sec^{-1}	100 sec^{-1}
Software Time vs Mechanism Time [assuming 50% elevation + 100% radial, azimuth & gripper]	2 sec 35 sec	0.2 sec 35 sec
CPU Margin	17x	170x

RoMPS EasyLab System V Controller Memory Map



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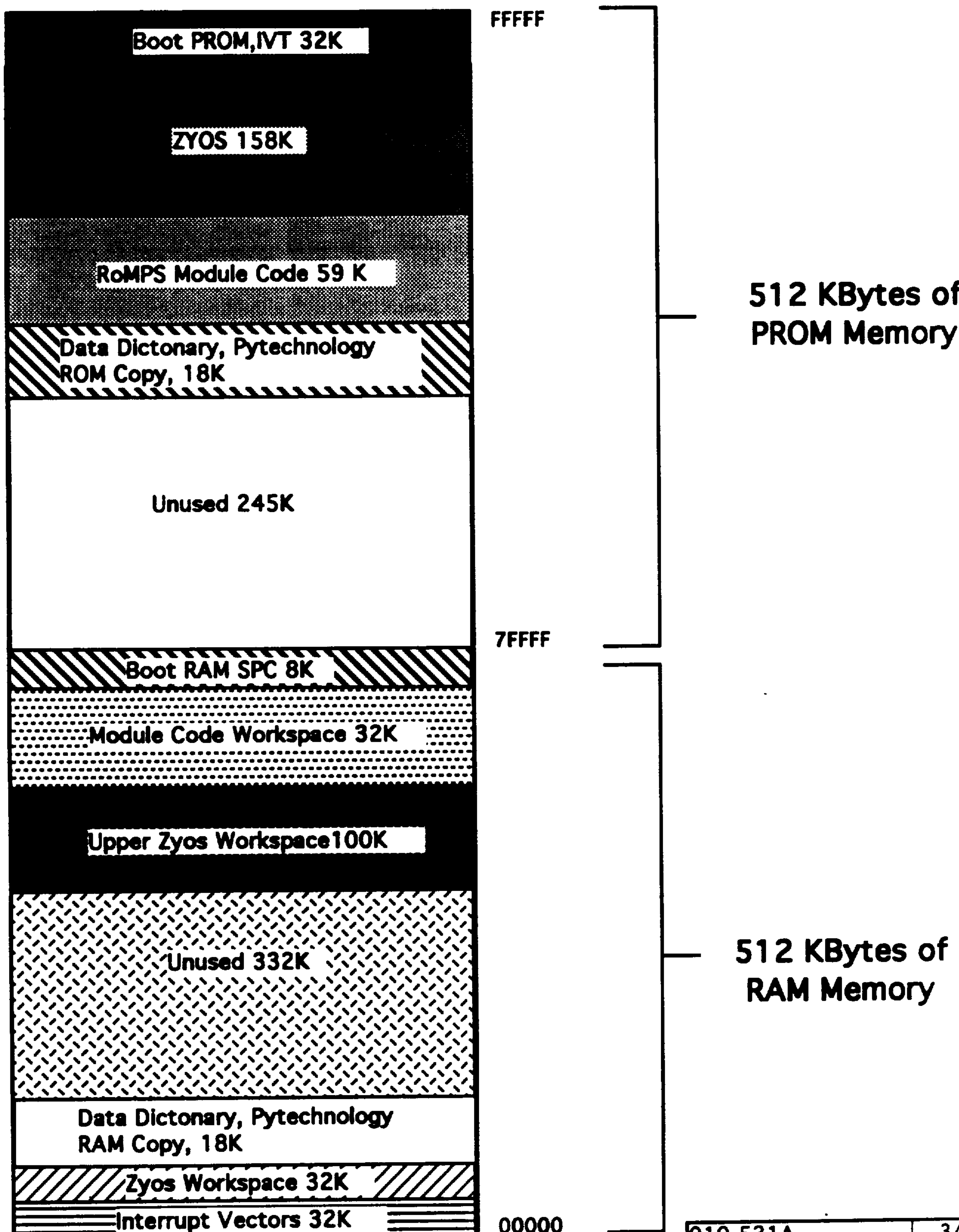
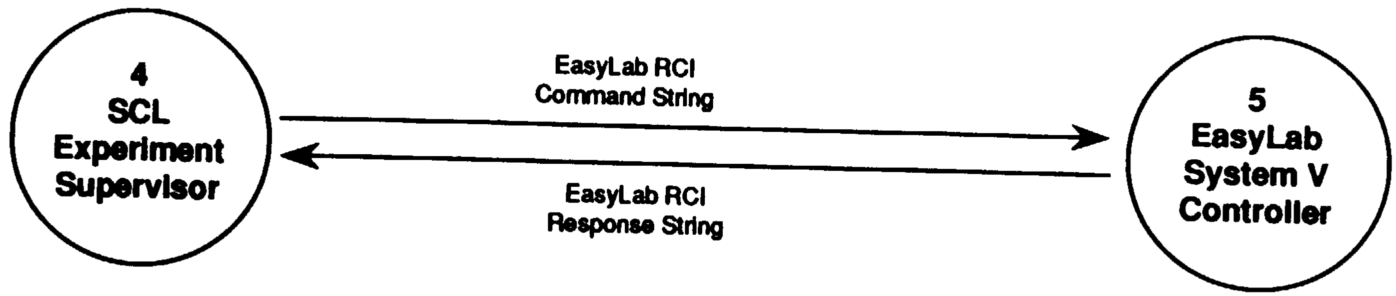
RoMPS EasyLab System V Controller Memory Map

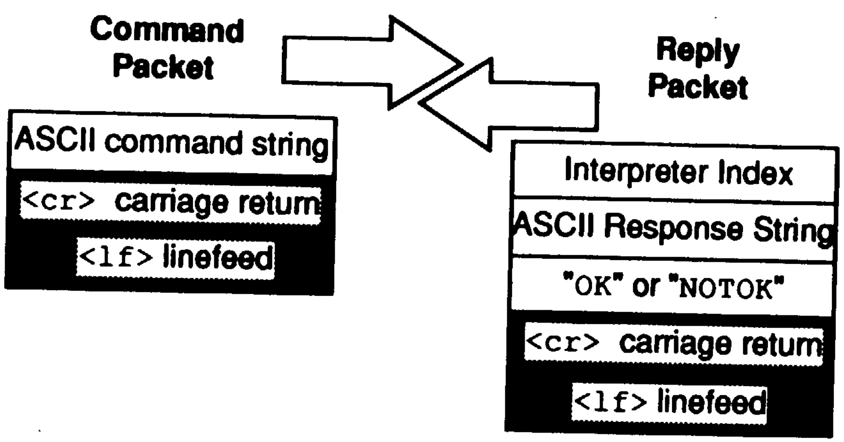


010-531A 3/23/92

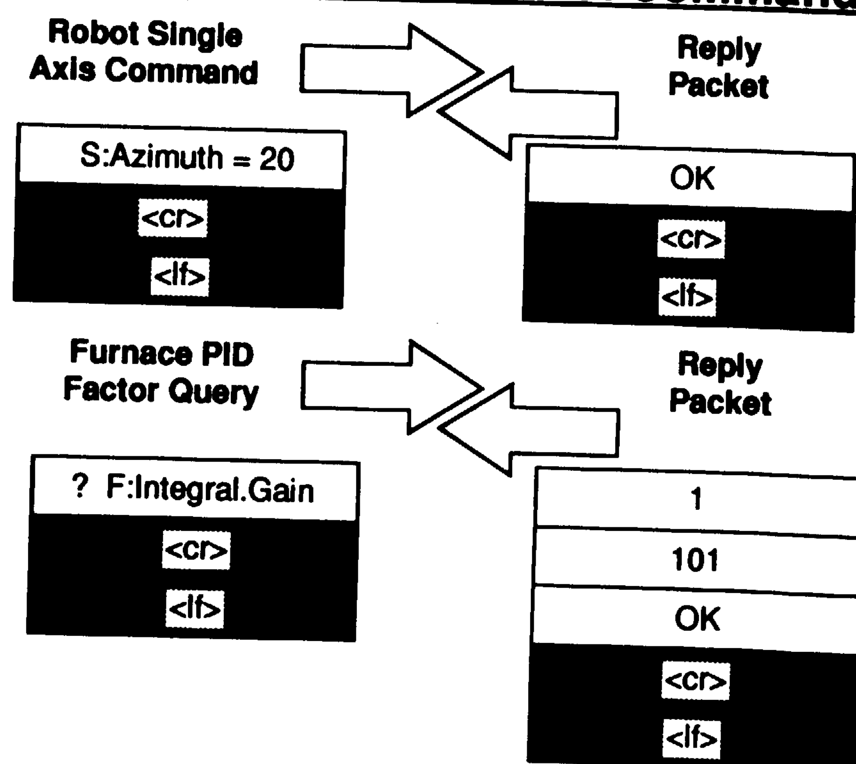
ROMPS
EasyLab Remote Control Interface Protocol



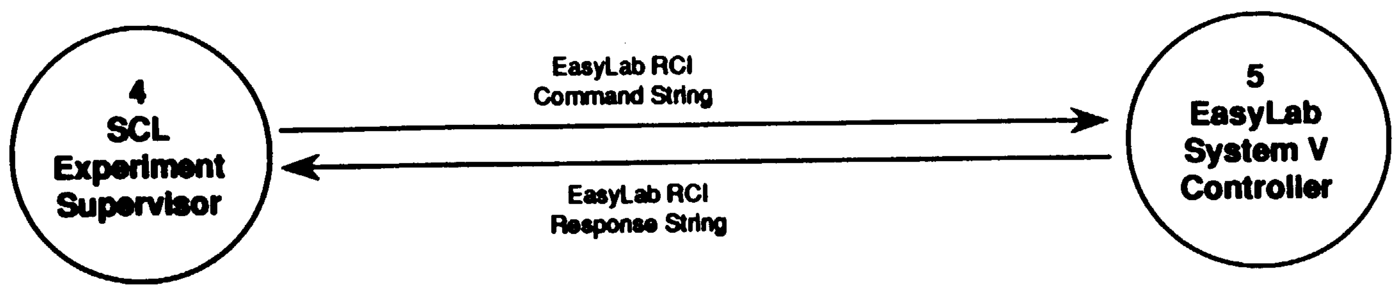
Command/Reply Packets for Generic RCI Command



Command/Reply Packets for Specific ROMPS RCI Commands



ROMPS
EasyLab Remote Control Interface Protocol



Command/Reply Packets for Generic RCI Command

Command Packet

ASCII command string
<cr> carriage return
<lf> linefeed

Reply Packet

Interpreter Index
ASCII Response String
"OK" or "NOTOK"
<cr> carriage return
<lf> linefeed

Command/Reply Packets for Specific ROMPS RCI Commands

Robot Single Axis Command

S:Azimuth = 20
<cr>
<lf>

Reply Packet

OK
<cr>
<lf>

Furnace PID Factor Query

? F:Integral.Gain
<cr>
<lf>

Reply Packet

1
101
OK
<cr>
<lf>

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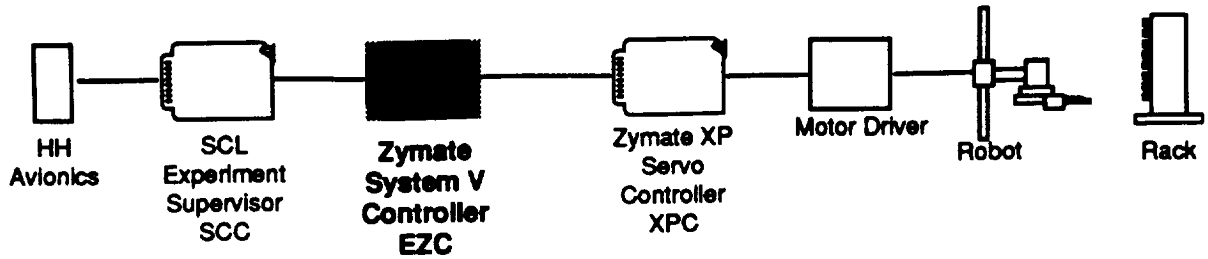
ROBOT MODULE

Nominal Operation of the ROMPS Robot Module



UPON Robot Module Becoming Active Task for the First Time

1) Enter Robot Module into Zymate Operating System Environment

- Create a Module Login Entry in the Zymate Data Dictionary
- Create a Message Exchange between EasyLab Interpreter and Robot Module

2) Initiallize the Robot Modules Operating Paramters

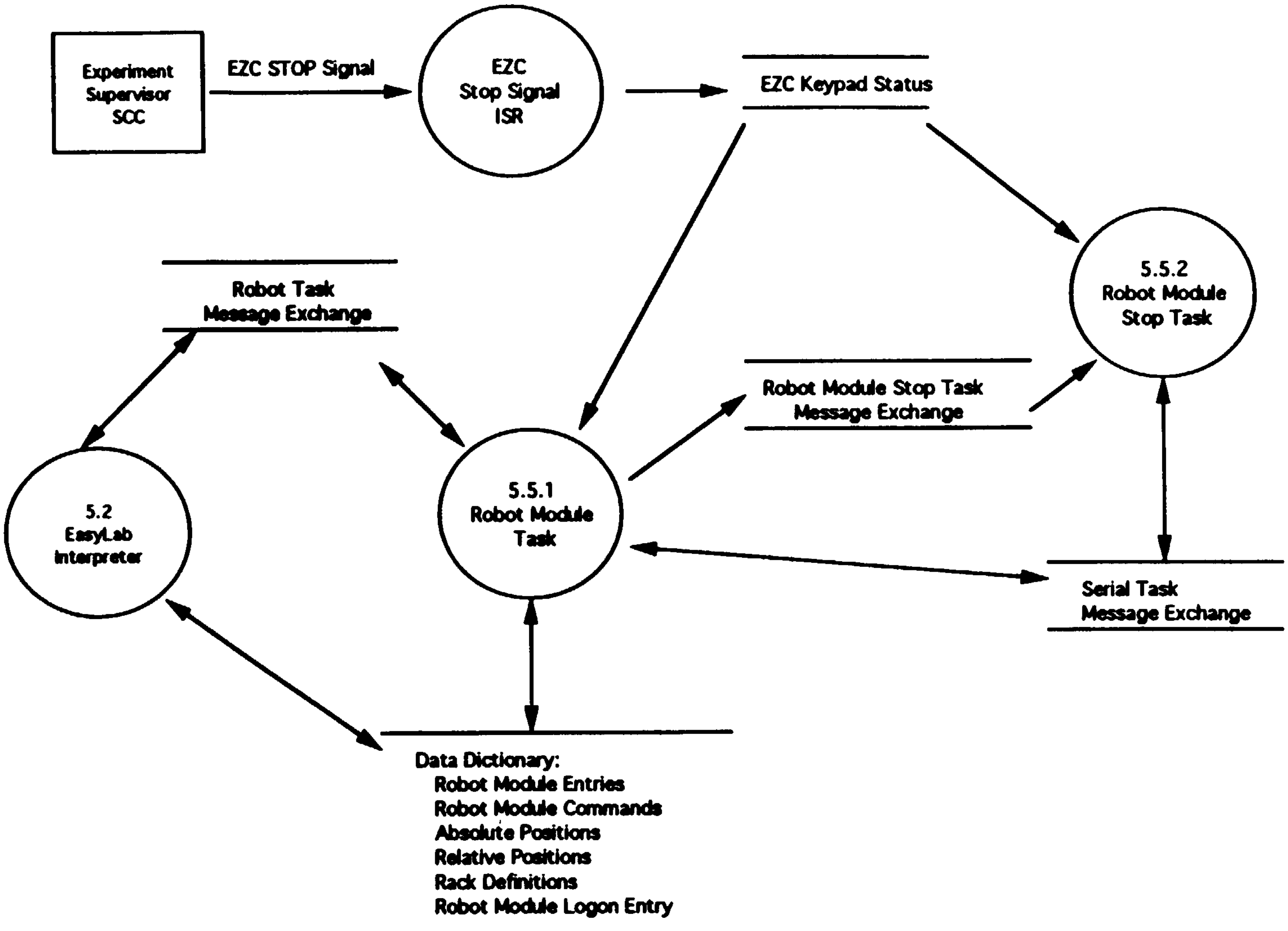
- Create a Message Exchange between Robot Module and Serial Task in order to communicate with XP Robot Servo via Serial Channel
- Create Stop task which monitors the STOP data structure during Moves
- Get user-unit to robot unit conversion factors from XP Robot Servo
- Get Present Base and Wrist Position from XP Robot Servo
- Compute default Base and Wrist Speeds.Accellerations, Robot Movement Wait and Transition parameters, send these settings to XP Robot Servo
- Send Base and Wrist Move commands for present position

3) Robot Module Begins Normal Command Processing

Loop Forever

- Wait for a Command Message from the EasyLab Interpreter
- Get the Command Code from the Command Message
- Send the appropriate Robot Servo Commands and update the appropriate internal data stores corresponding to the Command Code contained in the Command Message, **see Robot EasyLab Command Variable Table**
- Return the Command Message to the Interpreter, setting the Return.To.Exec code to Success or Stop, Cont, Step or Abort code if an Robot Module Detected error condition occurred

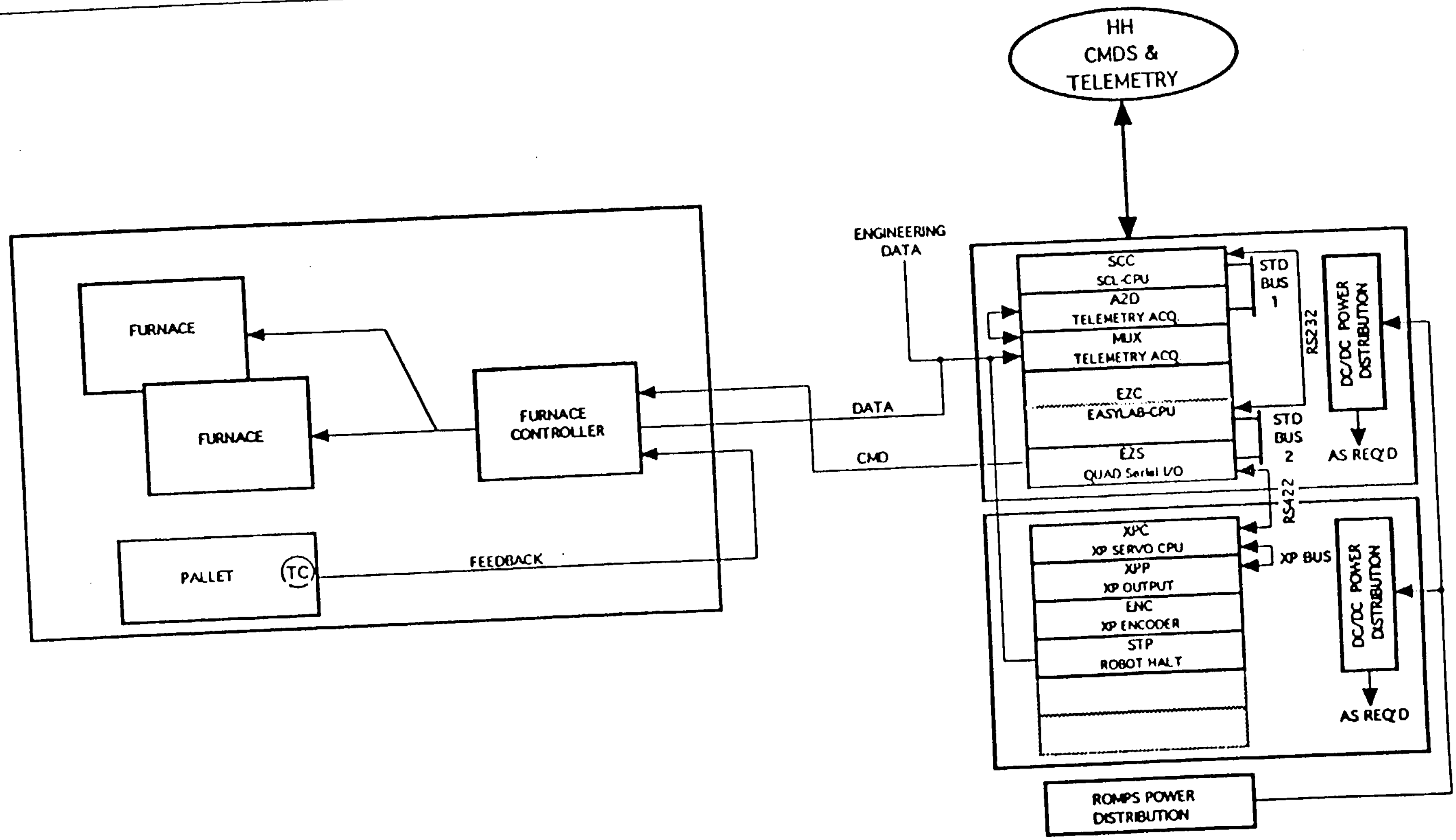
End Loop



Zymate System V
Controller Software

Robot Module DFD

010-914	11/24/92



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10/13/92
DATE

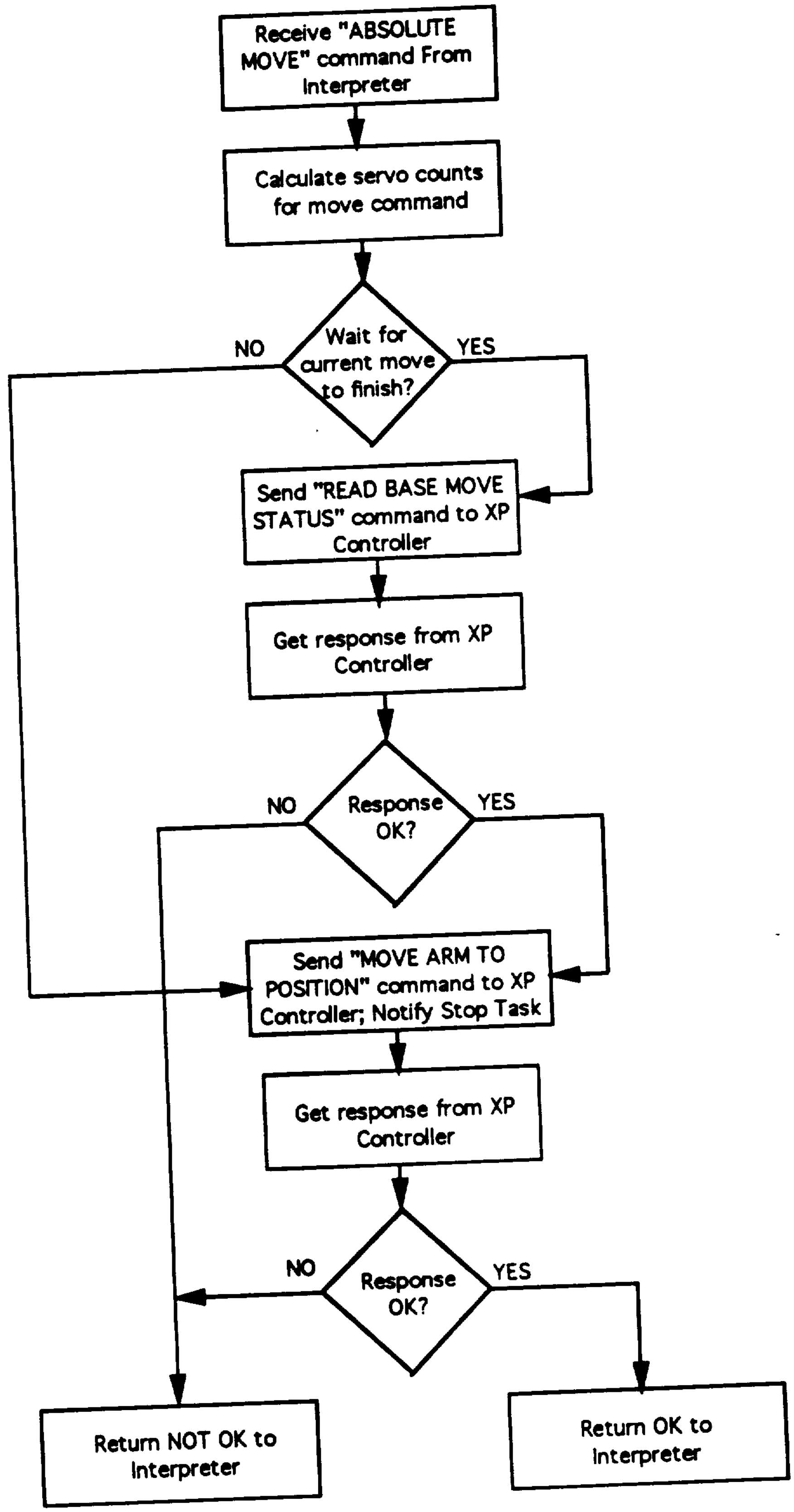
Summary Table of Original Robot Module EasyLab Command Variables

ID	NAME	FUNCTION
Ground Support/Systems Integration		
0	Program Zymate Robot	Bring up the Robot Module Teaching Screens (Ground Only)
Base and Gripper Positioning Commands		
1	Absolute Base Axis Postion	Move Robot Base Axis to Coordinates of a pre-defined Absolute Position
2	Relative Base Axis Postion	Move Robot Base Axis to Coordinates of a pre-defined Offset from last Absolute Move
3	Gripper Location	Move Robot Gripper Axis to Coordinates of a pre-defined Absolute Position
4	Rack Position	Move Robot Base Axis to Coordinates of a specified Rack Element
9	Elevation Axis Postion	Input : Moves the Robot Elevation Axis to Assigned Vertical Coordinate, cm units Output: Returns the last reached Elevation Axis Coordinate, cm units
10	Radial Axis Position	Input : Moves the Robot Radial Axis to Assigned Vertical Coordinate, cm units Output: Returns the last reached Radial Axis Coordinate, cm units
11	Azimuth Axis Position	Input : Moves the Robot Azimuth Axis to Assigned Vertical Coordinate, cm units Output: Returns the last reached Azimuth Axis Coordinate, cm units
37	Gripper Axis Position	Input : Moves the Robot Gripper Axis to Assigned Vertical Coordinate, cm units Output: Returns the last reached Gripper Axis Coordinate, cm units
Base and Gripper Position Control Commands		
15	All Base Axis Speed Setting	Input/Output: Speed Control setting for all Base Axis
16	Elevation Speed Setting	Input/Output: Speed Control setting for Elevation Axis
17	Radial Speed Setting	Input/Output: Speed Control setting for Radial Axis
18	Azimuth Speed Setting	Input/Output: Speed Control setting for Azimuth Axis
20	Gripper Speed Setting	Input/Output: Speed Control setting for Gripper Axis
28	Set Absolute Base Position	Sets the Last Position reached data store to a pre-defined Absolute Postion, no movement
31	Transition Positioning On Command	Turn on flag allowing Transitional Movement Command Processing
32	Transition Positioning Off Command	Turn off flag allowing Transitional Movement Command Processing
35	Gripper Definition	Sets Current Gripper Geometry to a predefined Gripper Definition

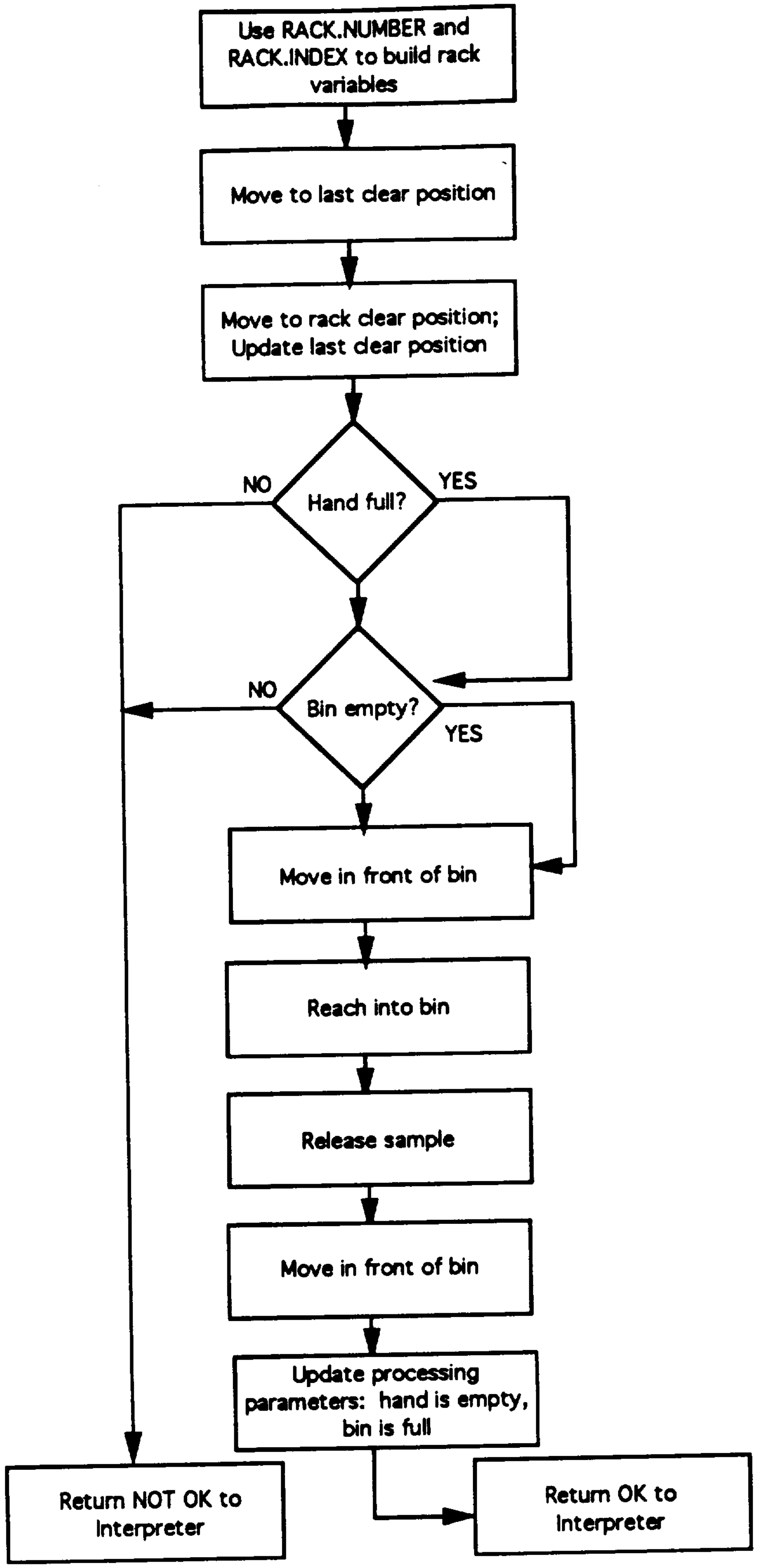
Summary Table of New Robot Module EasyLab Command Variables

ID	NAME	FUNCTION
Command Line Position Modification		
50	Elevation Position Storage	Input/Output: Elevation Coordinate for a Zymate Data Dictionary Robot Position
51	Radial Position Storage	Input/Output: Radial Coordinate for a Zymate Data Dictionary Robot Position
52	Azimuth Position Storage	Input/Output: Azimuth Coordinate for a Zymate Data Dictionary Robot Position
53	Gripper Position Storage	Input/Output: Gripper Coordinate for a Zymate Data Dictionary Robot Position
54	Define/Modify Robot Base Position	Updates Robot Base Position Variable to Values of Position Stores
55	Check Robot Base Position	Updates Position Stores to the coordinates of the Queried Base Position Variable
56	Define/Modify Robot Gripper Position	Updates Robot Gripper Position Variable to Values of Position Stores
57	Check Robot Gripper Position	Updates Position Stores to the coordinates of the Queried Gripper Position Variable
XP Servo Encoder Calibration		
58-61	Zero Elevation, Radial, Azimuth, or Gripper Encoder	Causes the STP Encoder Value to be rest for the specified Axis
62-65	Auto Zero Elevation, Radial, Azimuth, or Griiper	Causes the XP Servo to execute a series of moves which will caliabrate the speciefied Axis
XP Servo Algorithm Modification		
66-69	Servo Proportional Factors	Input/Output: Scaling Factors applied to Proportianal element of PID Algorithm
70-73	Servo Integral Factors	Input/Output: Scaling Factors applied to Integral element of PID Algorithm
74-77	Servo Derivative Factors	Input/Output: Scaling Factors applied to Derivative element of PID Algorithm
78-81	Servo Integral Limit	Input/Output: Scaling Factors applied to Proportianal element of PID Algorithm
82-85	Servo Intergral Window	Input/Output: Scaling Factors applied to Proportianal element of PID Algorithm
XP Servo Processing		
86-89	EOT Axis Overides	Input/Output: sets/gets status of flags used to overide the OVF status inputs to XP for an Axis
90-93	Overforce Axis Overides	Input/Output: sets/gets status of flags used to overide the EOT status inputs to XP for an Axis
Robot Module/XP Status		
94	Axis Overforce Status	Reports the Overforce Status returned from XP Servo
95	Axis EOT Status	Reports the EOT Status returned from XP Servo
96	Axis Velocity Anamolly Status	Reports the Velocity Anamolly Status returned from XP Servo
97	Base Axis Status	Reports if Servo reached commanded Base Axis coordinates
98	Gripper Axis Status	Reports if Servo reached commanded Grip Axis Coordinates
99	Robot to Servo Communication Status	Reports the Error Status of the last Servo Communication
100	Robot Module Error Status	Robot Module Command Processing Error Status Code

ABSOLUTE MOVE COMMAND VARIABLE PROCESSING FLOW CHART



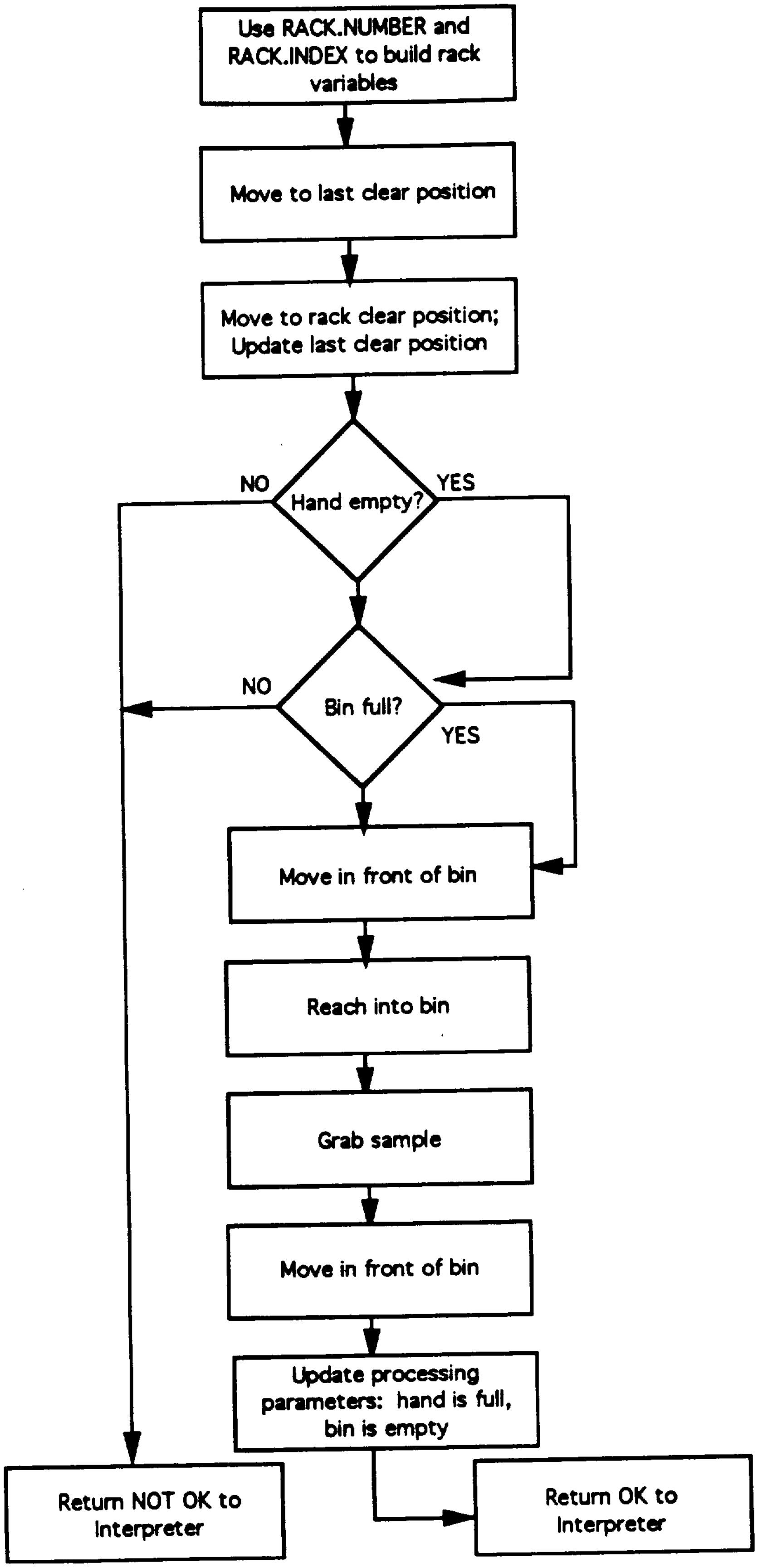
EASYLAB PROGRAM: PUT.INTO.RACK
PROCESSING FLOW CHART



Robot Module Software Fault Handling Summary

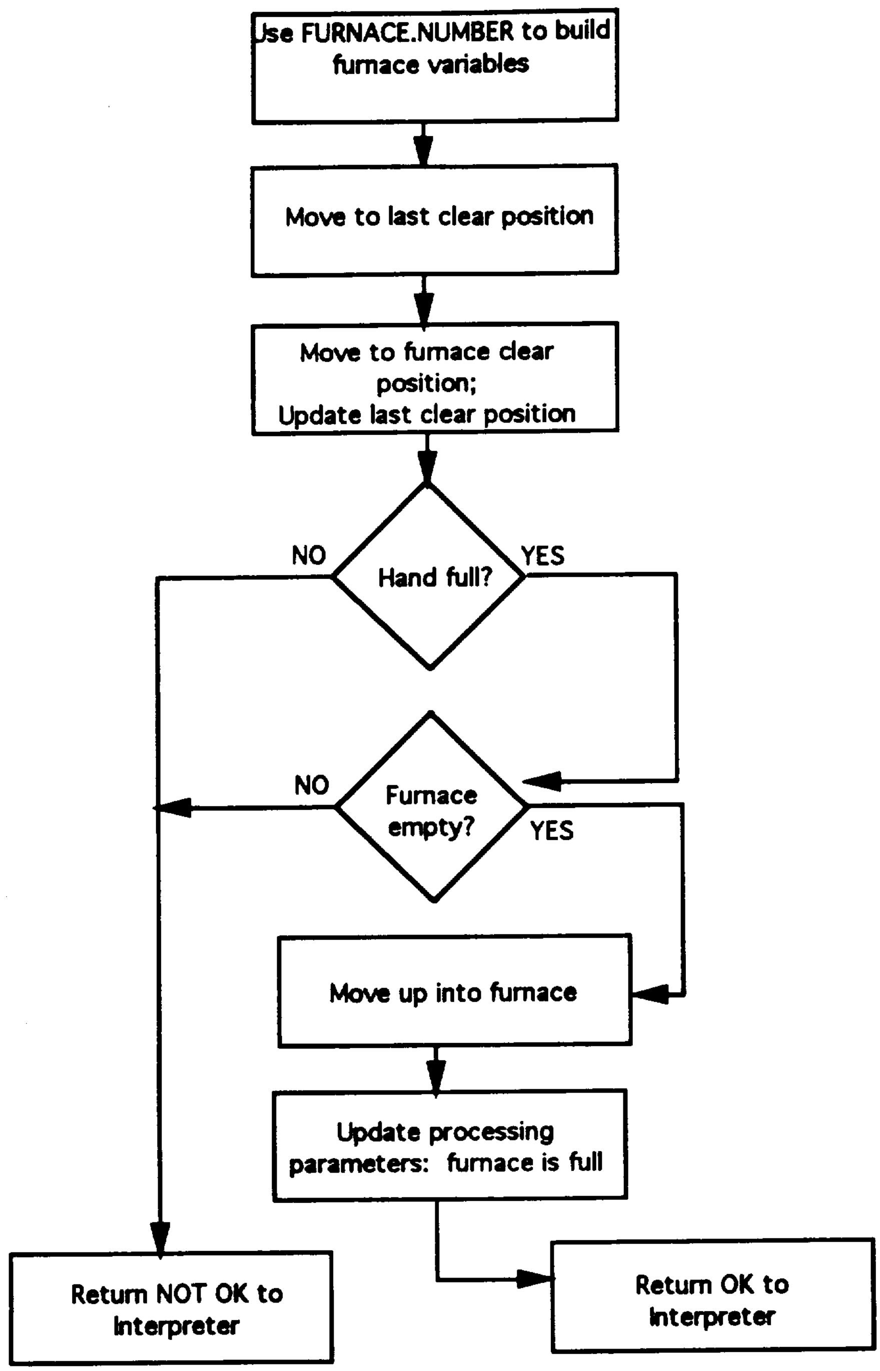
Fault Condition	Fault Detection	Fault Response
STOP EZC Processing	User presses STOP key OR System ISR updates EZC Processing status monitored by Robot Stop Task.	Robot Stop Task sends "STOP ROBOT" command to XP Servo Controller. Robot Task updates Error Status and terminates command.
Robot/XP Communication Error	Robot Task sends a message to the XP Servo Controller; XP Servo Controller sends a one byte error code in response.	Robot Task attempts to send the message until the retries are exhausted, then updates Error Status and terminates command.
End of Travel, Overforce, or Velocity Anomaly Fault	Robot Task sends a "READ LIMIT STATUS" message to the XP Servo Controller; XP Servo Controller sends three status bytes in response.	Robot Task updates Error Status and terminates command.
Axis Failed to Reach Position	Robot Task sends a "READ MOVE STATUS" message to the XP Servo Controller; XP Servo Controller sends one status byte in response.	Robot Task updates Error Status and terminates command.
Invalid Command	Robot Task compares Command Code to valid Command Codes.	Robot Task updates Error Status and terminates command.
Command Is Not For This Robot	Robot Task compares Command Module ID to it's own Module ID	Robot Task updates Error Status and terminates command.
Illegal Rack Index	Robot Task compares the Command Rack Index with the number of rows multiplied by the number of columns in the rack.	Robot Task updates Error Status and terminates command.

EASYLAB PROGRAM: GET.FROM.RACK
PROCESSING FLOW CHART

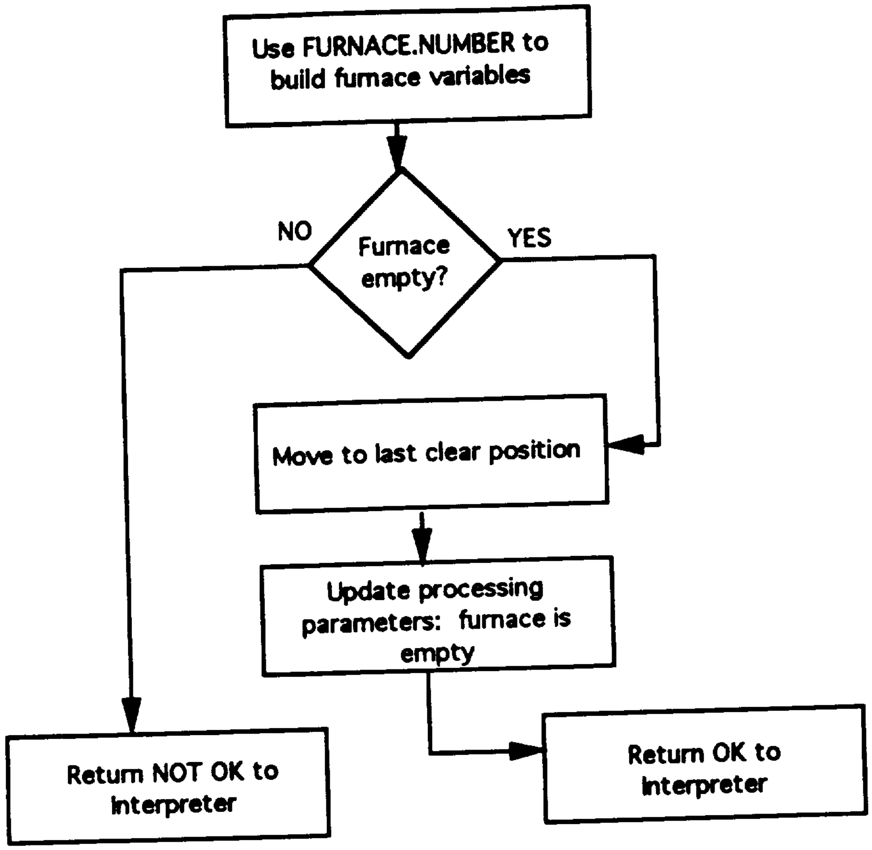


010-705	11/24/92

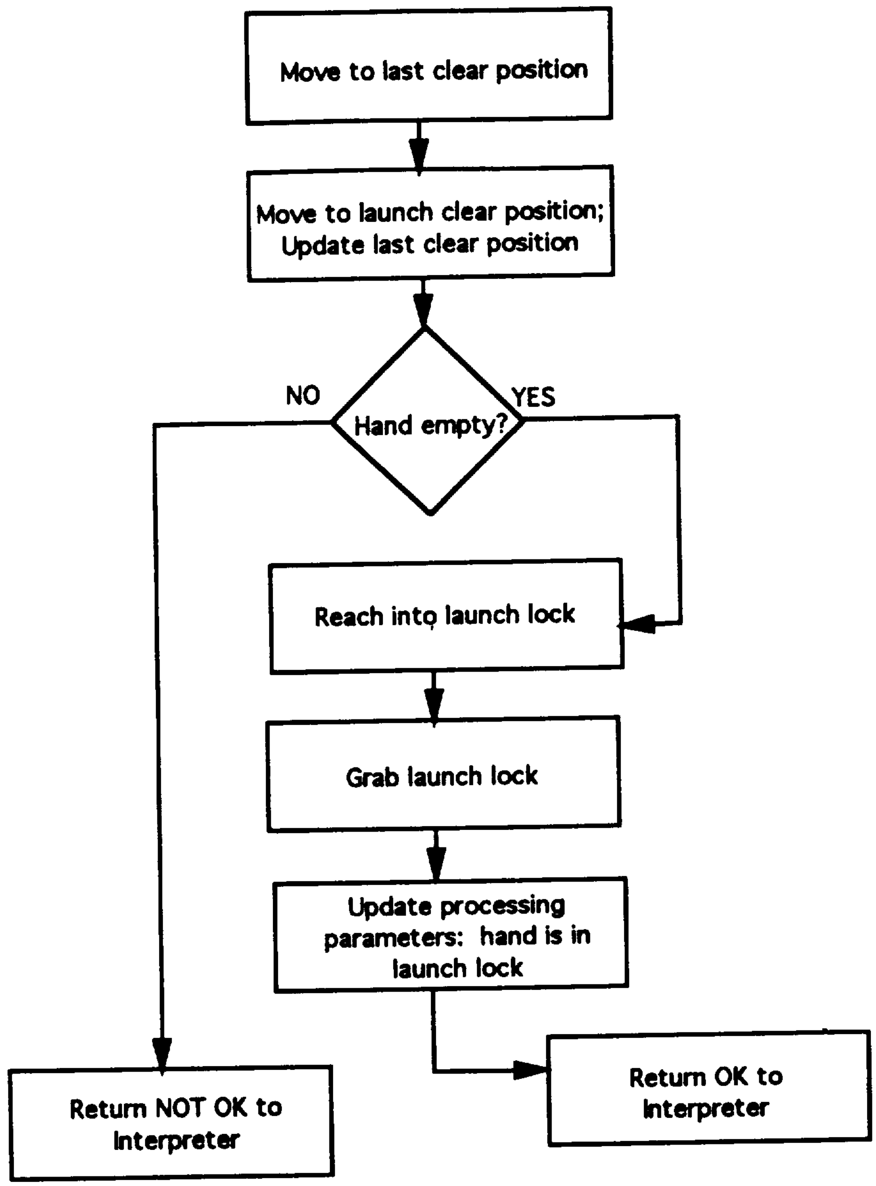
EASYLAB PROGRAM: PUT.INTO.FURNACE
PROCESSING FLOW CHART



EASYLAB PROGRAM: GET.FROM.FURNACE
PROCESSING FLOW CHART



EASYLAB PROGRAM: LAUNCH.LOCK
PROCESSING FLOW CHART



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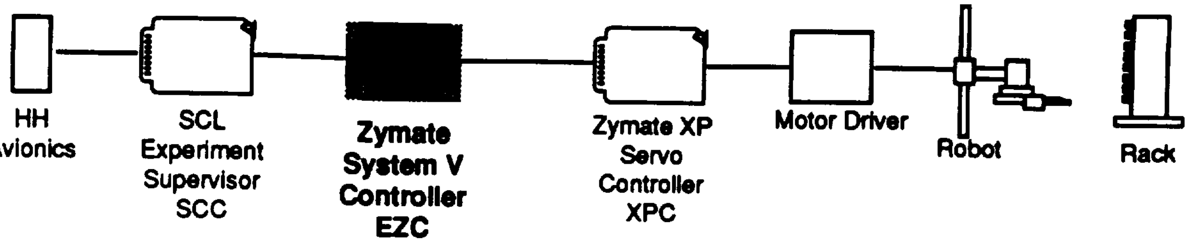
FURNACE MODULE

Nominal Operation of the ROMPS Furnace Module



UPON Furnace Module Becoming Active Task for the First Time

1) Enter Furnace Module into Zymate Operating System Environment

- Create a Module Login Entry for the Furnace Module in the Zymate Data Dictionary
- Create a Message Exchange between EasyLab Interpreter and Furnace Module

2) Initiallize the Furnace Modules Operating Paramters

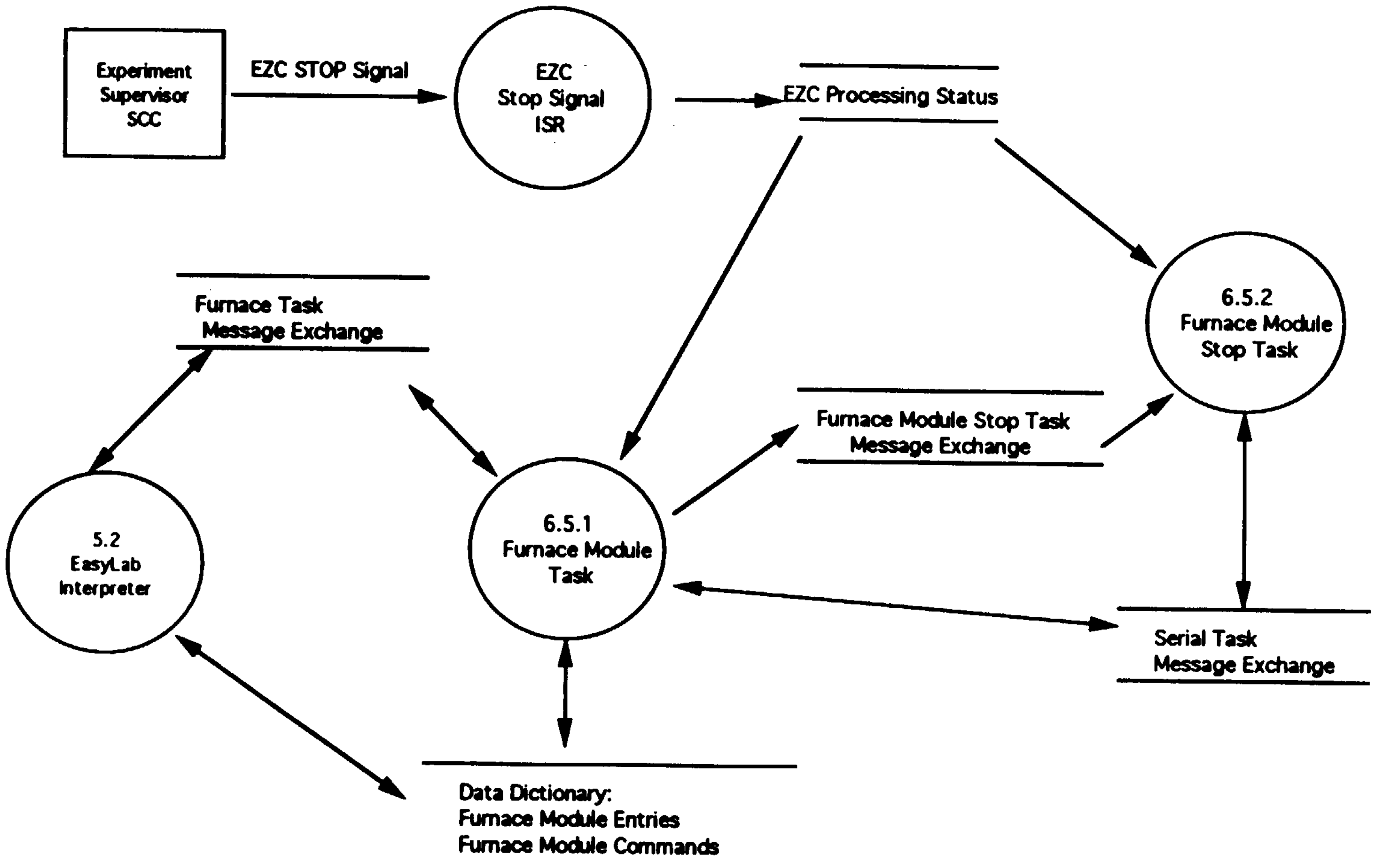
- Create a Message Exchange between Furnace Module and Serial Task in order to communicate with Furnace Controller via a Serial Channel
- Create Stop task which monitors the STOP data structure during Annealing Processing

3) Furnace Module Begins Normal Command Processing

Loop Forever

- Wait for a Command Message from the EasyLab Interpreter
- Get the Command Code from the Command Message
- Send the appropriate Furnace Controller Commands and update the appropriate internal data stores corresponding to the Command Code contained in the Command Message, see **Furnace EasyLab Command Variable Table**
- If the Command Sent was an Execute.Heating.Profile Command
  - for each Initialized Profile.Temp
    - Send a Power/Temp Control Furnace Command for Profile.Temp
    - wait until Profile Time or STOP Task Detects a STOP Signal
  - reset all Profile.Temp and Profile.Time data stores
- Return the Command Message to the Interpreter, setting the Return.To.Exec code to Success or Stop, Cont, Step or Abort code if a Furnace Module Detected error condition occurred

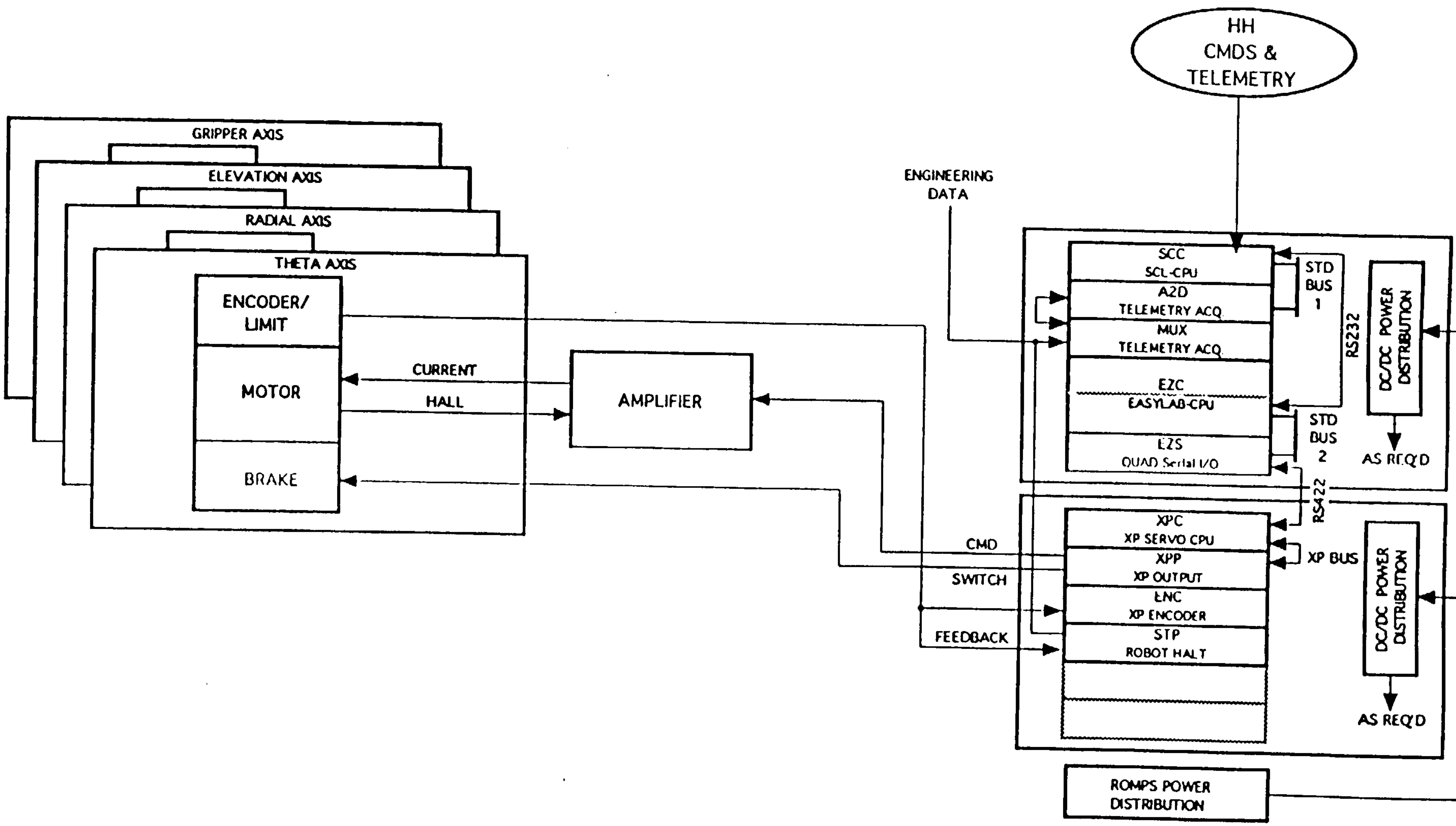
End Loop



Zymate System V
Controller Software

Furnace Module DFD

010-910	11/24/92



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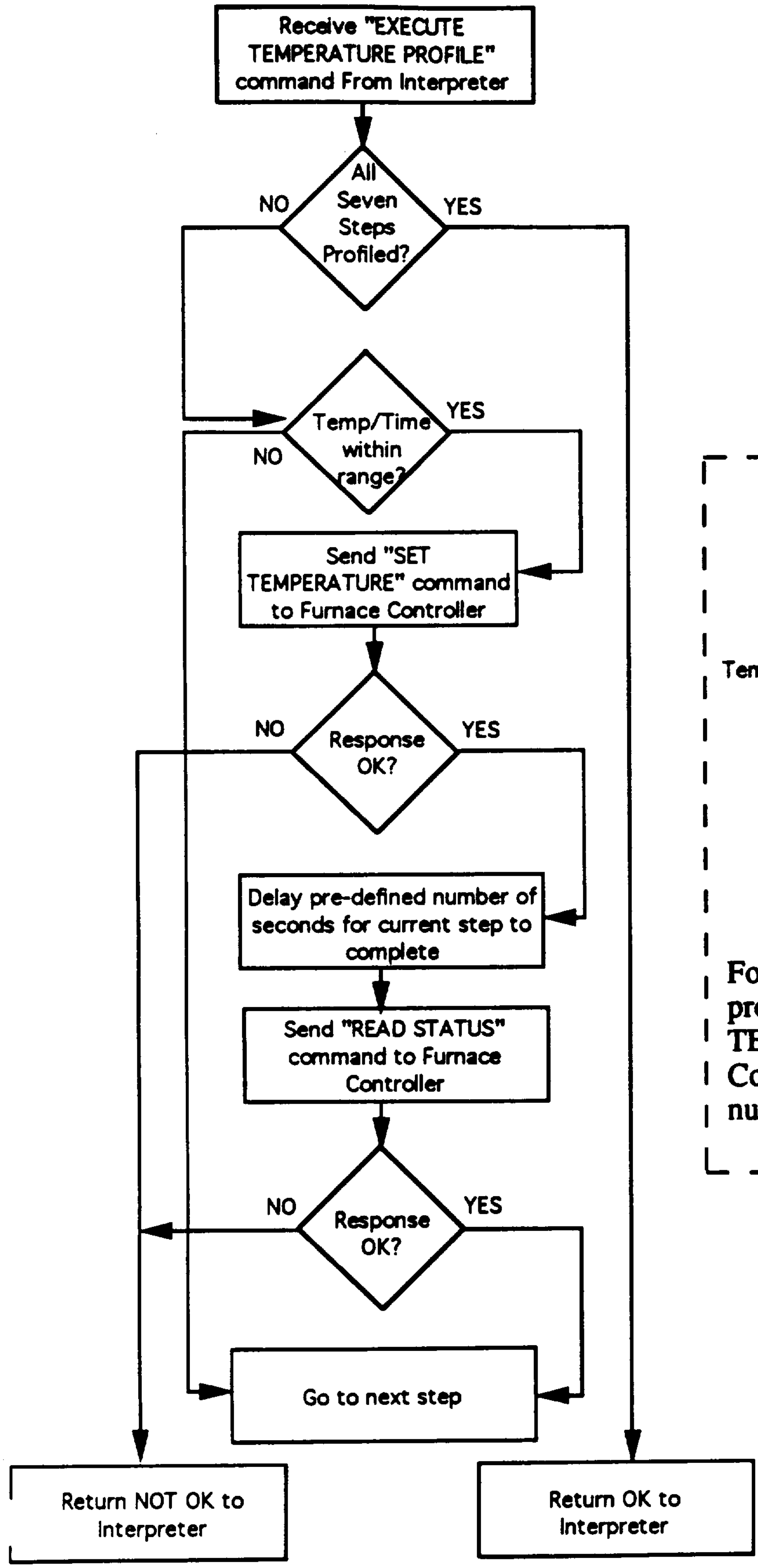
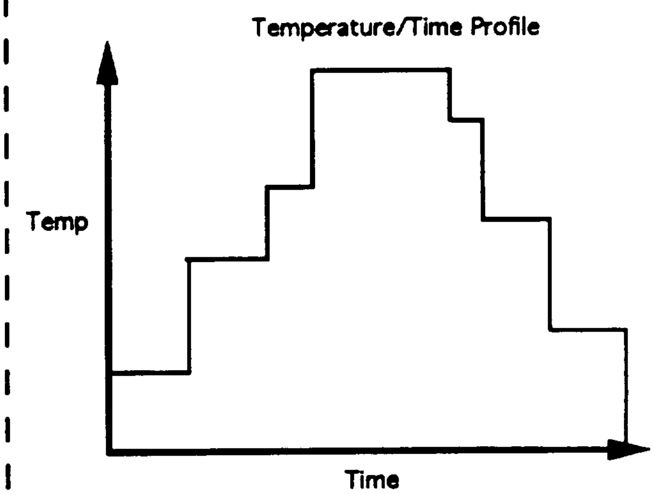
1.20

EXECUTE TEMPERATURE PROFILE COMMAND
VARIABLE PROCESSING FLOW CHART





For each of the seven steps of a temperature profile, the Furnace Module sends a "SET TEMPERATURE" command to the Furnace Controller, and then sleeps for a pre-defined number of seconds for the current step

Furnace Module Software Fault Handling Summary

Fault Condition	Fault Detection	Fault Response
STOP EZC Processing	User presses STOP key OR System ISR updates EZC Processing status monitored by Stop Task.	Stop Task sends "SET POWER = 0" and "SET TEMPERATURE = 0" commands to Furnace Controller. Furnace Task updates Error Status and terminates command.
Furnace/Furnace Controller Communication Error	Furnace Task sends a message to the Furnace Controller; Furnace Controller sends a one byte error code in response.	Furnace Task attempts to send the message until the retries are exhausted, then updates Error Status and terminates command.
Invalid controller command, 28V bus too low to achieve setpoint, overtemp occurred, invalid checksum, setpoint out of range, watchdog timeout	Furnace Task sends a "READ STATUS" message to the Furnace Controller; Furnace Controller sends ten status bytes in response.	Furnace Task updates Error Status and terminates command.
Invalid Command	Furnace Task compares Command Code to valid Command Codes.	Furnace Task updates Error Status and terminates command.
Command Is Not For This Furnace	Furnace Task compares Command Module ID to it's own Module ID	Furnace Task updates Error Status and terminates command.

Summary Table of Furnace Module EasyLab Command Variables

ID	NAME	FUNCTION
Power and Temperature Control		
1	Power Control Setting	Input/Output: Power Control Set Point of Furnace Controller (0-255 watts.)
2	Termperature Control Setting	Input/Output: Temperature Control Set Point of Furnace Controller (0-1600 cent.)
3-9	Temp Profile Steps 1 through 7	Input/Output: Temperature Control Set Points of Temp Controlled Heating Profile
10-16	Power Profile Steps 1 through 7	Input/Output: Power Control Set Points of Power Controlled Heating Profile
17-23	Time Profile Steps 1 through 7	Input/Output: Duration of second of corresponding Power/Temp Heating Profile Step
24	Execute Temp Control Profile Steps	Execute a Temperature Level Controlled Heating Profile
25	Execute Power Control Profile Steps	Execute a Power Level Controlled Heating Profile
26	Clear Power, Temp, and Time Profile Steps	Clear all the previously stored Temp, Power, and Time Profile Steps
Furnace Controller Programming		
27	Proportional Gain Term KP Storage	Input/Output: Scaling Factors applied to Proportianal element of PID Algorithm
28	Integral Gain Term KI Storage	Input/Output: Scaling Factors applied to Integral element of PID Algorithm
29	Derivative Gain Term KD Storage	Input/Output: Scaling Factors applied to Derivative element of PID Algorithm
30	Integrator Limit Storage	Input/Output: Scaling Factors applied to Proportianal element of PID Algorithm
31	Servo Intergral Window Storage	Input/Output: Scaling Factors applied to Proportianal element of PID Algorithm
32	Override Overtemp	Command Furnace Controller to ignore overtemp condtition
33	Override Overtemp Clear	Commands Furnace Controller to NOT ignore overtemp condition
Furnace Controller Status		
34	Furnace Power Status	Output: 1 => Oven A On, 2 => Oven B On
35	Furnace Control Start Status	Output: 1 => Control Start is Enabled, 0 => Control Start Is Disabled
36	Furnace Controller Watchdog Status	Output: 1 => WatchDog Inactive, 0 => WatchDog Active
37	Furnace Controller Setpoint Status	Output: 1 => Setpoint Out of Range, 0 => Setpoint In Range
38	Last Command CheckSum Status	Output: 1 => Last Command Checksum Bad, 0 => Last Command Checksum Good
39	Furnace OverTemp Status	Output: 1 => OverTemp has Occured, 0 => OverTemp has not Occured
40	28 V Bus Status	Output: 1 => 28 Volt Bus Too Low To Reach Setpoint, 0 => Bus Ok
41	Last Command ID Status	Output: 1 => Invalid Command ID received, 0 => Command ID OK
42	Furnace Module SW Detected Errors	Output: 0 => No Errors, >0 => Error Code of last Robot Module Detected

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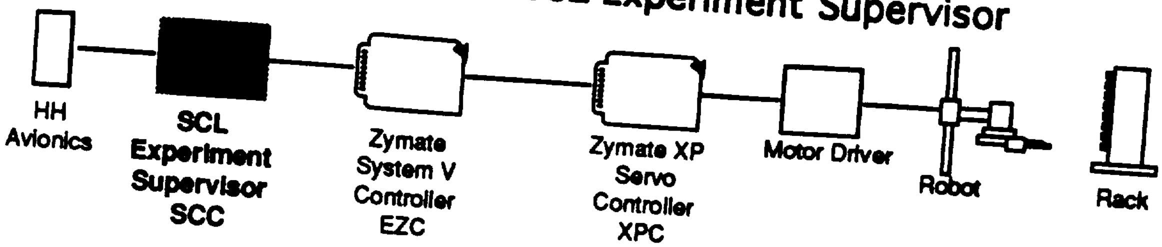
SCL EXPERIMENT SUPERVISOR

Nominal Operation of the SCL Experiment Supervisor



UPON RESET

1) **VRTX System Startup**
- System Hardware (timers, UARTS, ADs, etc.) is initialized and assocciated and Interupt Service Routines initiallized
- Call VRTX initiallization Routine
- Start SCL System Code Main Task

2) **Execute SCL System Code Main Task**
- Create Semaphores, Queues, and other VRTX data structures used for intertask communication
- Initiallize Telemetry Log Data Structures used for buffering System Error, SCL Message, and 1 and 30 Second TM packets
- Initiallize 1 second timer used to drive TM Acquisition Task
- Load SCL DB from ROM, update processing status records from battery backed RAM storage
- Start SCL System Code Tasks in Priority Level Multitasking mode: SCL RTE, SCL TM Reduction, Telemetry Acquisition, Command Input, and Telemetery Output

3) **VRTX Starts SCL System Code Task Dispatching**

Multitask Scheduling Forever Between

Telemetry Acquisition
- Collect all 1 Second Data Items, Create 1 Second Data Packet, Log to 1 and 30 Second TM Log, and Post to TM Reduction Queue

Telemetry Reduction
- Get 1 and 30 Second Packets from TM Reduction Queue, Update SCL Database Real Time Database, Send Database Update Packets to SCL Real Time Engine for records which have changed.

SCL Run Time Engine
- Upon Startup of Run Time Engine, execute Statup script
- Get Uplink Packets from Uplink Packet Queue, processing any Scheduled or Immediate script executions, data base assignments/queries, Run Time Engine Directives, project/script/rule/or database loads.
- Get SCL Data Base Update Packets from TM Reducition, and evaluate any Rules whose associated predicate SCL Database Records have changed

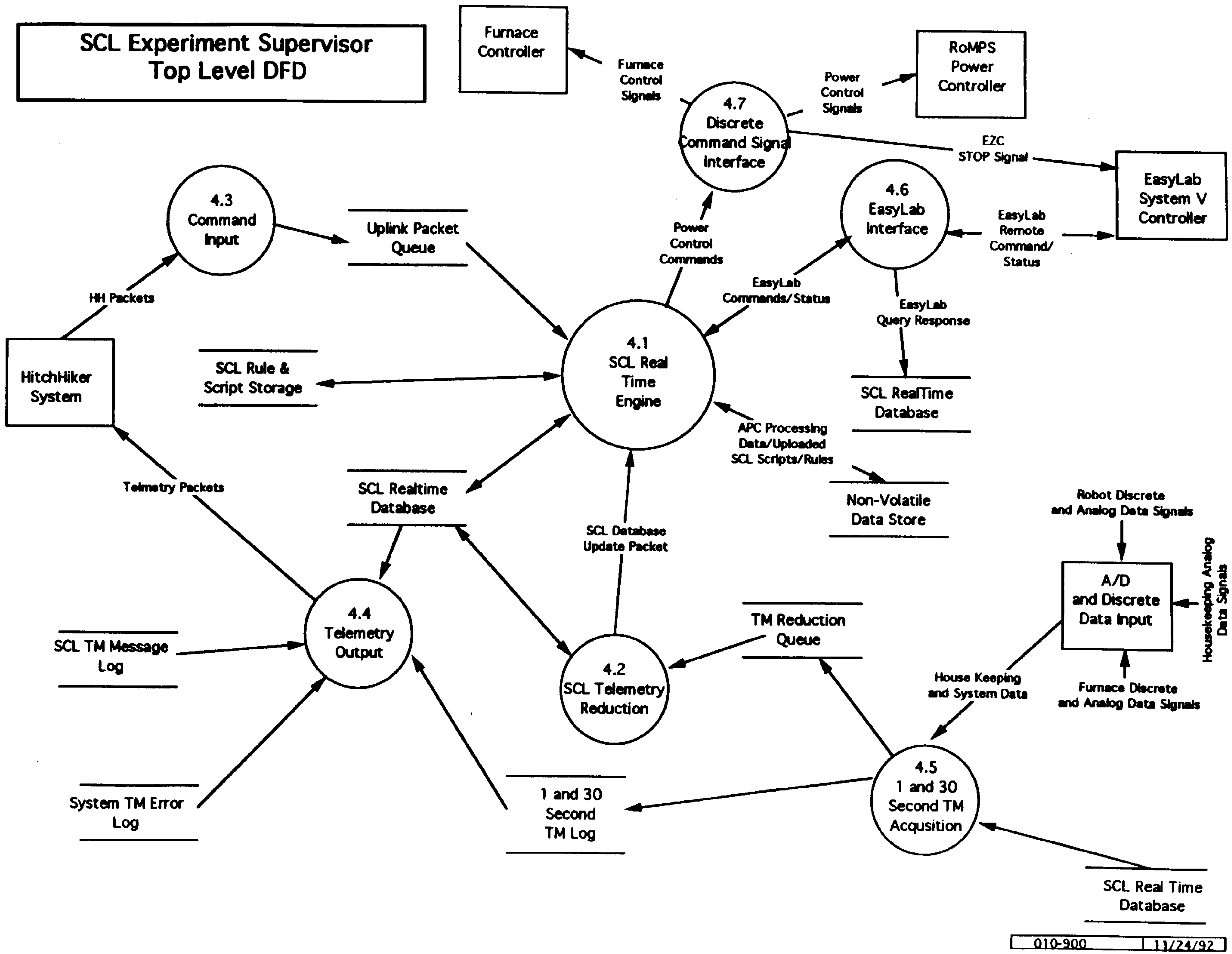
Command Input
- Get HH Packets from Hitchhiker System, 1 character at a time, strip off Hitchhiker protocol wrapper, and post to Uplink Packet Queue.

Telemetry Output

If Active Stream is 1 and 30 Second Packets
    Get TM Packet from 1 and 30 Second TM Log, and Transmit to HH Serial Port
Else If Active Stream is Error Log Packets
    Get TM Packet from Error Log, and Transmit to HH Serial Port
If Active Stream is SCL TM Message Packets
    Get TM Packet from SCL TM Message Log, and Transmit to HH Serial Port

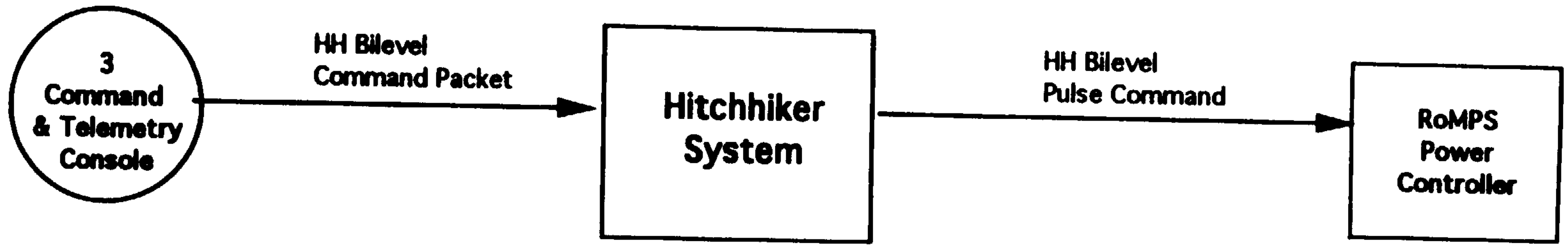
End Loop

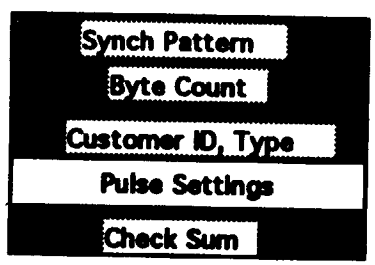
SCL Experiment Supervisor Top Level DFD



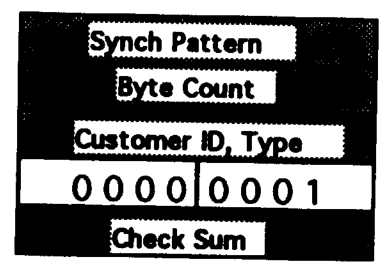
RoMPS Command Uplink Protocols

HH Bilevel Command Packet Protocol





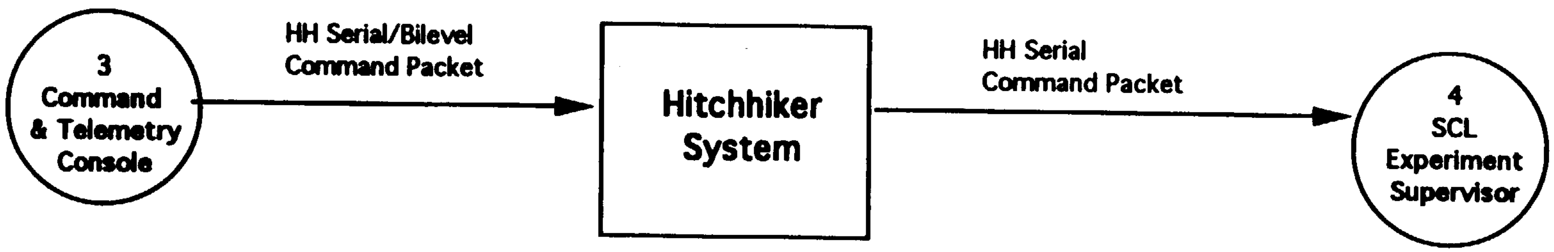
example of
Generic Bilevel Command Packet



example of
Bilevel Command Packet for
set HH_BILEVEL to MASTER_RESET

RoMPS Command Uplink Protocols

SCL-Command Packet Protocol



Synch Pattern
Byte Count
Customer ID, Type
SCL Command ID
SCL Command ID
Command Byte Count
Command Byte Count
Command Specfic Data
••••
••••
Command Specfic Data
Check Sum

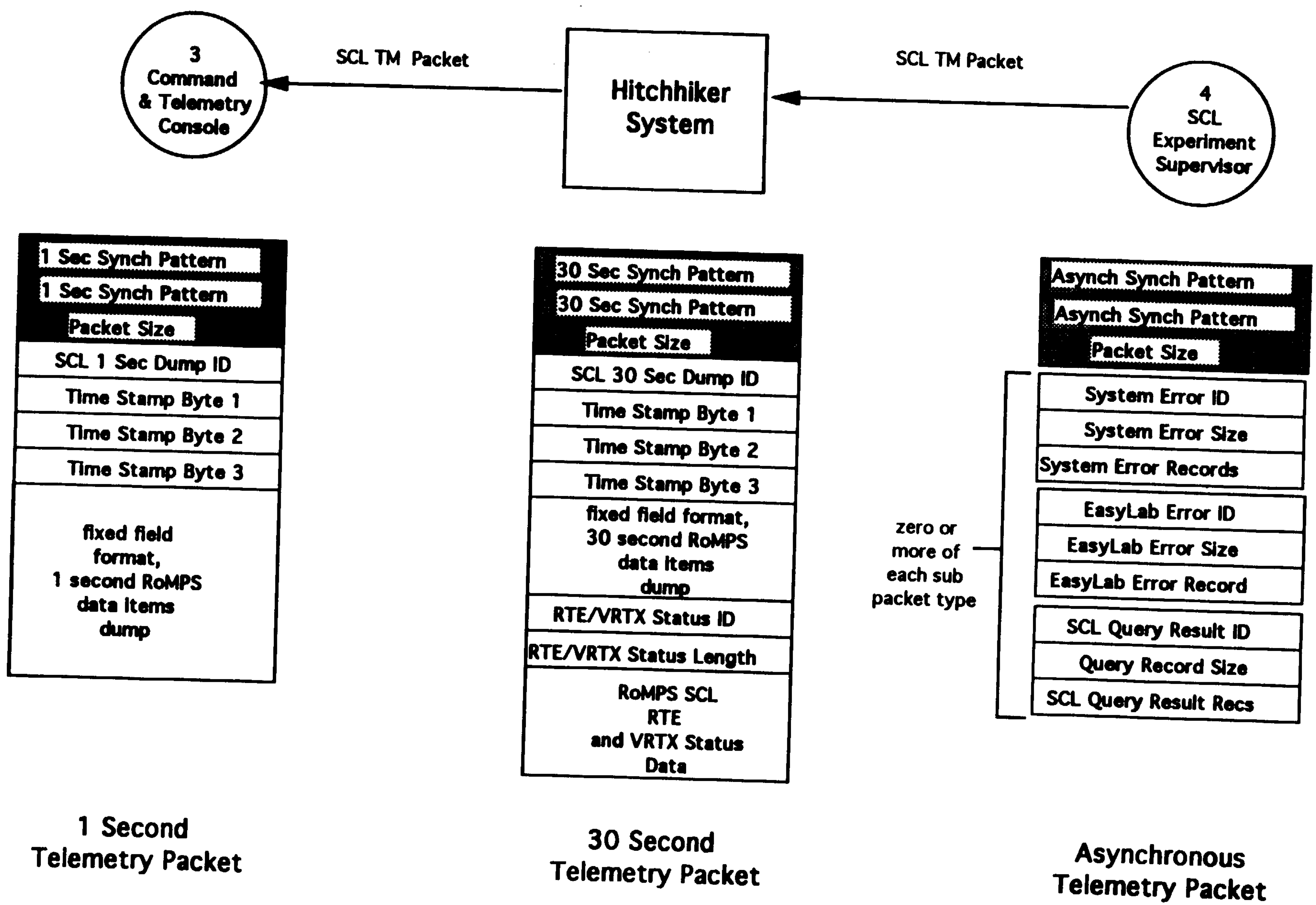
example of Generic SCL-Command Packet

Synch Pattern	
Byte Count	
Customer ID, Type	
SCL Command ID	
Command Byte Count =	
execute Token ID	number of Arguments
system function index of *execute subroutine*	
argument 1 subcode	SPC script ID
SPC script ID	argument 2 subcode
Time Byte 1	Time Byte 2
Time Byte 3	Time Byte 4
argument 3 subcode	*schedule* ID
sample_id ID	argument 4 subcode
script execution priority	
Check Sum	

example of SCL-Command Packet for
exectute SPS at 12:00:00 with sample_id

RoMPS Telemetry Downlink Protocols

SCL 1 Second, 30 Second and Asynchronous Downlink Packet Protocol



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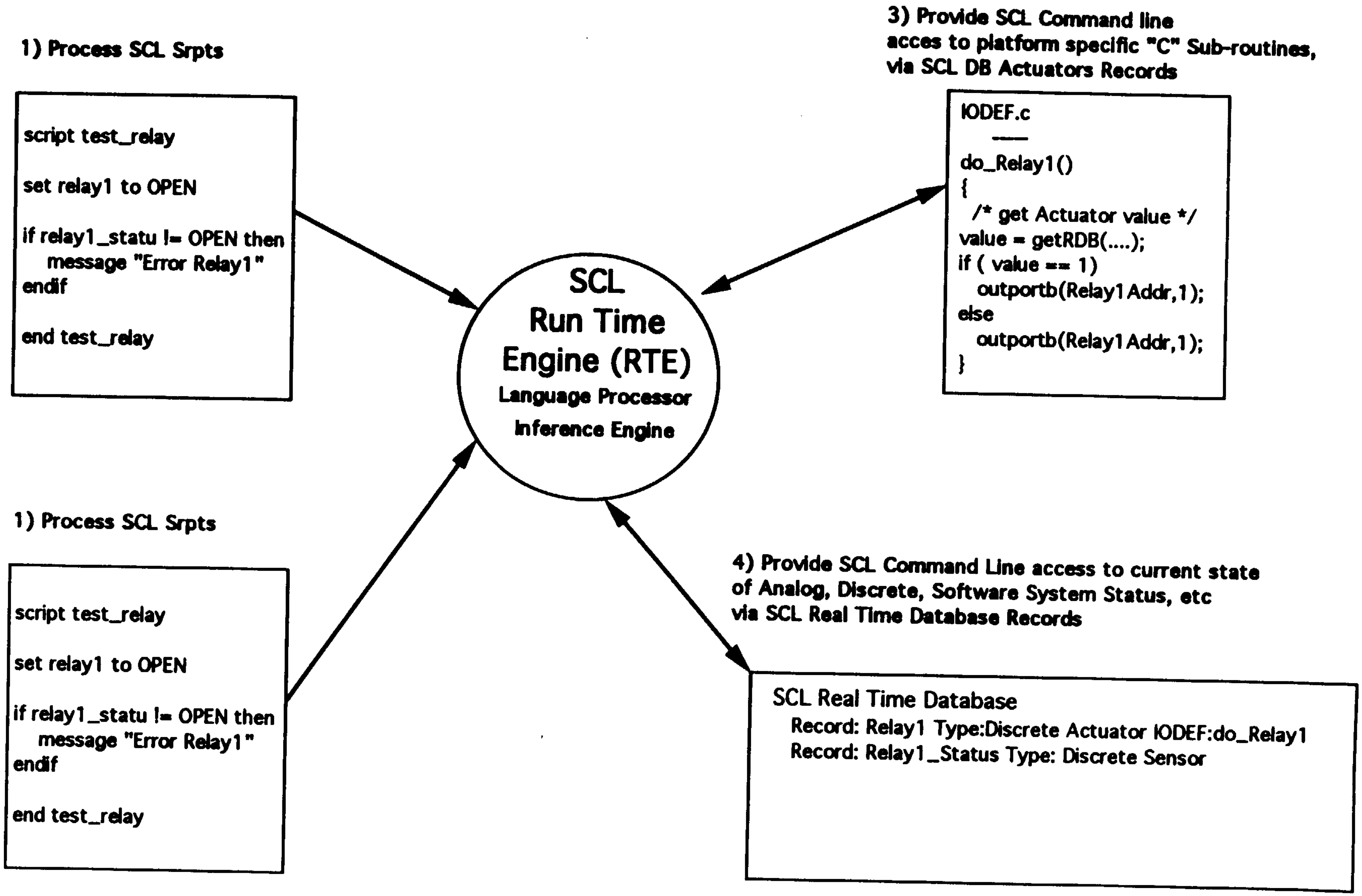
Spacecraft Command Language Run Time Engine Data Flow Diagram



Summary Table of Experiment Supervisor SCL Real Time Database Records

Analog Sensor Records - Value represents current state of corresponding A/D Signal Level

Battery_Temp	Furnace_Lamp_Voltage	Furnace_Lamp_Current *	Sample_Temp
Cal_Sample_Temp(x2)	Furnace_Rel_Temp(x2)	Axis_Position(x4)	Axis_Force(x4) *
Axis_Motor_Temp(x4) *	Motor_Current *	Power_Bus_Voltage	Sys_Cntrl_Temp(x2)
Sys_Cntrl_Ref_Volt(x2)	Motor_Drive_Temp	Motor_Drive_Box_Temp	Robot_Ref_Volt
Ref_Voltage(x3)	Furn_Cntrl_Box_Temp	Isothermal_Block_Temp	Furn_Str_TC_Temp(x3)
Furn_Str_Temp(x5)	Power_Cntrl_Box_Temp	Pallet_Rack_Temp(x5)	GAS1_Rad_Temp(x3) *
GAS1_Base_Temp(x2) *	Motor_Velocity	Axis_Ctrl_Sig_Lvl(x4)	Motor_Current

Discretes Sensor Records - Value represents current state of corresponding Parallel I/O Bit Signal Level

Furn_AB_Relay_Status	WD_Ena_Dis_Status	Bus_AB_Relay_Status	Battery_Relay_Status
Axis_OvF_Status(x4)	Sys_Enable_Relay_Status	Gen_Mtr_Drv_ENA_Status	Mtr_Drv_AB_Relay_Status
Axis_EOT_Top(x8) *	Axis_Brake_Status(x3)	Furnace_Ctrl_Enable_Status	XPC_WD_Timer_Status
Furn_WD_Status	EZC_WD_Timer_Status	Axis_Enable_Status(x4)	SCC_WD_Timer_Status

Derived System Records - Value represents current status of SCL System Code

Num_ErrorLog_Packets	Num_MessageLog_Packets	Num_1and30Log_Packets	Num_Good_Packets_RCV
Num_Bad_Packets_RCV	EasyLab_Var_Query_Result		

*APC/SPC Records - Values are used by SCL Scripts and Rules to Control Processing Flow ***

Time_Profile(x7)	Temp_Profile(x7)	Sample_ID	Rack Number
Rack_Index	SPC_Processing_Step	Proccessing_Status	Min_Cooling_Time
Max_Cooling_Time	Min_Cooling_Temp	APC_Schedule_Index	APC_Schedule_ID
APC_ParametersID			

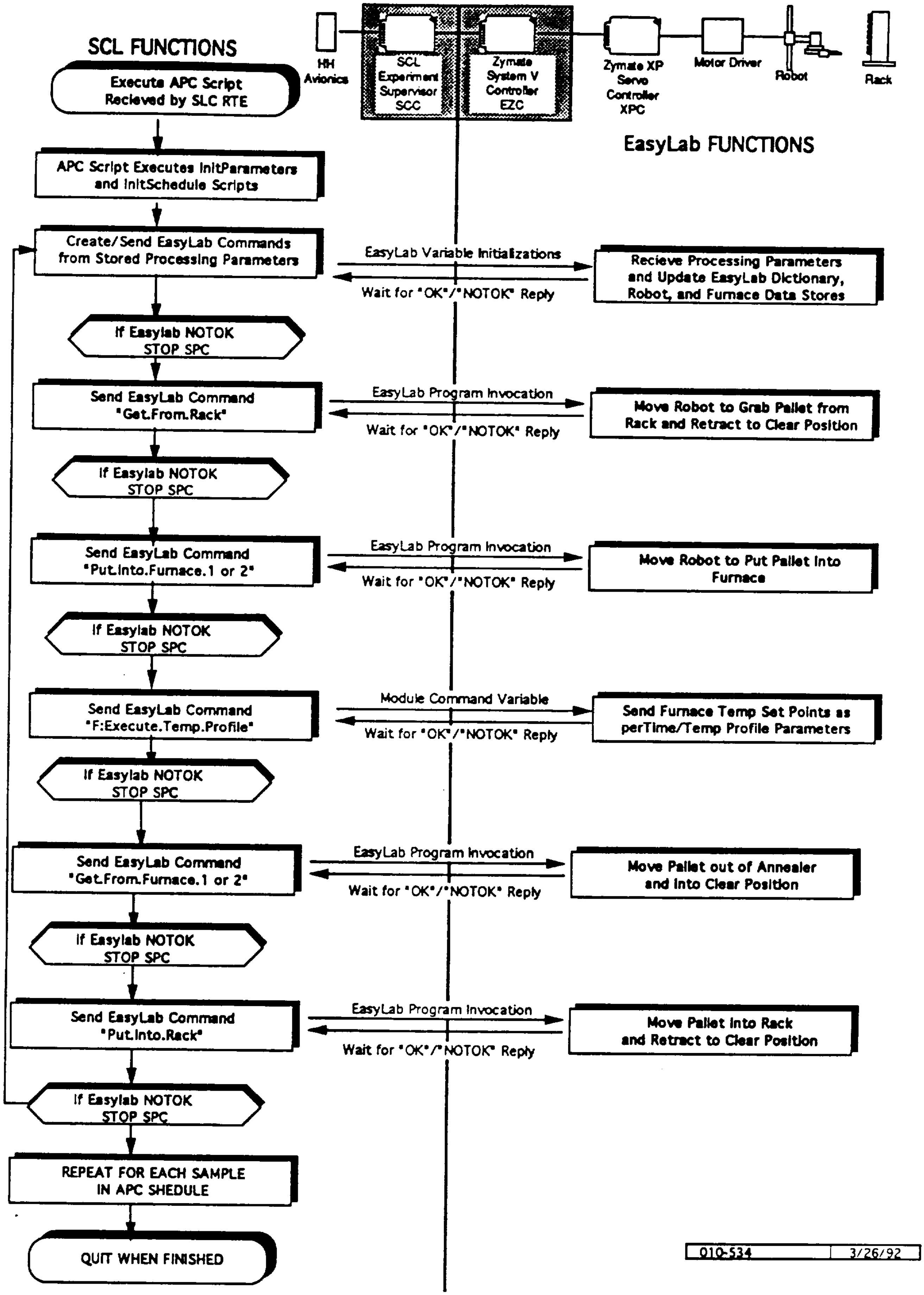
* *These SCL Database Records are monitored by Rules*

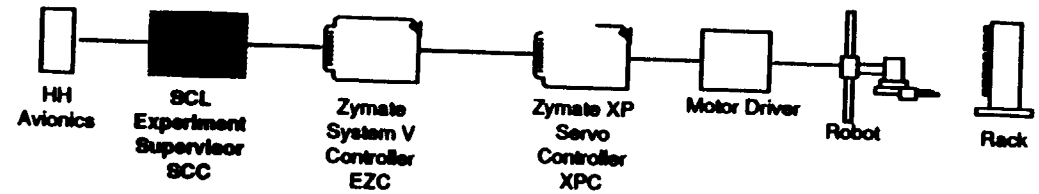
** *These SCL Database Records are saved in non-volatile memory for recovery from power loss*

Summ...y Table of ROMPS Flight SCL Project Scrip..., Rules, and Commands

Name	Type	FUNCTION
Sample Pallet Processing Control		
InitAPCParametersX	SCRIPT	Initiallizes SCL Global Arrays with Initial Sample Processing Parameters
InitAPCScheduleX	SCRIPT	Initiallizes SCL Global Array with Initial Sample Scheduling Parameters
SPC	SCRIPT	Issues EasyLab Commands to the Robot and Furnace for Sample Processing
APC	SCRIPT	Initiallizes Processing Parameter Records used by SPC, and calls SPC fore each Sample in Schedule
Pause_Processing	SCRIPT	Stops SPC script from sending EasyLab commands until Processing_Resume script is invoked
Resume_Processing	SCRIPT	Resumes SPC script sending EasyLab Commands after Pause_Processing script
Interface with Zymate System V Controller		
EasyLab_Command	EXTERNAL COMMAND	Sends an EasyLab Command to System V Controller and returns response Status
EasyLab_Query	EXTERNAL COMMAND	Sends an EasyLab Command to System V Controller and returns response Status
Stop_EZC_Processing	ACTUATOR	Sets STOP_EZC_PROCESSING signal, which aborts System V Controller current EasyLab Program
Query_RobotStatus	SCRIPT	Issue EasyLab Queries for the Robot Status variables, create Message Log entries with results
Query_FurnaceStatus	SCRIPT	Issue EasyLab Queries for the Furnace Status variables, create Message Log entries with results
Health and Safety/Process Control Monitoring		
Monitor_Temp_Sensor_X	RULE(x9)	Stops Autonomous Processing Cycle if monitored SCL DB Sensor X execedes Temp Range
Monitor_Current_Sensor_X	RULE(x1)	Stops Autonomous Processing Cycle if monitored SCL DB Sensor X execedes Current Range
Monitor_EOT_Axis_X	RULE(x8)	Stops Autonomous Processing Cycle if monitored SCL DB EOT sensor X unexpectedly is hit
Monitor_Overforce_Axis_X	RULE(x8)	Stops Autonomous Processing Cycle if monitored SCL DB Overforce sensor X excedes range
Telemetry System Control		
TM_Stream_ON/OFF	ACTUATOR(x2)	Enables transmission of Active TM Stream Packets to HH Interface
TM_Active_Stream	ACTUATOR	Sets TM Stream to be 1and30 Second, Error, or SCL message Packets
TM_Flush_Error_Log	ACTUATOR	Clear the Error TM Log of the packets currently stored in it
TM_Flush_Message_Log	ACTUATOR	Clear the 1and30_Second TM Log of the packets currently stored in it
TM_Flush_1and30_Log	ACTUATOR	Clear the SCL Message TM Log of the packets currently stored in it
TM_Reset_Good_Packets	ACTUATOR	Reset the Command Input Counter which records number of good packets received from HH
TM_Reset_Bad_Packets	ACTUATOR	Reset the Command Input Counter which records number of bad packets received from HH
External Sub Systems Control		
Furnace_Select_A/B	ACTUATOR(x2)	Sets/Clears control signals to Furnace Controller which selects Oven A or Oven B as active oven
PowerBus_Select_A/B	ACTUATOR(x2)	Pulses Power Bus Select A/B control lines to Power Distribution System
Motor_Drive_Enable/Disable	ACTUATOR(x2)	Sets/Clears Motor Drive A/B select signal level to Motor Drive Unit
Battery_Relay_Open/Close	ACTUATOR(x2)	Pulse Open/Close Battery Relay control signals to WDT Unit for encoder battery backup
Motor_Driver_Select_A/B	ACTUATOR(x2)	Sets/Clears Motor Driver A/B Select control signals level to Motor Drive Unit
Furnace_Reset	ACTUATOR	Resets the Furnace Controller by pulsing the Furnace Reset/WD Disable line
Furnace_WD_Enable/Disable	ACTUATOR(x2)	Sets/Clears the Furnace Reset/WD Disable control signal, which enables/disables Furnace WD timer
SCC_WDG_Timer_Strobe	ACTUATOR	Sets SCC Watchdog Strobe control signal level based on assigned value
XPC_Reset	ACTUATOR	Pulses the XPC reset line to the XPC servo controller computer
SCL RealTime Clock Control		
RTC_Reset	ACTUATOR	Resets the SCC Real Time Clock hardware and sets counters to 0
RTC_Set_HHMMSS	ACTUATOR	Sets the Hour, Minute, and Second counters of SCC Real Time Clock to assigned value

SCL Versus EasyLab Command Processing Functions

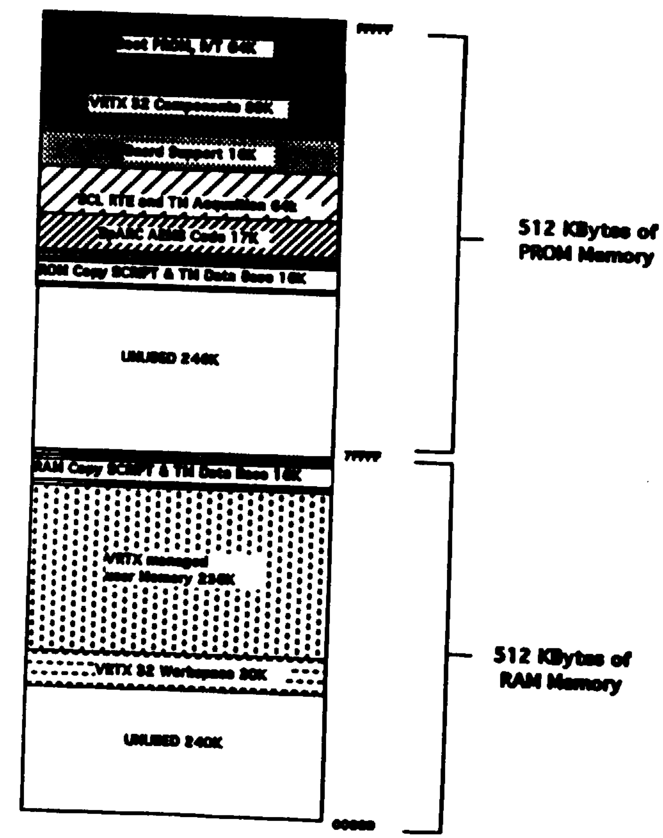




SCL SOFTWARE PERFORMANCE/MARGIN

SCL Experiment Supervisor	ARD-1 Measured V53	RoMPS Estimate V53
SCL System Code CPU Loading	23.8%	23.8%
SCL Rule Processing #lines of SCL CPU loading	n a 5% est	230 32%
SCL Script Processing #lines of SCL	n a	3226 [144 samples + setup]
CPU loading	1%est	1.5% [mission average]
CPU Margin	50% est [other tasks in ARD]	42%

RoMPS Experiment Supervisor Memory Map



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SCL SOFTWARE PERFORMANCE/MARGIN

SCL Experiment Supervisor	ARD-1 Measured V53	RoMPS Estimate V53
SCL System Code CPU Loading	23.8%	23.8%
SCL Rule Processing		
#lines of SCL	n a	230
CPU loading	5% est	32%
SCL Script Processing		
#lines of SCL	n a	3226 [144 samples + setup]
CPU loading	1%est	1.5% [mission average]
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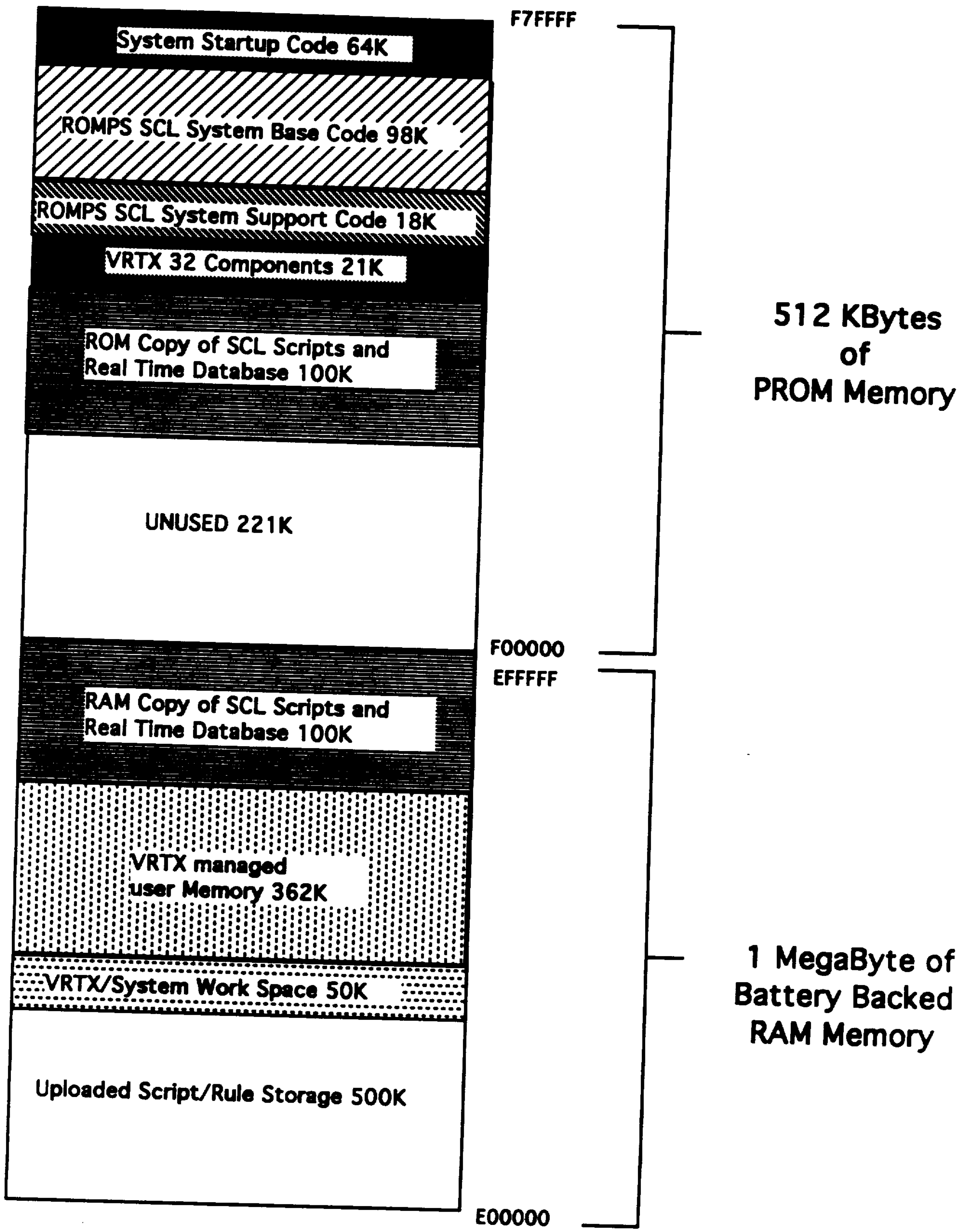
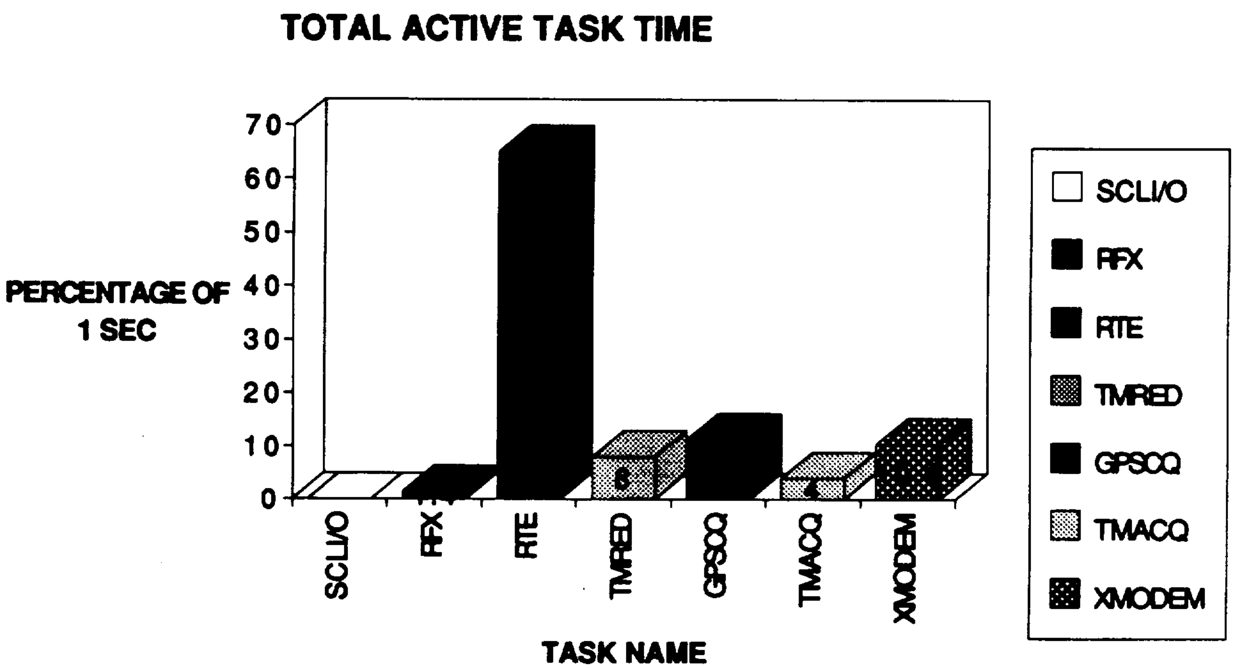
RoMPS Experiment Supervisor Memory Map



	A	B	C	D
1	**SCC Processor Loading for System Code Estimates**			
2	ROMPS Task	ARD 1 Task	ARD 1 Task Loading	Est. ROMPS Loading
3	1 and 30 Second TM Acquistion	TM ACQ	4%	4.00%
4	Command Input	X-MODEM	10.40%	10.40%
5	Telemetry Output	RFX	1.40%	1.40%
6	SCL Telmetry Reduction	TM RED	8%	8.00%
7				
8	Duty Cycle for System Code Processing (WORST CASE)			76.20%
9	**ROMPS SCL Rule Processing**			
10	Rule	Lines of SCL	Zymate Commands	
11	Monitor_Axis_OverForce(x4)	40	0	
12	Monitor_Axis_Motor_Temp(x4)	40	0	
13	Monitor_Furnace_Current	10	0	
14	Monitor_MOtor_Current	10	0	
15	Monitor_Axis_EOT(x8)	80	0	
16	Monitor_GAS1_Rad_Temp(x3)	30	0	
17	Monitor_GAS1_Base_Temp(x2)	20	0	
18				
19	Duty Cycle to Process all Rules each second(WORST case)			31.41%
20	**ROMPS SCL Script Processing**			
21	Script	Lines of SCL	Zymate Commands	RTE Processing Time
22	Init_APC_Parameters	2736	0	6.356406205
23	Init_APC_Schedule	60	0	0.139394873
24	APC	100	0	0.232324788
25	SPC	100	12	9.232324788
26				
27	Total Processing Time (minutes) for 144 Samples(WORST CASE)			22.82
28	**Assumptions**			
29	Processor = 89ct01			
30	EasyLab Remote Interface = 1200 Baud			
31	EasyLab Remote Command Time = .75 Seconds/ Blocking I/O			
32	Rules Execute Like Scripts			
33	Script Execution Speed			
34				
35	**Task Comparability Justification**			
36	TM ACQ	code size/code complexity/devices accessed similar		
37	X-MODEM	Both tasks Input 120 byte packets and post to RTE		
38	RFX	Both tasks Output 120 byte TM Packets		
39	TM RED	Identical Code, similar data input		


TOTAL ACTIVE TASK TIME
PERCENTAGE OF 1 SEC
70
60
50
40
30
20
10
0
SCLI/O
RFX
RTE
TMRED
GPSCQ
TMACQ
XMODEM
TASK NAME
6
4

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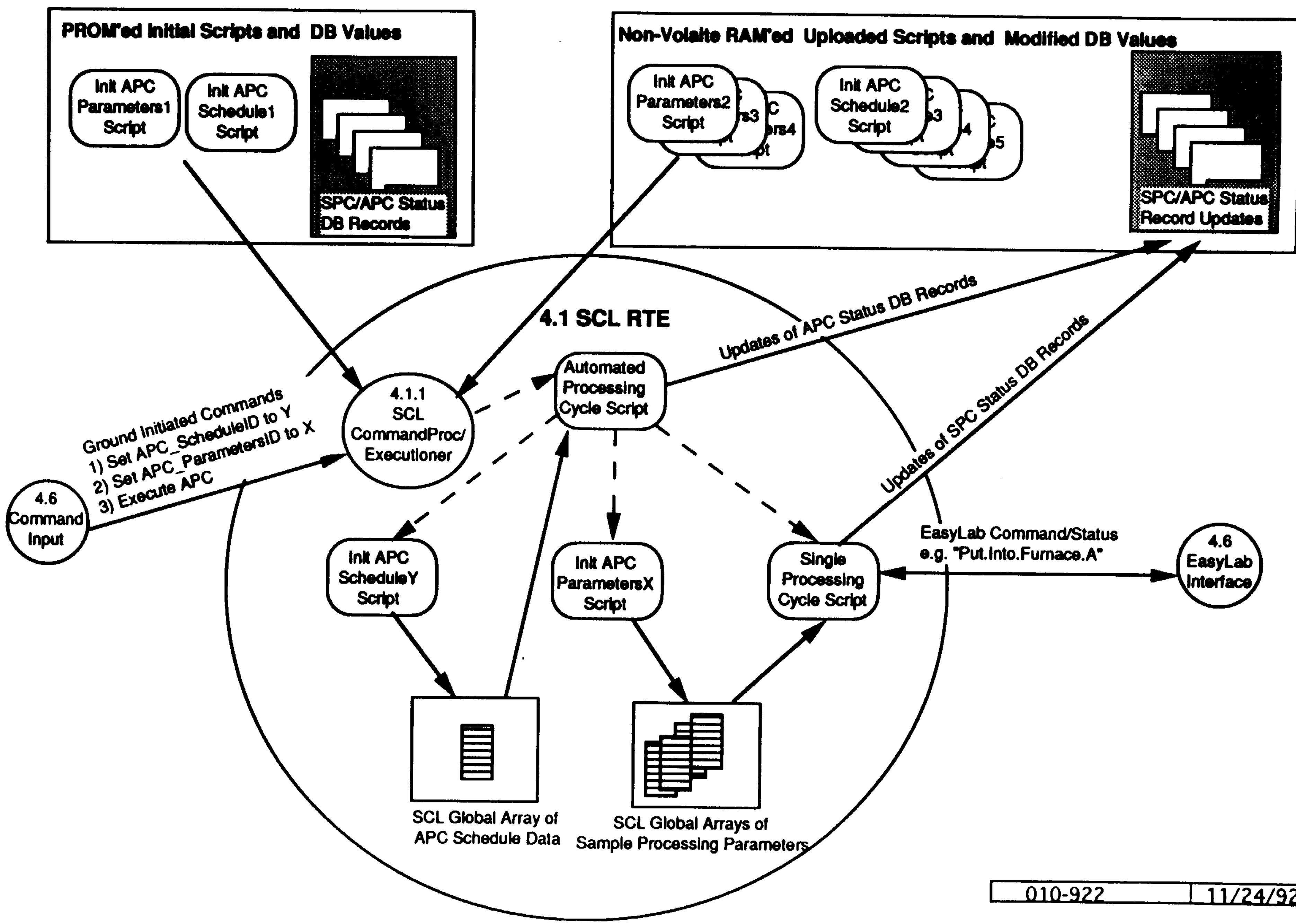
SCL SCRIPT SAMPLE PROCESSING CONTROL

SCL Script Automated Sample Processing Overview



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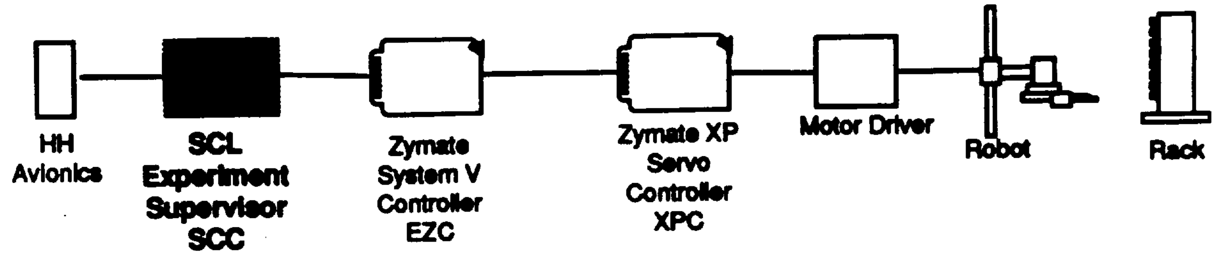
Nominal Operation of the SCL APC and SPC Scripts



Upon Ground Based Execution of Autonomous Processing Cycle Script

1) APC script calls InitAPCScheduleY Script

- The Autonomous Processing Script (APC) calls the InitAPCScheduleY script identified by the APC_ScheduleID SCL DB Record value, in this example Y
- The InitSchedule script initializes an SCL global array gSchedule with an ordered list of the Sample Pallets to be processed

2) APC script calls InitParameterX Script

- The Autonomous Processing Script calls the InitParameters script identified by the APC_ParameterID SCL DB Record value, in this example X
- The InitParametersX script initializes a set of SCL global arrays with an ordered list of the Processing Parameters, indexed by the Sample ID. The Processing Parameters include seven step Time/Temerature profile for Furnace Control, Maximum/Minimum Cooling Times for samples after annealing, and Rack Locations of the sample pallet.

3) APC Script Calls SPC Script for each Sample in ScheduleY

- Call the Single Processing Cycle Script (SPC) for each SampleID listed in the APC Schedule array, begin execution at the index, APC_Schedule_Index
- Initiallize the SCL Database records used by the SPC with the processing parmaters for the current sample before calling the SPC script

4) Single Processing Cycle processes SampleID Pallet

- The SPC script creates and sends EasyLab Command Variables and EasyLab Program invokations to the Zymate System V Controller which process the sample pallets. The Command Variables are constructed by the Concatenation of the EasyLab Command Variable name base and the global APC processing paramter arrays. The EasyLab Commands sent to the System V Controller for the SPC script are listed below.

Zymate "Rack.Number = " | Rack_Number	-- Identifies which Rack to get from
Zymate "Rack.Index = " | Rack_Index	-- Identifies whcich Rack Slot
Zymate "Get.From.Rack"	-- Robot movent EasyLab Program
Zymate "Put.Into.Furnace.A" or "Put.Into.Furnace.B"	-- Robot movent EasyLab Program
Zymate "F:Temp.Profile.1" = Temp_Profile1	-- Stores an Annealing a 7
Zymate "F:Time.Profile.1" = Time_Profile1	-- Time/Temp Step Profile in Furnace Module
● ● ● ●	
Zymate "F:Temp.Profile.7" = Temp_Profile7	
Zymate "F:Time.Profile.7" = Time_Profile7	
Zymate "F:Execute.Temp.Profile"	
Zymate "Get.From.Furnace.A" or "Get.From.Furnace.B"	-- Robot movent EasyLab Progra
Zymate "Put.Into.Rack"	-- Robot movent EasyLab Program

- ALL SCL Database APC and SPC are updated after each step to track processing and are stored in Non-Volatile RAM to allow recovery from power Loss

SPC (Single Processing Cycle) Script

```
-- Function : send EasyLab Commands to Zymate System V controller to perform
-- a timed annealing of the sample specified by the SPC Processing DB Items

script SPC
-- Initialize the SPC_ProcessingStep DB Record, this is saved in non
-- volatile Ram along with the other SPC processing parameteters
set ProcessingStep to 0
set ProcessingStatus to SPC_PROCESSING_STARTED

-- Check that the user has not paused sample processing
if Processing_Status = SPC_PAUSED
      wait until Processing_Status = SPC_PROCESSING_STARTED
end if

Zymate_Command "RACK.NUMBER = " | Rack_Number
-- Check that the System V Controller processed the EasyLab Command properly
-- These and the previous checks are repeated after every EasyLab Command and are
-- omitted from subsequent steps for presentattion reasons
if result <> OK then
      set Processing_Status to SPC_EASYLAB_ERROR
    stop SPC
else
      set SPC_Processing_Step to SPC_Processing_Step + 1
endif
Zymate_Command "RACK.INDEX = " | Rack_Index
Zymate_Command "GET.FROM.RACK"

-- Put sample into the Furnace 1 or 2, depending on the value of SPC_ActiveOven
Zymate_Command "Active.Oven = " | Furn_AB_RelayStatus
Zymate_Command "PUT.INTO.FURNACE"

-- Set Furnace Module Time/Temp Profile processing parameters
Zymate_Command "F:Time.Profile.1 = " | TimeProfile1
Zymate_Command "F:Temp.Profile.1 = " | TempProfile1
      "      "      "      "      "      "      "      "      "
Zymate_Command "F:Time.Profile.7 = " | TimeProfile7
Zymate_Command "F:Temp.Profile.7 = " | TempProfile7
-- Perform Annealing.
Zymate_Command "F:EXECUTE.TIME.PROFILE"

-- Wait for the sample to reach a temperature after which it will be safe to move the
-- sample back to the rack.
execute COOL_DOWN_WAIT

-- Get Sample from Oven
-- Get Sample from Furnace
Zymate_Command "GET.FROM.FURNACE"

-- Return the sample pallet to the rack and position it was taken from
Zymate_Command "PUT.INTO.RACK"
Set SPC_Processing_Step to 0
Set Processing_Status to SPC_PROCESSING_COMPLETED
end SPC
```

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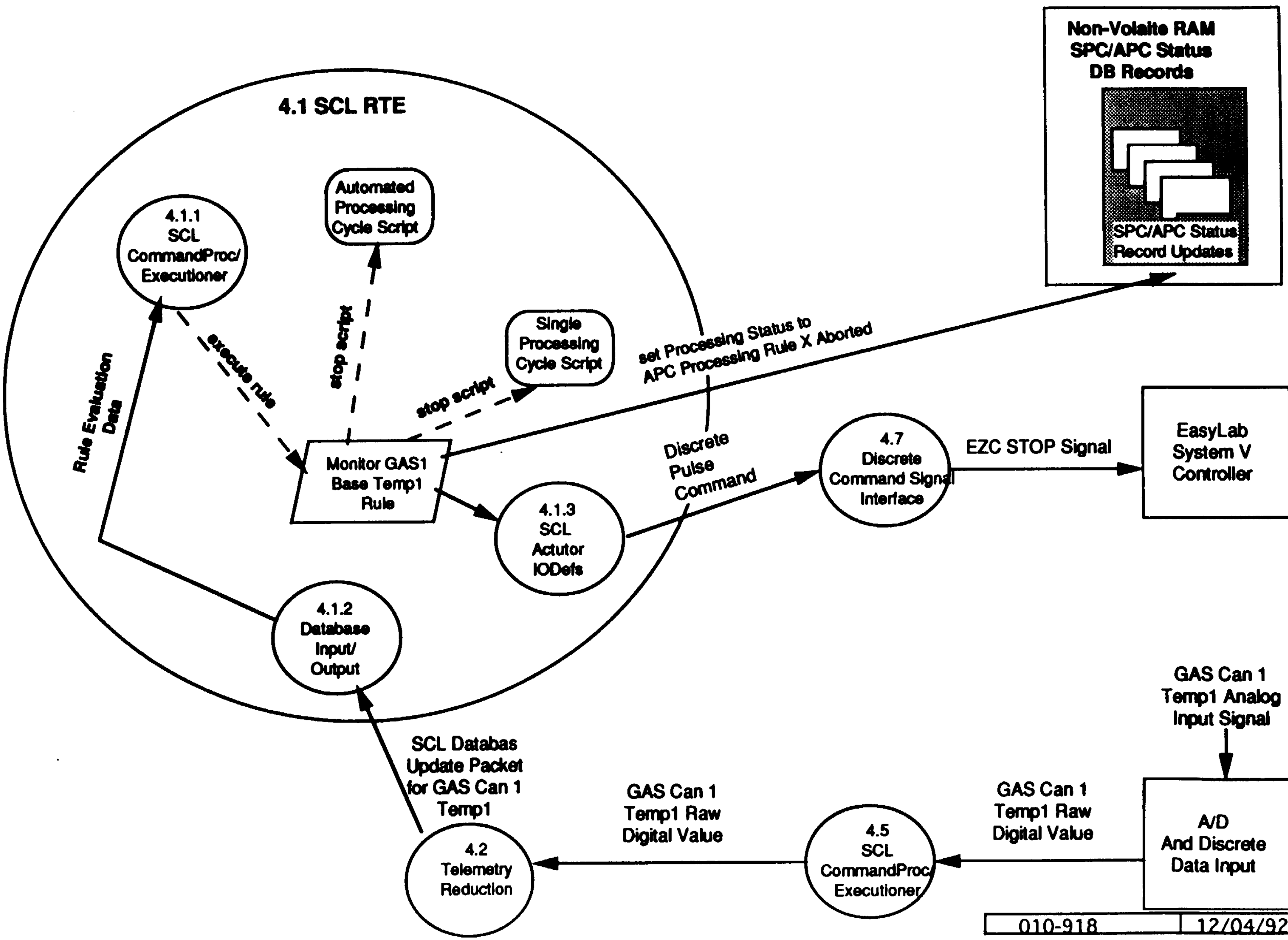
SCL EXPERIMENT SUPERVISOR FAULT HANDLING

Rule Based Automated Processing Script Shutdown Overview



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Monitor_GAS1_Base_Temp1 Rule

-- Function : Monitors the value of the GAS Can 1 Base
-- Temperature and if range exceeded stop APC processing

```
rule          Monitor_GAS1_BaseTemp1
subsystem     SYS
priority      15                    -- This rule preamble determines
activation    yes                   -- how and when this rule
continuous    yes                   -- is evaluated by Run Time Engine

If  GAS1_BaseTemp1 > MAX_GAS1_BASE_TEMP then
      stop APC
      stop SPC
      if (SPC_ProcessingStatus <> COMPLETE) then
            set SPC_ProcessingStatus to GAS1_BASETEMP1_SHUTDOWN
      endif
endif


end Monitor_GAS1_BaseTemp1
```

SCL Experiment Supervisor Fault Handling Summary

Fault Condition	Fault Detection	Fault Response
SCL System Code Software Error	"C" Level software checks return code of called routine or device status register.	Log error record to System TM Error Log and continue, back out effects when possible.
EasyLab Command Failure	EasyLab Interface Receives NOTOK from EZC, returns error status to calling Script/Rule	Script Logs error to SCL TM Message Log. Update SPC_Proc_Status. APC/SPC Scripts Diagnose and Stop. Run Query_RobotStatus and Query_FurnaceStatus Scripts.
EasyLab Command Response TimeOut	EasyLab Interface fails to receive response from EZC, returns error status to calling Script/Rule	Script Logs error to SCL TM Message Log. Update SPC_Proc_Status. APC/SPC Scripts Diagnose and Stop.
Unexpected EOT	SCL Rule Monitoring EOT Status Records in SCL RealTime DB detects EOT true	Rule Logs error to SCL TM Message Log. Update SPC_Proc_Status. Stop APC/SPC Scripts.
Axis Overforce	SCL Rule Monitoring Axis Force Records in SCL RealTime DB detect Axis Force out of range	Rule Logs error to SCL TM Message Log. Update SPC_Proc_Status. Stop APC/SPC Scripts. Disable Robot motor drive.
Current or Temp Over Limit	SCL Rule Monitoring Current/Temperature Records in SCL RealTime DB detect an out of range value for X seconds.	Rule Logs error to SCL TM Message Log. Update SPC_Proc_Status. Stop APC/SPC Scripts.
Power Loss/Power Up	SCC reset circuit detects power up.	SCC reset circuit restarts processor, restores Static SCL DB Records, from static RAM and resets outputs to safe states.
Single Event Processor Upset	SCC watchdog timer detects loss of periodic strobe.	SCC watchdog timer restarts processor.

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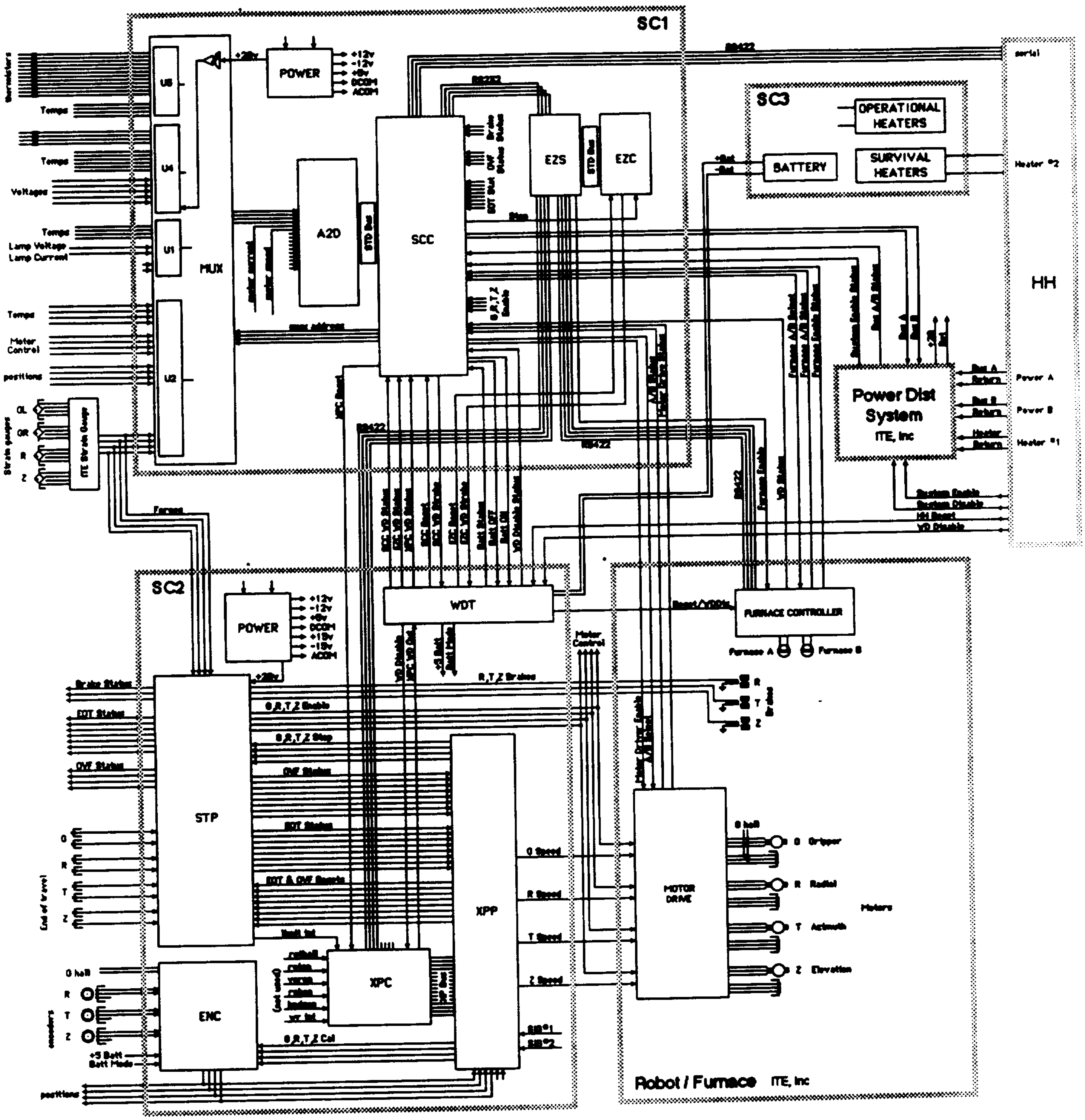
BLOCK DIAGRAMS

RoMPS Connection Diagram

12/5/92 GD rev C



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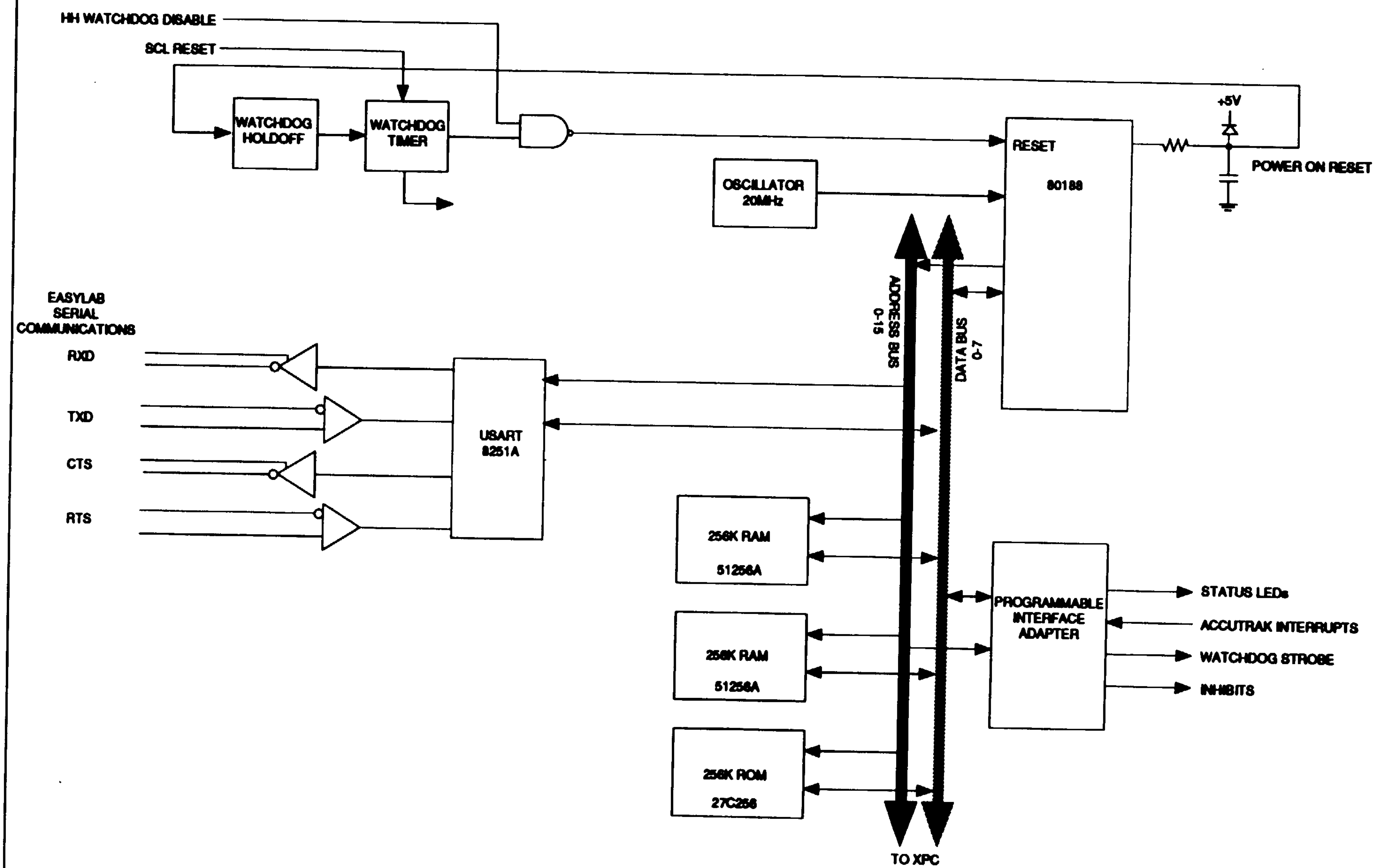
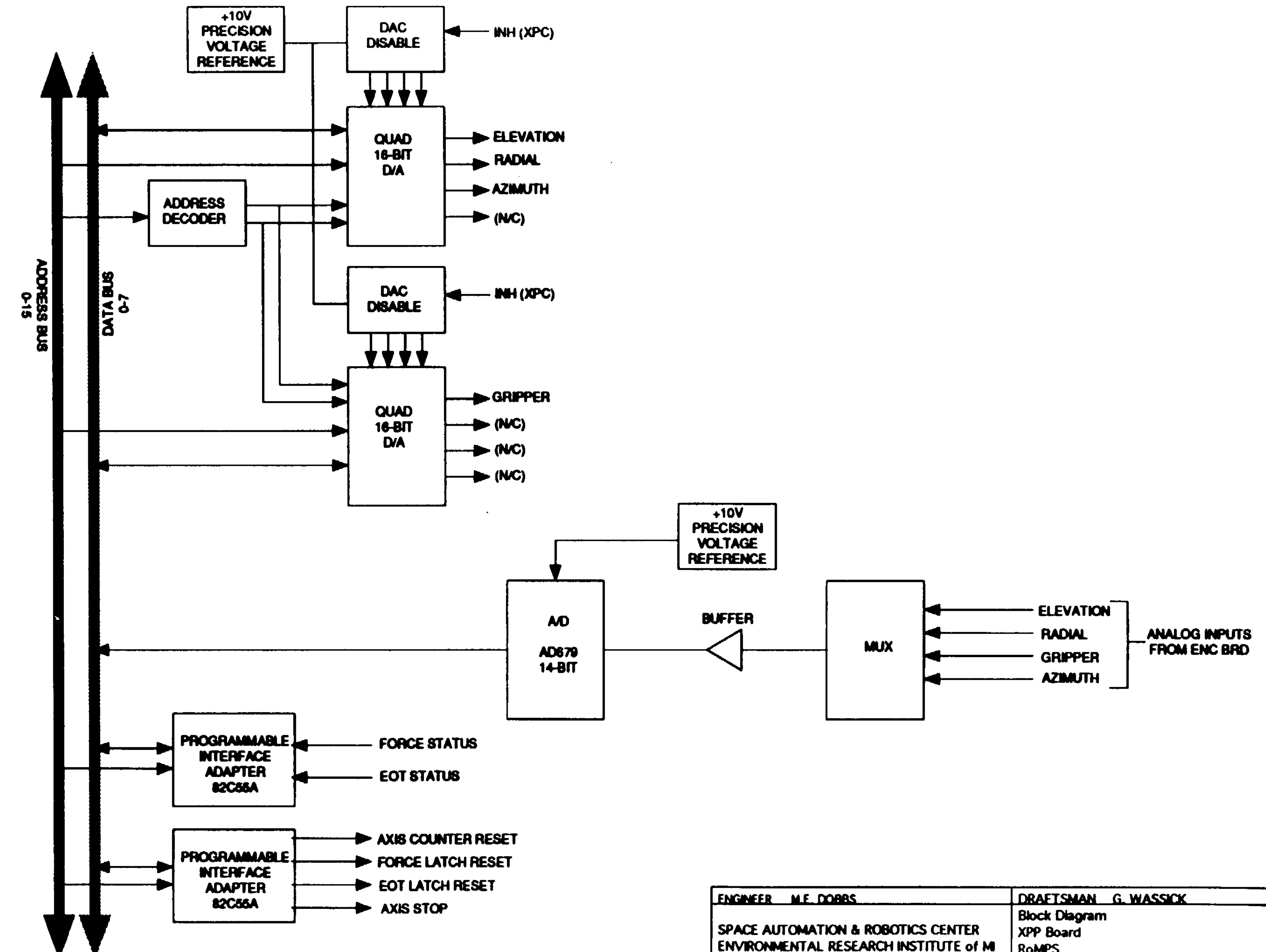
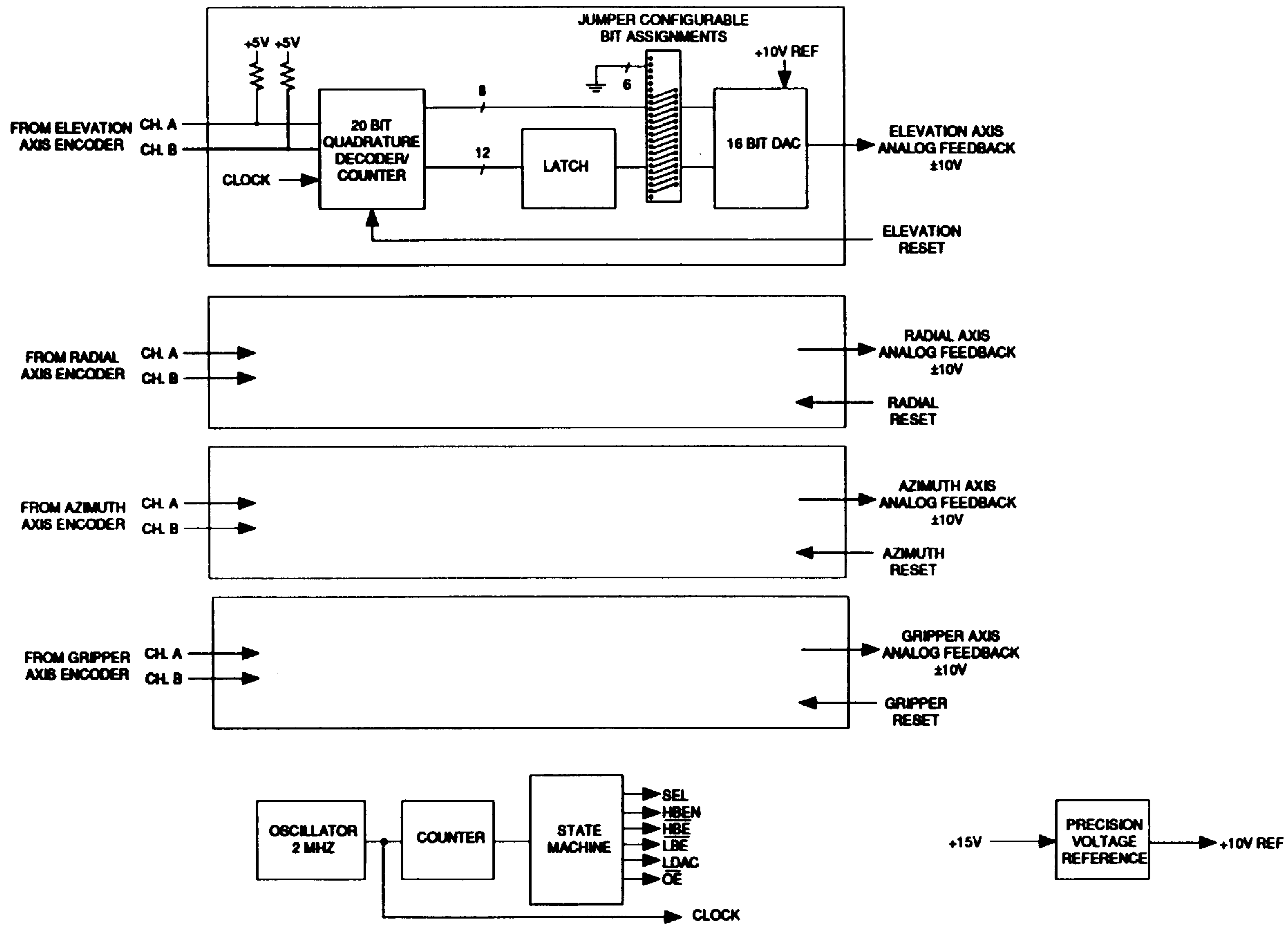


ENGINEER M.E. DOBBS	DRAFTSMAN G. WASSICK	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Block Diagram XPC Board RoMPS 010-436	12/05/92 DATE

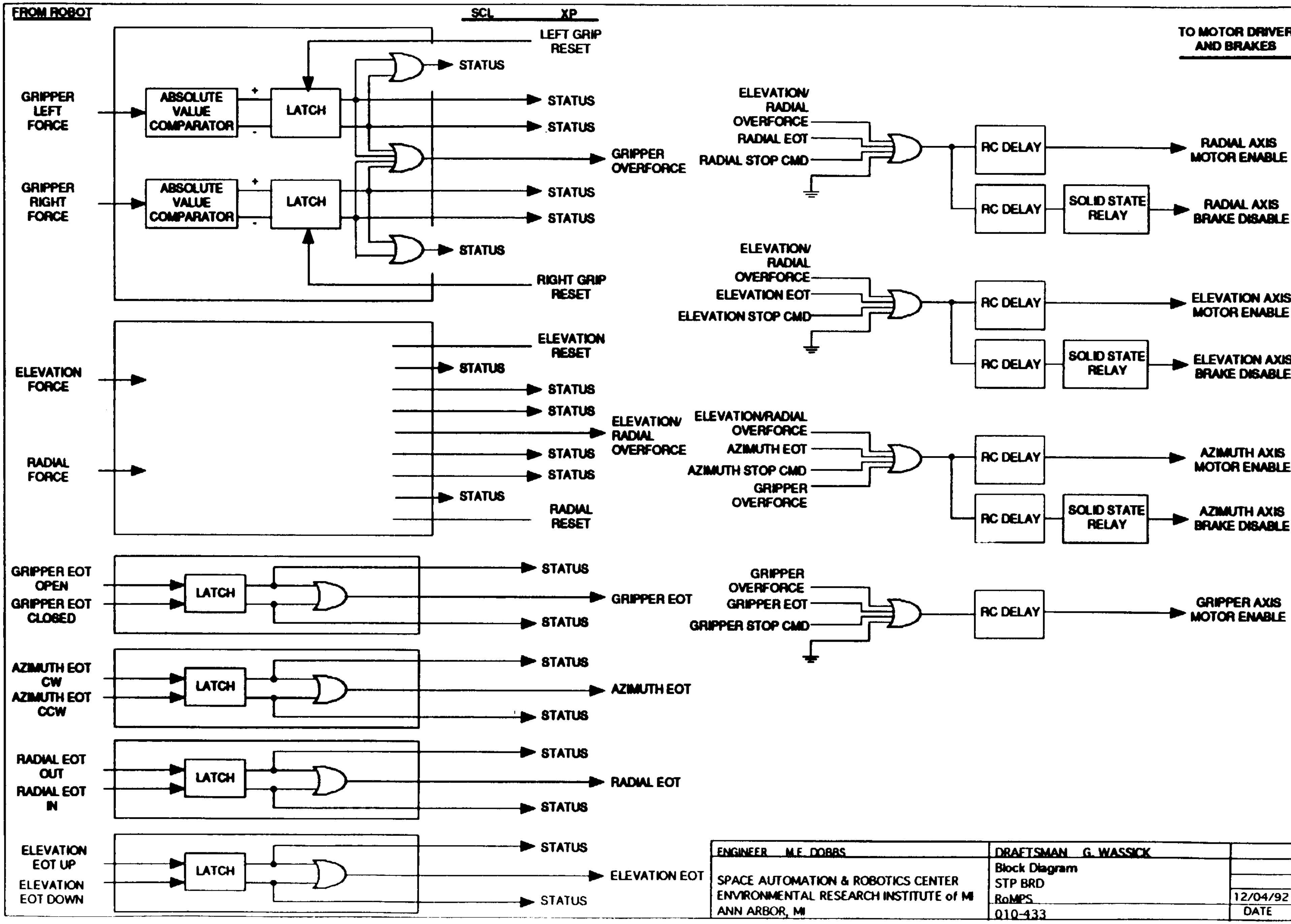


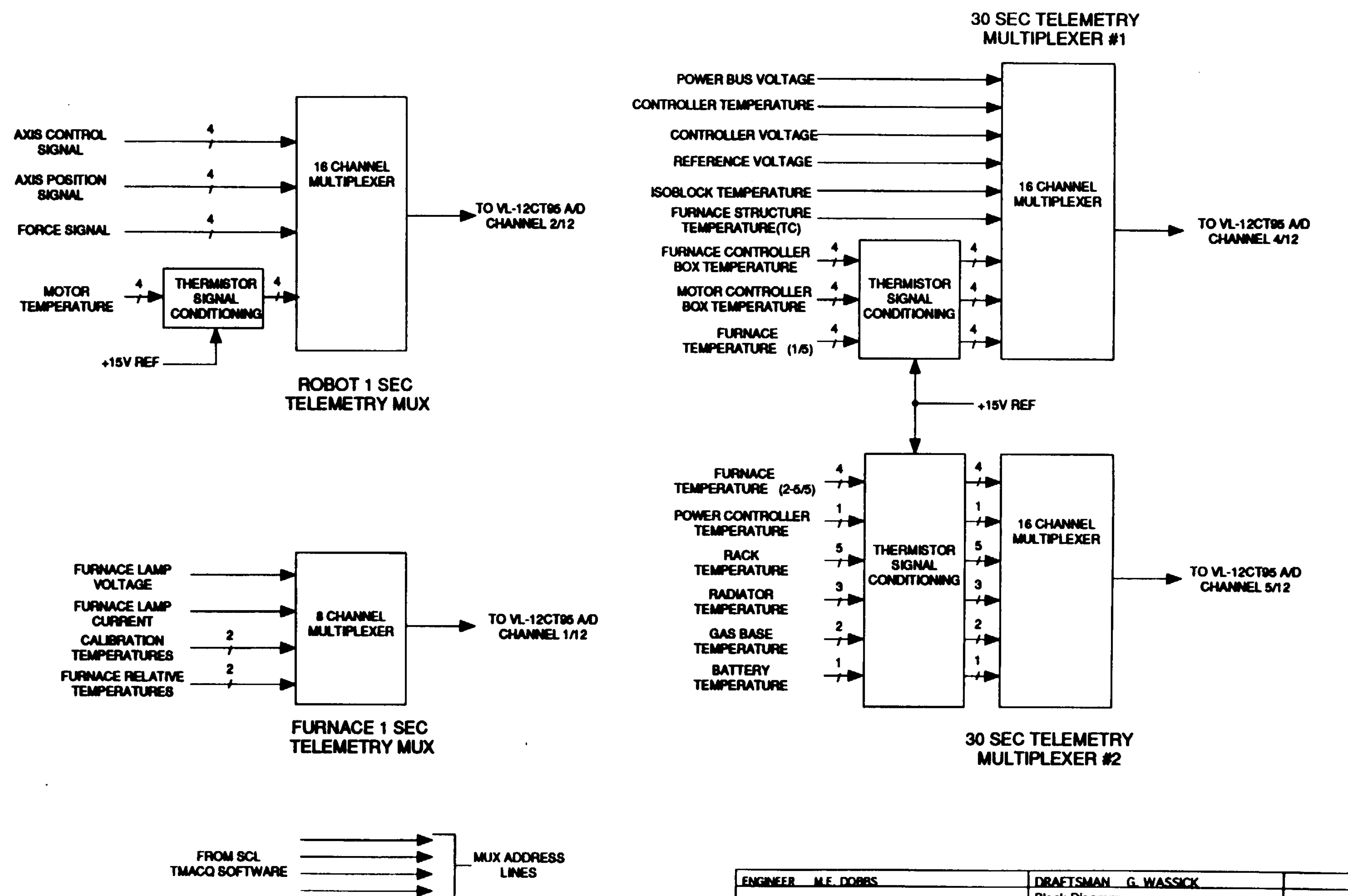
ENGINEER M.E. DOBBS	DRAFTSMAN G. WASSICK	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Block Diagram XPP Board RoMPS 010-437	12/05/92 DATE



MAX COUNT RATE = 14MHz
UPDATE RATE = 8μSec

ENGINEER M.E. DOBBS	DRAFTSMAN G. WASSICK	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Block Diagram ENC Board RoMPS 010-434	12/04/92 DATE


FROM ROBOT
SCL
XP
TO MOTOR DRIVER AND BRAKES
GRIPPER LEFT FORCE
GRIPPER RIGHT FORCE
ABSOLUTE VALUE COMPARATOR
ABSOLUTE VALUE COMPARATOR
LATCH
LATCH
LEFT GRIP RESET
RIGHT GRIP RESET
STATUS
GRIPPER OVERFORCE
ELEVATION FORCE
RADIAL FORCE
ELEVATION RESET
RADIAL RESET
ELEVATION/ RADIAL OVERFORCE
GRIPPER EOT OPEN
GRIPPER EOT CLOSED
GRIPPER EOT
AZIMUTH EOT CW
AZIMUTH EOT CCW
AZIMUTH EOT
RADIAL EOT OUT
RADIAL EOT IN
RADIAL EOT
ELEVATION EOT UP
ELEVATION EOT DOWN
ELEVATION EOT
ELEVATION/ RADIAL OVERFORCE
RADIAL EOT
RADIAL STOP CMD
ELEVATION EOT
ELEVATION STOP CMD
ELEVATION/RADIAL OVERFORCE
AZIMUTH EOT
AZIMUTH STOP CMD
GRIPPER OVERFORCE
GRIPPER EOT
GRIPPER STOP CMD
RC DELAY
SOLID STATE RELAY
RADIAL AXIS MOTOR ENABLE
RADIAL AXIS BRAKE DISABLE
ELEVATION AXIS MOTOR ENABLE
ELEVATION AXIS BRAKE DISABLE
AZIMUTH AXIS MOTOR ENABLE
AZIMUTH AXIS BRAKE DISABLE
GRIPPER AXIS MOTOR ENABLE
ENGINEER M.E. DOBBS
SPACE AUTOMATION & ROBOTICS CENTER
ENVIRONMENTAL RESEARCH INSTITUTE of MI
ANN ARBOR, MI
DRAFTSMAN G. WASSICK
Block Diagram
STP BRD
RoMPS
010-433
12/04/92
DATE



ENGINEER M.E. DOBBS	DRAFTSMAN G. WASSICK	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Block Diagram MUX Board RoMPS 010-435	12/05/92 DATE

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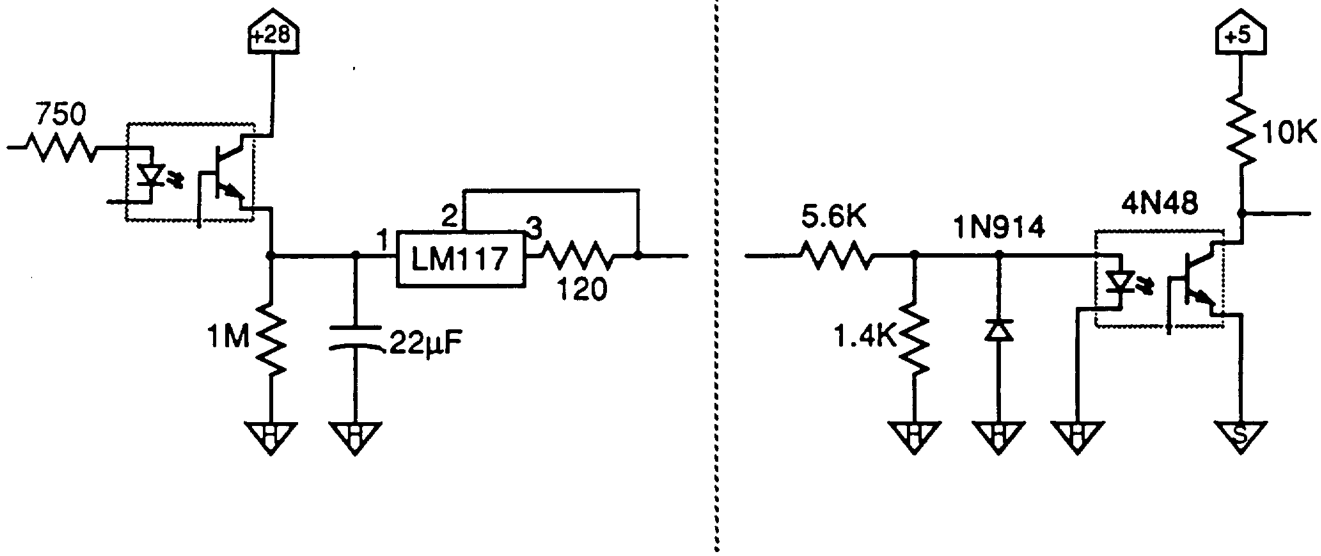
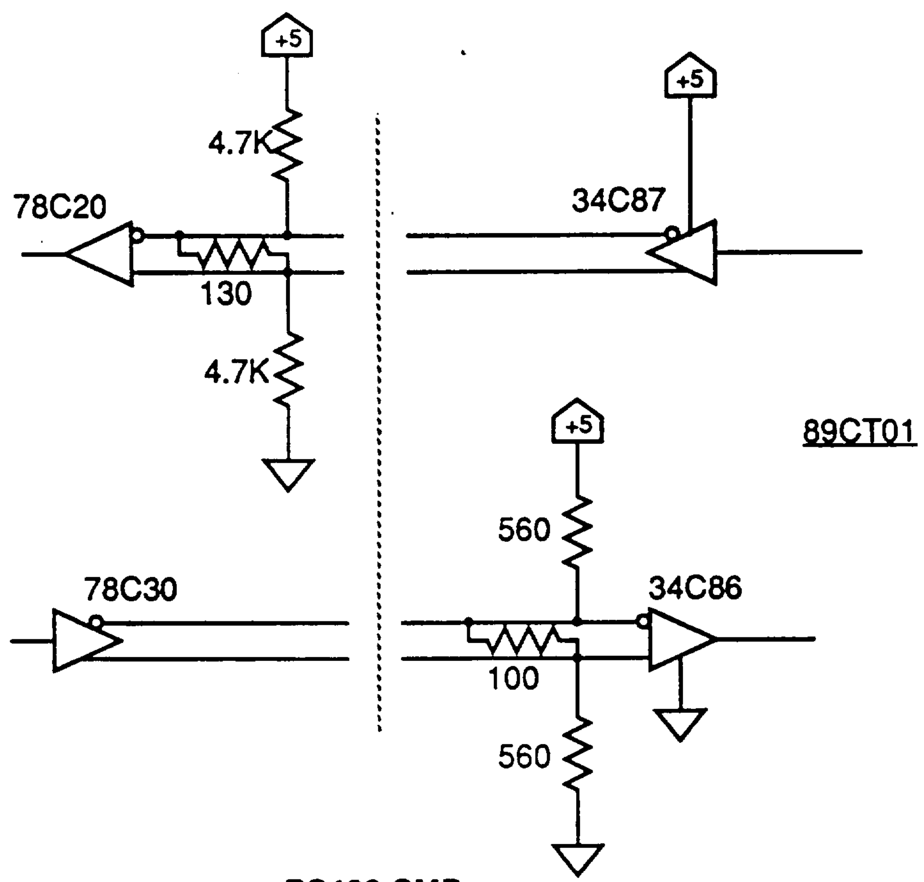
RoMPS

HITCHHIKER INTERFACES

ROMPS Hitchhiker/System Controller Interfaces



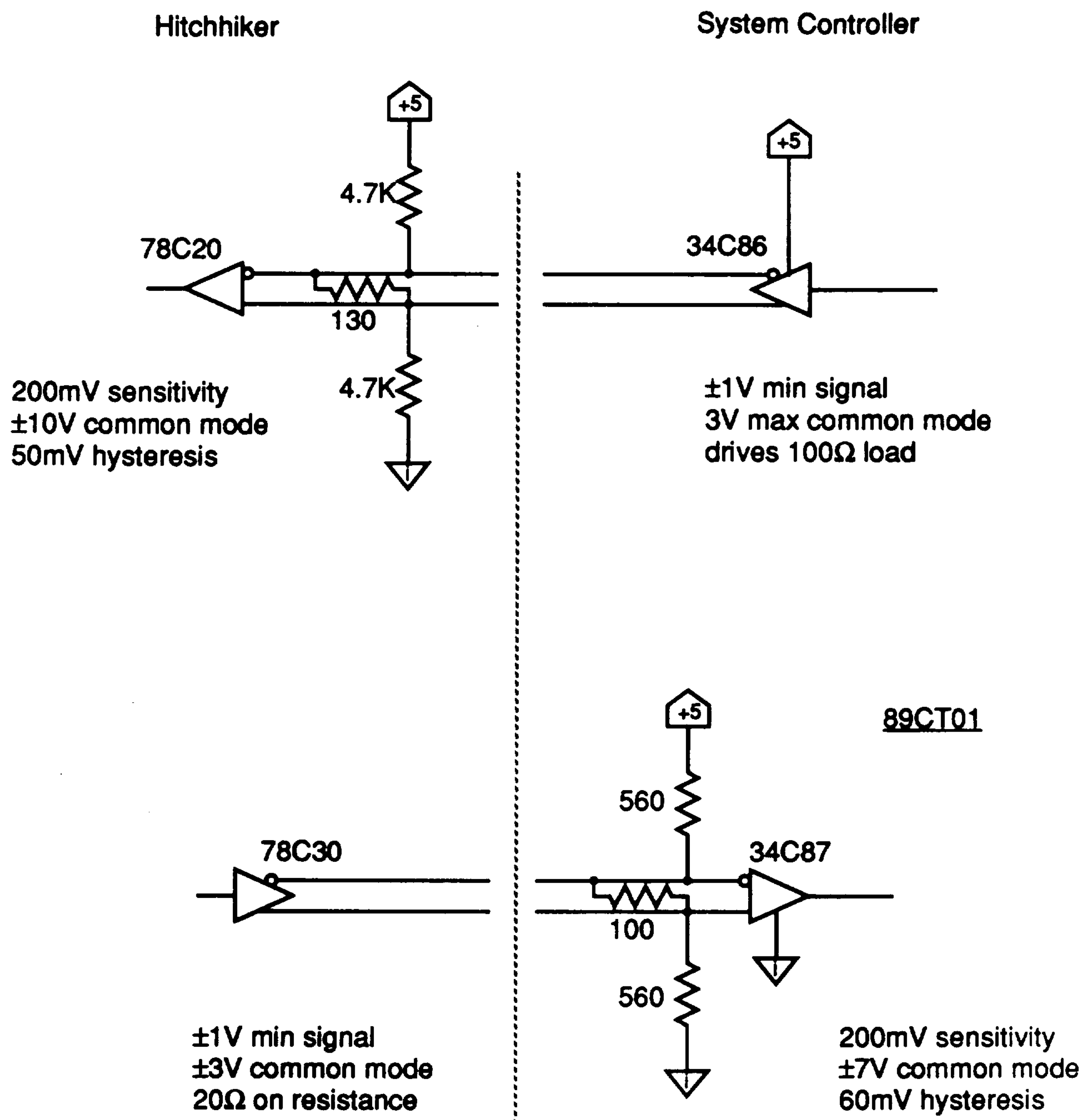
BILEVEL CMD



RS422 CMD

12/7/92 GD rev C

ROMPS Hitchhiker/System Controller Serial Compatibilty



12/5/92 GD

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& Robotics Center

RoMPS

BATTERY SYSTEM

LITHIUM THIONYL CHLORIDE BATTERY

CELL	PC
PART	3B880
MFGR	Electrochem
SPEC	manufactured under MIL-I-45208A
NOM VOLT	3.6 V
RATED CAP	1,000 mAH @ 3.4KOhm to 2.0V @ 25°C est @ 900 @ 0°C
OPER TEMP	-40°C TO +85°C
STOR TEMP	-40°C TO +85°C
SHELF LIFE	5.5% Loss per Year
INT. RES	0.6 < 1.0 Ohms
SHORT CKT	est @ < 6 amps w/o protection test results show about 180ma after 1sec short circuit temp rise of 42°C after 10 minutes
ENERGY	3.6 watt hours

EXPERIMENT CONTROL SYSTEM APPLICATION

OP MODE	Constant Current @ 110 uAmps Intermittent Duty - Static Memory Backup
CAP	est @ 800 mAh at final integration and test
OP TIME	> 8,45 hours with single cell cell capacity at EOL
PROTECTION	Two Fault Tolerant hot side current limiting resistor hot side diodes
SHORT CKT	30mA ~ (3.6-0.3) / 100 @BOL 17mA ~ (2.0-0.3) / 100 @EOL
FUSE	100 ohm resistor

ALKALINE-MANGANESE DIOXIDE BATTERY

CELL	SIZE D
PART	MN1300
MFGR	DURACELL
SPEC	n a
NOM VOLT	1.5V
RATED CAP	14,250 mAH @ 4.7 ohm to 0.8V @ 21°C est @ 11,000 mAH @ 4.7 ohm to 0.8V @ 0°C
OPER TEMP	-20°C TO +54°C
STOR TEMP	-20°C TO +54°C
SHELF LIFE	4% Loss per Year
INT. RES	0.1 OHM
SHORT CKT	est @ 15 amps w/o protection
ENERGY	17.3 watthours

EXPERIMENT CONTROL SYSTEM APPLICATION

OP MODE	Constant Power @ ~1 watt Intermittent Duty - Logic Circuits
CAP	est @ >10,000 mAh at final integration and test
OP TIME	>32 Hours with 2, three cell strings cell capacity at EOL current requirement
PROTECTION	Two Fault Tolerant ground leg fuse hot side diodes
SHORT CKT	14 amp ~ ((3*1.5)-0.4) / (3*0.1) BOL 1 amp ~ ((3*0.8)-0.4) / (3*0.8) EOL
FUSE	2 Amp Fuse is ~3X Load at EOL

ALKALINE-MANGANESE DIOXIDE BATTERY

CELL	SIZE D
PART	MN1300
MFGR	DURACELL
SPEC	n a
NOM VOLT	1.5V
RATED CAP	14,250 mAH @ 4.7 ohm to 0.8V @ 21°C est @ 11,000 mAH @ 4.7 ohm to 0.8V @ 0°C
OPER TEMP	-20°C TO +54°C
STOR TEMP	-20°C TO +54°C
SHELF LIFE	4% Loss per Year
INT. RES	0.1 OHM
SHORT CKT	est @ 15 amps w/o protection
ENERGY	17.3 watthours

EXPERIMENT CONTROL SYSTEM APPLICATION

OP MODE	Constant Power @ ~1 watt Intermittent Duty - Logic Circuits
CAP	est @ >10,000 mAh at final integration and test
OP TIME	>32 Hours with 2, three cell strings cell capacity at EOL current requirement
PROTECTION	Two Fault Tolerant ground leg fuse hot side diodes
SHORT CIRCUIT	14 amp ~ ((3*1.5)-0.4) / (3*0.1) BOL 1 amp ~ ((3*0.8)-0.4) / (3*0.8) EOL
FUSE	2 Amp Fuse is ~3X Load at EOL

LITHIUM THIONYL CHLORIDE BATTERY

CELL	PC
PART	3B880
MFGR	Electrochem
SPEC	manufactured under MIL-I-45208A
NOM VOLT	3.6 V
RATED CAP	1,000 mAH @ 3.4KOhm to 2.0V @ 25°C est @ 900 @ 0°C
OPER TEMP	-40°C TO +85°C
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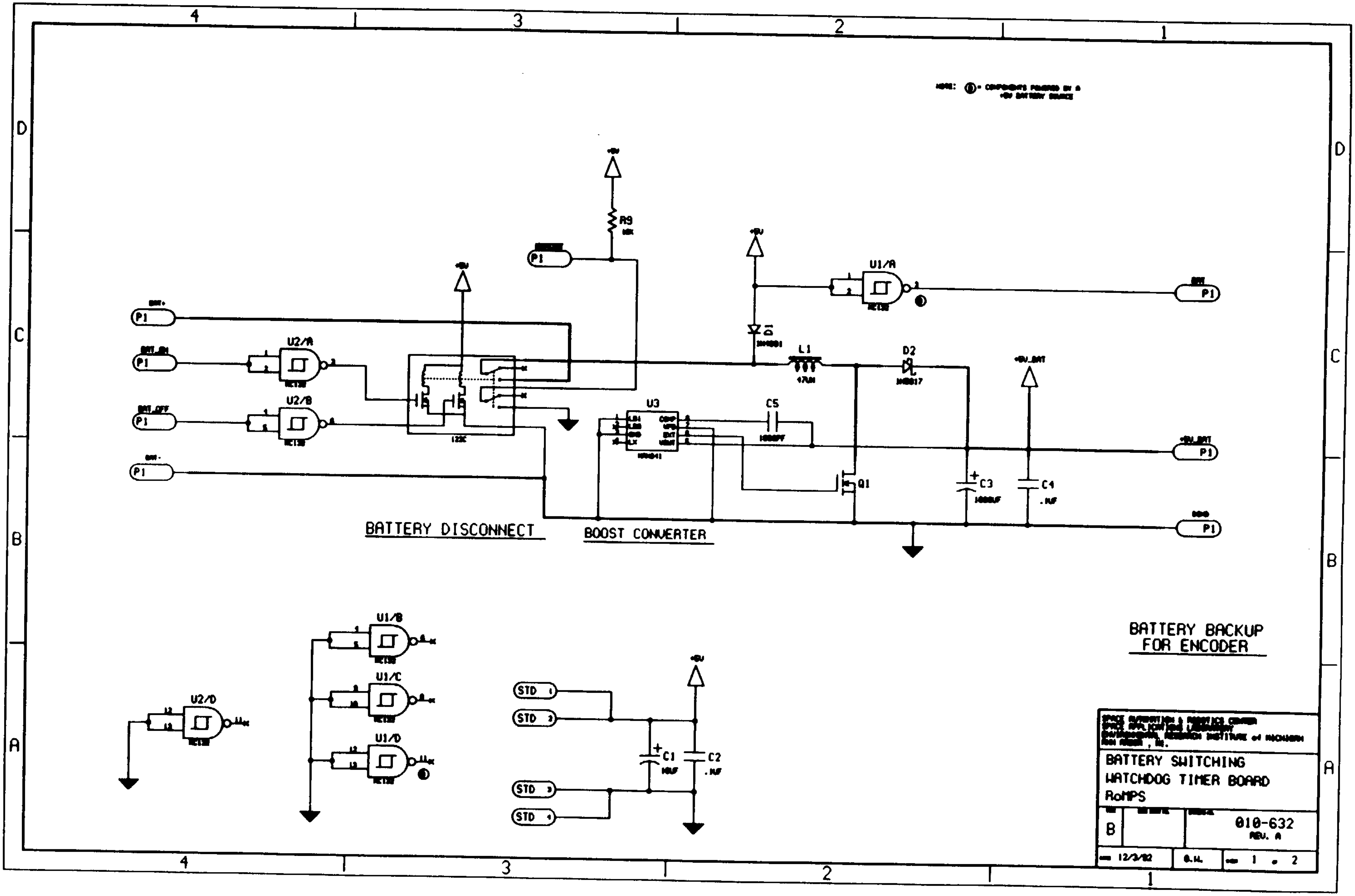
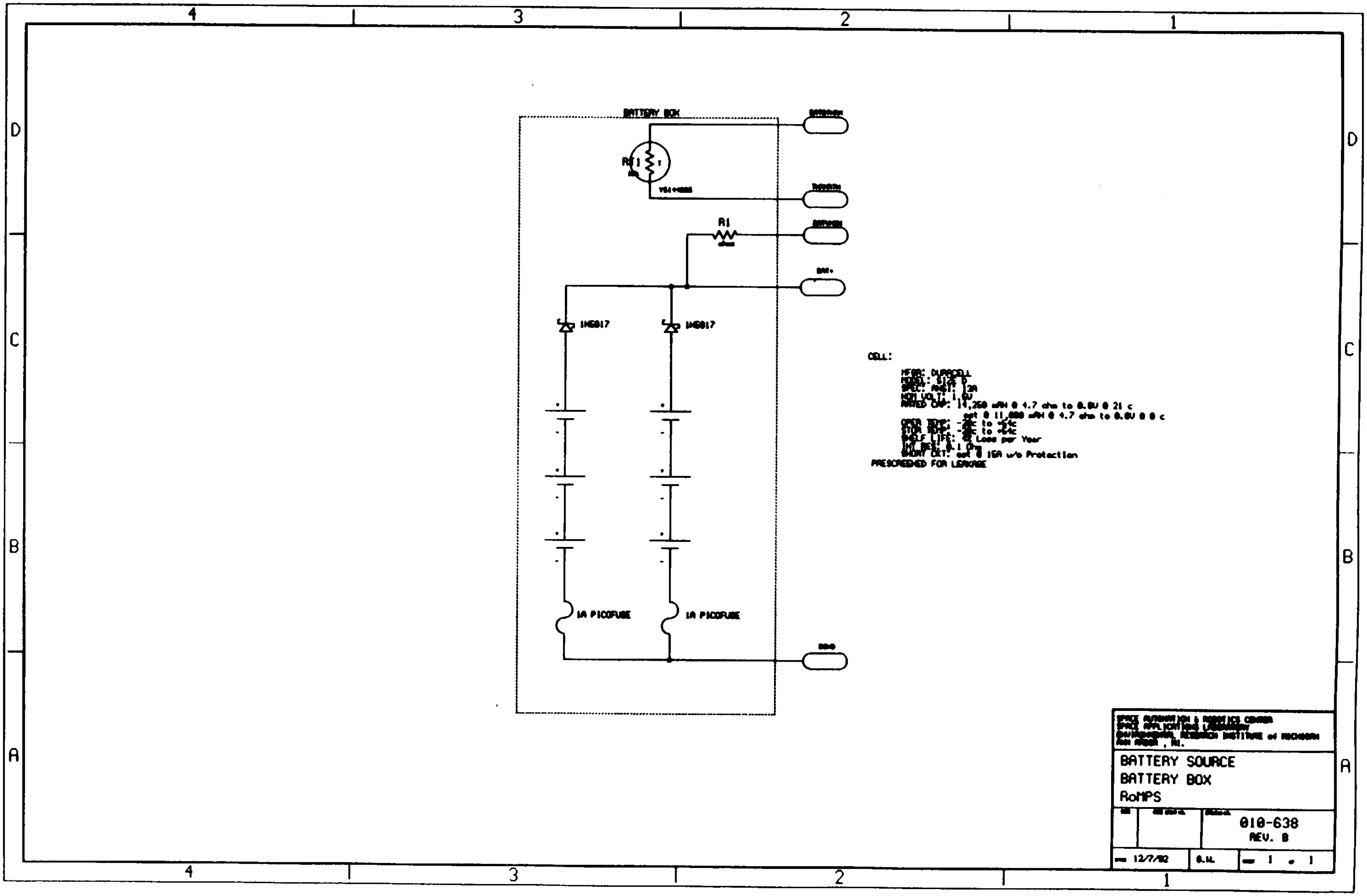
SHELF LIFE	5.5% Loss per Year
INT. RES	0.6 < 1.0 Ohms
SHORT CKT	est @ < 6 amps w/o protection test results show about 180ma after 1sec short circuit temp rise of 42°C after 10 minutes
ENERGY	3.6 watt hours

EXPERIMENT CONTROL SYSTEM APPLICATION

OP MODE	Constant Current @ 110 uAmps Intermittent Duty - Static Memory Backup
CAP	est @ 800 mAh at final integration and test
OP TIME	> 8,454 hours with single cell cell capacity at EOL
PROTECTION	Two Fault Tolerant hot side current limiting resistor hot side diodes
SHORT CIRCUIT	30mA ~ (3.6-0.3) / 100 @BOL 17mA ~ (2.0-0.3) / 100 @EOL
FUSE	100 ohm resistor



BATTERY DISCONNECT
BOOST CONVERTER
BATTERY BACKUP FOR ENCODER
U1/A
U1/B
U1/C
U1/D
U2/A
U2/B
U2/D
U3
R9
L1
D1
D2
Q1
C1
C2
C3
C4
C5
P1
STD
+5V_BAT
BAT_ON
BAT_OFF
BATTERY SWITCHING
WATCHDOG TIMER BOARD
RoMPS
B
010-632
REV. A
12/3/92
1 of 2



BATTERY BOX
R1
1N5817
1N5817
1A PICOFUSE
1A PICOFUSE
BAT+
CELL:
MFGR: DURACELL
RATED CAP: 14,250 mAH @ 4.7 ohm to 0.8V @ 21 c
est @ 11,000 mAH @ 4.7 ohm to 0.8V @ 0 c
SHELF LIFE: Loss per Year
SHORT CKT: est @ 15A w/o Protection
PRESCREENED FOR LEAKAGE
BATTERY SOURCE
BATTERY BOX
RoMPS
010-638
REV. B

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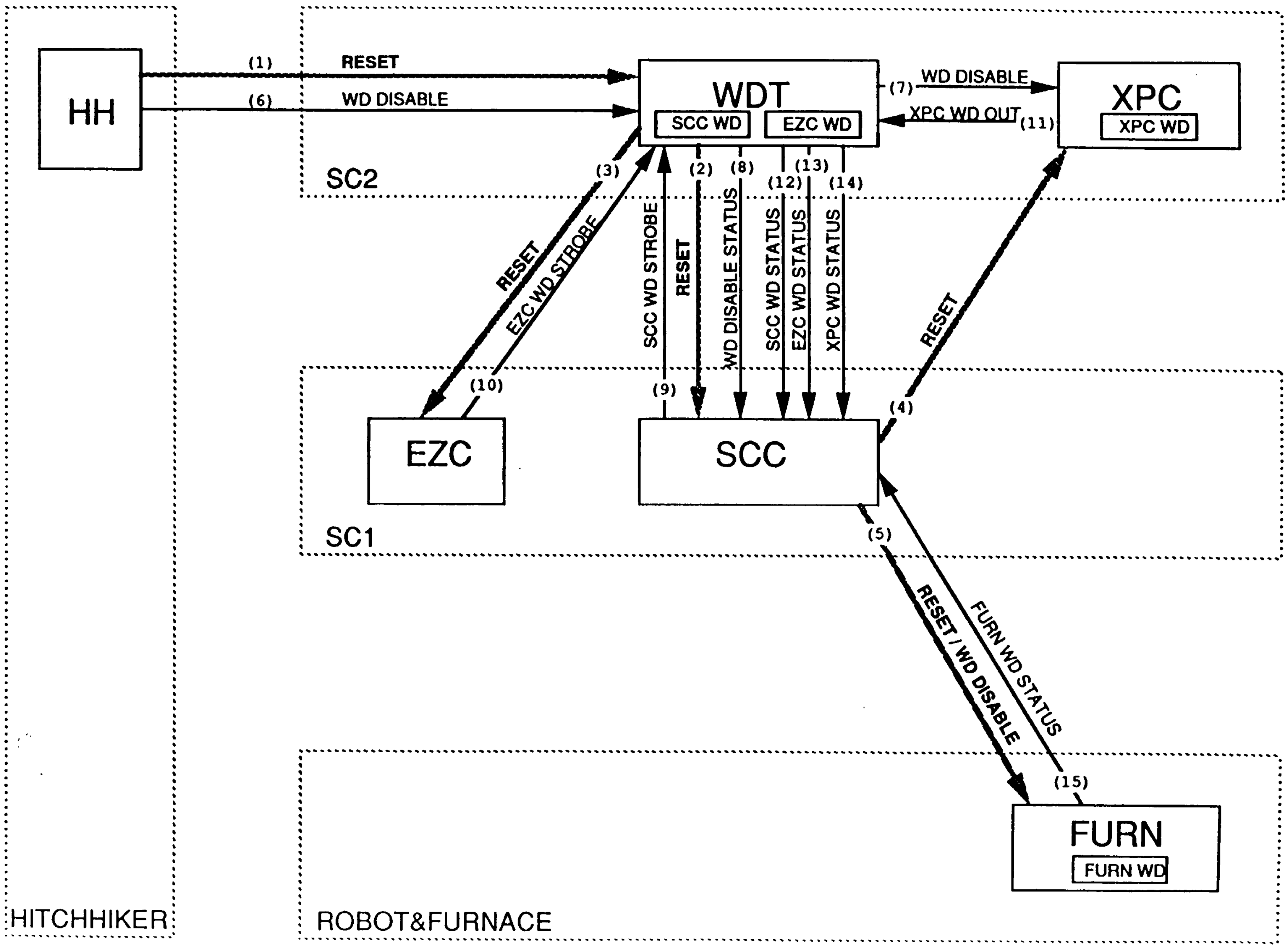
RoMPS

WATCHDOG TIMERS

ROMPS Reset and Watchdog Timer Signals

12/5/92 GD rev B



Notes for "ROMPS Reset and Watchdog Timer Signals" Diagram

12/5/92 GD rev C

RESETS

1) RESET	HH > WDT
2) RESET	WDT > SCC
3) RESET	WDT > EZC
4) RESET	SCC > XPC
5) RESET / WD DISABLE	SCC > FURN

A bilevel Reset cmd (1) from HH is converted to logic level in the WDT, which passes the cmd to SCC (2) and EZC (3).

The SCC software may then send Reset cmds to the XPC (4) or FURN (5). The lines are normally high (+5v); they should go low (0v) for one second, then go high again. Since these output lines go high (+5v) upon reset of the SCC, they do NOT automatically reset the XPC or FURN upon SCC reset, although those units will have there own internal power-up resets.

The Reset line to the FURN (5) also serves as a WD Disable (see below). The Reset is defined as the falling edge of the cmd; the WD DISABLE is defined by the sustained level of the cmd.

WATCHDOGS

6) WD DISABLE	HH > WDT
7) WD DISABLE	WDT > XPC
8) WD DISABLE STATUS	WDT > XPC
9) SCC WD STROBE	SCC > WDT
10) EZC WD STROBE	EZC > WDT
11) XPC WD OUT	XPC > WDT
12) SCC WD STATUS	WDT > SCC
13) EZC WD STATUS	WDT > SCC
14) XPC WD STATUS	WDT > SCC
15) FURN WD STATUS	FURN > SCC

A WD Disable cmd (6) from HH is converted to logic level and disables both SCC AND EZC watchdog timers in the WDT, and is also passed along to the XPC (7), which has its own watchdog timer.

The FURN does not receive this WD Disable cmd; rather the SCC software must control the enable/disable state of the watchdog timer in the FURN by setting the RESET / WD DISABLE (5) line either TBD to enable, or not TBD to disable.

The SCC may read WD DISABLE STATUS (8) from the WDT, which shows the current disable state affecting the SCC, EZC and XPC watchdog timers.

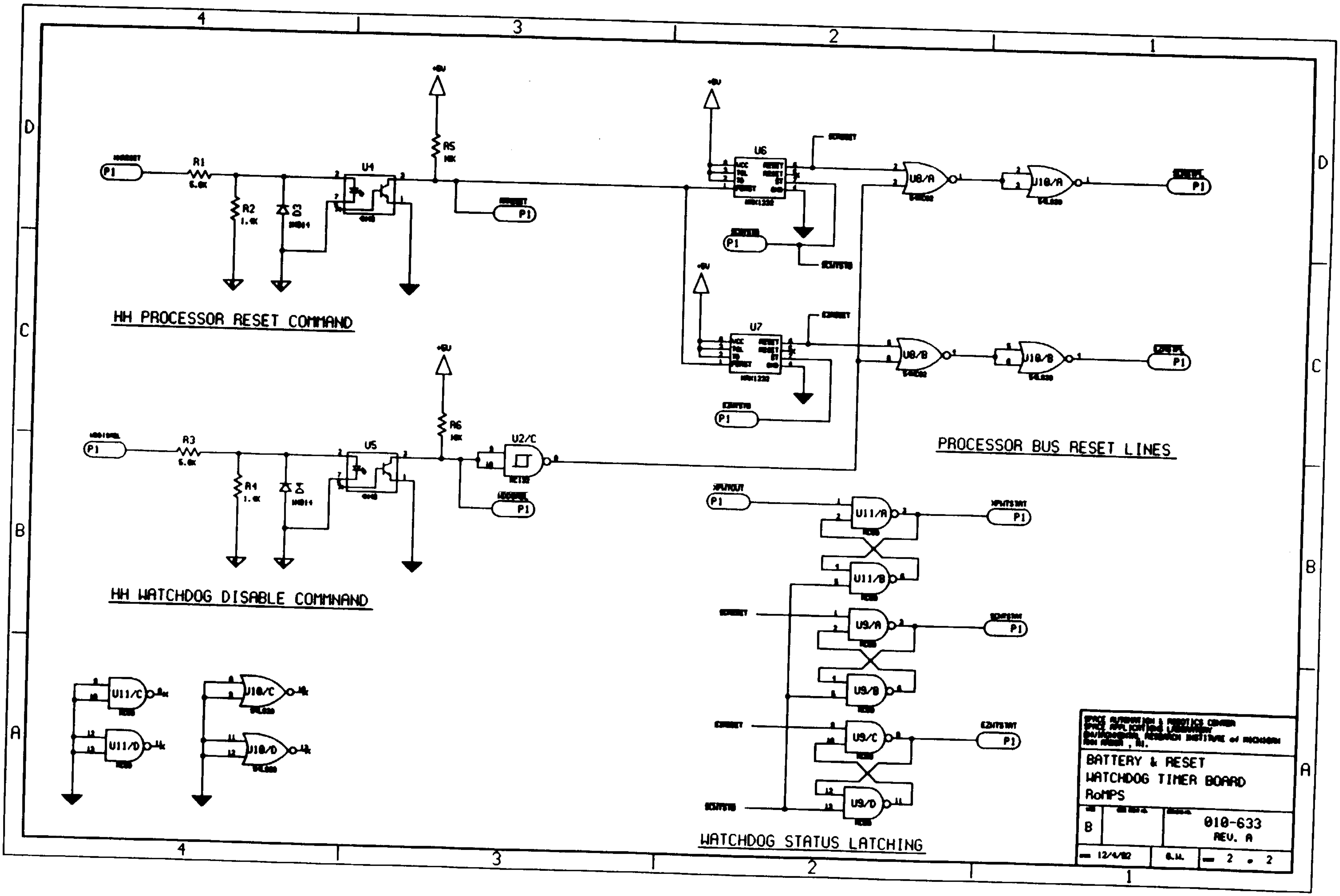
The two watchdog timers in the WDT are strobed by WD STROBE from SCC (9) and WD DISABLE from EZC (10).

The XPC watchdog timer state goes via XPC WD OUT (11) to the WDT, where the event is latched.

The SCC may read latches in the WDT that capture watchdog timeouts via SCC WD STATUS (12) and EZC WD STATUS (13), XPC WD STATUS (14), and the latch in the FURN via FURN WD STATUS (15).

The WDTimeout latches in the WDT will be cleared by the SCC WD STROBE signal (9). Therefore the SCC software should read the WD Status lines just before it kicks its own watchdog.

At the present time there is no method, either cmd wire or serial cmd, to clear a WD timeout latch in the FURN.


HH PROCESSOR RESET COMMAND
HH WATCHDOG DISABLE COMMAND
PROCESSOR BUS RESET LINES
WATCHDOG STATUS LATCHING
R1
R2
R3
R4
R5
R6
U4
U5
U6
U7
U2/C
U8/A
U8/B
U10/A
U10/B
U10/C
U10/D
U11/A
U11/B
U11/C
U11/D
U9/A
U9/B
U9/C
U9/D
P1
BATTERY & RESET
WATCHDOG TIMER BOARD
RoMPS
B
010-633
REV. A
12/4/92
2 of 2

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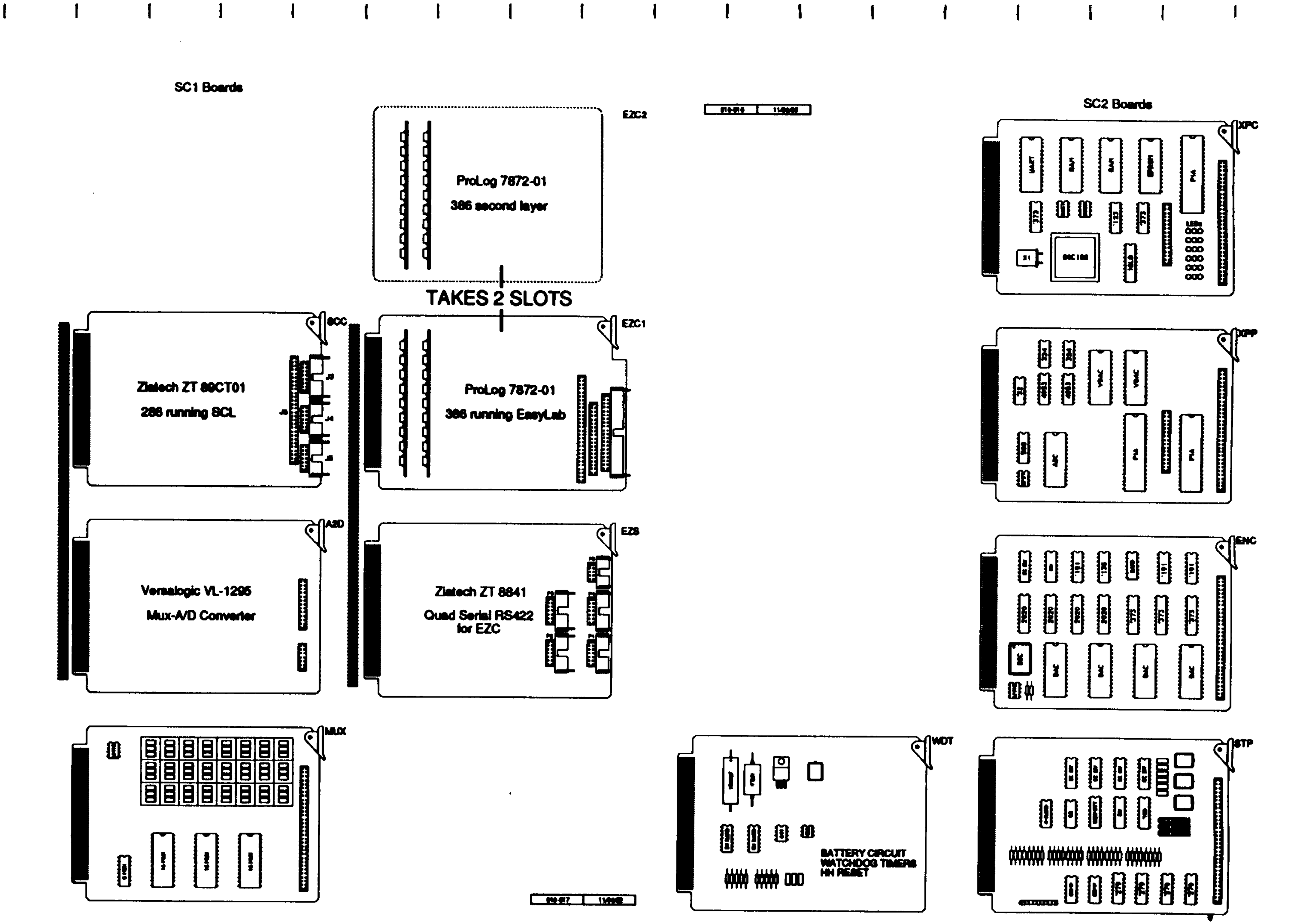
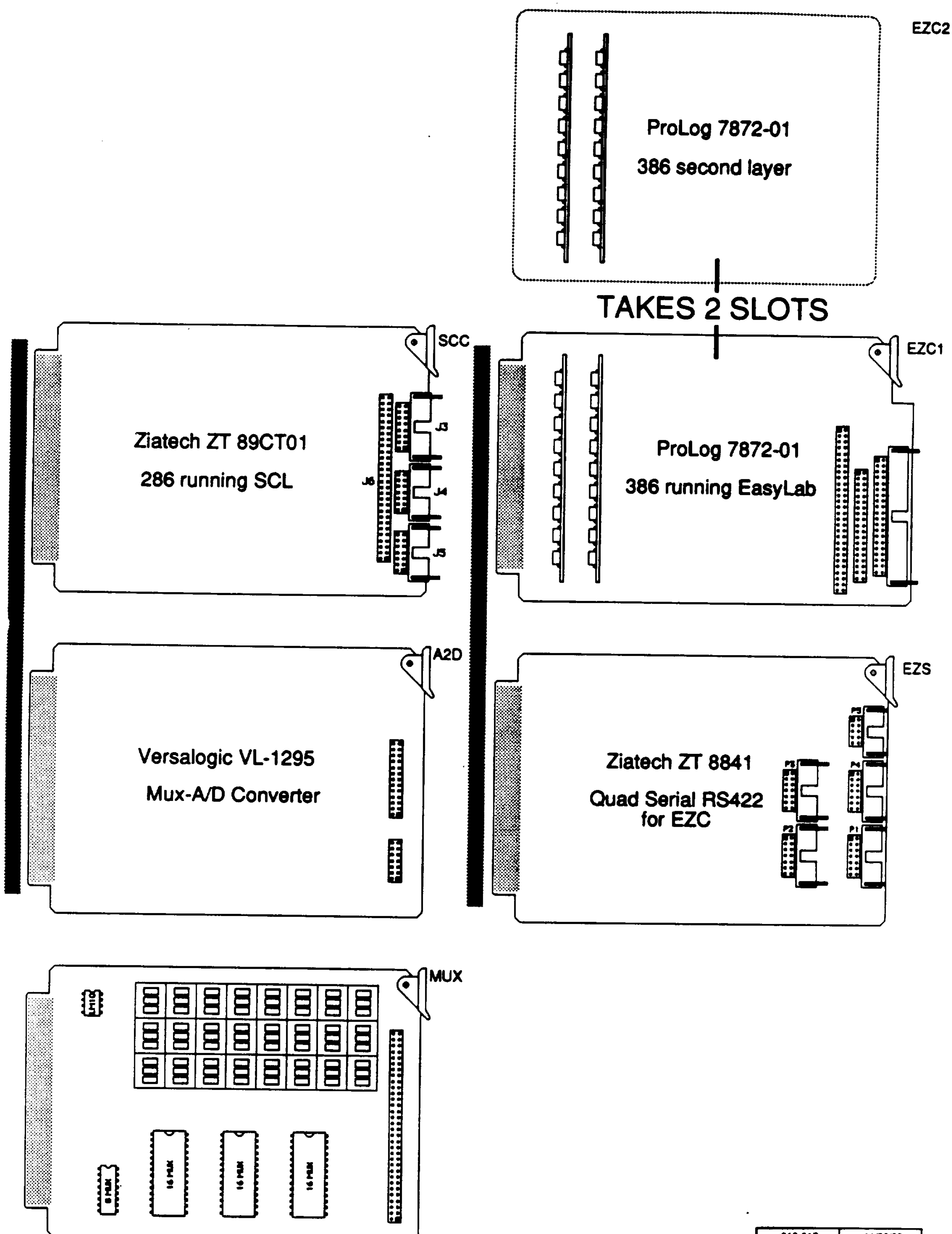
RoMPS

MECHANICAL AND THERMAL DESIGN AND ANALYSIS



SC1 Boards
EZC2
ProLog 7872-01
386 second layer
TAKES 2 SLOTS
SCC
Ziatech ZT 89CT01
286 running SCL
EZC1
ProLog 7872-01
386 running EasyLab
A2D
Versalogic VL-1295
Mux-A/D Converter
EZS
Ziatech ZT 8841
Quad Serial RS422
for EZC
MUX
SC2 Boards
XPC
XPP
ENC
WDT
BATTERY CIRCUIT
WATCHDOG TIMERS
HH RESET
STP

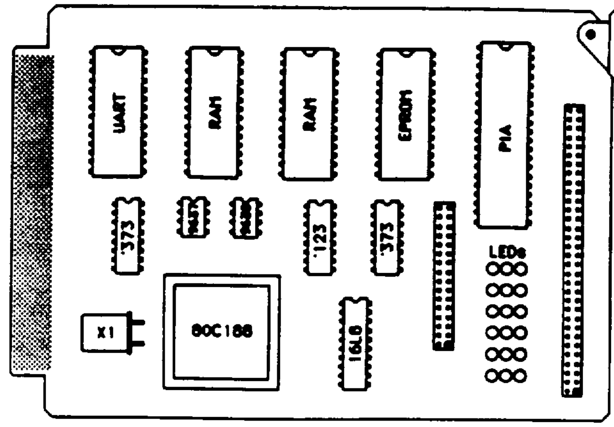
SC1 Boards


EZC2
ProLog 7872-01
386 second layer
TAKES 2 SLOTS
SCC
Ziatech ZT 89CT01
286 running SCL
J3
J4
J5
J6
EZC1
ProLog 7872-01
386 running EasyLab
A2D
Versalogic VL-1295
Mux-A/D Converter
EZS
Ziatech ZT 8841
Quad Serial RS422
for EZC
MUX

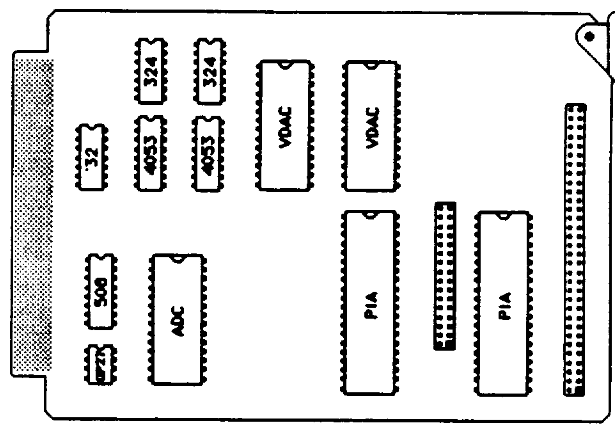
010-816	11/30/92

SC2 Boards

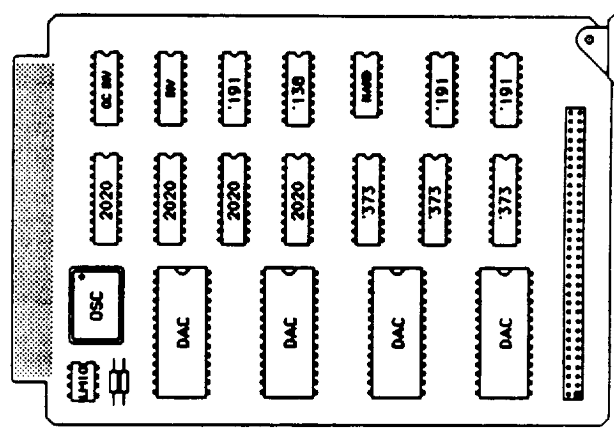
XPC



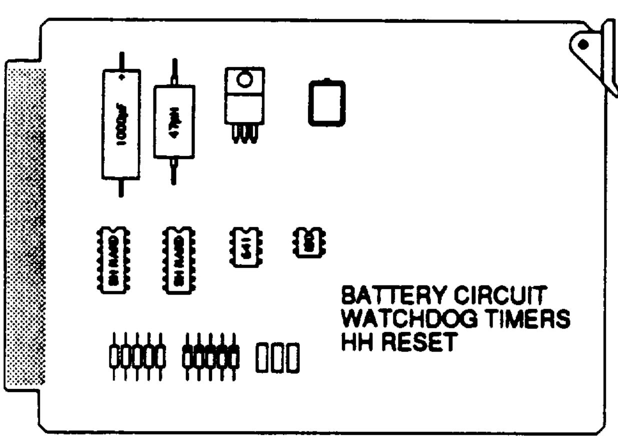
XPP



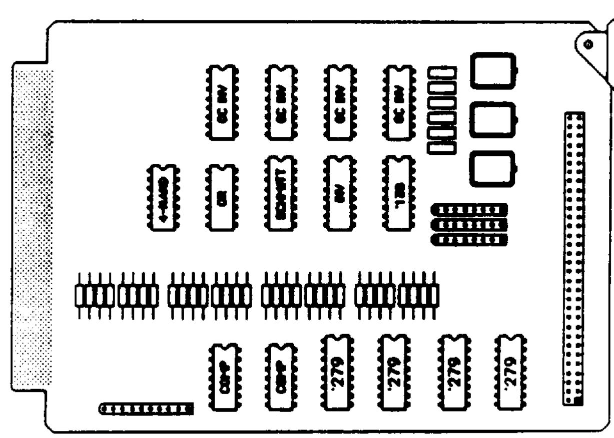
ENC



WDT



STP



SpARC Space Automation & Robotics Center

CONTROL SYSTEM DESIGN
WEIGHT & POWER SUMMARY

ITEM	SIZE	MASS	POWER
SUBASSEMBLY A	10.4 X 5.8 X 8.6	10 LBS	9.4 AVG
SCC PROCESSOR			
A2D ANALOG TO DIGITAL CONVERTER			
MUX SINGLE CONDITIONING			
EZC PROCESSOR			
SUBASSEMBLY B	10.4 X 5.8 X 8.6	10 LBS	12.0 AVG
XPC PROCESSOR			
ENC ENCODER INTERFACE			
XPP OUTPUT INTERFACE			
STP STOP CONTROL			
WATCHDOG TIMERS			
SUBASSEMBLY C	7.1 X 3.2 X 2.3	5 LBS	NA
BATTERY			
HARNESS	NA	2	NA
HARDWARE	NA	5.75	NA
TOTAL	1/2 GAS	36.1 LBS	23.6 WATTS

	A	B	C	D	E	F	G	H
1	RoMPS Weight & Power Summary 1/1							
2	12/9/91	11/12/92	gw					
3	.							
4	Subassembly	Mfgr	Size LWH in	Vol in3	Mass lbs	Pavg(w)	Ppk(w)	Comments
5								
6								
7	ELEC ASSY A							
8	SCC		(incl)	(incl)	0.5	(incl)	(incl)	
9	A2D		(incl)	(incl)	0.5	(incl)	(incl)	
10	MUX		(incl)	(incl)	0.5	(incl)	(incl)	
11	EZC		(incl)	(incl)	0.5	(incl)	(incl)	
12	EZS		(incl)	(incl)	0.5	(incl)	(incl)	
13	SC housing	SwRI	10.37x5.807x8.544	532.37	7.5	(incl)	(incl)	rugged housing
14	Subtotal				10	9.43	18.77	
15	Robot Interfaces				incl			
16								
17	ELEC ASSY B							
18	WDT		(incl)	(incl)	0.5	(incl)	(incl)	
19	ENC		(incl)	(incl)	0.5	(incl)	(incl)	
20	XPP		(incl)	(incl)	0.5	(incl)	(incl)	
21	XPC		(incl)	(incl)	0.5	(incl)	(incl)	
22	STP		(incl)	(incl)	0.5	(incl)	(incl)	
23	SC housing	SwRI	10.37x5.807x8.544	532.37	7.5	(incl)	(incl)	rugged housing
24	Subtotal				10	12.011	14.373	
25	Robot Interfaces				incl			
26								
27	ELEC ASSY C							
28	Battery Box		7.1x3.125x2.313	51.32	5	0	0	rugged housing
29								
30	MISC							
31	Ext Harness		n/a		2	0	0	
32	Int Harness		n/a		2	0	0	
33	Spacers		0.25x10.62x17	45.135	0.75	0	0	
34	Mounting Hardware		n/a		0.5	0	0	
35	Adapter Plate		0.25x6x10	15	4.5	0	0	
36	Subtotal			60.135	9.75	0	0	
37								
38								
39								
40								
41								
42								

	A	B	C	D	E	F	G	H
43								
44								
45								
46								
47								
48	t.encoder							
49	t.eot							
50	z.encoder							
51	z.eot							
52	r.encoder							
53	r.eot							
54	g.eot							
55	5 ysi 30k thermistors @ 25°C @ 15v bias							
56								
57								
58								
59	TOTAL			1176.2	34.75	21.441	33.143	
60								
61								
62								
63								

	A	B	C	D	E	F	G	H
64								
65								
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67								
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82								

	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	Romps Power Breakdown 1/n															
2													Modules/PCB/Etc			
3																
4	Secondary current in mA															
5	5		12		-12		15		-15		28					
6	typ	max	typ	max	typ	max	typ	max	typ	max	typ	max				
7																
8	500	900	10	20	10	20										
9	375	450														
10	1	1					3	6	1	1						
11	500	1000	15	30	15	30										
12	90	350	60	200	60	130										
13																
14	1466	2701	85	250	85	180	3	6	1	1	336.8	670.4	28V Value for SwRI Power			
15											421	837.9	SwRI Power @ 28V			
16													w/ converter @ 80% effiency			
17	232	294					0	0	0	0						
18	30	51					48	72	48	72						
19	332	337	18	20	25	34	74	91	58	66						
20	776	857														
21	53	63					32	40	32	40						
22																
23	1423	1602	18	20	25	34	154	203	138	178	429	513.3	28V Value for SwRI Power			
24											536.2	641.7	SwRI Power @ 28V			
25													w/ converter @ 80% effiency			
26																
27											765.8	1184	Total Controller Power @ 28V			
28											957.2	1480	Total Controller Power @ 28V			
29													w/ converter @ 80% effiency			
30																
31																
32																
33																
34																
35																
36																
37																
38																
39																
40																
41																
42																

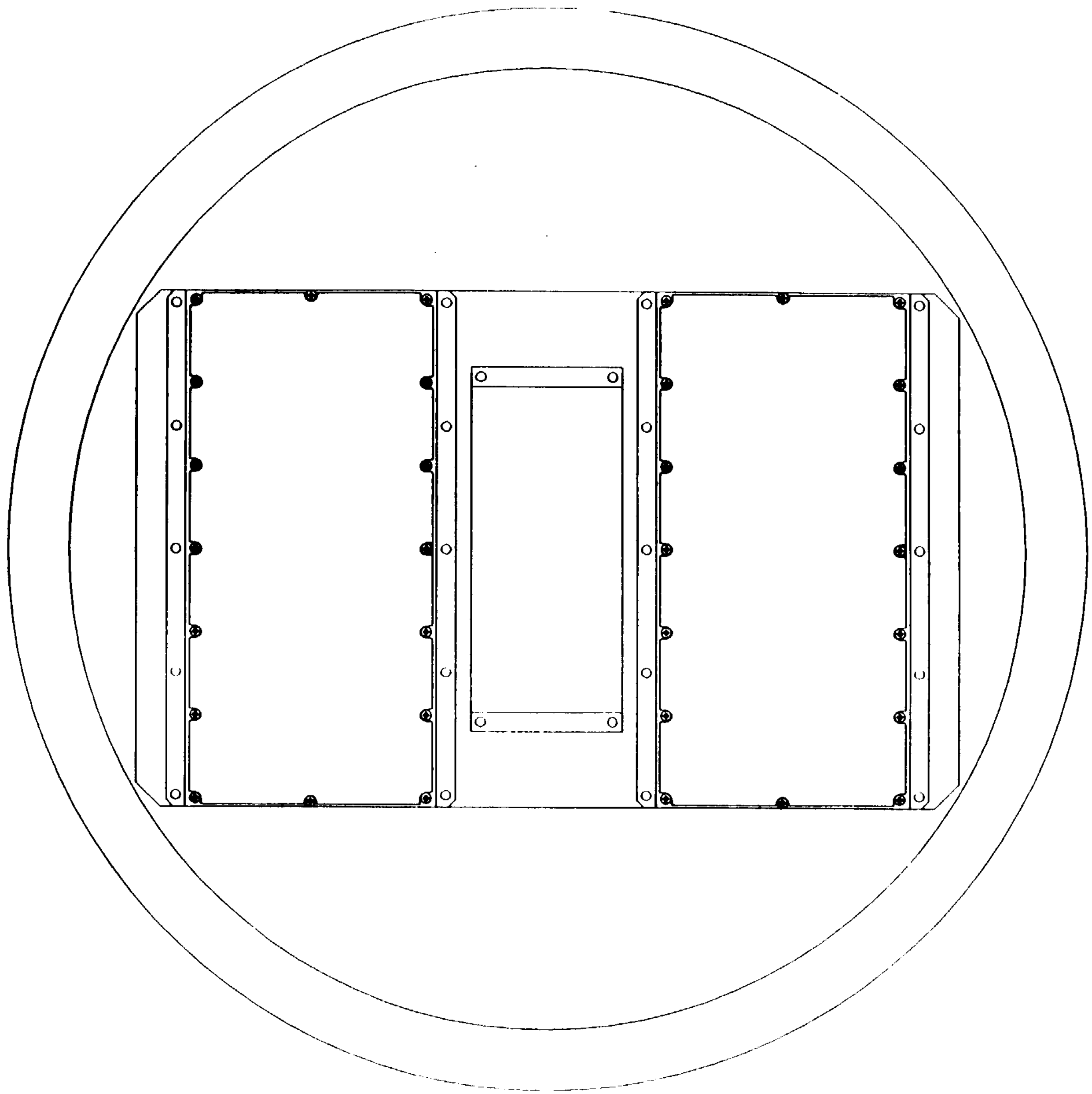
	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
43	Romps Power Breakdown 2/n												Individual Components			
44	Secondary current in mA															
45	5		12		-12		15		-15							
46	typ	max	typ	max	typ	max	typ	max	typ	max						
47																
48	17	40											t.encoder	HEDS-9100		
49	21.85	21.85											t.eot			
50	17	40											z.encoder	HEDS-9100		
51	21.85	21.85											z.eot			
52	17	40											r.encoder	HEDS-9200		
53	21.85	21.85											r.eot			
54	21.85	21.85											g.eot			
55							2.5						5 ysi 30k thermistors @ 25°C @ 15v bias			
56																
57																
58	138.4	207.4	0	0	0	0	2.5	0	0	0	26.05	37.04	component subtotal @ 28V			
59																
60											33	46	Total component Power @ 28V			
61													w/ converter @ 80% effiency			
62																
63																

	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
64	Romps Power Breakdown 3/n SUMMARY															
65	Secondary current in mA															
66																
67																
68																
69																
70																
71																
72																
73																
74																
75																
76																
77																
78																
79																
80																
81																
82																

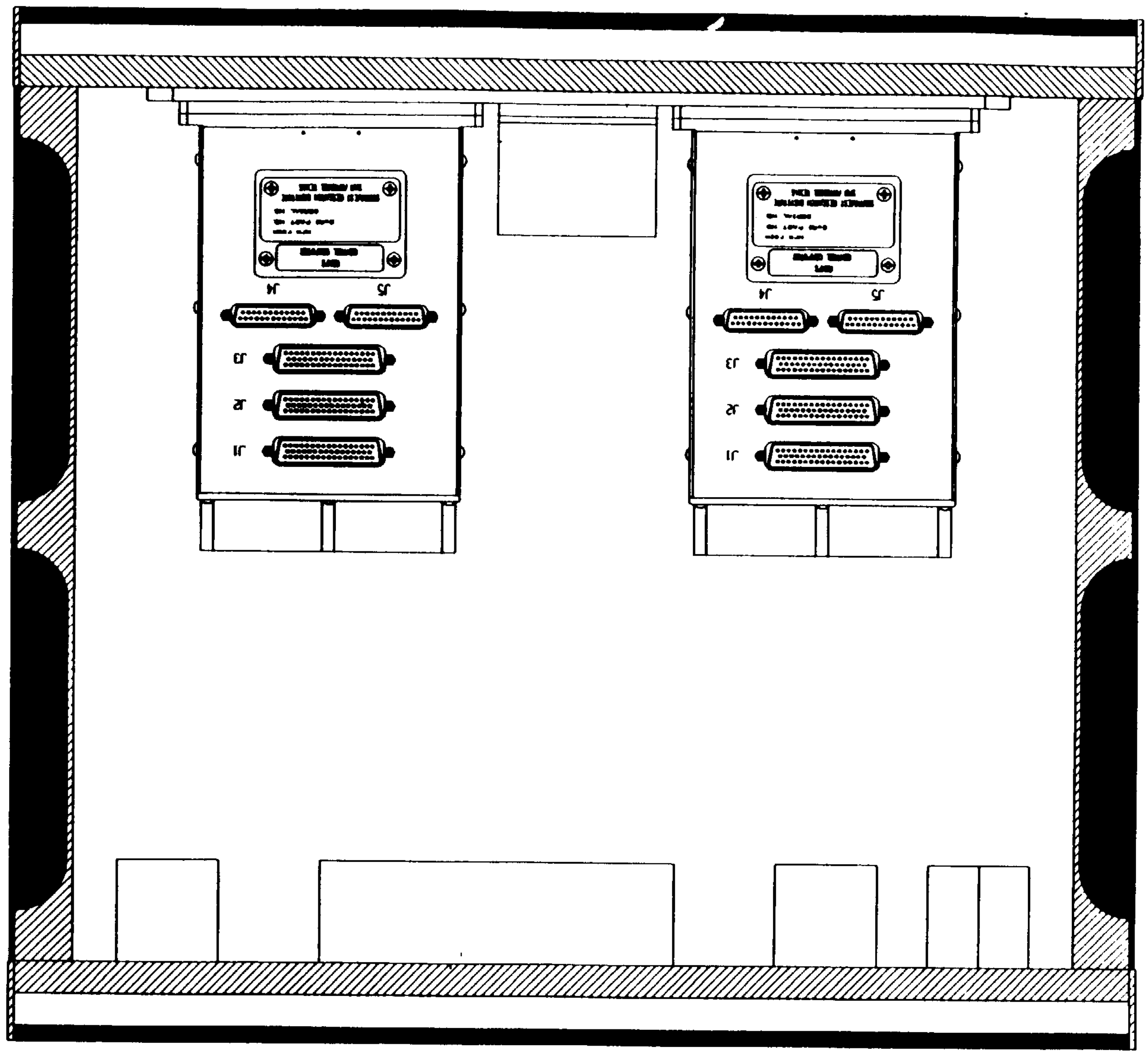
RoMPS Individual Board Power Summary

						Max Current(mA) for each voltage							
Board	Part	Qty		5		12		-12		15		-15	Battery
			TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	MAX
XFC													
	HT123	1	2.6	3.2									
	80C188	1	180	180									
	HT373	1	1.3	1.5									
	51256A	2	200	200									
	E27C256	1	30	30									
	82C55A	1	10	10									
	PAL16L8	1	140	185									
	8251A	1	100	100									
	LED	16	32	32									
	UA9637	1	35	50									
	UA9638	1	45	65									
	7400	1	0.1	0.1									
			776	856.8	0	0	0	0	0	0	0	0	
XPP													
	AD396	2							40	56	36	44	
	HT32	1	1.2	1.5									
	C4053	2	0.4	0.4									
	LM324AN	2	1.4	2.4									
	AD679	1	8	12	18	20	25	34					
	OP-27	1							3.3	3.3	3.3	3.3	
	DG508	1							0.6	1.5	0.1	0.2	
	82C55A	2	20	20									
	74AC138	1	0.1	0.2									
			31.1	36.5	18	20	25	34	43.9	60.8	39.4	47.5	
ENC													
	54HT138	1	0.5	0.5									0.5
	HT00	1	0.2	0.5									0.5
	54HT191	5	5	6.5									6.5
	HC04	2	0.2	0.2									0.2
	HC05	1	0.1	0.1									0.1
	HP2020	4	4	4									4
	AD669	4	12	30					48	72	48	72	
	54HT373	6	7.8	9									9
			29.8	50.8	0	0	0	0	48	72	48	72	
MUX													
	DG508	1							0.6	1.5	0.1	0.2	
	LM10CN	1	0.3	0.6									
	DG506	3							1.8	4.5	0.3	0.6	
			0.3	0.6	0	0	0	0	2.4	6	0.4	0.8	
WDT													
	RY122C	1	116	116									
	MAX641	1	0.2	53									53
	HC132	2	0.2	0.2									
	54LS33	1	14	14									
	54HC02	1	0.1	0.1									
	MAX1232	2	0.4	10									
	HC00	1	0.2	0.5									
	4N48	2	100	100									
			231.1	293.8	0	0	0	0	0	0	0	0	
STP													
	LM139	2							32	40	32	40	
	C4044B	4	0.4	0.8									
	C4072B	3	0.3	0.3									
	C4071B	1	0.1	0.1									
	HC04	3	0.3	0.3									
	HC05	3	0.3	0.3									
	HC14	1	0.3	0.3									
	CD21CDW	3	51	60									
			52.7	62.1	0	0	0	0	32	40	32	40	
SCC													
	ZT89CT01		500	1000	10	20	10	20					
EZC													
	7872-01		500	1000	15	30	15	30					
A2D													
	VL12C95		375	500									
EZS													
	ZT88CY41		90	350	60	200	60	130					
Discrete													
	HEDS-9100	2	34	80									80
	HEDS-9200	1	17	40									40

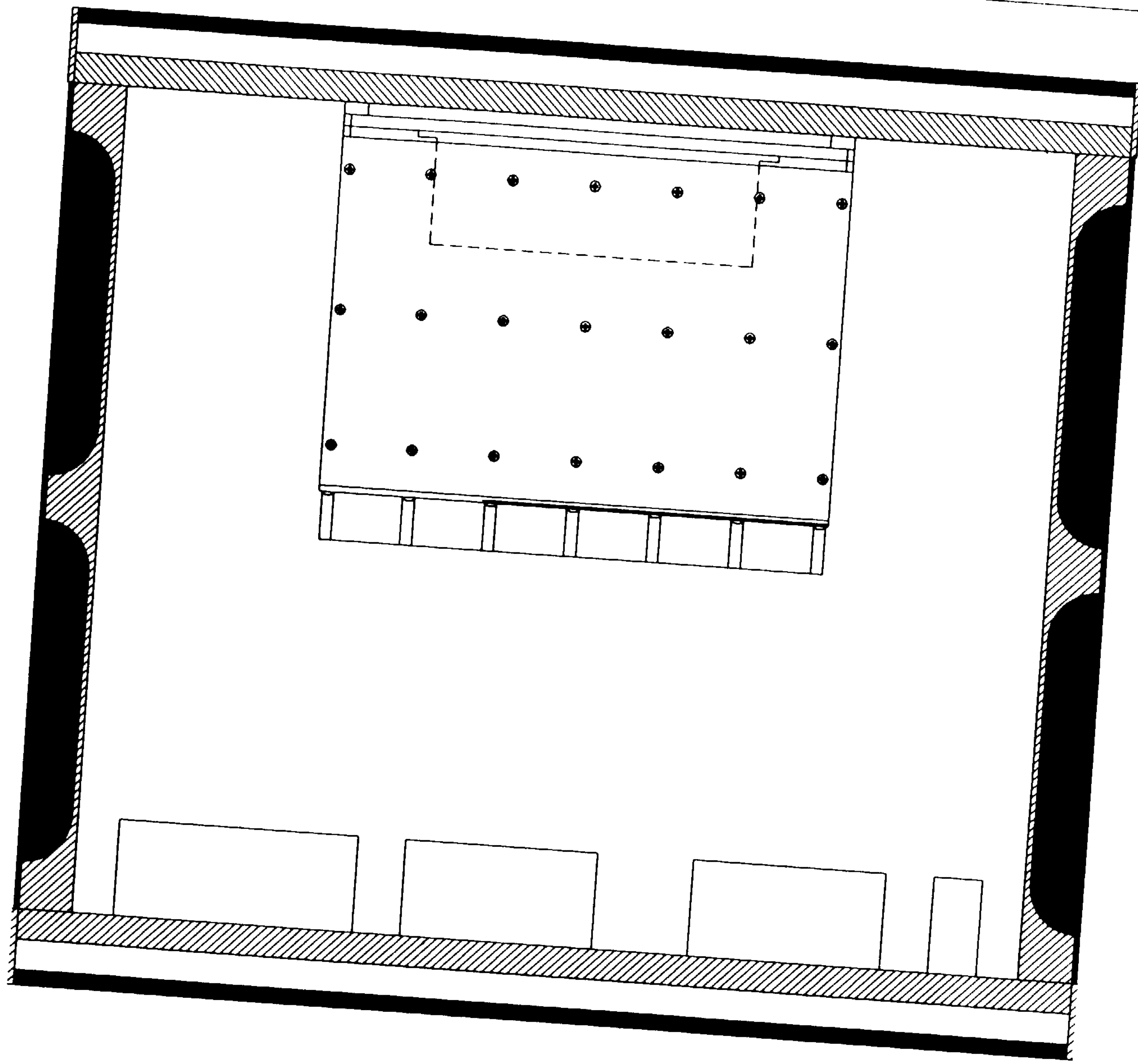
	EOT	8	175.2	175.2											
													193.8	Battery Total 5V	
													323	Battery	



ENGINEER R.E. QUADA	DRAFTPERSON N.J. THOMAS	UNITS: INCHES TOLERANCES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	ELECTRONICS LAYOUT ROMPS 010-250 PAGE 1 OF 3	UNLESS SPECIFIED: ± 0.005" ± 30 MINUTES	11/02/92 DATE



ENGINEER R.E. QUADA	DRAFTPERSON N.J. THOMAS	UNITS: INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	ELECTRONICS LAYOUT ROMPS 010-250 PAGE 2 OF 3	TOLERANCES UNLESS SPECIFIED: ± 0.005" ± 30 MINUTES	11/02/92 DATE



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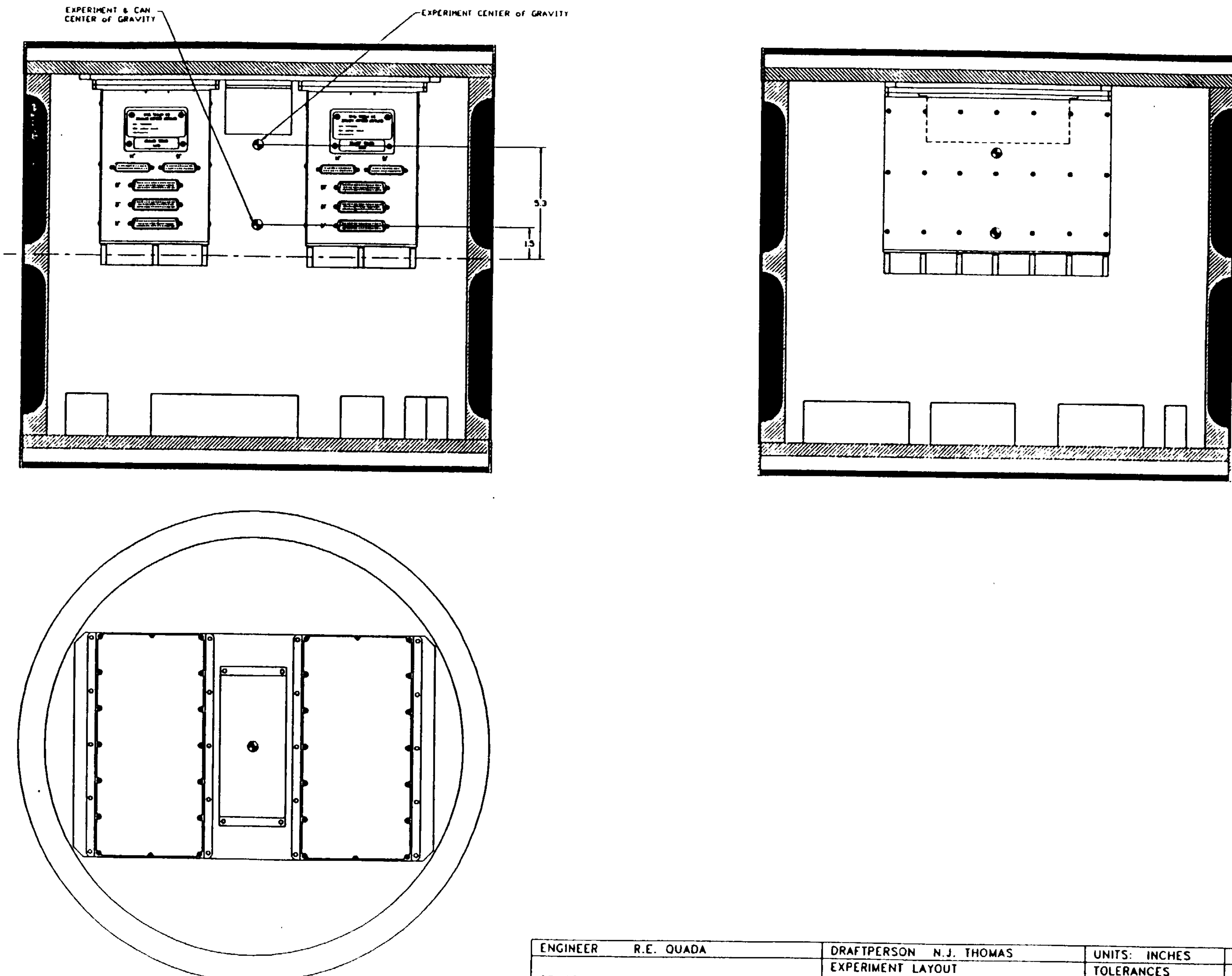
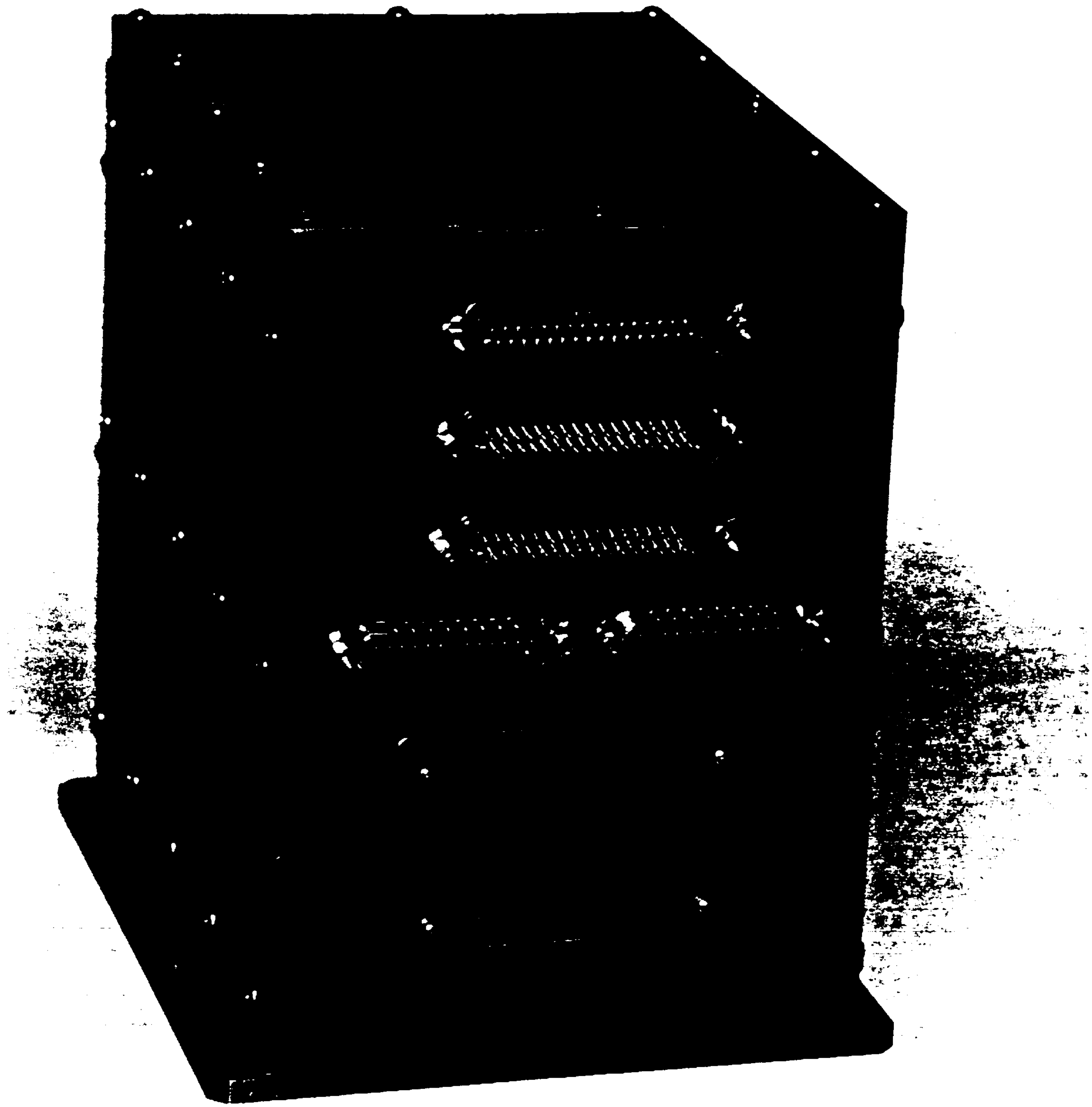
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	ELECTRONICS LAYOUT ROMPS	TOLERANCES UNLESS SPECIFIED:	
	010-250 PAGE 3 OF 3	± 0.005" ± 30 MINUTES	11/02/92 DATE



ENGINEER R.E. QUADA	DRAFTPERSON N.J. THOMAS	UNITS: INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	EXPERIMENT LAYOUT & CENTER OF GRAVITY ROMPS 010-257	TOLERANCES UNLESS SPECIFIED: ± 0.005" ± 30 MINUTES	12/04/92 DATE



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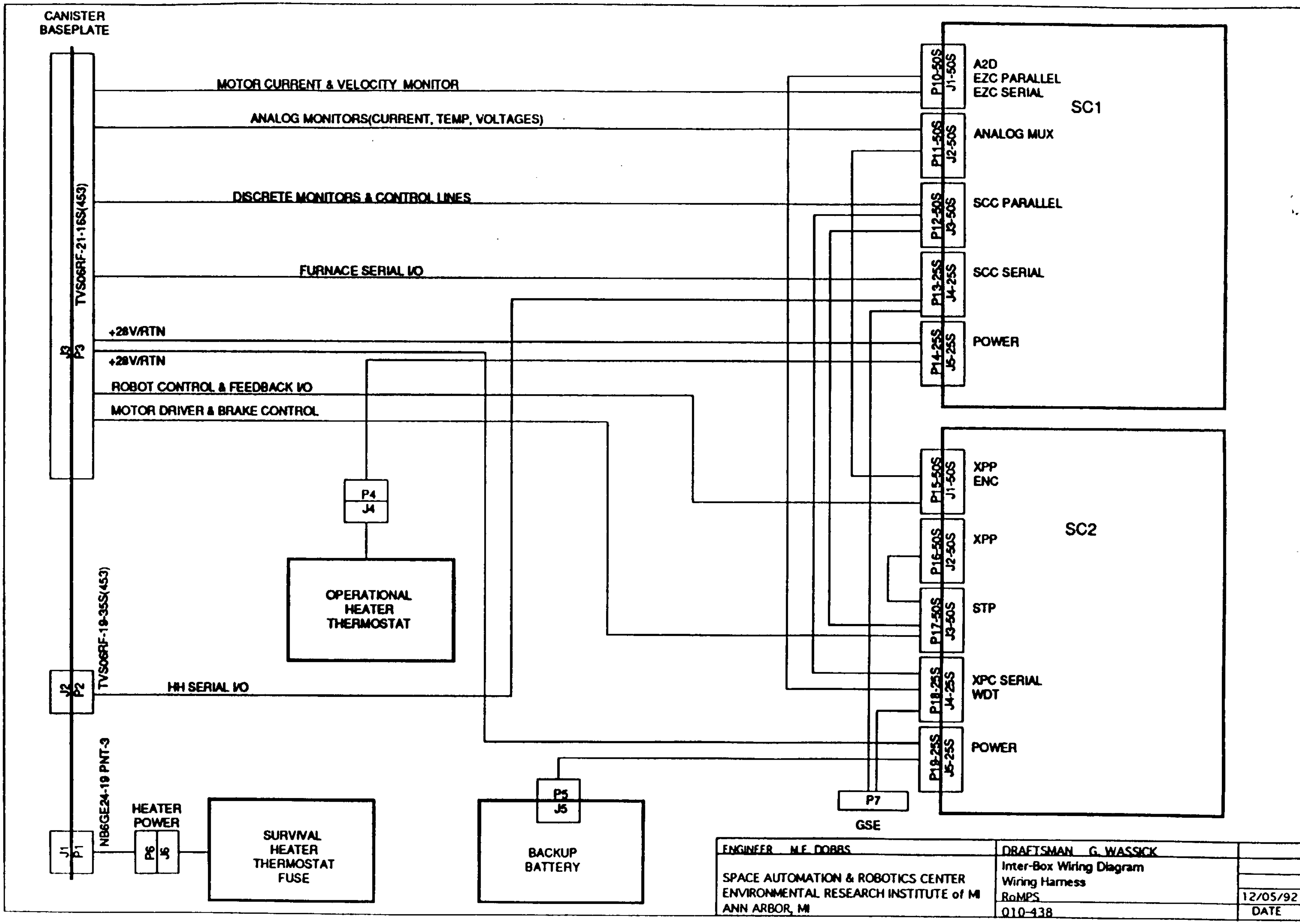
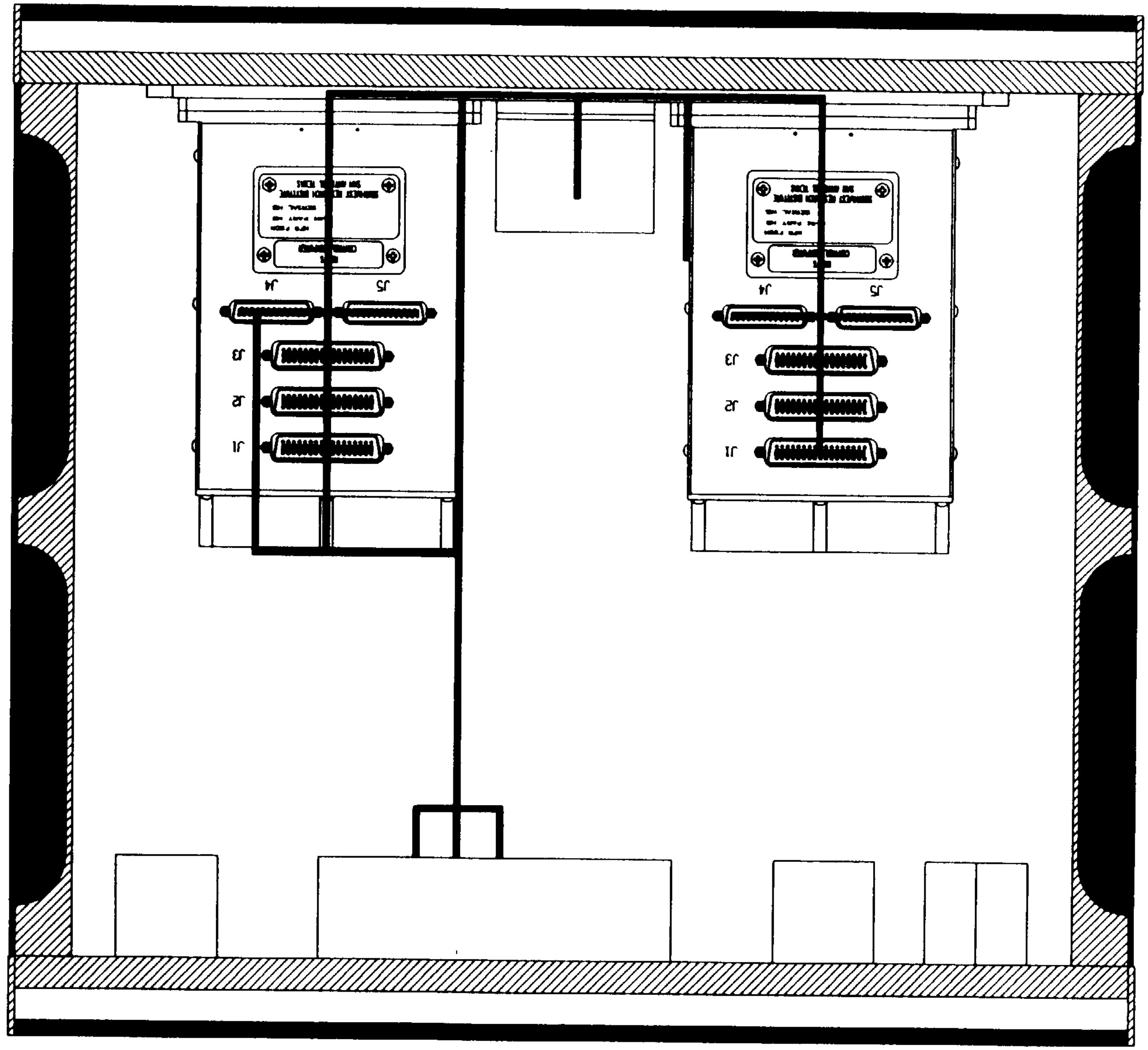
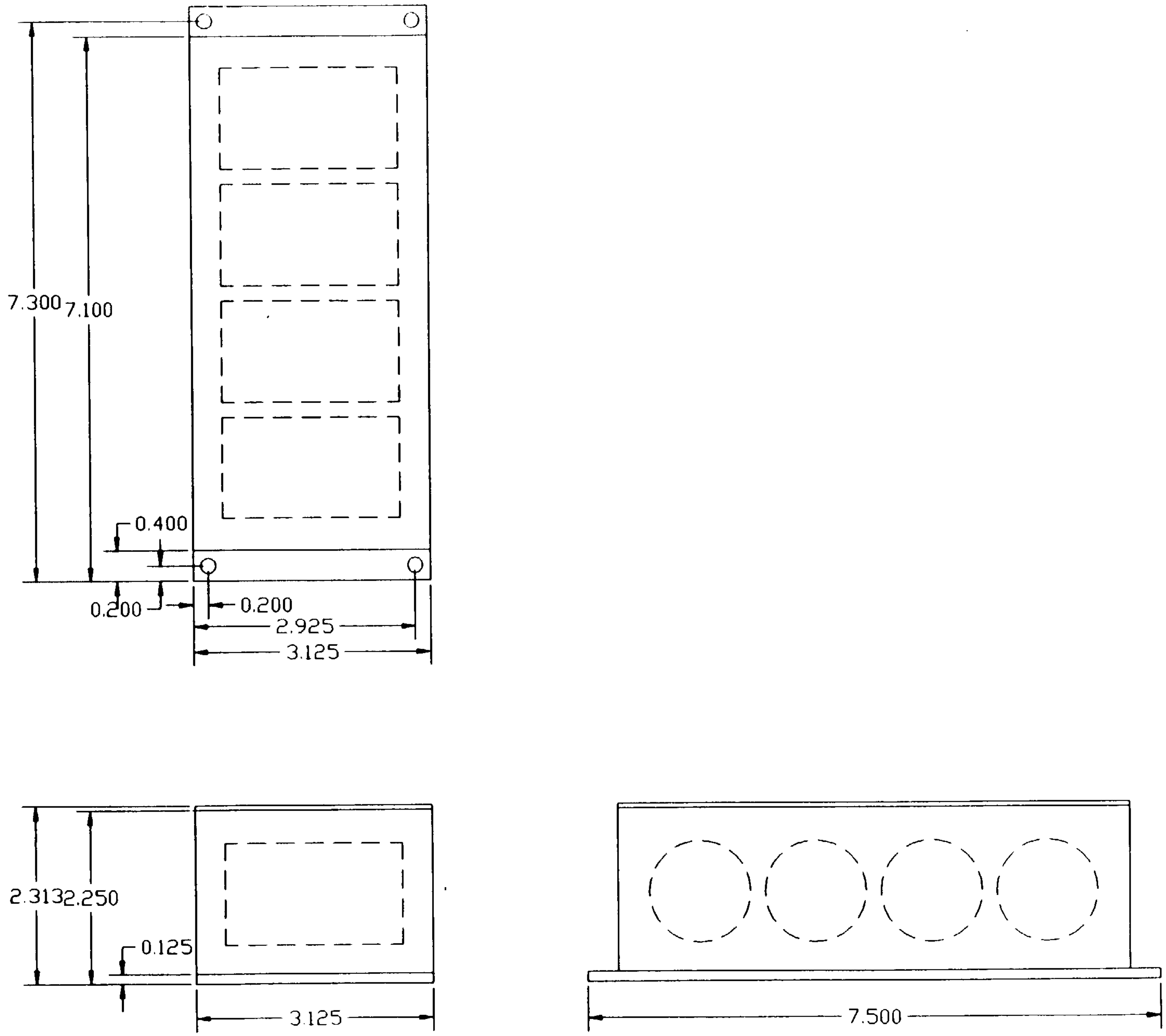
OF POOR QUALITY



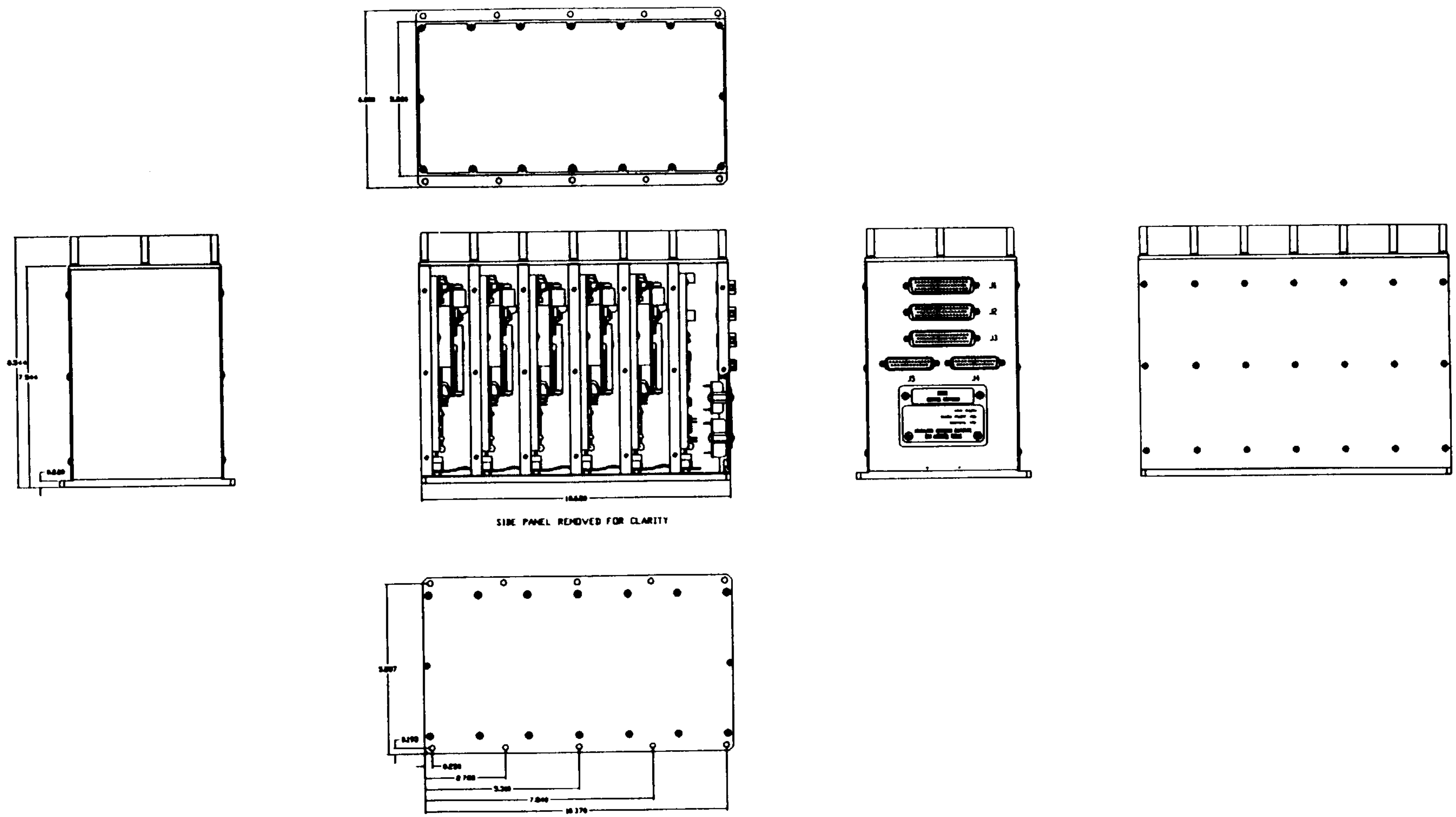
CANISTER BASEPLATE
TVS06RF-21-16S(453)
J3 P3
TVS06RF-19-35S(453)
J2 P2
NB6GE24-19 PNT-3
J1 P1
HEATER POWER
P6 J6
SURVIVAL HEATER THERMOSTAT FUSE
MOTOR CURRENT & VELOCITY MONITOR
ANALOG MONITORS(CURRENT, TEMP, VOLTAGES)
DISCRETE MONITORS & CONTROL LINES
FURNACE SERIAL I/O
+28V/RTN
+28V/RTN
ROBOT CONTROL & FEEDBACK I/O
MOTOR DRIVER & BRAKE CONTROL
HH SERIAL I/O
P4
J4
OPERATIONAL HEATER THERMOSTAT
P5
J5
BACKUP BATTERY
P7
GSE
SC1
P10-50S J1-50S
A2D
EZC PARALLEL
EZC SERIAL
P11-50S J2-50S
ANALOG MUX
P12-50S J3-50S
SCC PARALLEL
P13-25S J4-25S
SCC SERIAL
P14-25S J5-25S
POWER
SC2
P15-50S J1-50S
XPP
ENC
P16-50S J2-50S
XPP
P17-50S J3-50S
STP
P18-25S J4-25S
XPC SERIAL
WDT
P19-25S J5-25S
POWER
ENGINEER M.F. DOBBS
SPACE AUTOMATION & ROBOTICS CENTER
ENVIRONMENTAL RESEARCH INSTITUTE of MI
ANN ARBOR, MI
DRAFTSMAN G. WASSICK
Inter-Box Wiring Diagram
Wiring Harness
RoMPS
010-438
12/05/92
DATE



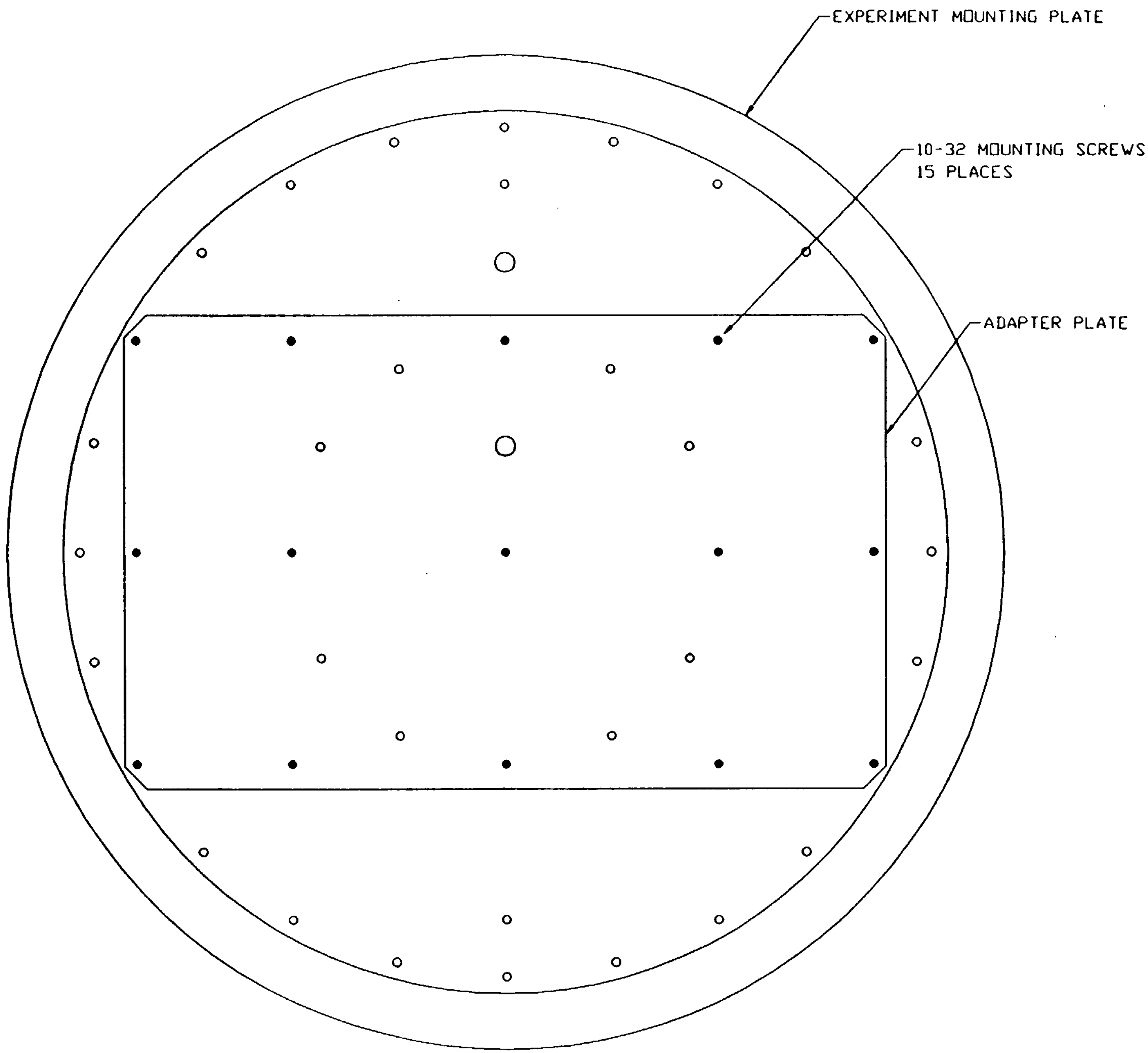
ENGINEER R.E. QUADA	DRAFTPERSON N.J. THOMAS	UNITS: INCHES		
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	ELECTRONICS HARNESS ROUTING ROMPS 010-260	TOLERANCES UNLESS SPECIFIED: ± 0.005" ± 30 MINUTES	12/07/92 DATE	



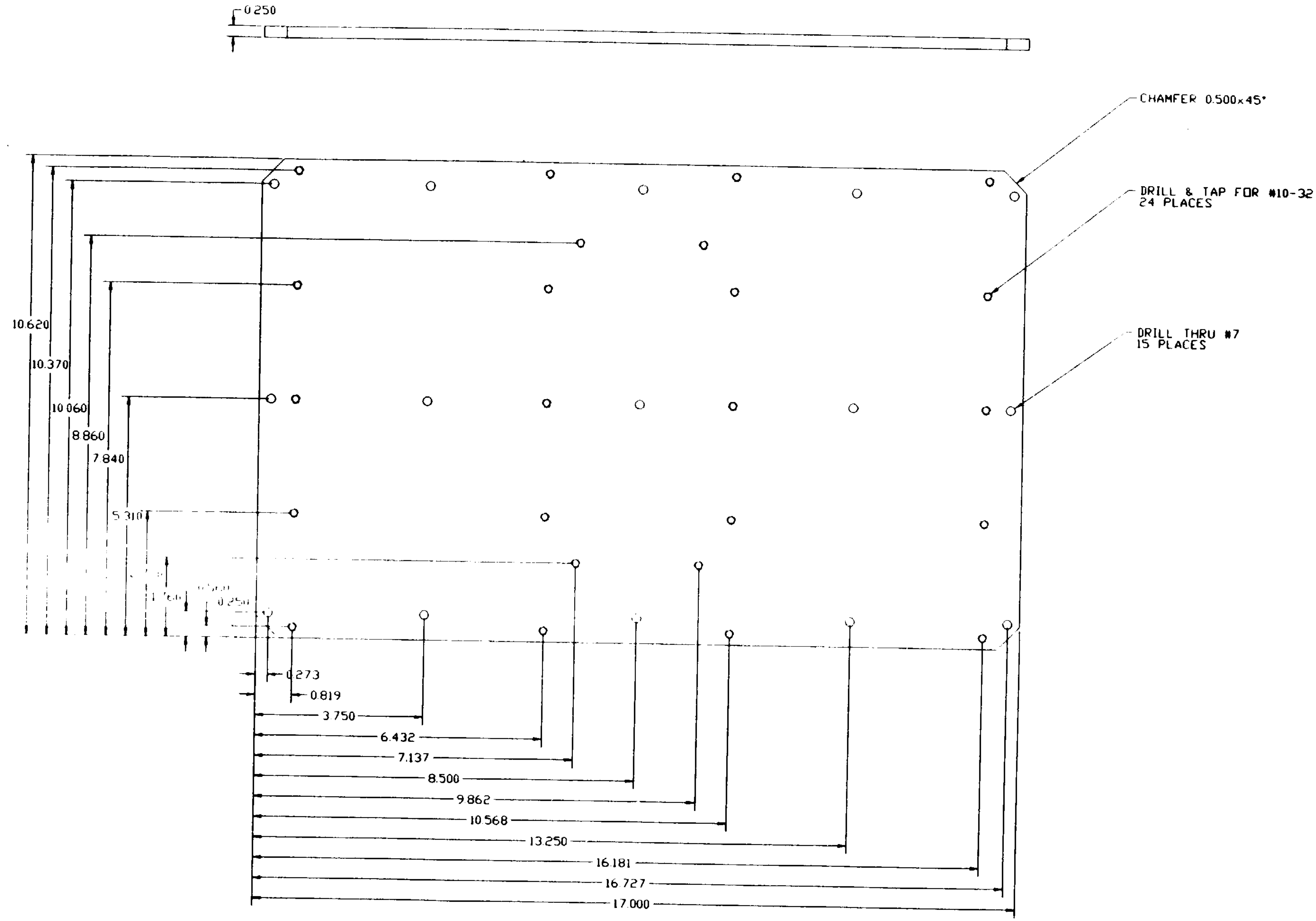
ENGINEER R.E. QUADA	DRAFTPERSON N.J. THOMAS	UNITS: INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	BATTERY BOX ASSEMBLY ROMPS 010-251	TOLERANCES UNLESS SPECIFIED: ± 0.005" ± 30 MINUTES	10/29/92 DATE



ENGINEER R.E. QUADA	DRAFTPERSON N.J. THOMAS	UNITS: INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	PAYLOAD CONTROLLER ROMPS 010–	TOLERANCES UNLESS SPECIFIED: ± 0.005" ± 30 MINUTES	10/30/92 DATE

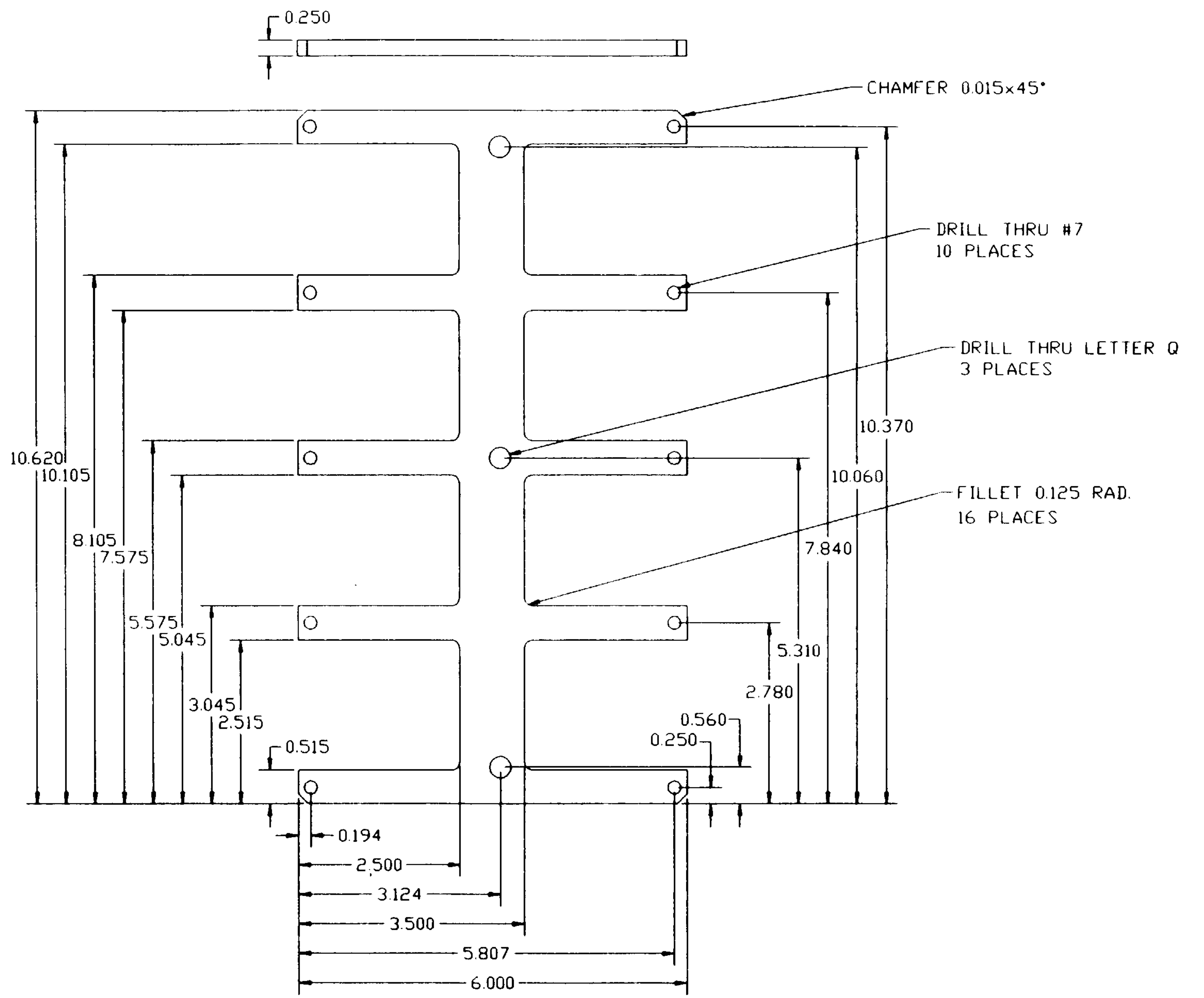


ENGINEER R E QUADA	DRAFTPERSON N J THOMAS	UNITS INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	ADAPTER PLATE/INSTRUMENT PLATE INTERFACE ROMPS	TOLERANCES UNLESS SPECIFIED ± 0 005"	12/04/92
	010-258	± 30 MINUTES	DATE

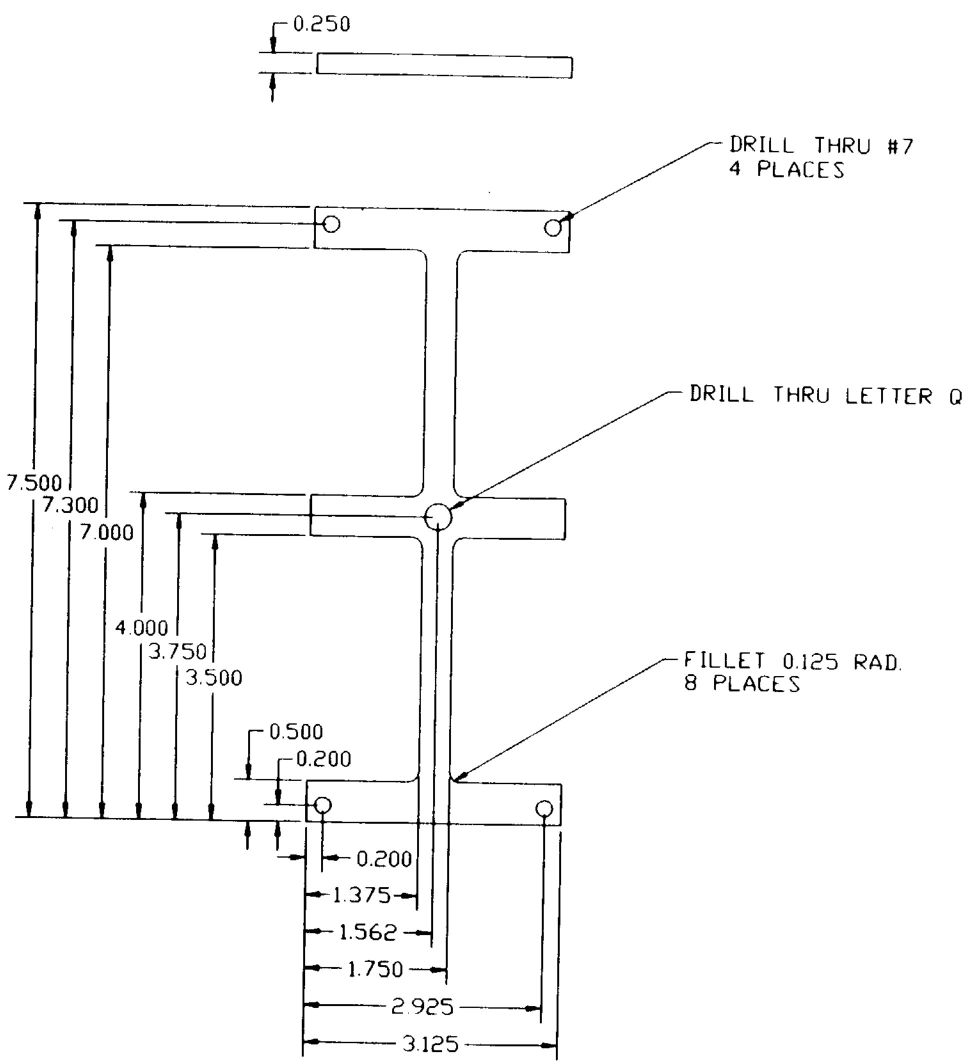


NOTES Iridite MIL-5541, Class 1A

1					PLATE		6061-T6
L.H.	R.H.	PART NO.	L.H.	R.H.	PART NAME	SIZE	DESCRIPTION
NO. REQ'D.			DASH NO.			MATERIAL	
ENGINEER	R.E. QUADA				DRAFTPERSON N.J. THOMAS	UNITS: INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI					ADAPTER PLATE ROMPS 010-254	TOLERANCES UNLESS SPECIFIED: ±0.005" ±30 MINUTES	11/02/92 DATE



2				G-10
L H / R H / NO REQ'D	PART NO	L.H / R.H. / DASH NO.	PART NAME	SIZE / DESCRIPTION / MATERIAL
ENGINEER N J THOMAS		DRAFTPERSON N J THOMAS		UNITS: INCHES
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI		COMPUTER P.C. SPACER ROMPS 010-256		TOLERANCES UNLESS SPECIFIED ± 0.005" ± 30 MINUTES
				11/11/92 DATE



1							G-10
L.H.	R.H.	PART NO.	L.H.	R.H.	PART NAME	SIZE	DESCRIPTION
NO. REQ'D			DASH NO.			MATERIAL	
ENGINEER	N.J. THOMAS				DRAFTPERSON N.J. THOMAS	UNITS: INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI					BATTERY BOX SPACER ROMPS 010-255	TOLERANCES UNLESS SPECIFIED: ± 0.005" ± 30 MINUTES	11/11/92 DATE

Control System Thermal Design

- 2.5 cu. ft. container without insulated endcap
- 1/4" G-10 spacers under payload controllers and battery box
- Payload controller and battery box external surfaces iridite
- Thermostatically controlled survival heaters on payload controllers and battery box
- Thermostatically controlled operational heaters on payload controllers and battery box

Control System Temperature Predictions

Operation

Case	Temperature PC 1	Temperature PC 2	Temperature B.B.	Avg. Heater Power PC 1	Avg. Heater Power PC 2	Avg. Heater Power B.B.
Hot	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Moderate	31 °C	34 °C	16 °C	0.0 W	0.0 W	0.0 W
Earth view	23	26	10/20	0.0	0.0	1.0
Mod. cold	0/10	3	10/20	3.0	0.0	5.0
Cold	0/10	0/10	10/20	9.0	6.0	6.0

Control System Temperature Requirements and Power Dissipation

	Temperature		Power
	Minimum	Maximum	
Survival			
PC 1	-20 °C	65 °C	N.A.
PC 2	-20	65	N.A.
Battery Box	-20	54	N.A.
Operation			
PC 1	0	45	12.0 W
PC 2	0	45	15.0
Battery Box	10	54	0.0

Control System Thermal Design

- 2.5 cu. ft. container without insulated endcap
- 1/4" G-10 spacers under payload controllers and battery box
- Payload controller and battery box external surfaces iridite
- Thermostatically controlled survival heaters on payload controllers and battery box
- Thermostatically controlled operational heaters on payload controllers and battery box

Control System Thermostats and Heaters

Survival

	Ton	Toff	Power
PC 1	-10 °C	0 °C	15 W
PC 2	-10	0	15
Battery box	-10	0	5

Operational

	Ton	Toff	Power
PC 1	0 °C	10 °C	15 W
PC 2	0	10	15
Battery box	10	20	10

Control System Thermal Analysis
Surface Model

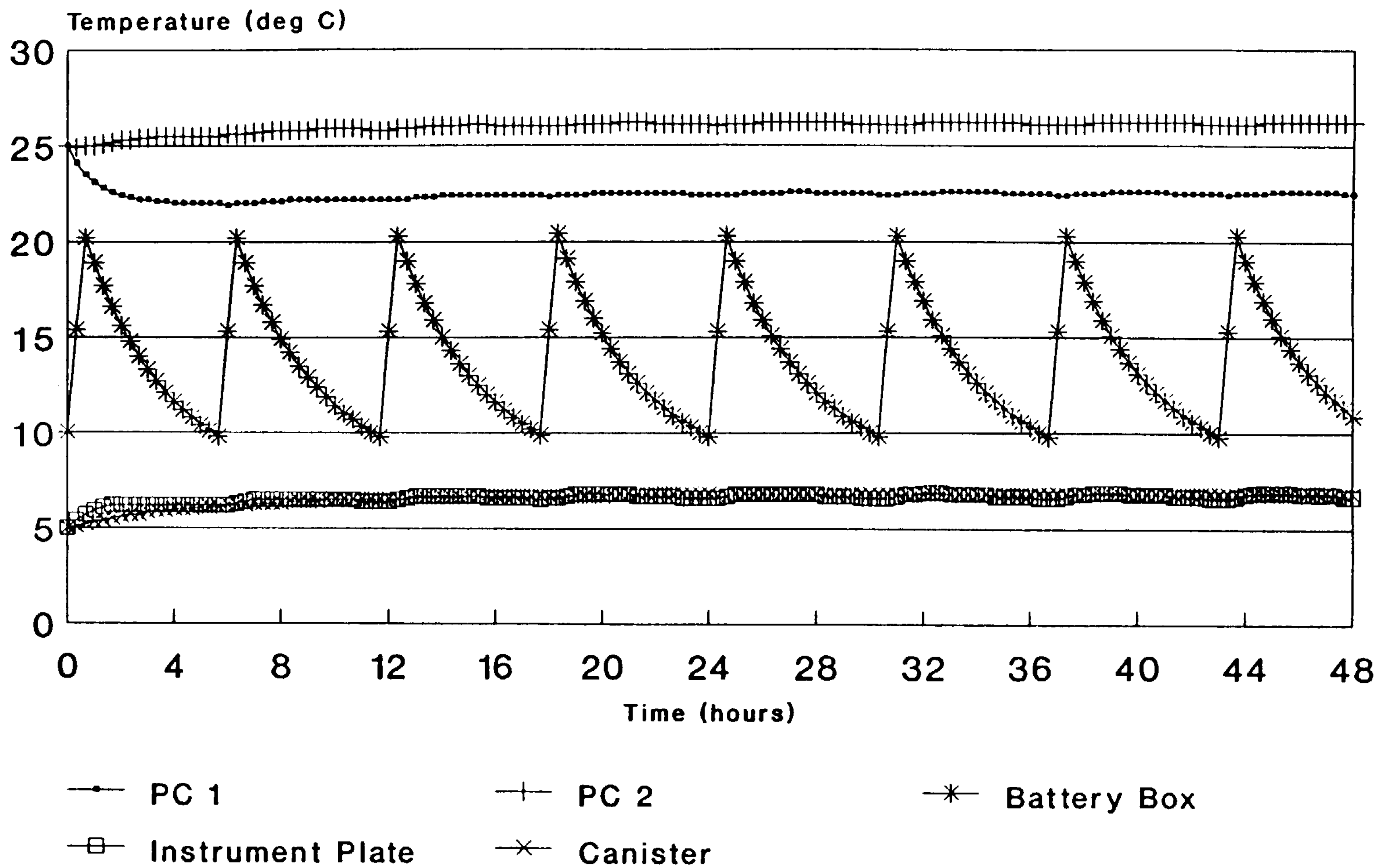
- TRASYS Version P23
- Payload controllers, battery box, and canister interior modeled
- Payload controllers iridite with epsilon = .13
- Battery box iridite with epsilon = .13
- Canister bare aluminum with epsilon = .07

Control System Thermal Analysis
Math Model

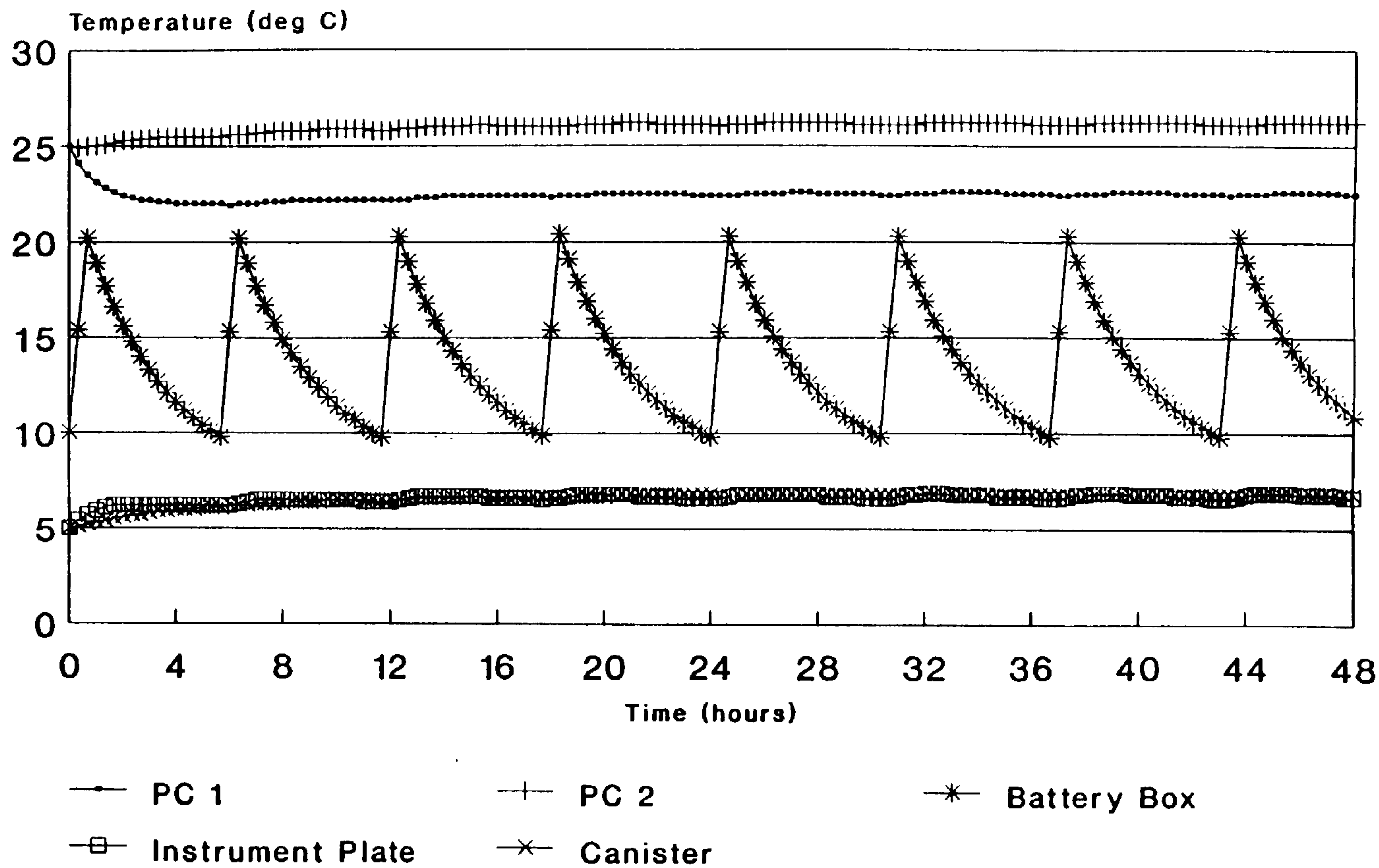
- SINDA '85 Version P2.3
- Set up for both steady state and transient analysis
- Canister and payload plate assigned separate nodes to account for nonuniform temperature distribution
- Nitrogen conductivity = .014 BTU/hr.ft.°F
- Interface conduction = 100 BTU/hr.ft**2°F
- Aluminum conductivity = 90 BTU/hr.ft.°F
- Boundary temperatures from Hitchhiker CARS
- Box temperatures are given in following tables
- Thermal balance results for similar unit give maximum junction to box delta T of 45°C for payload controllers

Control System Transient Response

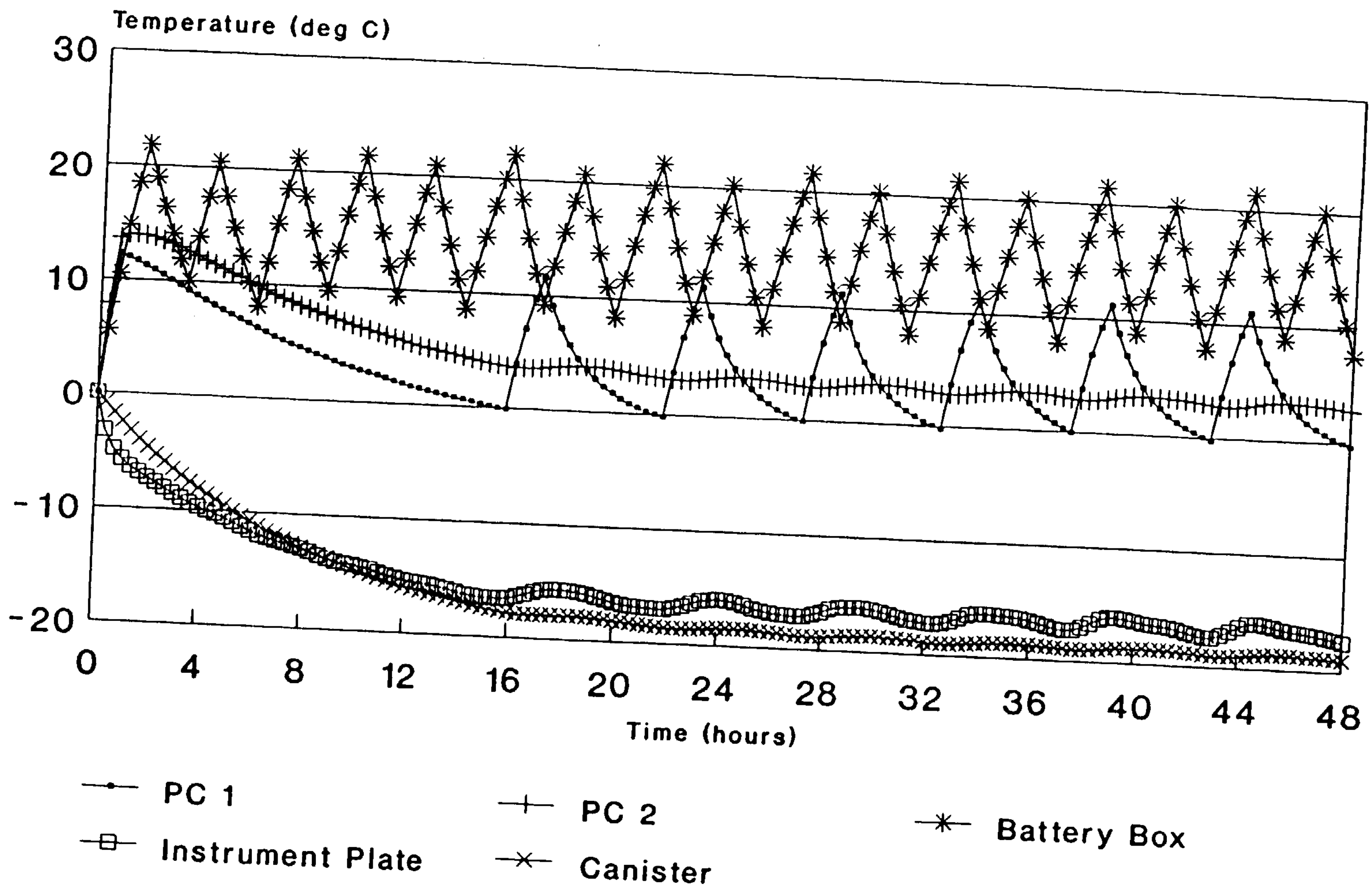
Earth Viewing; Instrument On



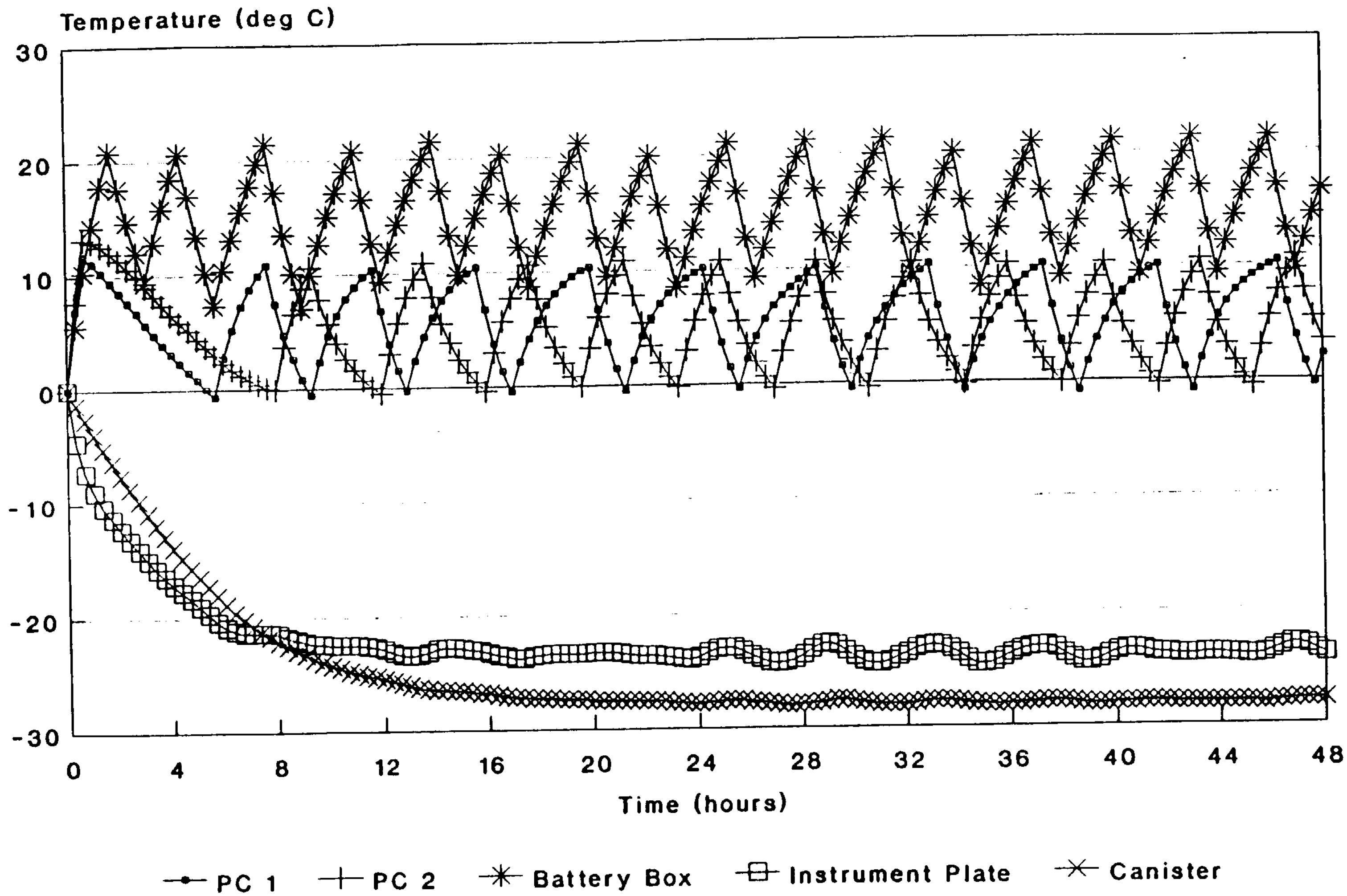
Control System Transient Response
Earth Viewing; Instrument On



Control System Transient Response
Moderately Cold Case; Instrument On

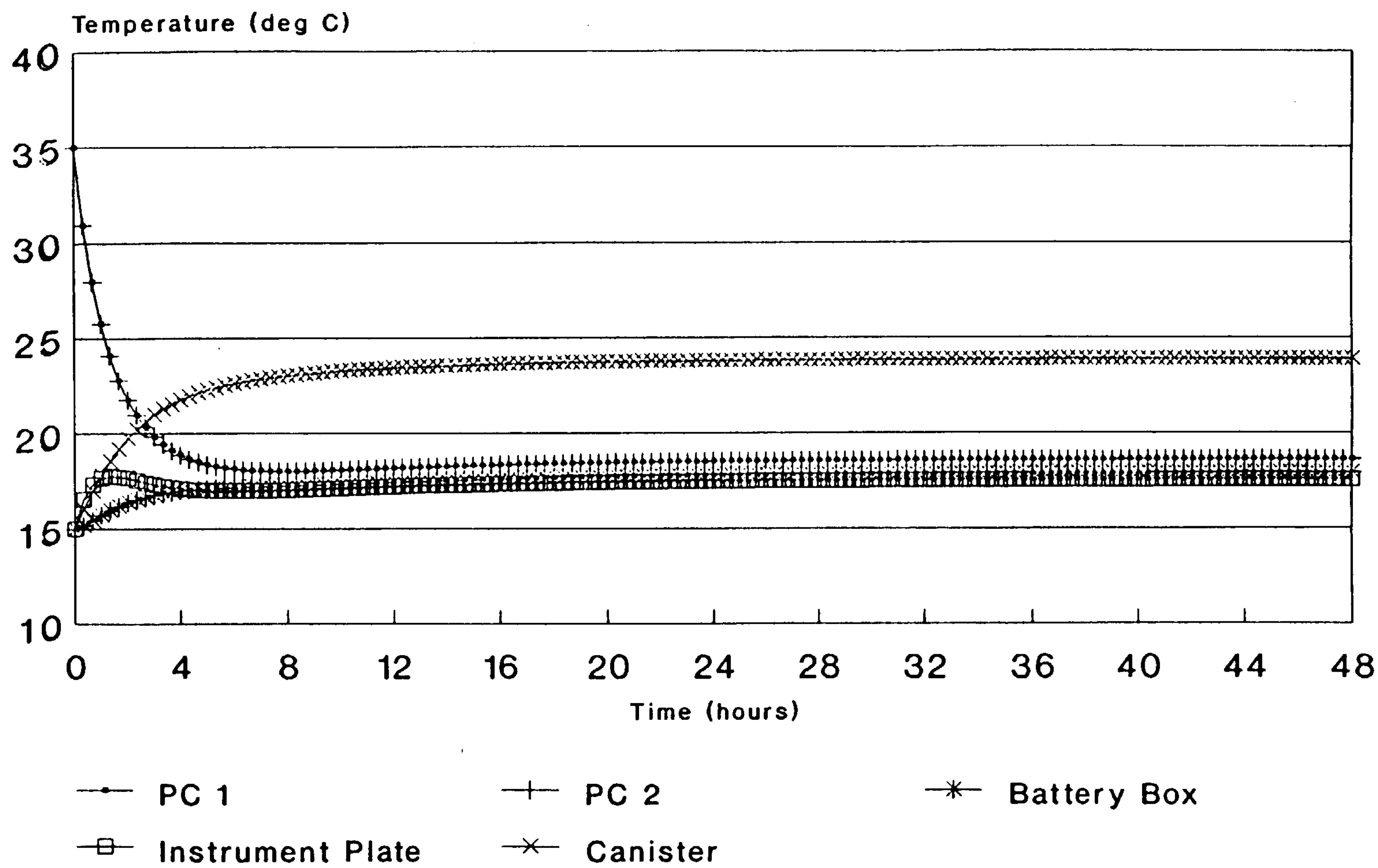


Control System Transient Response
Cold Case; Instrument On

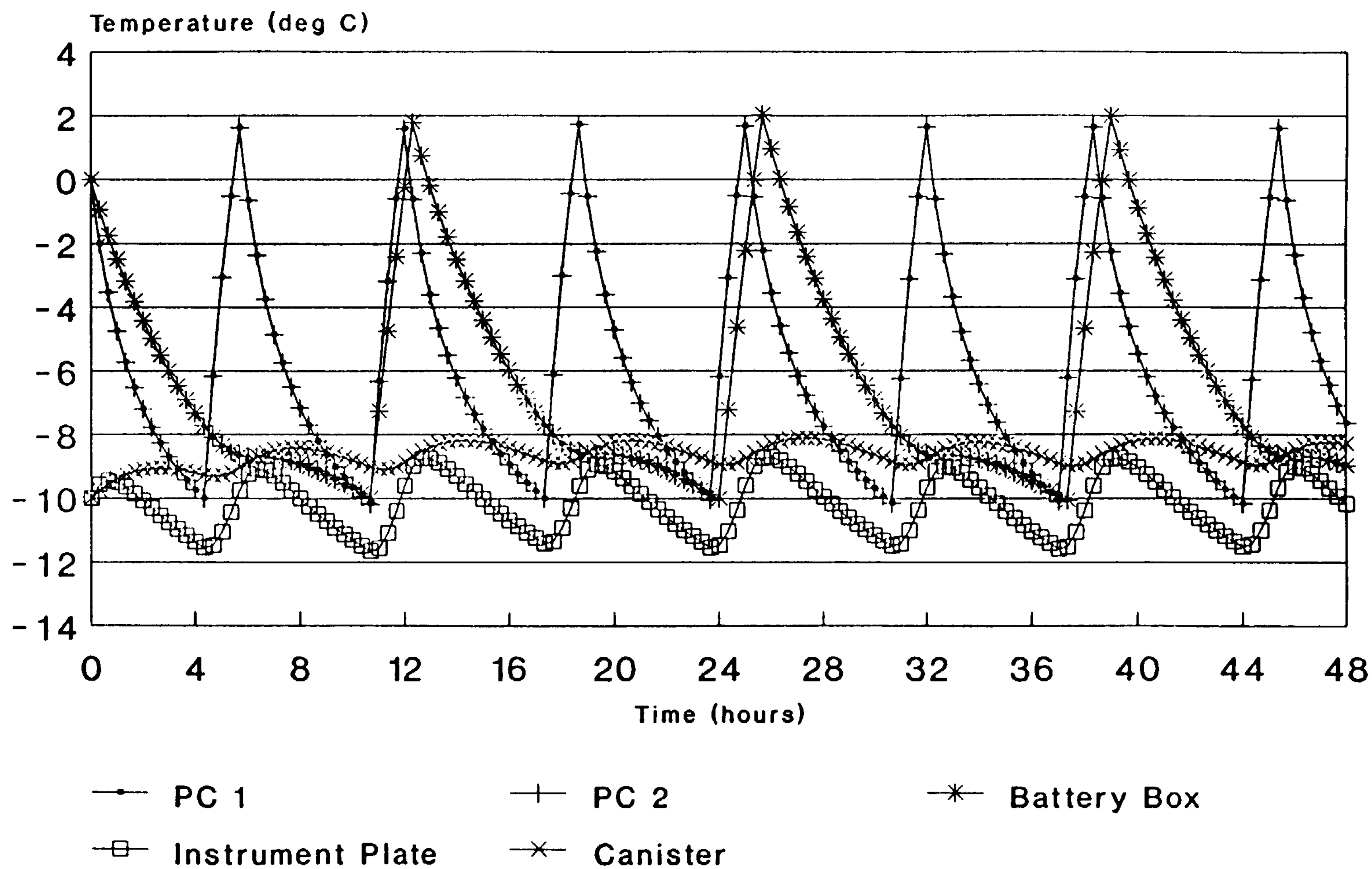


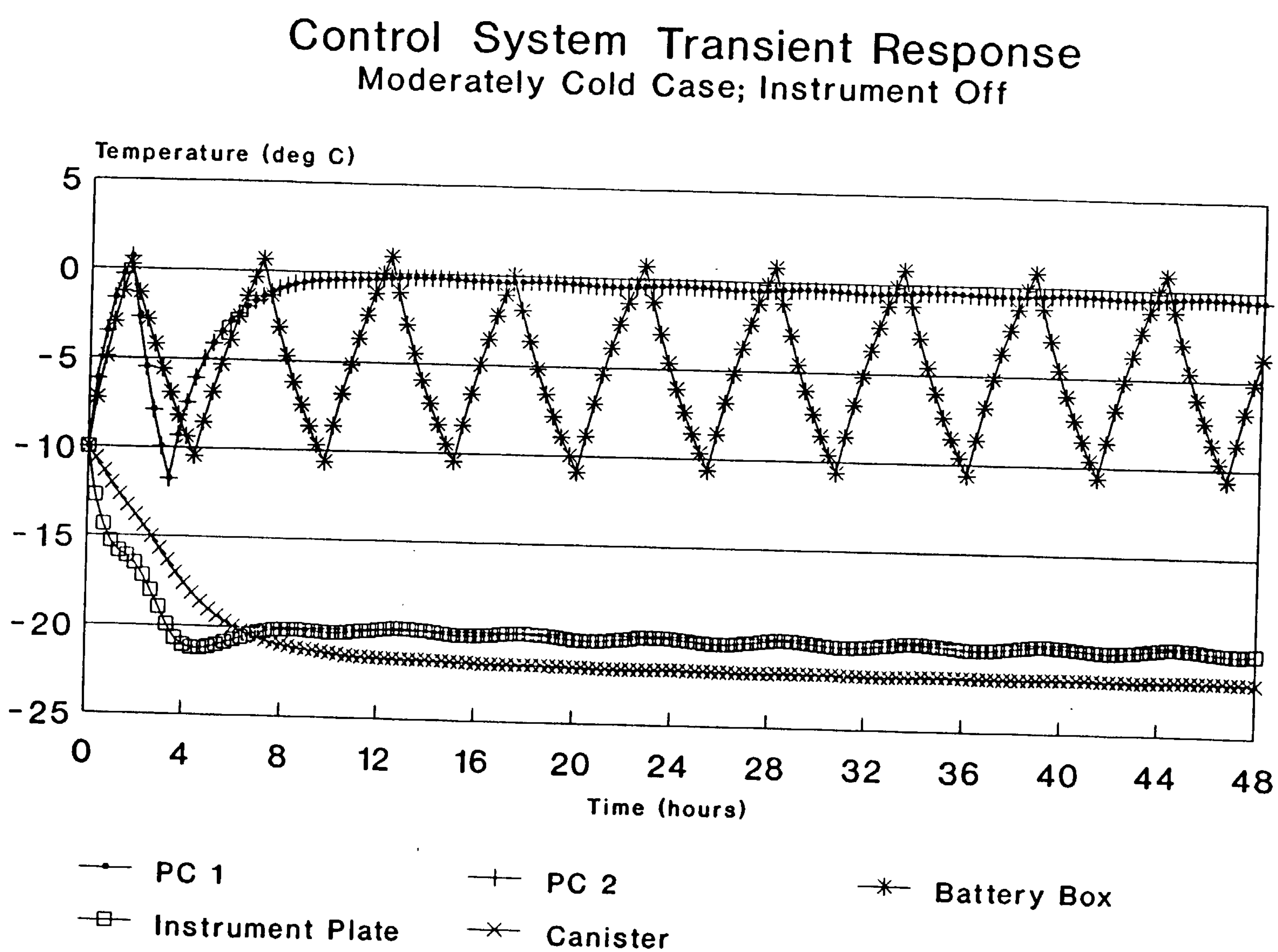
Control System Transient Response

Hot Case; Instrument Off

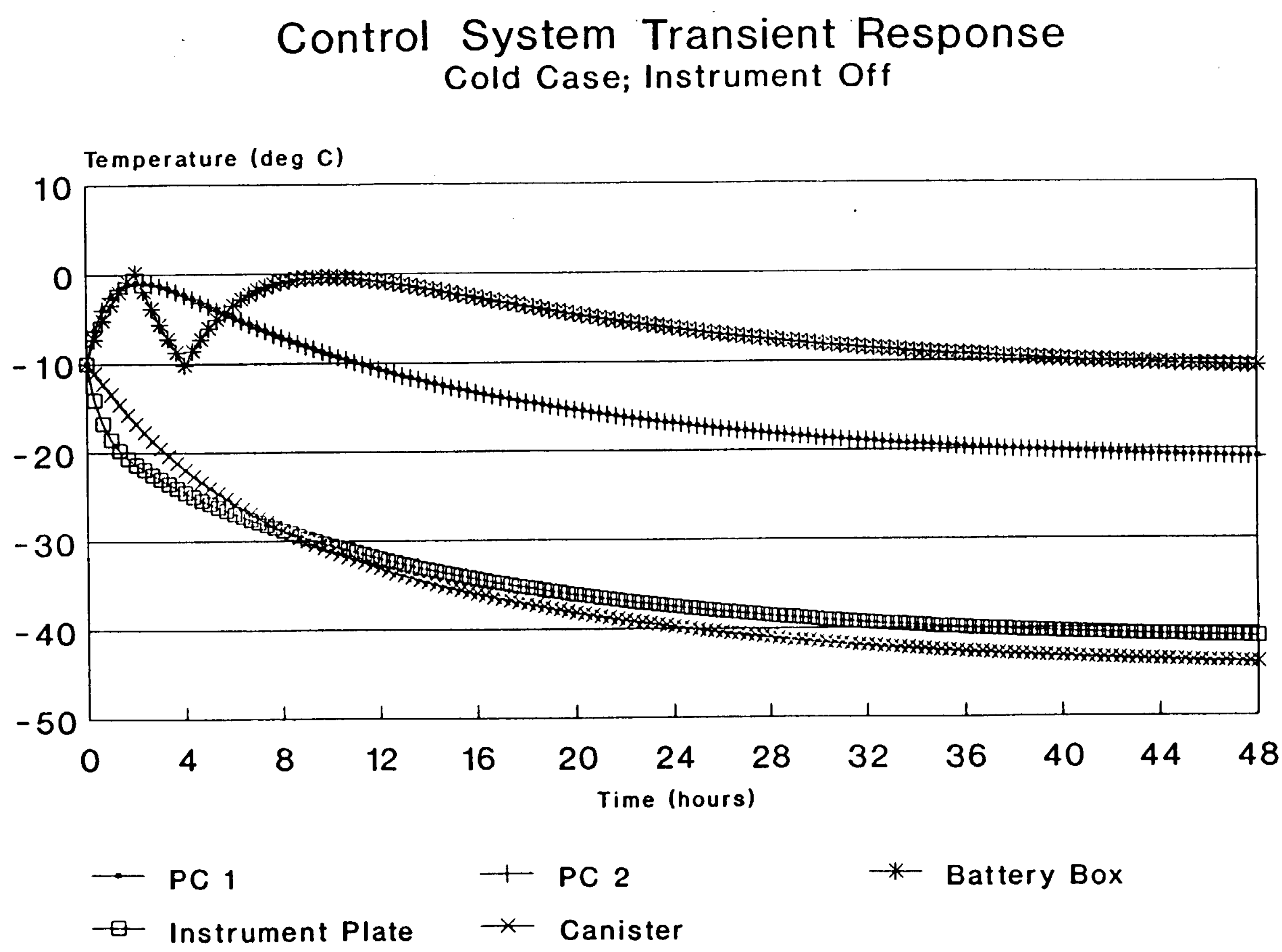


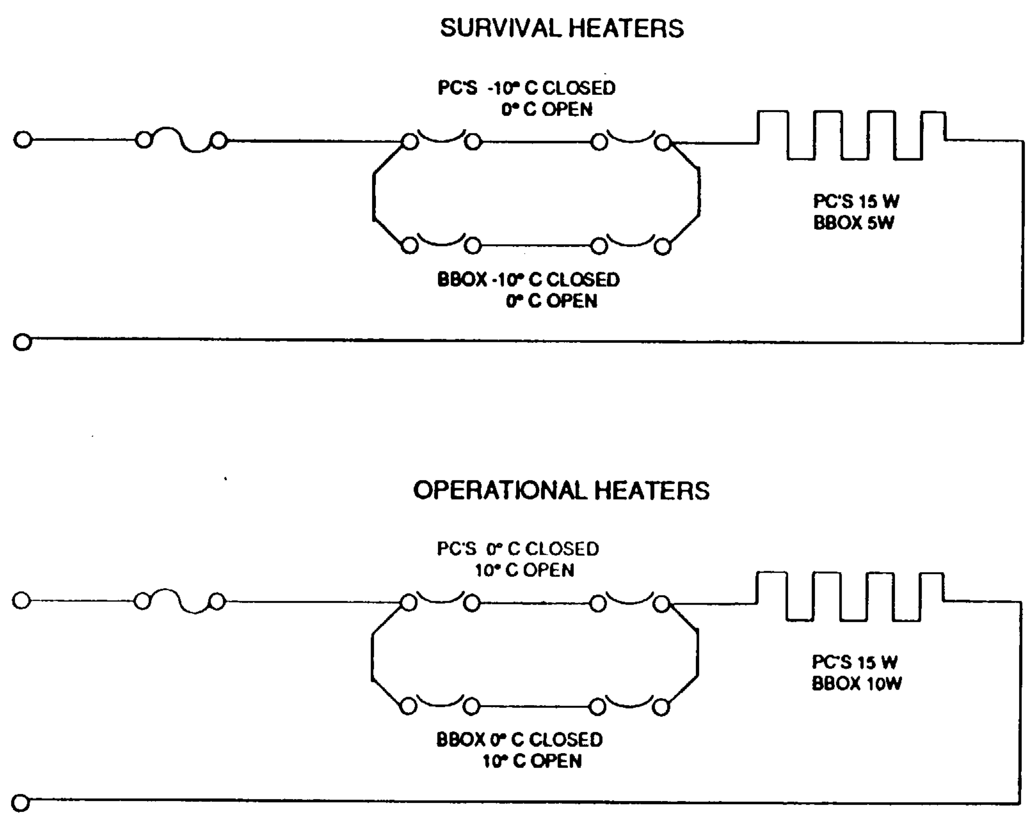
Control System Transient Response
Earth Viewing; Instrument Off





Control System Transient Response
Moderately Cold Case; Instrument Off
Temperature (deg C)
5
0
-5
-10
-15
-20
-25
0
4
8
12
16
20
24
28
32
36
40
44
48
Time (hours)
PC 1
PC 2
Battery Box
Instrument Plate
Canister


Control System Transient Response
Cold Case; Instrument Off
Temperature (deg C)
10
0
-10
-20
-30
-40
-50
0
4
8
12
16
20
24
28
32
36
40
44
48
Time (hours)
PC 1
PC 2
Battery Box
Instrument Plate
Canister



ENGINEER M.F. DOBBS	DRAFTSMAN G. WASSICK	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Block Diagram Heaters RoMPS 010-439	12/07/92 DATE

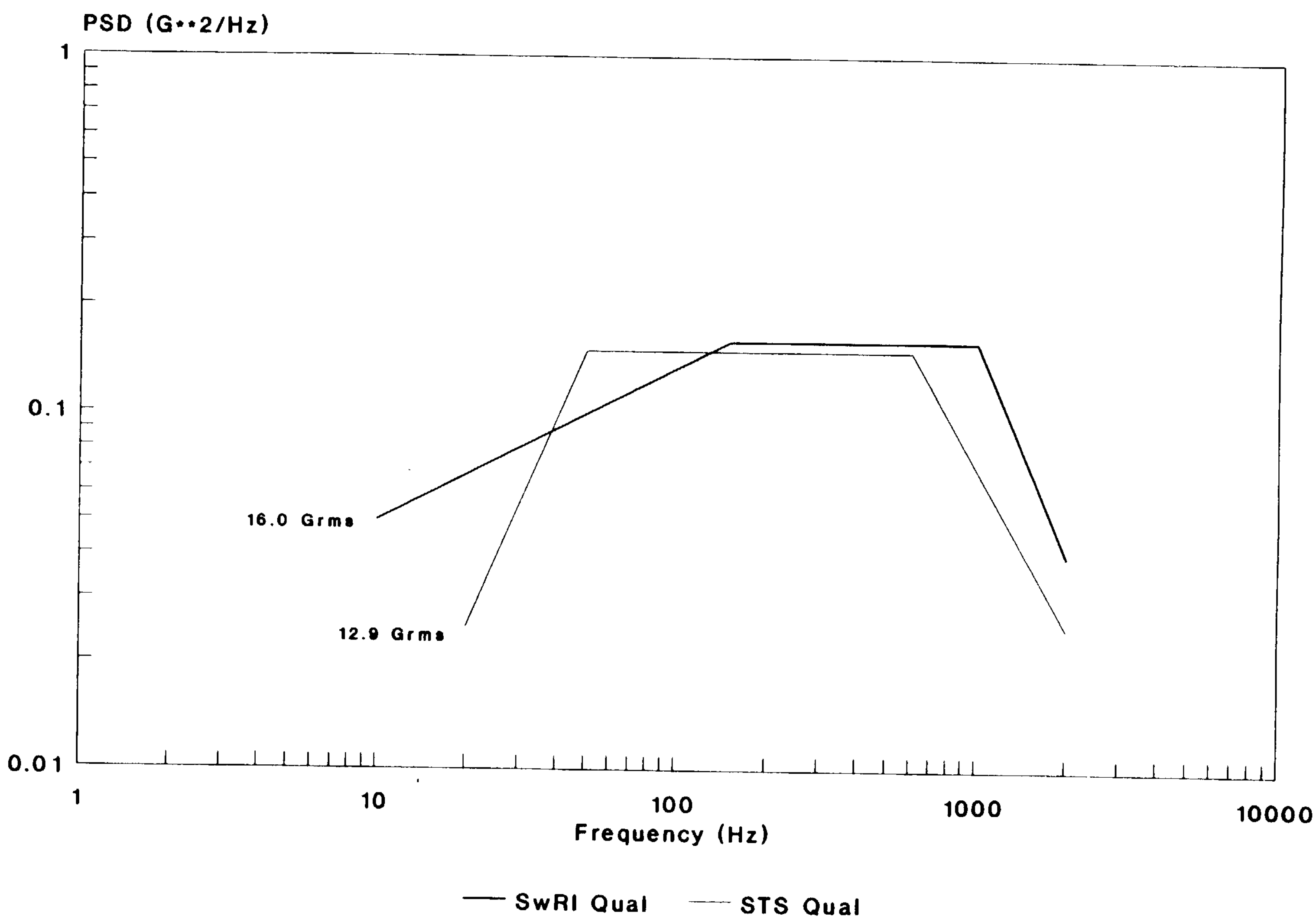
Control System Mechanical Design

- Payload contoller housings made of 6061-T6 aluminum
- Battery box made of 6061-T6 aluminum
- Adapter plate made of 6061-T6 aluminum
- Payload controller and battery box spacers made of G-10
- 160 ksi stainless steel fasteners used for mounting payload controllers and battery box

Control System Structural Analysis

- Hitchhiker CARS Table 3.3 load factors: 11 G, 85 rad/sec**2
- Factors of safety of 2.0 for yield and 2.6 for ultimate for qualification by analysis
- Allowable stresses from MIL-HDBK-5F
- Natural frequency expected to be >100 Hz
- Natural frequency of similar payload controller was 350 Hz

Payload Controller Random Vibration



Both one minute per axis, three axes

Control System Stress Analysis

Assembly	Item	Condition	Allowable Stress	F.S.	MOS
Payload Controller	Mounting flanges	Bearing	50000 psi	2.0	>10
			67000	2.6	>10
		Shear	27000	2.6	>10
		Tension	35000	2.0	>10
			42000	2.6	>10
	10-32 screws	Combined	160000	2.6	0.5
Battery Box	Mounting flanges	Bearing	50000	2.0	>10
			67000	2.6	>10
		Shear	27000	2.6	>10
		Tension	35000	2.0	>10
			42000	2.6	9.4
	10-32 screws	Combined	160000	2.6	0.5
Adapter Plate	Mounting holes	Bearing	50000	2.0	>10
			67000	2.6	>10
		Shear	27000	2.6	>10
	10-32 screws	Combined	160000	2.6	0.5

SpARC
Space Automation
& Robotics Center

RoMPS

FAULT CONDITIONS AND RECOVERY

CONTROL SYSTEM DESIGN
SINGLE EVENT UPSET CONSIDERATIONS

PROBLEM

SEU INDUCED BEHAVIOR THAT MAY DAMAGE EXPERIMENT HARDWARE

DESIGN SOLUTIONS EMPLOYED

SUBSYSTEM SELF PROTECTION
- END-OF-TRAVEL DETECTION
- FORCE LIMITING
- OVER-TEMPERATURE SHUTDOWN
- WATCHDOG TIMERS

INVESTIGATING HARDENING OF XP AND REDUNDANT STORAGE OF CRITICAL DATA

DESIGN SOLUTIONS NOT EMPLOYED

ROBOT DESIGN THAT CANNOT CAUSE DAMAGE
PARITY
ERROR-DETECT-CORRECT
RAD-HARD

REDESIGN COST
REQUIRES CUSTOM DESIGN
SWRI @ $85K
SWRI @ $1,000K

REVISE

Fault Conditions and Responses

Fault	STP	XPC	EZC	SCC
Robot SERVO USART Communication Errors (USART cable disconnect, parity, overrun, or framing error)	**Detection:** N/A	**Detection** → : Servo Controller detects communication error while polling USART line status register.	**Detection** → : Robot Module times out waiting for a command response from the Servo Controller.	**Detection** → : SCC receives NOTOK error status from RCI.
Description: In the process of receiving a command message from the Robot Module, a communication error is detected by USART.	**Action:** N/A	**Action:** Servo Controller stops the robot and resets the USART.	**Action:** Robot Module retries communication until retries are exhausted, terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	**Action:** APC script diagnoses error and quits.
Robot SERVO Communication Protocol Error (Interbyte timeout, bad byte count, bad command code, bad checksum)	**Detection:** N/A	**Detection** → : Servo Controller detects communication protocol error.	**Detection** → : Robot Module receives error status from Servo Controller/	**Detection** → : SCC receives NOTOK error status from RCI.
Description: In the process of receiving a command message from the Robot Module, a communication protocol error is detected by the Servo Controller.	**Action:** N/A	**Action:** Servo Controller stops the robot and reports error status.	**Action:** Robot Module retries communication until retries are exhausted, terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	**Action:** APC script diagnoses error and quits.
Robot Controller Current Over Limit	**Detection:** N/A	**Detection** ← : Servo Controller receives STOP command from Robot Module.	**Detection** ← : Robot Module receives ABORT signal from SCC.	**Detection** ← : SCC acquires current data every 1 Second and updates SCL DB.
Description: One of the monitored current sensors exceeds its operating limits for some period.	**Action:** N/A	**Action:** Servo Controller sets target position to current position and aborts current move.	**Action:** Robot Module sends STOP command to Servo Controller.	**Action:** Rule sets Robot Module ABORT signal and stops APC script.

Fault Conditions and Responses

Fault	STP	XPC	EZC	SCC
Robot SERVO End of Travel (Detected by STP)	**Detection** → : Hardware Logic monitors EOT input signals and latches EOT event.	**Detection** → : Servo Controller receives EOT status signal from Hardware Logic during a 5 millisecond poll.	**Detection** → : Robot Module receives error status from Servo Controller during a GetLimitStatus command.	**Detection** → : SCC receives NOTOK error status from RCI.
Description: During a robot move one of the 8 EOT sensors is set.	**Action:** Hardware Logic sets corresponding EOT status signal, disables all axes and applies brakes.	**Action:** Servo Controller sets target position to current position, aborts current move, and reports error status.	**Action:** Robot Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	**Action:** APC script diagnoses error and quits.
Robot SERVO End of Travel (Detected by SCC)	**Detection:** N/A	**Detection** ← : Servo Controller receives STOP command from Robot Module.	**Detection** ← : Robot Module receives ABORT signal from SCC.	**Detection** ← : SCC acquires EOT status every 1 second and updates SCL database.
Description: During a robot move one of the 8 EOT sensors is set.	**Action:** N/A	**Action:** Servo Controller sets target position to current position and aborts current move.	**Action:** Robot Module sends STOP command to Servo Controller.	**Action:** Rule sets Robot Module ABORT signal and stops APC script.
Robot SERVO Overforce (Detected by STP)	**Detection** → : Hardware Threshold Logic monitors strain gauge input signals, and latches OVF event.	**Detection** → : Servo controller receives OVF status signal from Hardware Threshold Logic during a 5 millisecond poll.	**Detection** → : Robot Module receives error status from Servo Controller during a GetLimitStatus command.	**Detection** → : SCC receives NOTOK error status from RCI.
Description: During a robot move one of the ITE strain gauge readings exceeds its nominal operating range.	**Action:** Hardware Threshold Logic sets corresponding OVF status signal, disables all axes and applies brakes.	**Action:** Servo Controller sets target position to current position, aborts current move, and reports error status.	**Action:** Robot Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	**Action:** APC script diagnoses error and quits.
Robot SERVO Overforce (Detected by SCC)	**Detection:** N/A.	**Detection** ← : Servo Controller receives STOP command from Robot Module.	**Detection** ← : Robot Module receives ABORT signal from SCC.	**Detection** ← : SCC acquires ITE Strain Gauge Forces every 1 second and updates SCL database.
Description: During a robot move one of the ITE strain gauge readings exceeds its nominal operating range.	**Action:** N/A	**Action:** Servo Controller sets target position to current position and aborts current move.	**Action:** Robot Module sends STOP command to Servo Controller.	**Action:** Rule sets Robot Module ABORT signal and stops APC script.

Fault Conditions and Responses

Fault	STP	XPC	EZC	SCC
Robot SERVO Move Velocity Anomaly (Stall)	**Detection:** N/A	**Detection** → : Servo Controller detects a velocity anomaly during execution of a move command.	**Detection** → : Robot Module receives error status from Servo Controller during a GetStatus command.	**Detection** → : SCC receives NOTOK error status from RCI.
Description: During a move command, the arm or gripper does not move more than x counts for a duration of y seconds.	**Action:** N/A	**Action:** Servo Controller sets target position to current position, aborts current move and reports error status.	**Action:** Robot Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	**Action:** APC script diagnoses error and quits.
Robot SERVO Move Timeout	**Detection:** N/A	**Detection** → : Servo Controller detects a failure to reach position before timing out during a move command.	**Detection** → : Robot Module receives error status from Servo Controller during a GetStatus command.	**Detection** → : SCC receives NOTOK error status from RCI.
Description: During a move command, the target position is not reached within the maximum allowed time.	**Action:** N/A	**Action:** Servo Controller sets target position to current position, aborts current move and reports error status.	**Action:** Robot Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	**Action:** APC script diagnoses error and quits.

Fault Conditions and Responses

Fault	Furnace CPU	XPC	EZC	SCC
Furnace Controller USART Communication Errors (parity, overrun, or framing error)	**Detection → : Furnace** Controller detects communication error.	**Detection:** N/A	**Detection → : Furnace** Module times out waiting for a command response from the Furnace Controller.	**Detection → :** SCC receives NOTOK error status from RCI.
Description: In the process of receiving a command message from the Furnace Module, a communication error is detected.	**Action:** None.	**Action:** N/A	**Action:** Furnace Module retries communication until retries are exhausted, terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	**Action:** APC script diagnoses error and quits.
Furnace Controller Communication Protocol Error (Interbyte timeout, bad byte count, bad command code, bad checksum)	**Detection → : Furnace** Controller detects communication protocol error.	**Detection:** N/A	**Detection → : Furnace** Module receives error status from Furnace Controller.	**Detection → :** SCC receives NOTOK error status from RCI.
Description: In the process of receiving a command message from the Furnace Module, a communication protocol error is detected by the Furnace Controller.	**Action:** Furnace Controller reports error status.	**Action:** N/A	**Action:** Furnace Module retries communication until retries are exhausted, terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	**Action:** APC script diagnoses error and quits.
Furnace Controller Current Over Limit	**Detection ← : Furnace** Controller receives SET POWER = 0 command from Furnace Module.	**Detection:** N/A	**Detection ← : Furnace** Module receives ABORT signal from SCC.	**Detection ← :** SCC acquires current data every 1 Second and updates SCL DB.
Description: One of the monitored current sensors exceeds its operating limits for some period.	**Action:** Furnace Controller sets power level to 0.	**Action:** N/A	**Action:** Furnace Module sends SET POWER = 0 command to Furnace Controller.	**Action:** Rule sets Furnace Module ABORT signal and stops APC script.

Fault Conditions and Responses

Fault	Furnace CPU	XPC	EZC	SCC
Furnace Controller 28V Bus Too Low To Achieve Setpoint	**Detection** → : Furnace Controller determines that the current setpoint cannot be achieved.	**Detection:** N/A	**Detection** → : Furnace Module receives error status from Furnace Controller during a GetStatus command.	**Detection** → : SCC receives NOTOK error status from RCI.
Description: Setpoint cannot be achieved with 28 volt power supply.	**Action:** Furnace Controller aborts current setpoint and reports error status.	**Action:** N/A	**Action:** Furnace Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	**Action:** APC script diagnoses error and quits.
Furnace Controller Temperature Over Limit (Detected by Furnace Controller)	**Detection** → : Furnace Controller detects an overtemp condition.	**Detection:** N/A	**Detection** → : Furnace Module receives error status from Furnace Controller during a GetStatus command.	**Detection** → : SCC receives NOTOK error status from RCI.
Description: One of the monitored temperature sensors exceeds its operating limits for some period.	**Action:** Furnace Controller sets power level to 0 and reports error status.	**Action:** N/A	**Action:** Furnace Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	**Action:** APC script diagnoses error and quits.
Furnace Controller Temperature Over Limit (Detected by SCC)	**Detection** ← : Furnace Controller receives SET POWER = 0 command from Furnace Module.	**Detection** ← : N/A	**Detection** ← : Furnace Module receives ABORT signal from SCC.	**Detection** ← : SCC acquires temperature data every 1 second and updates SCL database.
Description: One of the monitored temperature sensors exceeds its operating limits for some period.	**Action:** Furnace Controller sets power level to 0.	**Action:** N/A	**Action:** Furnace Module sends SET POWER = 0 command to Furnace Controller.	**Action:** Rule sets Furnace Module ABORT signal and stops APC script.
Furnace Controller Setpoint Out Of Range	**Detection** → : Furnace Controller determines that the current setpoint is invalid.	**Detection:** N/A	**Detection** → : Furnace Module receives error status from Furnace Controller during a GetStatus command.	**Detection** → : SCC receives NOTOK error status from RCI.
Description: Temperature or power setpoint is invalid.	**Action:** Furnace Controller aborts current setpoint and reports error status.	**Action:** N/A	**Action:** Furnace Module terminates current command and sets error status. EasyLab interpreter terminates current EasyLab program. RCI returns NOTOK.	**Action:** APC script diagnoses error and quits.

Fault Conditions and Responses

Fault	STP	XPC	EZC	SCC
XPC WatchDog	**Detection:** N/A	**Detection:** Servo Controller internal watchdog timer times out.	**Detection:** N/A	**Detection:** N/A
Description: The XPC watchdog timer circuitry fails to be strobed in the required time and the XPC processor is reset.	**Action:** N/A	**Action:** Servo Controller internal watchdog timer restarts the processor and resets outputs to safe states.	**Action:** N/A	**Action:** N/A
EZC WatchDog	**Detection:** N/A	**Detection:** N/A	**Detection:** WDT board watchdog timer times out.	**Detection:** N/A
Description: The EZC watchdog timer circuitry fails to be strobed in the required time and the EZC processor is reset.	**Action:** N/A	**Action:** N/A	**Action:** WDT board watchdog timer restarts the processor and resets furnace enable.	**Action:** N/A
SCC WatchDog	**Detection:** N/A	**Detection:** N/A	**Detection:** N / A	**Detection:** WDT board watchdog timer times out.
Description: The SCC watchdog timer circuitry fails to be strobed in the required time and the SCC processor is reset.	**Action:** N/A	**Action:** N/A	**Action:** N/A	**Action:** WDT board watchdog timer restarts the processor. SCC reads latched watchdog status for telemetry before clearing the latch.

Fault Conditions and Responses

Fault	STP	XPC	EZC	SCC
Strain Gauge Open	**Detection:** STP OVF latch fails to reset after robot is moved.	**Detection:** Reads latches.	**Detection:** Gets status from XPC.	**Detection:** Gets report from EZC.
Description: An STP OVF latch fails to reset after axis is moved.	**Action:** Each axis OVF latch may be overridden by XPC if necessary.	**Action:** Performs override and move commands from EZC.	**Action:** Sends commands to back off, retry, and if still OVF, to override the channel.	**Action:** Diagnoses fault, sends command to recover.
Power Loss	**Detection:** N/A	**Detection:** WDT circuit detects loss of power. Brakes are energize-to-release type.	**Detection:** N/A	**Detection:** N/A
Description: System Power is lost.	**Action:** N/A	**Action:** WDT circuit provides uninterrupted battery-backed power to encoder circuits.	**Action:** N/A	**Action:** N/A
Power Up	**Detection:** N/A	**Detection:** XPC reset circuit detects power up.	**Detection:** Processor is restarted by WDT and by its own POC circuit.	**Detection:** Processor is restarted by WDT and by its own POC circuit.
Description: System Power returns.	**Action:** Motor drives are disabled and brakes applied at startup by XPC outputs.	**Action:** XPC reset circuit restarts processor and resets outputs to safe states.	**Action:** Software is initialized, stored programs are retained, but any operations not completed before power loss are aborted. Furnace is disabled.	**Action:** Software is initialized, stored programs are retained, any scripts not completed before power loss are aborted, stored data is retained as acquired before power loss, including rule states.

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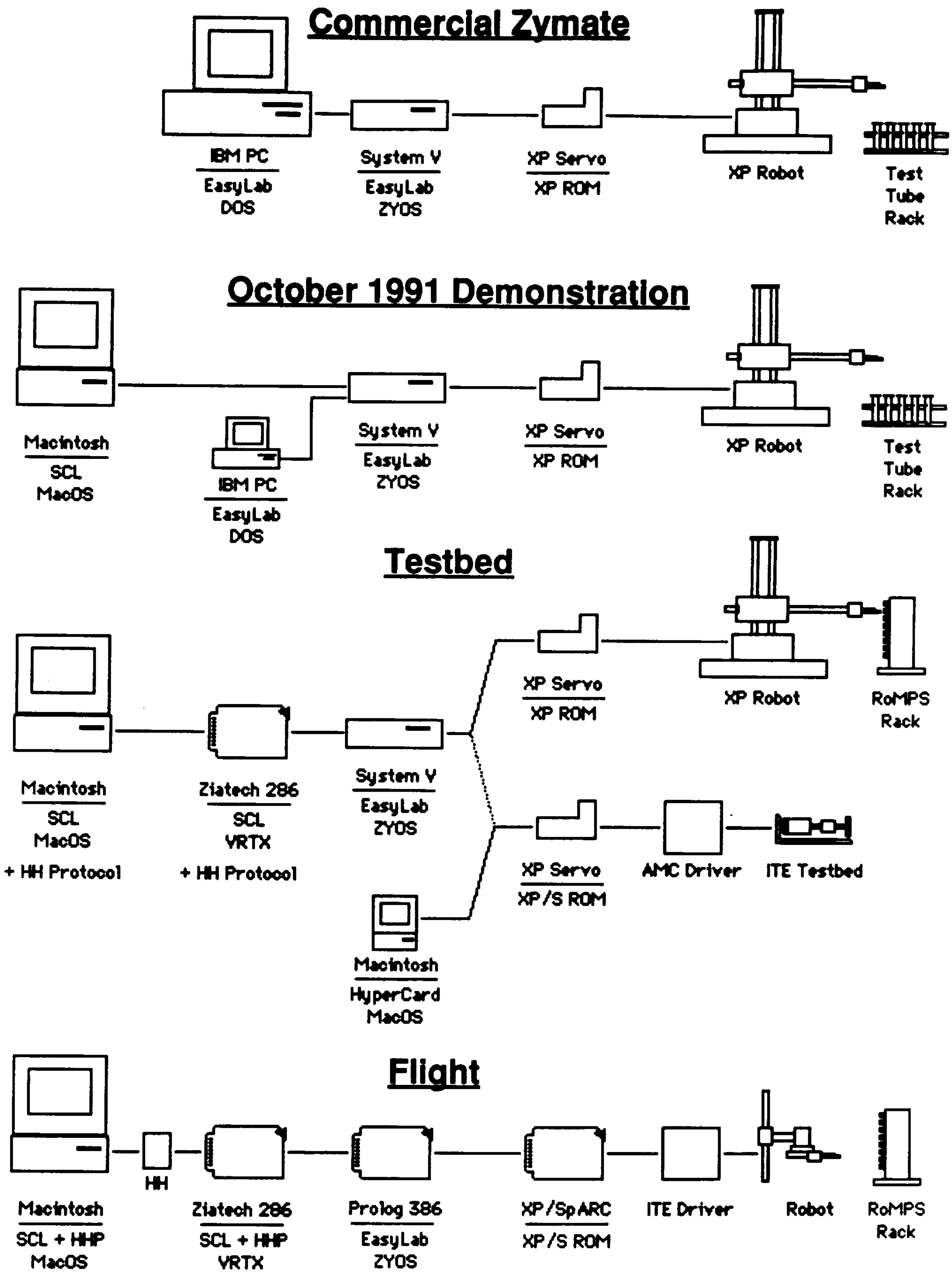
RoMPS

SUMMARY

CONTROL SYSTEM ELEMENT	HARDWARE STATUS	SOFTWARE STATUS	BREADBOARD STATUS	DESIGN HERITAGE
SCC Processor				
Realtime Engine	COTS	COTS	BrBd 100%	OCP, ARD pgm
HH serial I/o	Des 100%	Oper by 12/31	planned	OCP, ARD pgm
command	na	Oper by 12/31		OCP, ARD pgm
telemetry	na	Des 100%		OCP, ARD pgm
a/d	COTS	COTS		OCP, ARD pgm
mux	Des 100%	Des 80%		OCP, FHPE pgm
EZC Processor				
EASYLAB	COTS	Oper by 12/15	BrBd 100%	Zymark, System V
robot	na	Des 100%	planned	Zymark, 80%, Robot
furnace	na	Des 100%	planned	Zymark, 50%, Vortexer
serial i/o	COTS	COTS	BrBd 100%	OCP, ARD pgm
SERVO Controller				
xpc	Des 100%	Des 100%	BrBd 100% + simulation	Zymark, Zymate
enc	Des 100%	incl	BrBd 100%	Zymark, Zymate
xpp	Des 100%	incl	BrBd 100%	Zymark, Zymate
stp	Des 100%	Des 80%		
watchdog	Des 100%	Des 100%		
battery	Des 100%	na	planned	
PID algorithm	na	Des 85%	BdBd 80%	
serial i/o	na	Des 100%	BrBd 100%	
MECHANICAL	Des 100%	na		SwRI, Qual'd to 17grms
THERMAL	Des 100%			COSMOS, Sinda, Traysis

Evolution from Zymate to ROMPS



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RoMPS

OPERATIONS

Issuing Hitchhiker Bi-Level Commands

Command

set HH_BILEVEL to OVENS_ENABLE

Sends a 28 volt HH Pulse Command Packet for
Oven Enable control line

Command

set HH_BILEVEL to OVENS_DISABLE

Sends a 28 volt HH Pulse Command Packet for
Oven Disable control line

Command

set HH_BILEVEL to ROBOT_DISABLE

Sends a 28 volt HH Pulse Command Packet for
Robot Disable control line

Command

set HH_BILEVEL to MASTER_RESET

Sends a 28 volt HH Pulse Command Packet for
Master Reset control line

RoMPS Ground Operations

Issuing Hitchhiker Serial Commands

Command	Command
execute Bus_A_Enable	execute Bus_B_Enable

Executes Payload Controller's scripts which issues pulse commands to enable power bus A or B.

Command	Command
execute Oven_A_On	execute Oven_B_On

Executes a Payload Controller script which issues pulse commands to enable Oven A or Oven B, it also sets a SCL global variable used by SPC script which indicatates which oven to be put sample into.

Command

execute RoMPSDiagnostics

Executes Payload Controller script which runs a low level dianostic program for hardware and software.

Command

execute SPC with *sample_id*

Executes Payload Controller script which gets the processing parameters for the specified sample, then issues the necessary robot and annealer EasyLab commands and programs to process the sample.

Command

execute APC with *schedule_setup*

Executes Payload Controller script which calls SPC for each sample specified in the *schedule_setup*.

Command

execute Stop_Processing

Executes Payload Controller script which stops SPC and APC scripts and generates control signals to Zymate System V Controller to stop processing current command EasyLab command and send Stop to XP Servo Controller.

Command

execute Zero_Motors

Executes Payload Controller script which issues a series of EasyLab robot commands to the Zymate System V Controller which calibrate each individual robot axis, and leaves robot in known position.

Command

execute Time_Set with *Hrs,Mins,Sec*

Executes Payload Controller script which updates the Payload Controllers internal clock.

RoMPS: Experiment Parameters

Check Parameters

Sample Index	Annealer Time 1	Annealer Temp 1	Time 2	Temp 2	Time 3	Temp 3	Time 4	Temp 4	Time 5	Temp 5	Time 6	Temp 6	Time 7	Temp 7	Minimum Cool Time	Cool Down Temp	Rack No.	Rack Index
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
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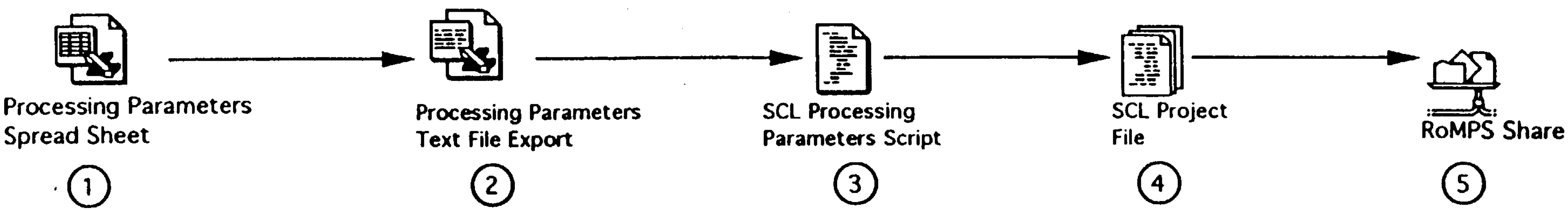
42																		
43																		

Modification of Experiment Processing Parameters



1. At the SCL Script Development Console, the PI Invokes the Excel Processing Parameters Spread Sheet and changes the desired processing parameters by entering new values into the appropriate cell.

2. After the desired processing parameters have been modified, the PI checks the validity of the data entered by clicking on the Check Data button. This button will check the range of the annealing time and temperature parameters. The PI then exports the processing parameter data by clicking on the Export Data button. This creates a tab delimitted text file which can be read by SCL.

3. After the Processing Parameters Text File Export has been created the Payload Engineer invokes the Generate_Parameters which reads this file and generates the SCL Processing Parameters Script.

4. The SCL Parameters Processing script is then compiled by the Payload Engineer into the SCL Project File.

5. The SCL Project File is then transferred to the RoMPS Share folder, which makes it available to the Command and Telemetry Console for subsequent uplink to the RoMPS Experiment Supervisor for execution.

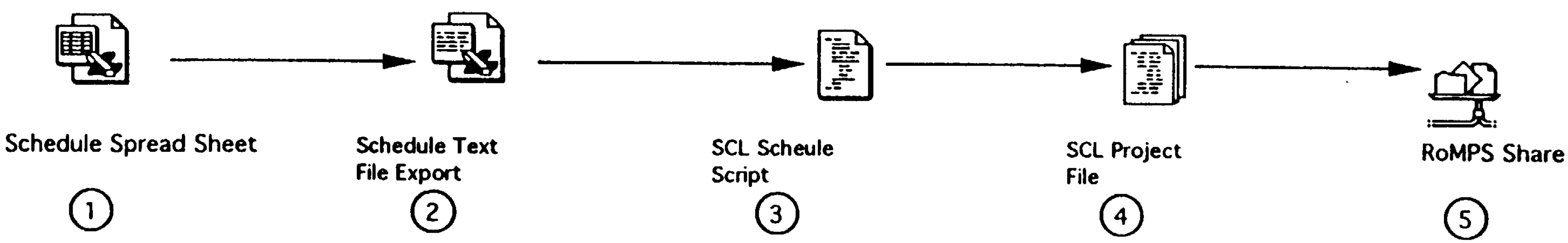
RoMPS: Processing Schedule

Sample Index	Sample Processing Time	Total Processing Time

Check Indices

Save Schedule

Creating a Processing Schedule



(1) At the SCL Script Development Console, the PI Invokes the Schedule Spread Sheet and creates a list of processing runs by typing in the sample identifiers to be processed. The spread sheet will compute the time to process that sample and maintain running total for all samples in the schedule.

(2) After the desired processing schedule has been created, the PI then exports the scheduling data by clicking on the Export Data button. This creates a tab delimitted text file which can be read by SCL.

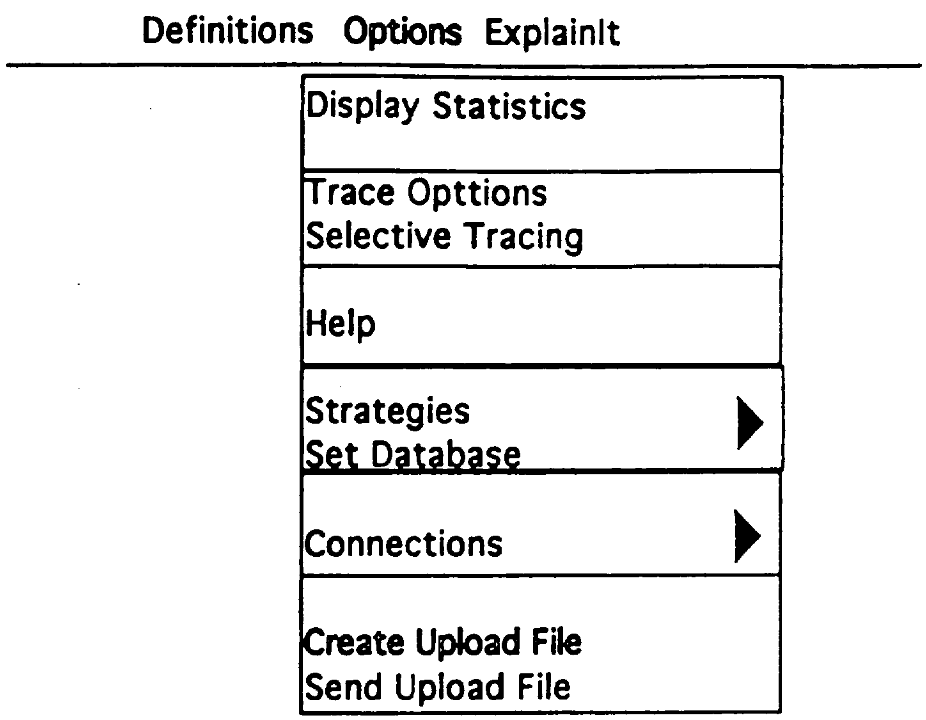
(3) After a Processing Schedule Text File Export has been created, the Payload Engineer invokes a Generate_Schedule SCL script which reads this file and generates the SCL Schedule Script which contains the decleration and initialization of an SCL global array specifying the samples to be processed.

(4) The Schedule script is then compiled by the Payload Engineer into the SCL Project File.

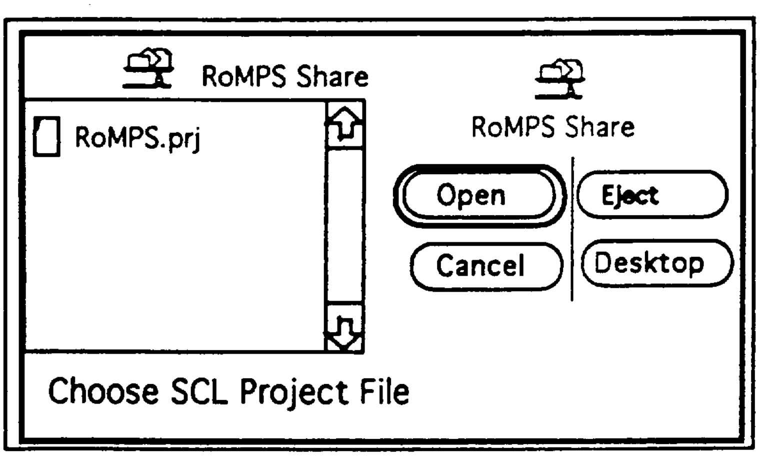
(5) The SCL Project File is then transferred to the RoMPS Share folder, which makes it available to the Command and Telemetry Console for subsequent uplink to the RoMPS Experiment Supervisor for execution.

RoMPS Ground Operations

Uploading SCL Scripts and Rules to the Experiment Supervisor



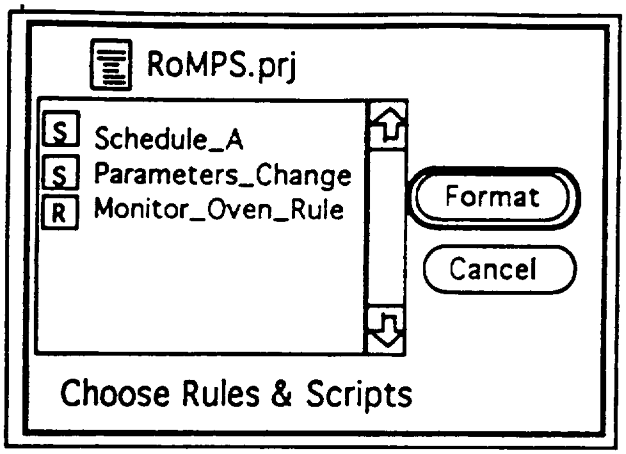
1) Choose Options from SCL Menu Bar then walk down to Create Upload File Menu Item. This Will bring up the Choose SCL Project File Dialog Box.



2) Using the Choose SCL Project File Dialog Box, Select the SCL project file which contains the scripts and rules to be uploaded. This will bring up the Choose Rules & Scripts Dialog Box.

RoMPS Ground Operations

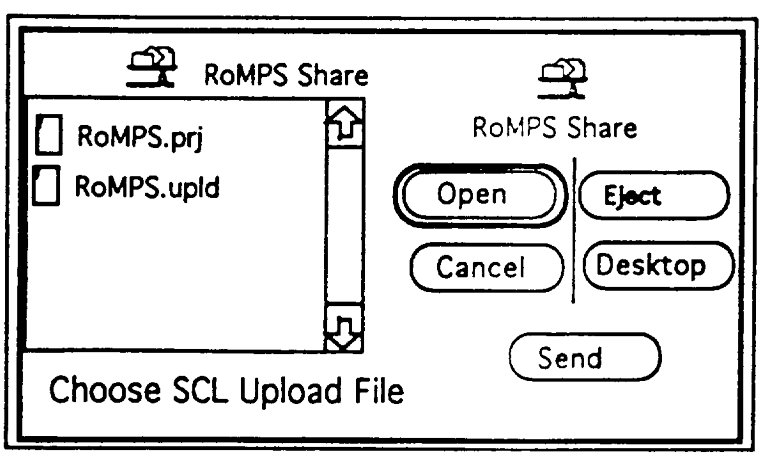
Uploading SCL Scripts and Rules to the Experiment Supervisor (Continued)



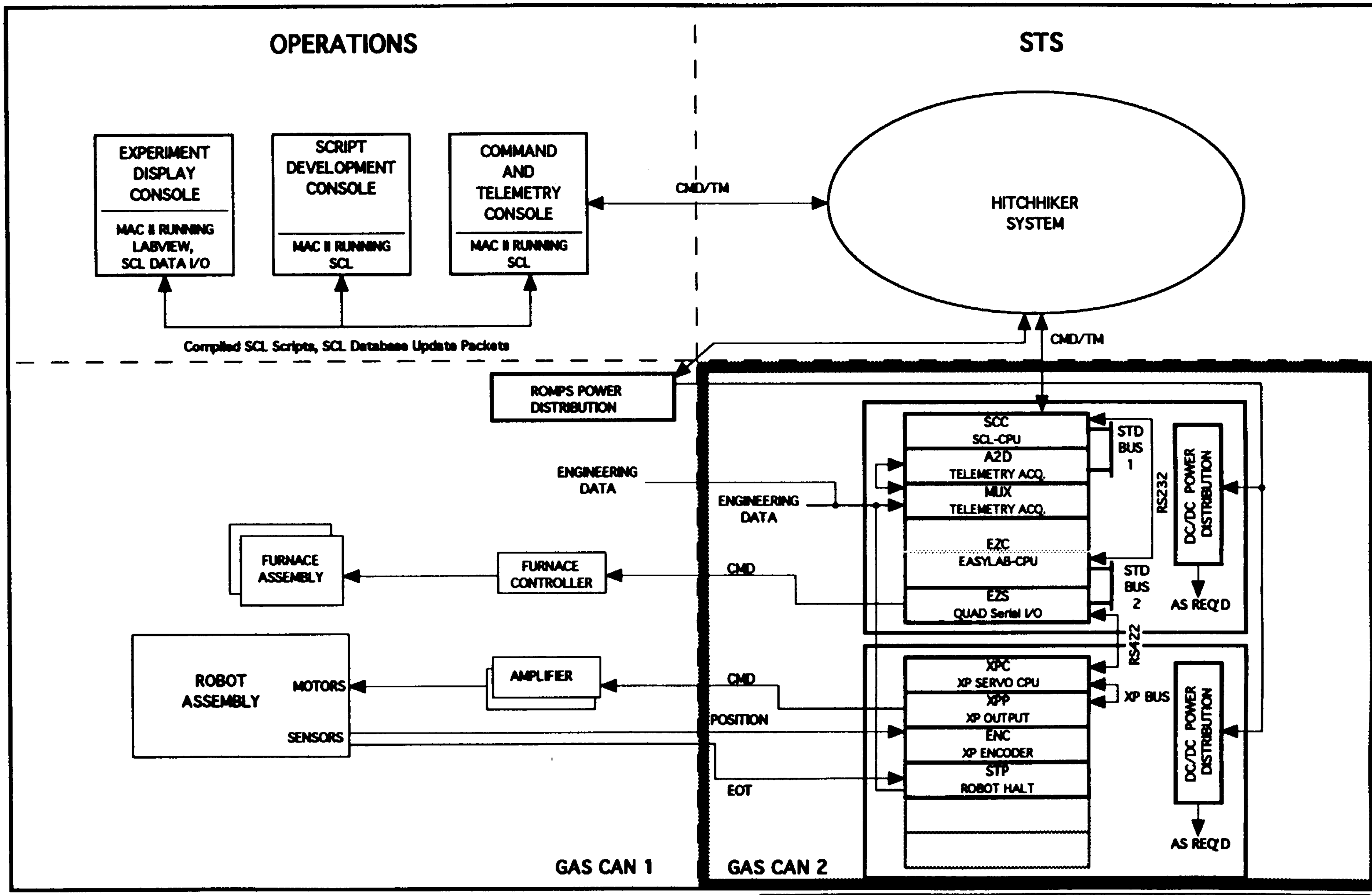
3) Select the rules and scripts to be uploaded by clicking on them with the mouse. After all the rules and scripts to be uploaded have been selected, click on Format to create a named upload file.

Create Upload File
Send Upload File

4) Choose Options from SCL Menu Bar then walk down to Send Upload File Menu Item. This Will bring up the Choose SCL Upload File Dialog Box.



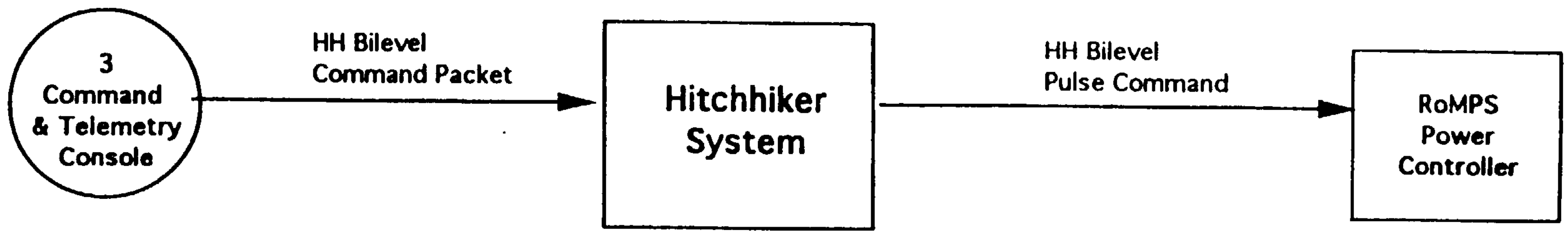
5) Select the file to be uploaded with the Choose SCL Upload Dialog Box. After the desired file has been selected click on the Send button to upload the file.

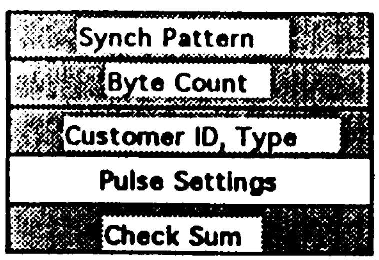


ENGINEER M. F. Dobbs	DRAFTSMAN	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	Zymark RoMPS OPERATIONAL CONCEPT RoMPS 010-539	10/13/92 DATE

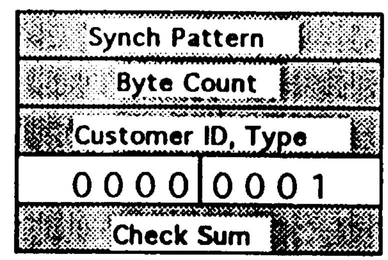
RoMPS Command Uplink Protocols

HH Bilevel Command Packet Protocol





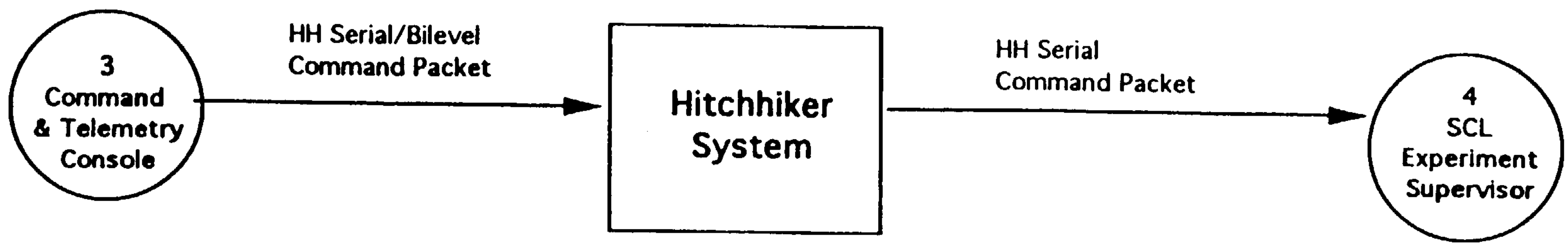
example of
Generic Bilevel Command Packet



example of
Bilevel Command Packet for
set HH_BILEVEL to MASTER_RESET

RoMPS Command Uplink Protocols

SCL-Command Packet Protocol



Synch Pattern
Byte Count
Customer ID, Type
SCL Command ID
SCL Command ID
Command Byte Count
Command Byte Count
Command Specfic Data
••••
••••
Command Specfic Data
Check Sum

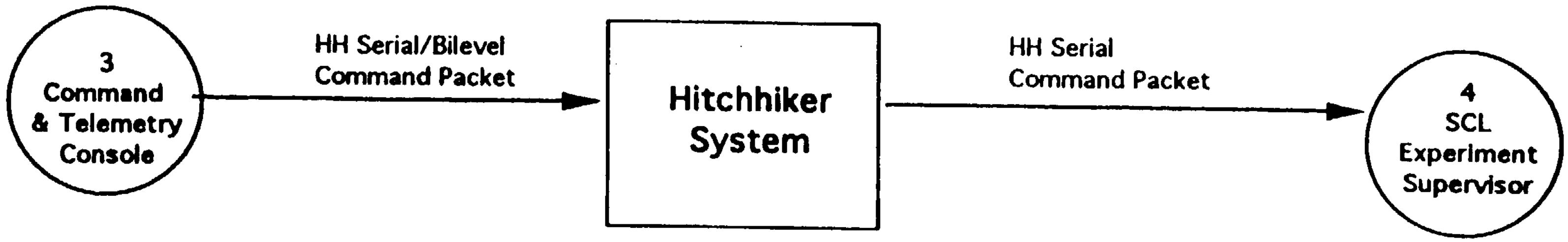
example of
Generic SCL-Command Packet

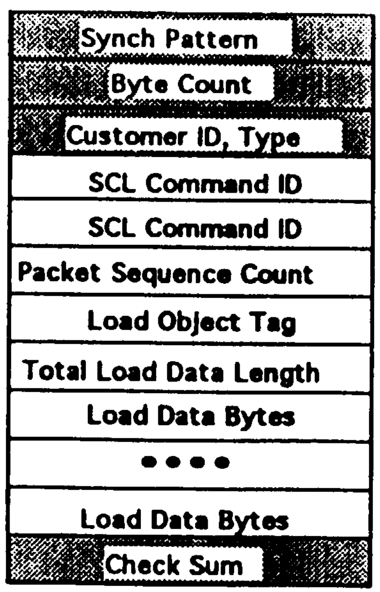
Synch Pattern	
Byte Count	
Customer ID, Type	
SCL Command ID	
Command Byte Count =	
execute Token ID	number of Arguments
system function index of *execute subroutine*	
argument 1 subcode	SPC script ID
SPC script ID	argument 2 subcode
Time Byte 1	Time Byte 2
Time Byte 3	Time Byte 4
argument 3 subcode	*schedule* ID
sample_id ID	argument 4 subcode
script execution priority	
Check Sum	

example of SCL-Command Packet for
exectute SPS at 12:00:00 with sample_id

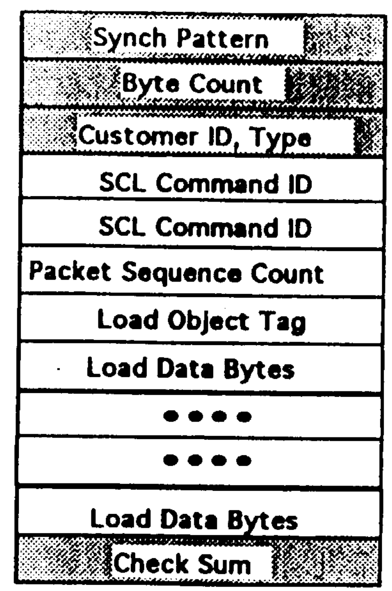
RoMPS Command Uplink Protocols

SCL-Uplink Packet Protocol



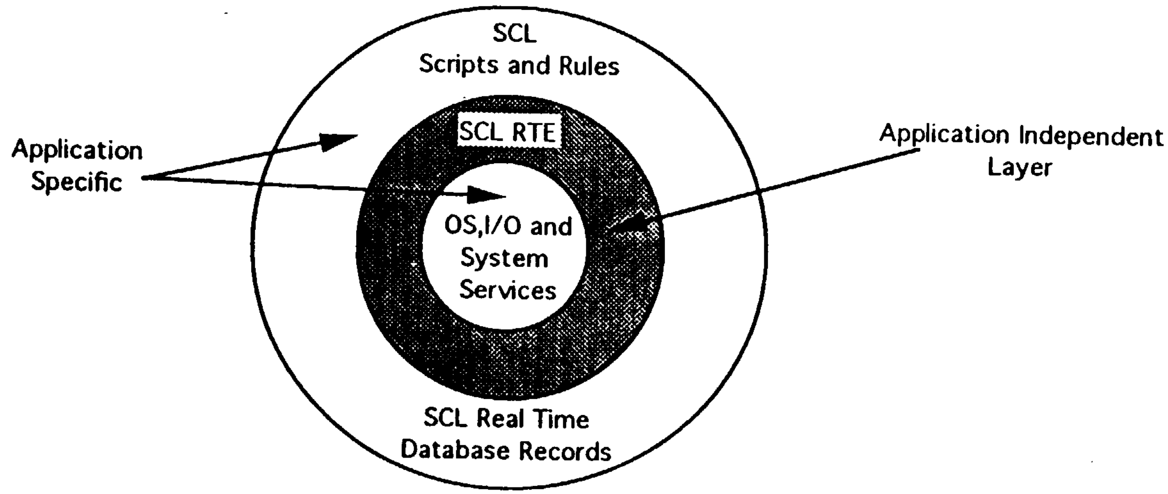


SCL Initial Load Packet



SCL Subsequent Load Packets

What is Spacecraft Command Language (SCL)?



Application Independent Embedded System Programming Language

Applications

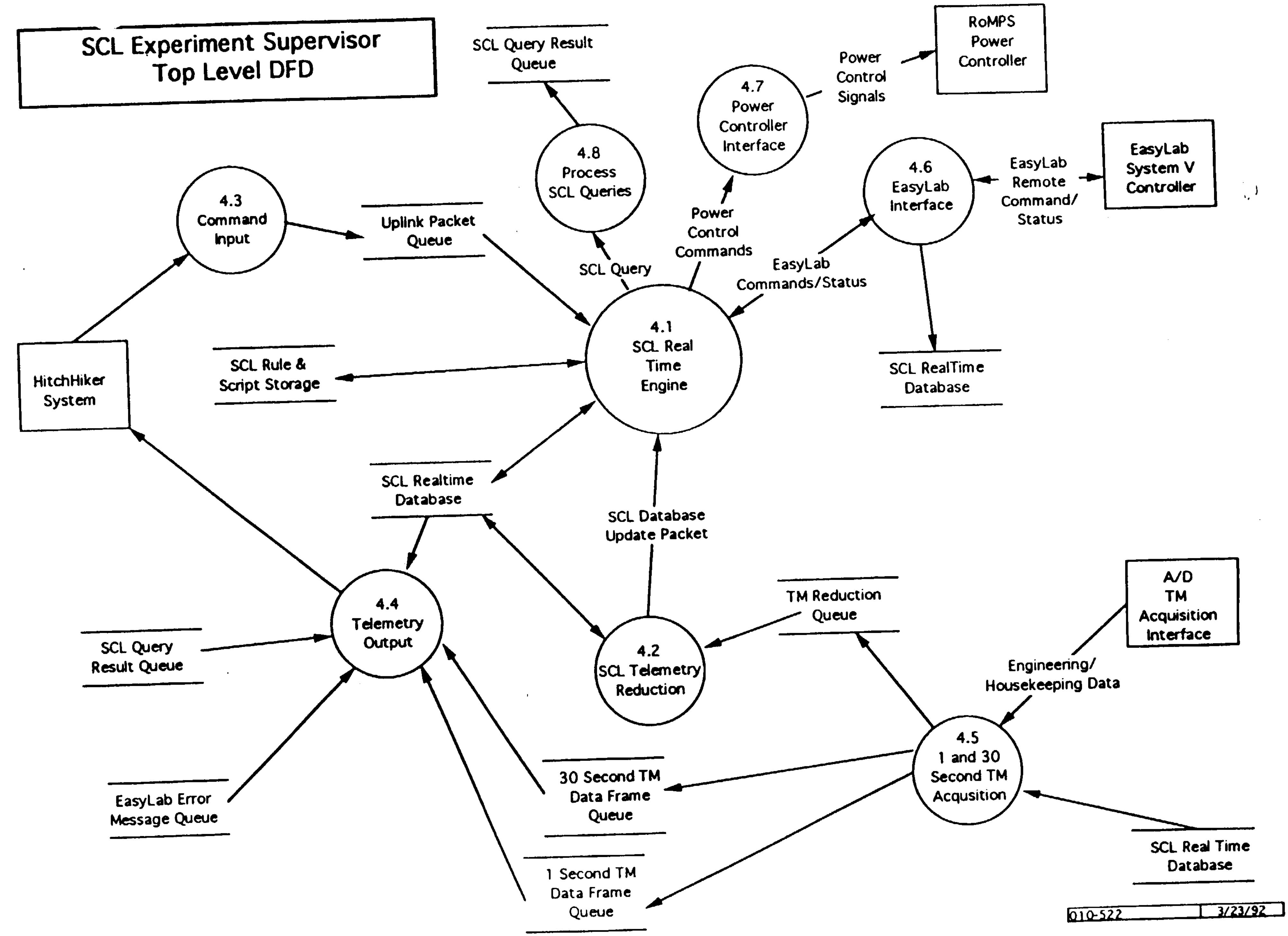
- Spacecraft & Experiment Control
- Real-Time Data Monitoring
- Payload Operations & Control Centers
- Automated Test Equipment

Description

- 5th Generation Procedural Language
- Independent of Operating System
- Script Driven & Asyncronous Event Driven
- Real-Time Database
- Real-Time Rule Evaluation
- Extensible Command Set
- Device Drivers

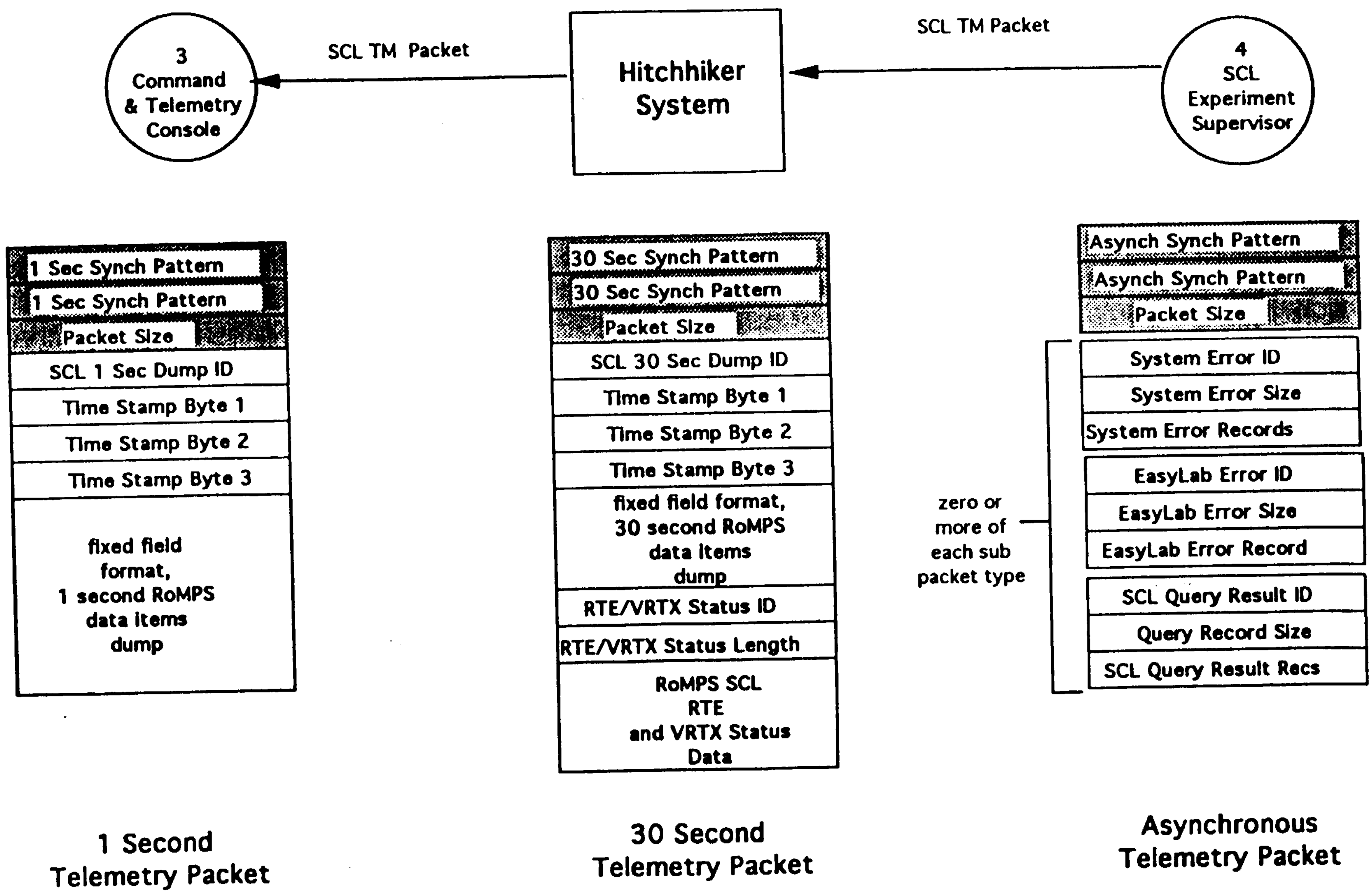
Stand-Alone or Integrated in Distributed System

- Database Syncronization


SCL Experiment Supervisor
Top Level DFD
SCL Query Result Queue
4.8 Process SCL Queries
4.7 Power Controller Interface
Power Control Signals
RoMPS Power Controller
4.6 EasyLab Interface
EasyLab Remote Command/Status
EasyLab System V Controller
4.3 Command Input
Uplink Packet Queue
SCL Query
Power Control Commands
EasyLab Commands/Status
4.1 SCL Real Time Engine
SCL RealTime Database
HitchHiker System
SCL Rule & Script Storage
SCL Realtime Database
SCL Database Update Packet
TM Reduction Queue
A/D TM Acquisition Interface
4.4 Telemetry Output
4.2 SCL Telemetry Reduction
SCL Query Result Queue
Engineering/ Housekeeping Data
4.5 1 and 30 Second TM Acqusition
30 Second TM Data Frame Queue
EasyLab Error Message Queue
SCL Real Time Database
1 Second TM Data Frame Queue
010-522
3/23/92

RoMPS Telemetry Dow..link Protocols

SCL 1 Second, 30 Second and Asynchronous Downlink Packet Protocol

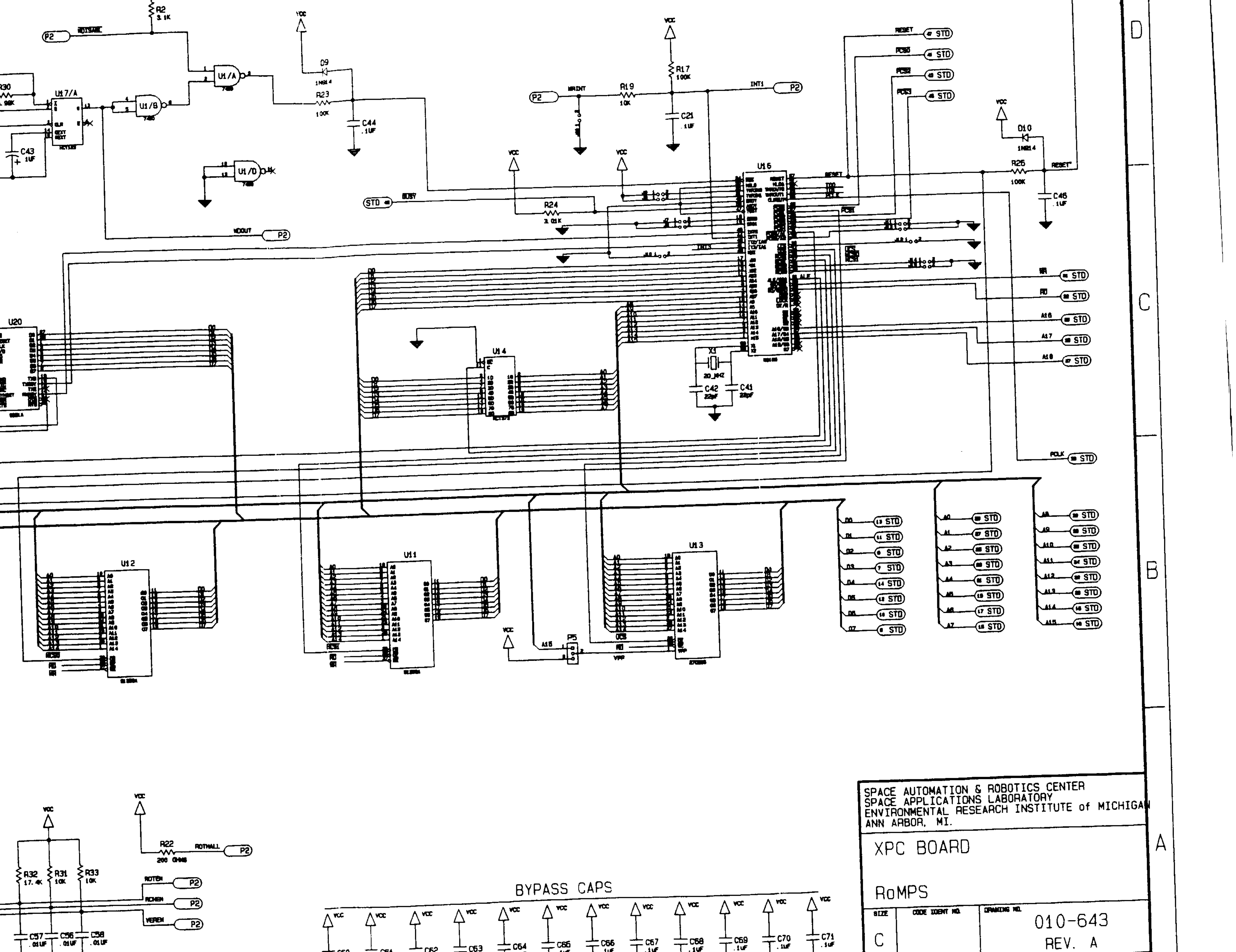


010-526	3/23/92

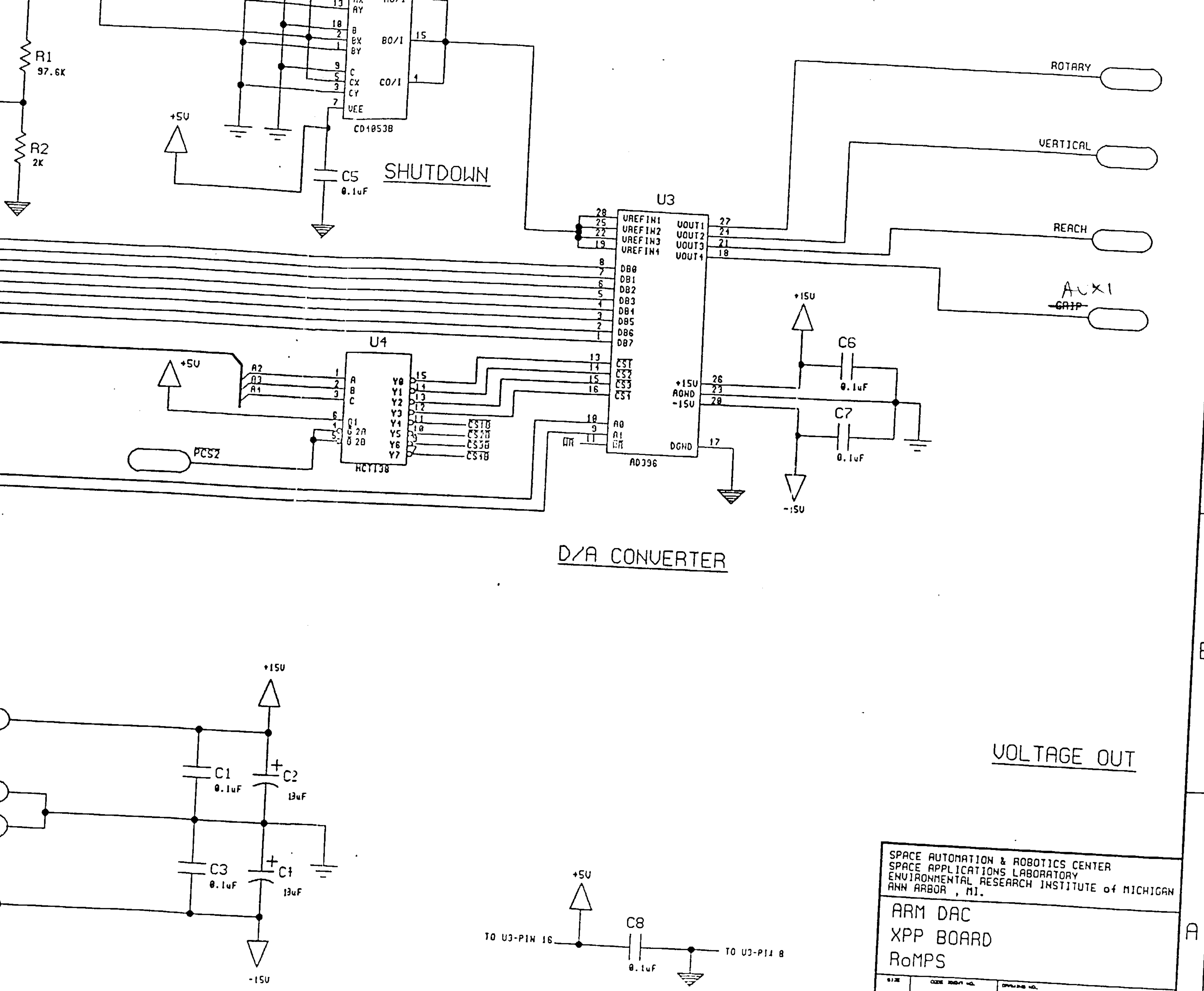
Space Automation & Robotics Center

RoMPS

SCHEMATICS

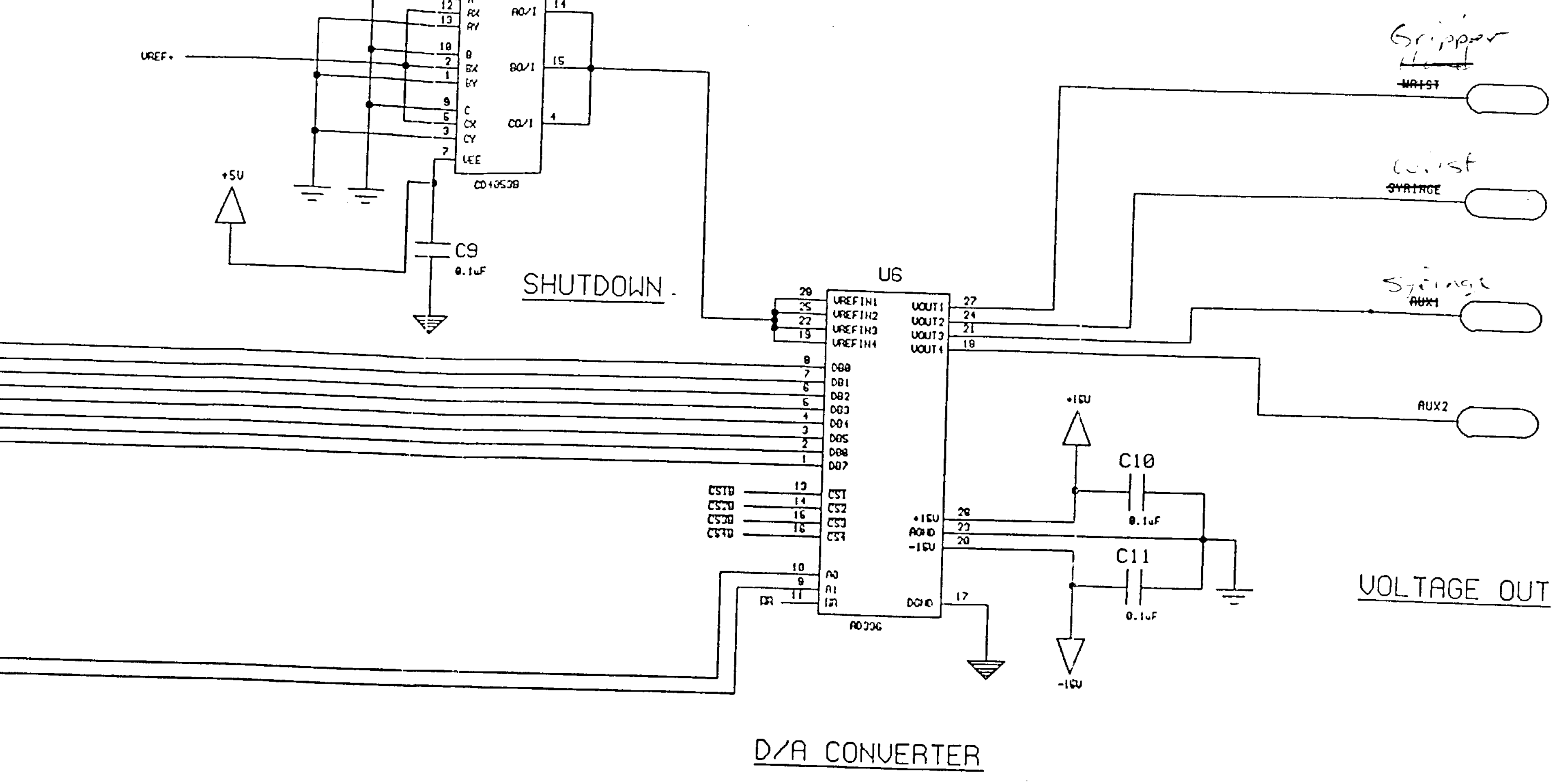


BYPASS CAPS
SPACE AUTOMATION & ROBOTICS CENTER
SPACE APPLICATIONS LABORATORY
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR, MI.
XPC BOARD
RoMPS
SIZE
C
CODE IDENT NO.
DRAWING NO.
010-643
REV. A



SPACE AUTOMATION & ROBOTICS CENTER
SPACE APPLICATIONS LABORATORY
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR , MI.

ARM DAC
XPP BOARD
RoMPS



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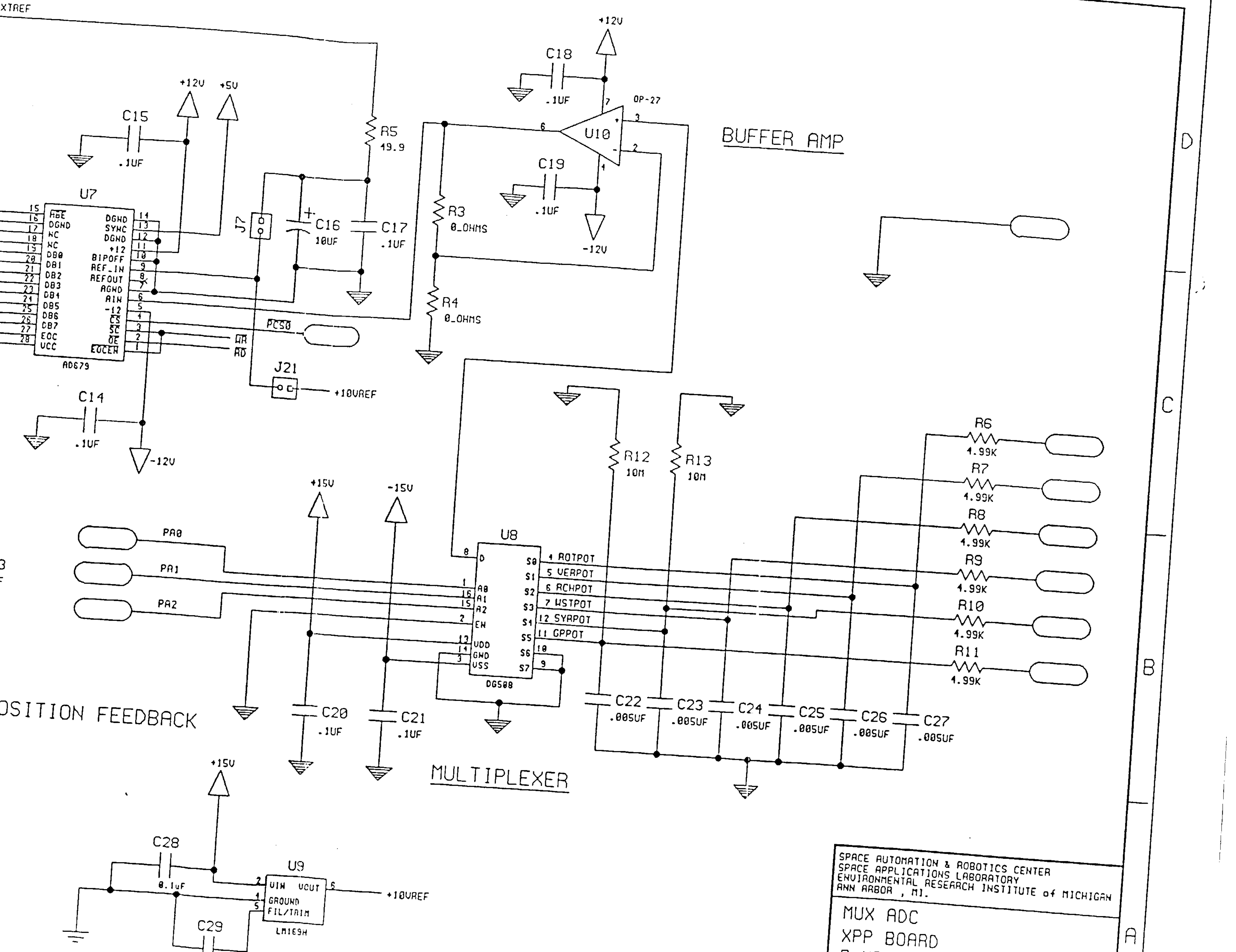
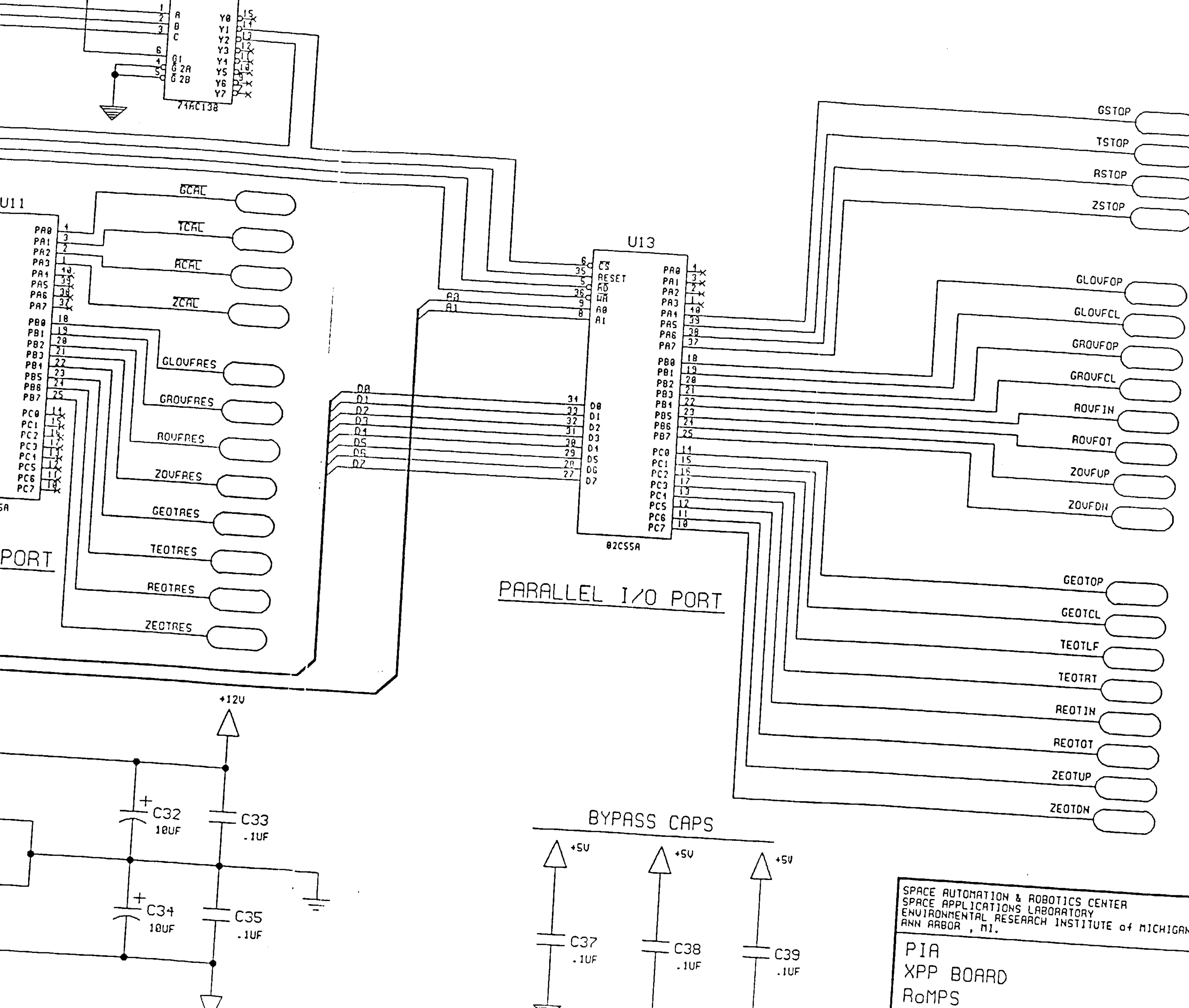
ANN ARBOR , MI.

HAND DAC
XPP BOARD
RoMPS


XTREF
BUFFER AMP
OP-27
U10
+12V
-12V
+5V
C18
C19
.1UF
R3
R4
0_OHMS
R5
49.9
C15
C16
10UF
C17
C14
J7
J21
+10VREF
PCS0
WR
RD
U7
AD679
DGND
SYNC
+12
BIPOFF
REF_IN
REFOUT
AGND
AIN
-12
CS
SC
OE
EOCEN
HBE
NC
DB0
DB1
DB2
DB3
DB4
DB5
DB6
DB7
EOC
VCC
PA0
PA1
PA2
OSITION FEEDBACK
+15V
-15V
C20
C21
MULTIPLEXER
U8
DG508
D
A0
A1
A2
EN
VDD
GND
VSS
S0
S1
S2
S3
S4
S5
S6
S7
4 ROTPOT
5 VERPOT
6 RCHPOT
7 WSTPOT
12 SYRPOT
11 GPPOT
R6
R7
R8
R9
R10
R11
4.99K
R12
R13
10M
C22
C23
C24
C25
C26
C27
.005UF
C28
0.1uF
C29
U9
LM169H
VIN
VOUT
GROUND
FIL/TRIM
SPACE AUTOMATION & ROBOTICS CENTER
SPACE APPLICATIONS LABORATORY
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR , MI.
MUX ADC
XPP BOARD
D
C
B
A



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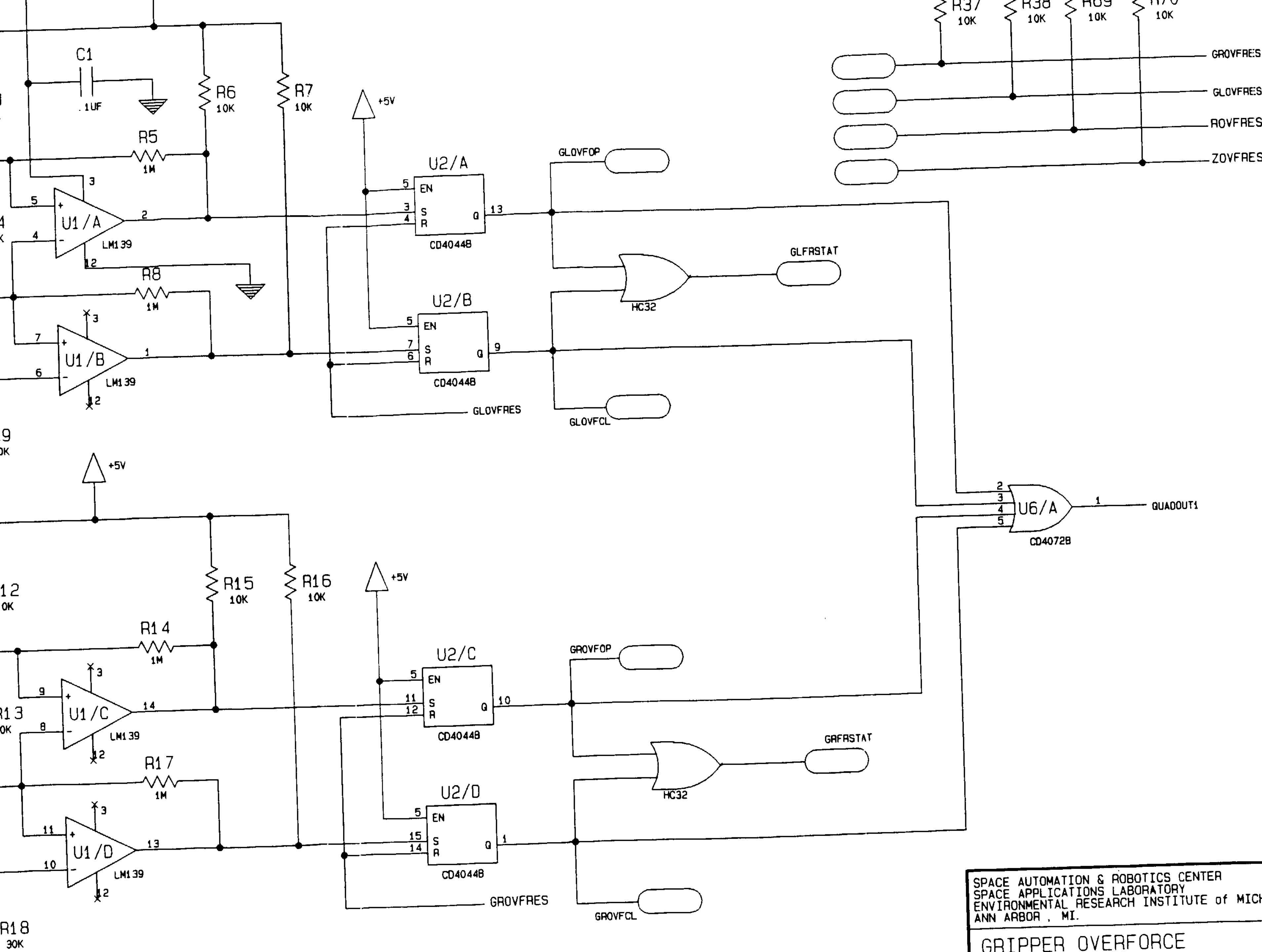
ANN ARBOR , MI.

PIA
XPP BOARD
RoMPS



GRIPPER LEFT & RIGHT OVERFORCE COMPARATORS

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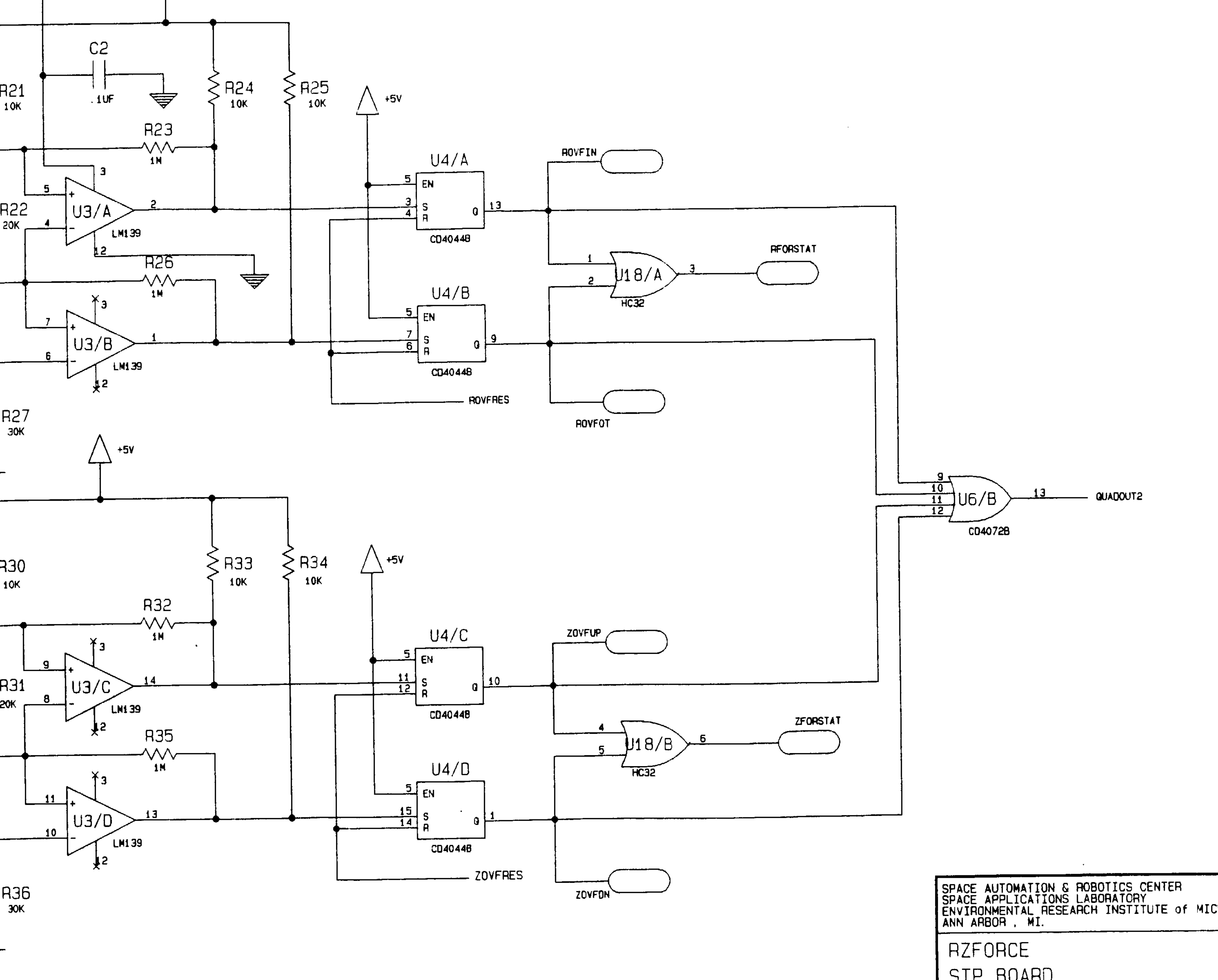
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR , MI.

GRIPPER OVERFORCE
STP BOARD
RoMPS

SIZE	CODE IDENT NO.	DRAWING NO.
		010-605 REV. A

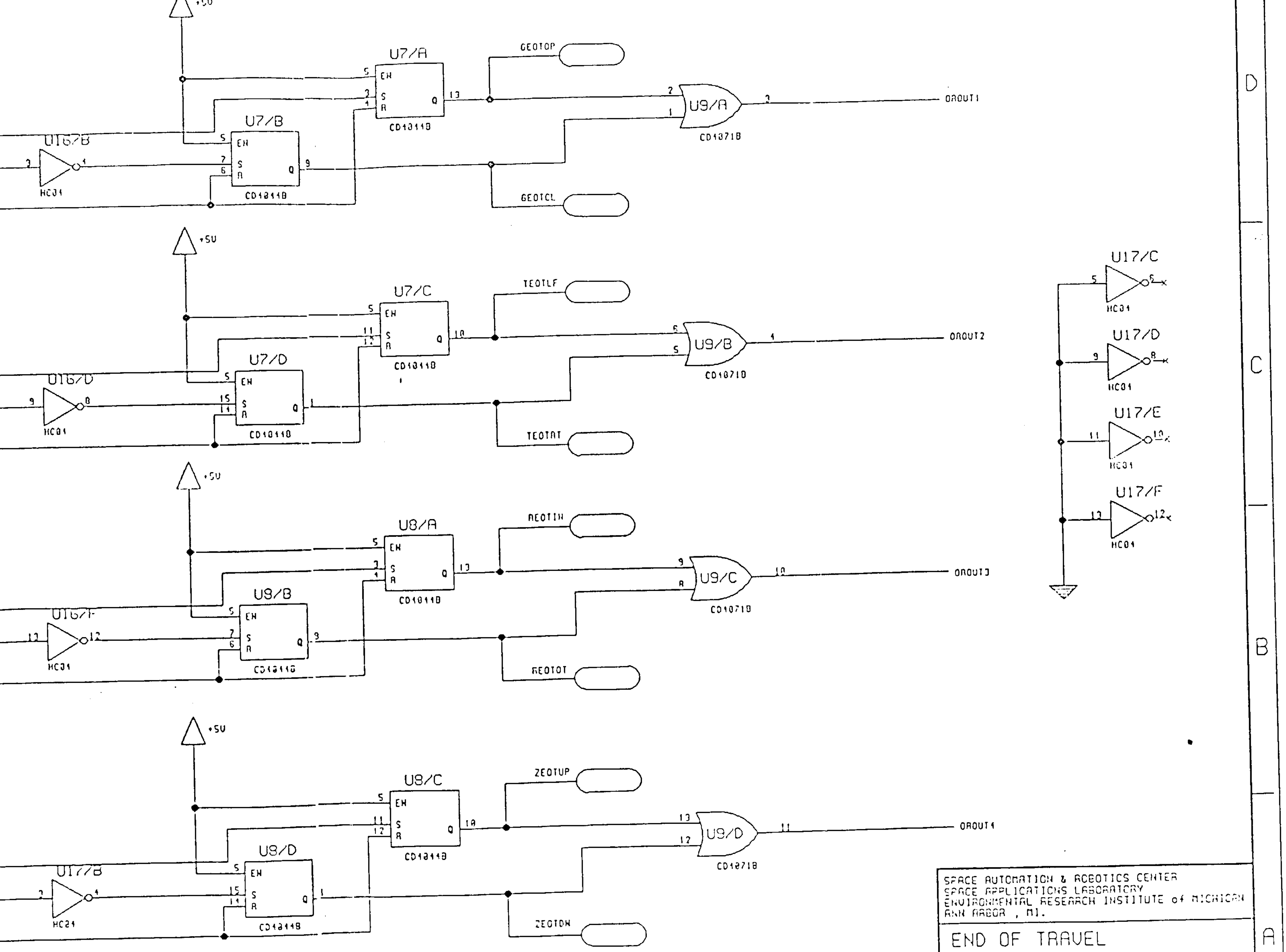


ELEVATION & RADIAL OVERFORCE COMPARATORS

SPACE AUTOMATION & ROBOTICS CENTER
SPACE APPLICATIONS LABORATORY
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR , MI.

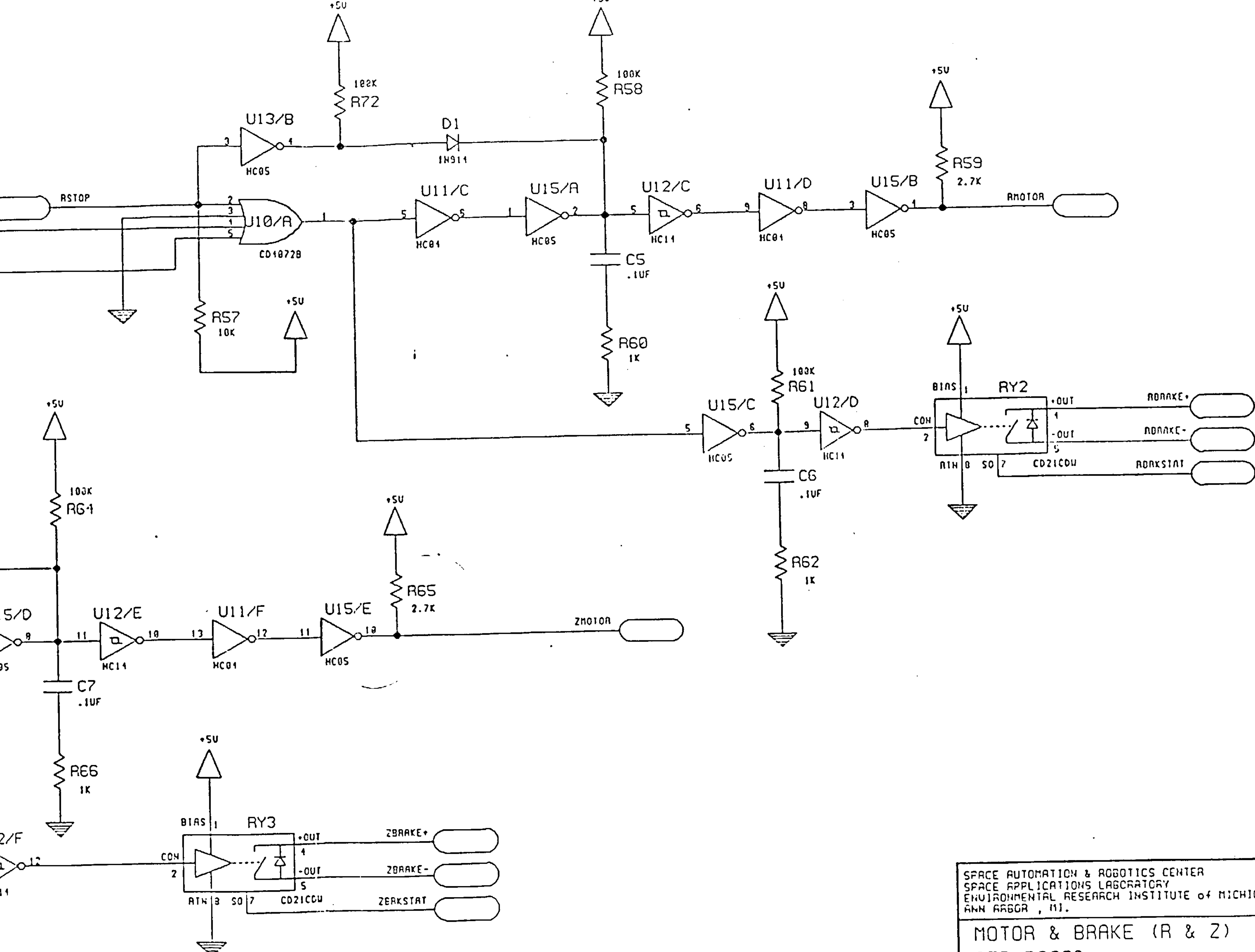
RZFORCE
STP BOARD
RoMPS

SIZE	CODE IDENT NO.	DRAWING NO.
		010-606



SPACE AUTOMATION & ROBOTICS CENTER
SPACE APPLICATIONS LABORATORY
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR , MI.

END OF TRAVEL
STP BOARD
RoMPS



ALTITUDE & RADIAL
BRAKE DRIVE & MOTOR ENABLE

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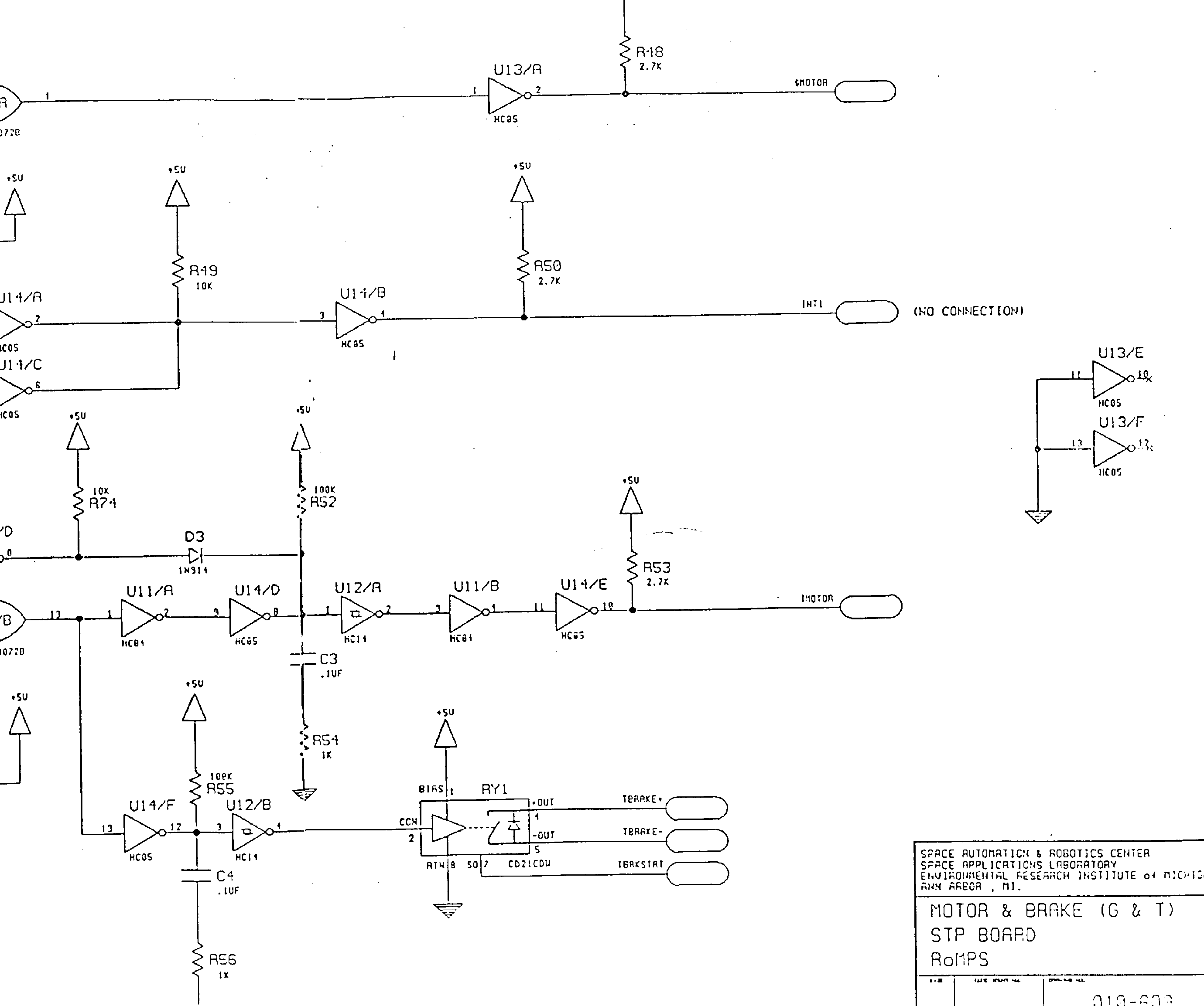
SPACE APPLICATIONS LABORATORY
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR , MI.

MOTOR & BRAKE (R & Z)
STP BOARD
RoMPS

010-608



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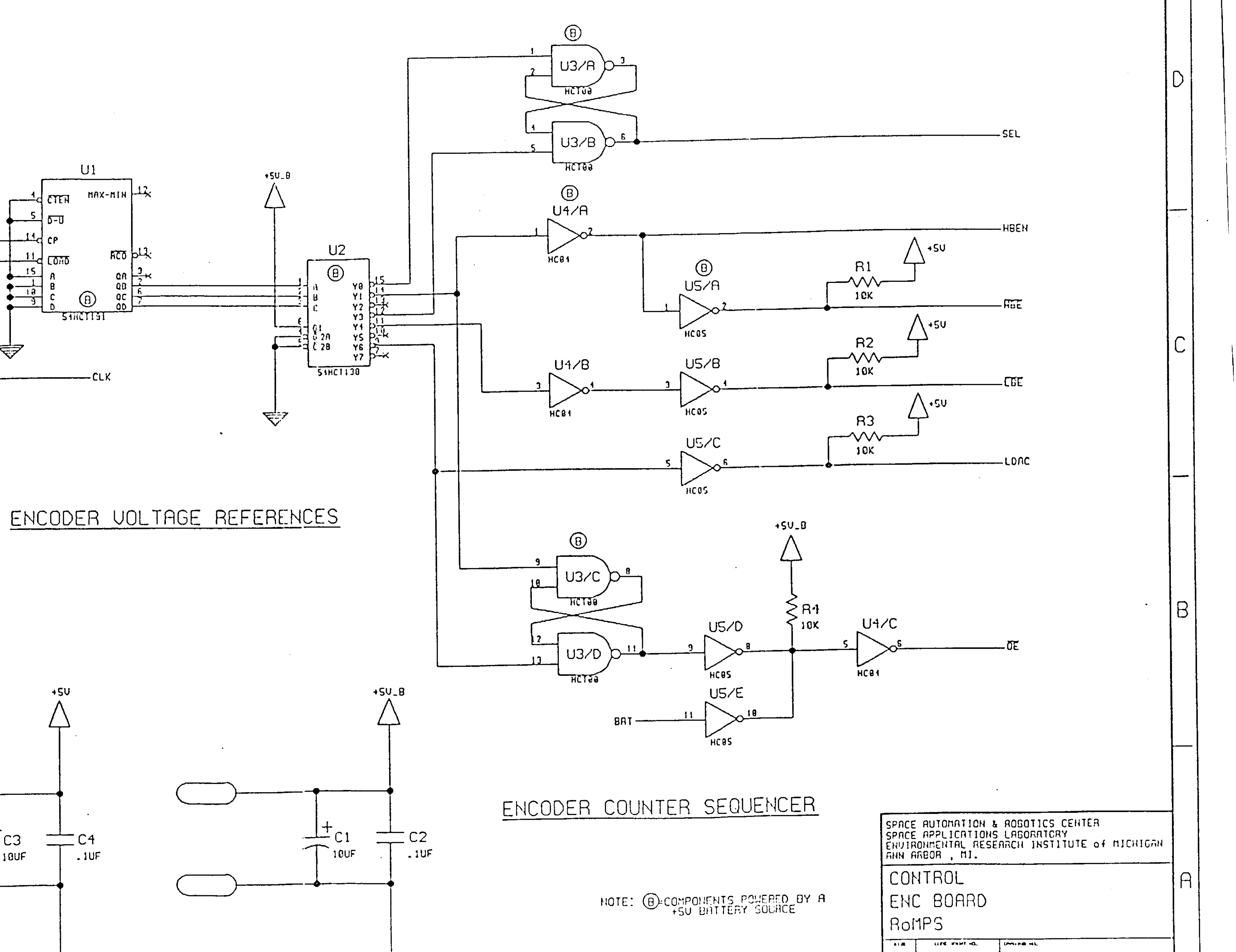
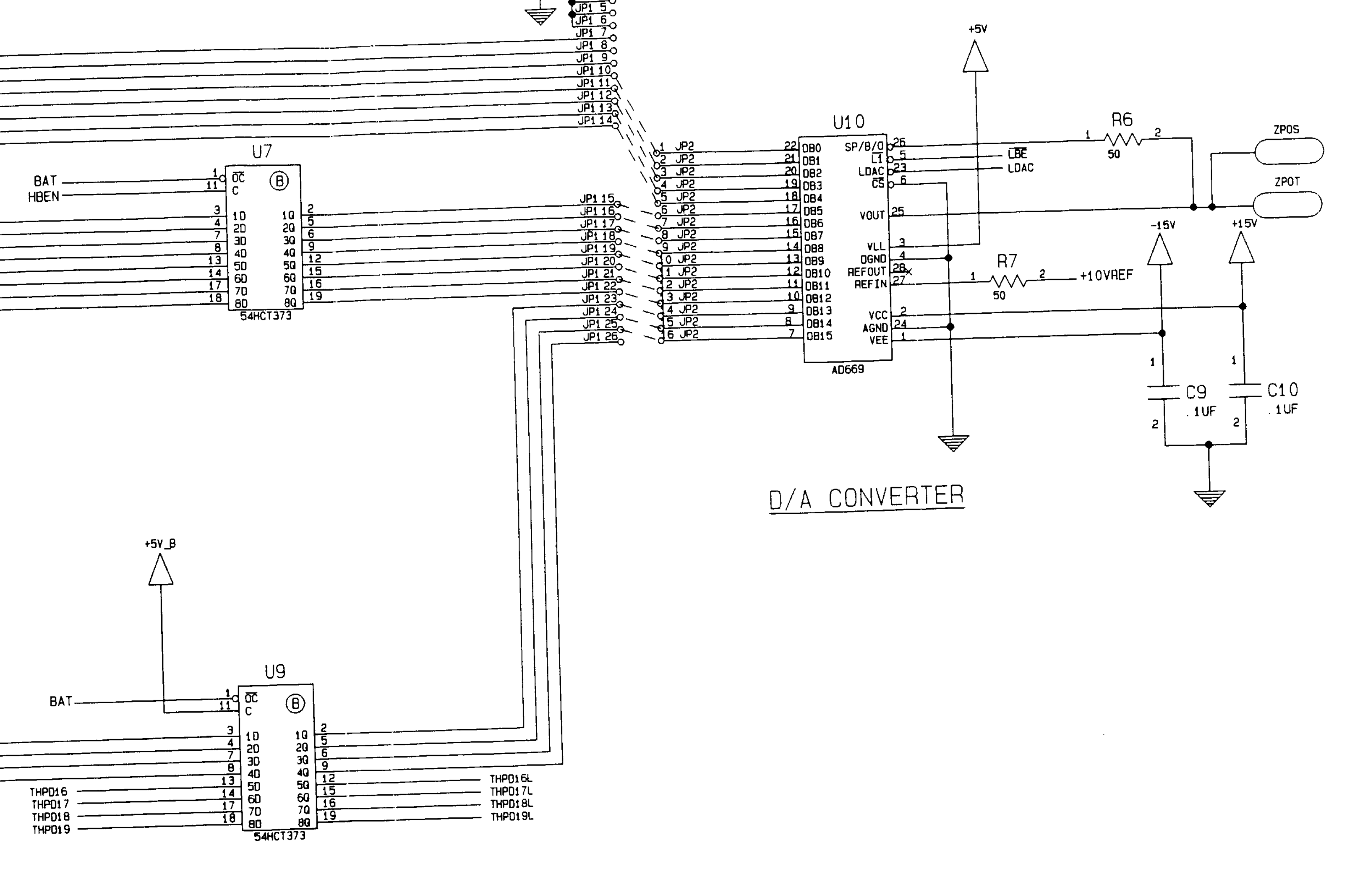
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR , MI.

MOTOR & BRAKE (G & T)
STP BOARD
RoMPS


U1
CTEN
D-U
CP
LOAD
MAX-MIN
RCO
QA
QB
QC
QD
54HCT191
CLK
U2
Y0
Y1
Y2
Y3
Y4
Y5
Y6
Y7
54HCT138
+5V_B
U3/A
U3/B
HCT00
SEL
U4/A
U4/B
U4/C
HC04
HBEN
U5/A
U5/B
U5/C
U5/D
U5/E
HC05
R1
R2
R3
R4
10K
+5V
LOAC
U3/C
U3/D
BAT
C1
10UF
C2
.1UF
C3
C4
ENCODER VOLTAGE REFERENCES
ENCODER COUNTER SEQUENCER
NOTE: (B)=COMPONENTS POWERED BY A +5V BATTERY SOURCE
SPACE AUTOMATION & ROBOTICS CENTER
SPACE APPLICATIONS LABORATORY
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR , MI.
CONTROL
ENC BOARD
RoMPS
D
C
B
A



JUMPER CONFIGURATION

PIN NUMBERS	PIN NAMES
JP1/10 - JP2/1	ZHPD3/11 - ZDACDB0
JP1/11 - JP2/2	ZHPD4/12 - ZDACDB1
JP1/12 - JP2/3	ZHPD5/13 - ZDACDB2
JP1/13 - JP2/4	ZHPD6/14 - ZDACDB3
JP1/14 - JP2/5	ZHPD7/15 - ZDACDB4
JP1/15 - JP2/6	ZHPD8L - ZDACDB5
JP1/16 - JP2/7	ZHPD9L - ZDACDB6
JP1/17 - JP2/8	ZHPD10L - ZDACDB7
JP1/18 - JP2/9	ZHPD11L - ZDACDB8
JP1/19 - JP2/10	ZHPD12L - ZDACDB9
JP1/20 - JP2/11	ZHPD13L - ZDACDB10
JP1/21 - JP2/12	ZHPD14L - ZDACDB11
JP1/22 - JP2/13	ZHPD15L - ZDACDB12
JP1/23 - JP2/14	ZHPD16L - ZDACDB13

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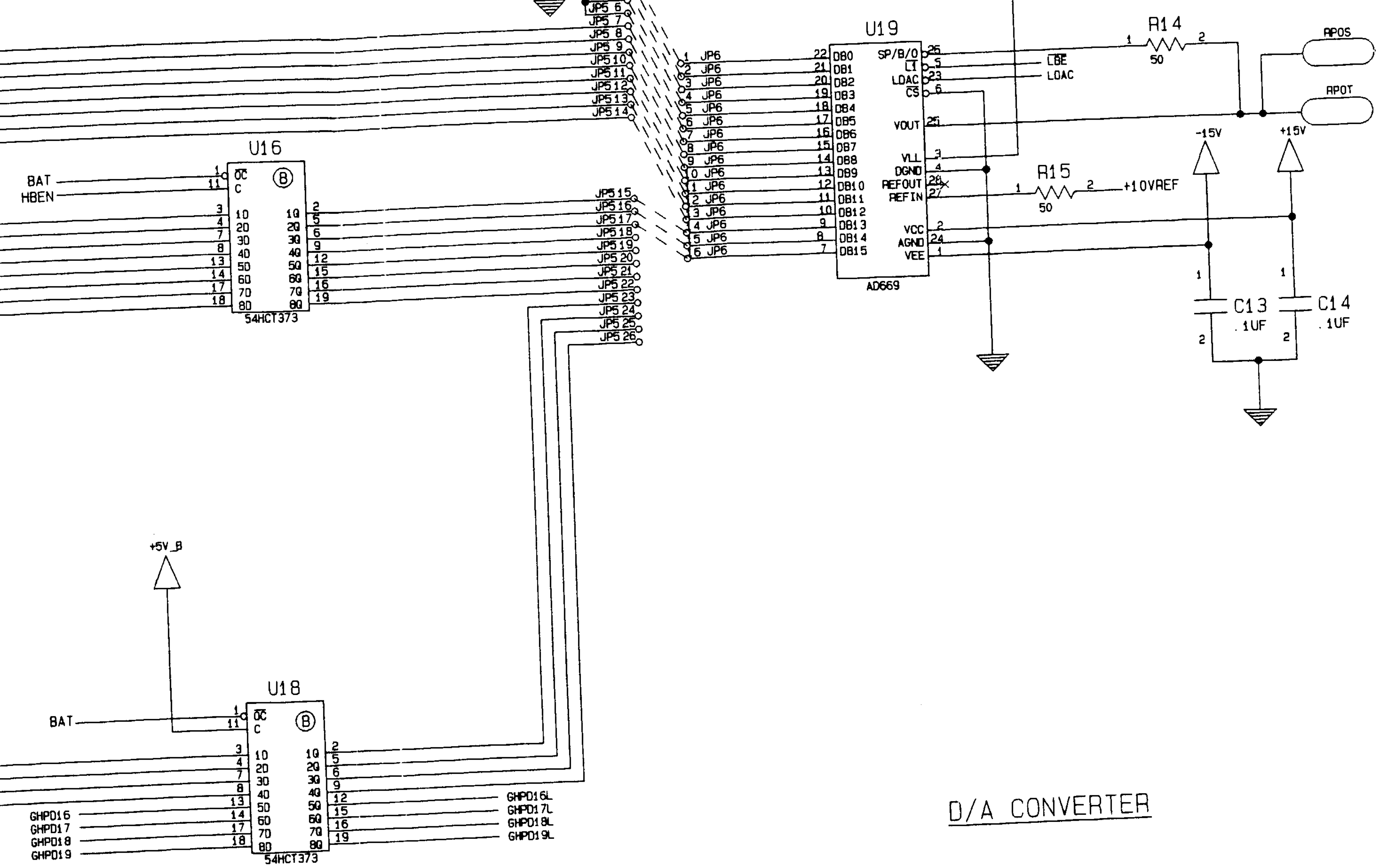
ANN ARBOR, MI.

ELEVATION (Z) AXIS
ENC BOARD
RoMPS

SIZE	CODE IDENT NO.	DRAWING NO.
		010-621 REV. A



D/A CONVERTER

NOTE: (B)=COMPONENTS POWERED BY A +5V BATTERY SOURCE

JUMPER CONFIGURATION

PIN NUMBERS	PIN NAMES
JP5/2 - JP6/1	RHPD3/11 - RDACDB0
JP5/3 - JP6/2	RHPD4/12 - RDACDB1
JP5/4 - JP6/3	RHPD5/13 - RDACDB2
JP5/5 - JP6/4	RHPD6/14 - RDACDB3
JP5/6 - JP6/5	RHPD7/15 - RDACDB4
JP5/7 - JP6/6	RHPD8L - RDACDB5
JP5/8 - JP6/7	RHPD9L - RDACDB6
JP5/9 - JP6/8	RHPD10L - RDACDB7
JP5/10 - JP6/9	RHPD11L - RDACDB8
JP5/11 - JP6/10	RHPD12L - RDACDB9
JP5/12 - JP6/11	RHPD13L - RDACDB10
JP5/13 - JP6/12	RHPD14L - RDACDB11
JP5/14 - JP6/13	RHPD15L - RDACDB12
JP5/15 - JP6/14	RHPD16L - RDACDB13
[illegible]	RHPD17L - RDACDB14

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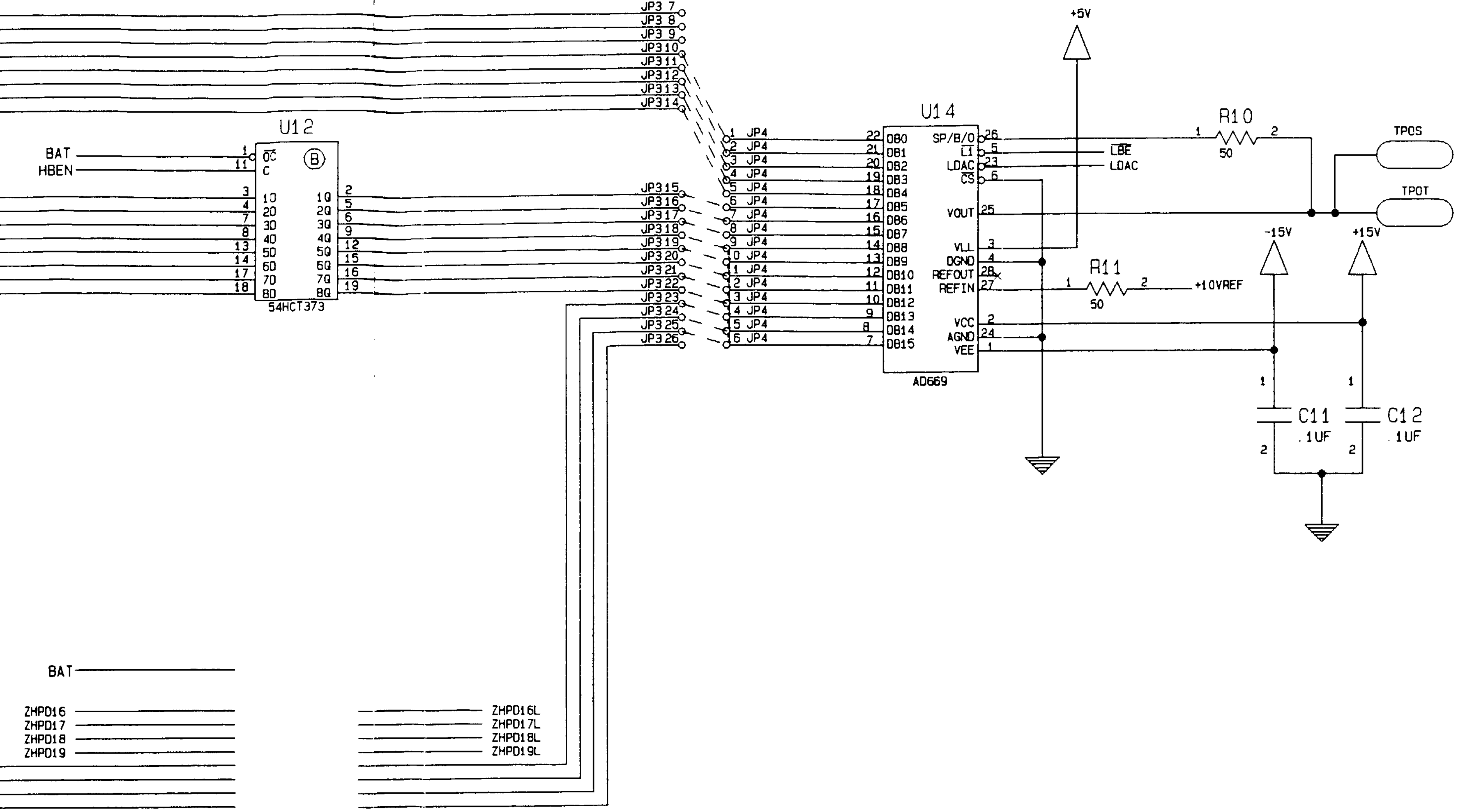
RADIAL (R) AXIS
ENC BOARD
RoMPS

SIZE	CODE IDENT NO.	DRAWING NO.
		010-623 REV. A



D/A CONVERTER

NOTE: Ⓑ=COMPONENTS POWERED BY A +5V BATTERY SOURCE

JUMPER CONFIGURATION	
PIN NUMBERS	PIN NAMES
JP3/10 - JP4/1	THPD3/11 - TDACDB0
JP3/11 - JP4/2	THPD4/12 - TDACDB1
JP3/12 - JP4/3	THPD5/13 - TDACDB2
JP3/13 - JP4/4	THPD6/14 - TDACDB3
JP3/14 - JP4/5	THPD7/15 - TDACDB4
JP3/15 - JP4/6	THPD8L - TDACDB5
JP3/16 - JP4/7	THPD9L - TDACDB6
JP3/17 - JP4/8	THPD10L - TDACDB7
JP3/18 - JP4/9	THPD11L - TDACDB8
JP3/19 - JP4/10	THPD12L - TDACDB9
JP3/20 - JP4/11	THPD13L - TDACDB10
JP3/21 - JP4/12	THPD14L - TDACDB11
JP3/22 - JP4/13	THPD15L - TDACDB12
JP3/23 - JP4/14	THPD16L - TDACDB13
JP3/24 - JP4/15	THPD17L - TDACDB14
JP3/25 - JP4/16	THPD18L - TDACDB15

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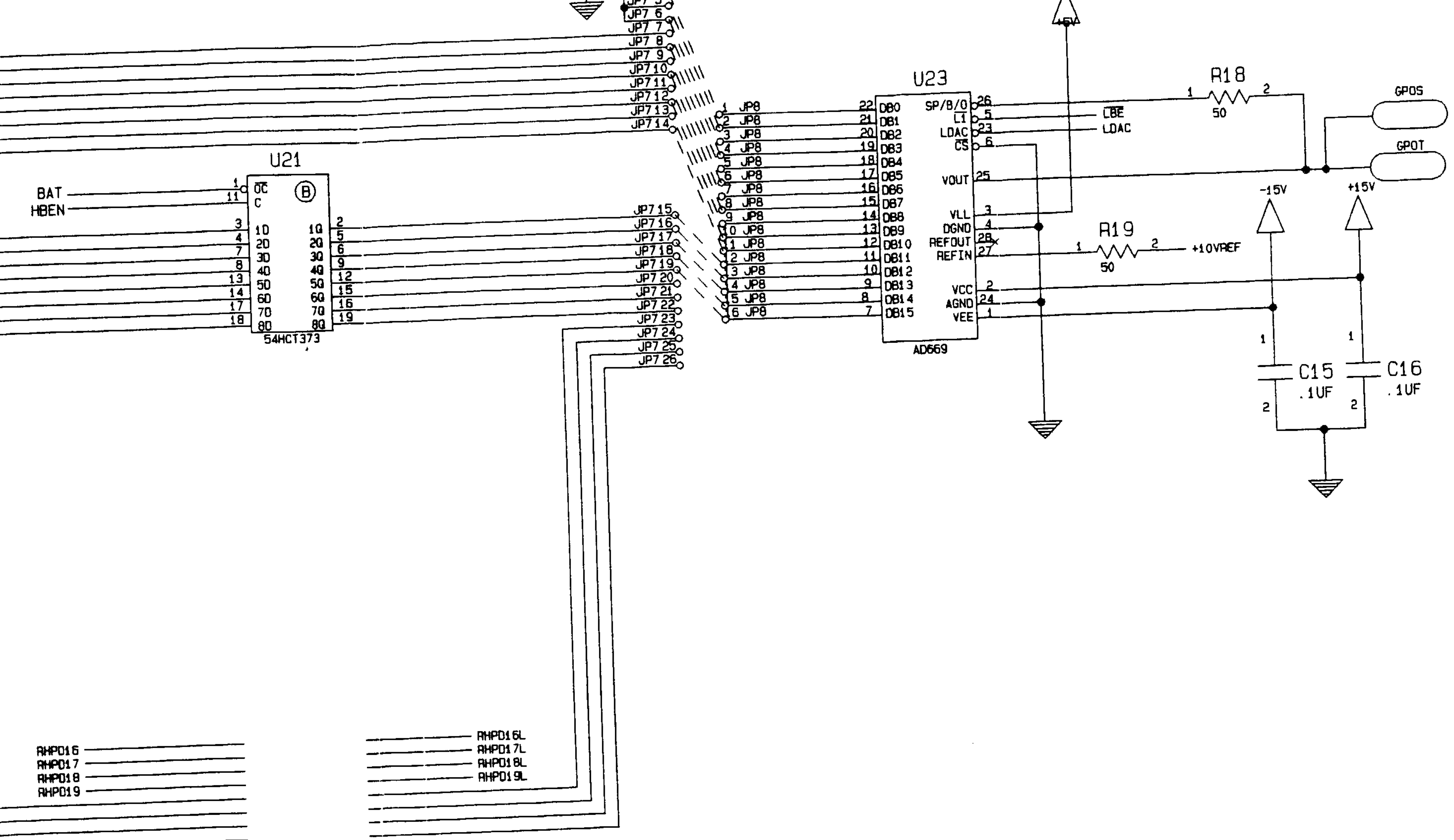
AZIMUTH (T) AXIS
ENC BOARD
RoMPS

SIZE	CODE IDENT NO.	DRAWING NO.
		010-622 REV. A



D/A CONVERTER

JUMPER CONFIGURATION	
PIN NUMBERS	PIN NAMES
JP7/4 - JP8/1	THPD3/11 - TDACDB0
JP7/5 - JP8/2	THPD4/12 - TDACDB1
JP7/6 - JP8/3	THPD5/13 - TDACDB2
JP7/7 - JP8/4	THPD6/14 - TDACDB3
JP7/8 - JP8/5	THPD7/15 - TDACDB4
JP7/9 - JP8/6	THPD8L - TDACDB5
JP7/10 - JP8/7	THPD9L - TDACDB6
JP7/11 - JP8/8	THPD10L - TDACDB7
JP7/12 - JP8/9	THPD11L - TDACDB8
JP7/13 - JP8/10	THPD12L - TDACDB9
JP7/14 - JP8/11	THPD13L - TDACDB10
JP7/15 - JP8/12	THPD14L - TDACDB11
JP7/16 - JP8/13	THPD15L - TDACDB12
JP7/17 - JP8/14	THPD16L - TDACDB13

NOTE: (B)=COMPONENTS POWERED BY A +5V BATTERY SOURCE

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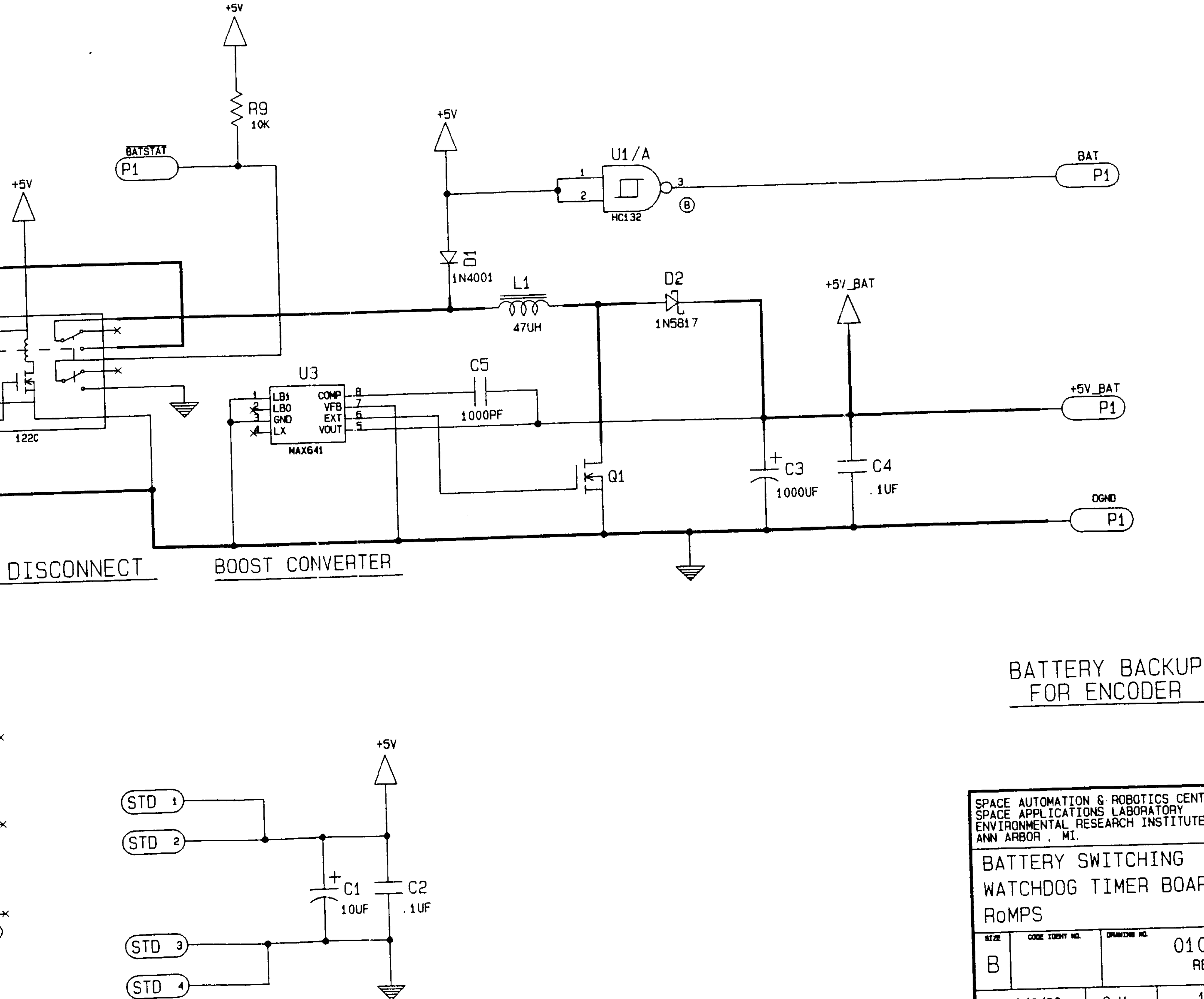
GRIPPER (G) AXIS
ENC BOARD
RoMPS

SIZE	CODE IDENT NO.	DRAWING NO.
		010-624 REV. A



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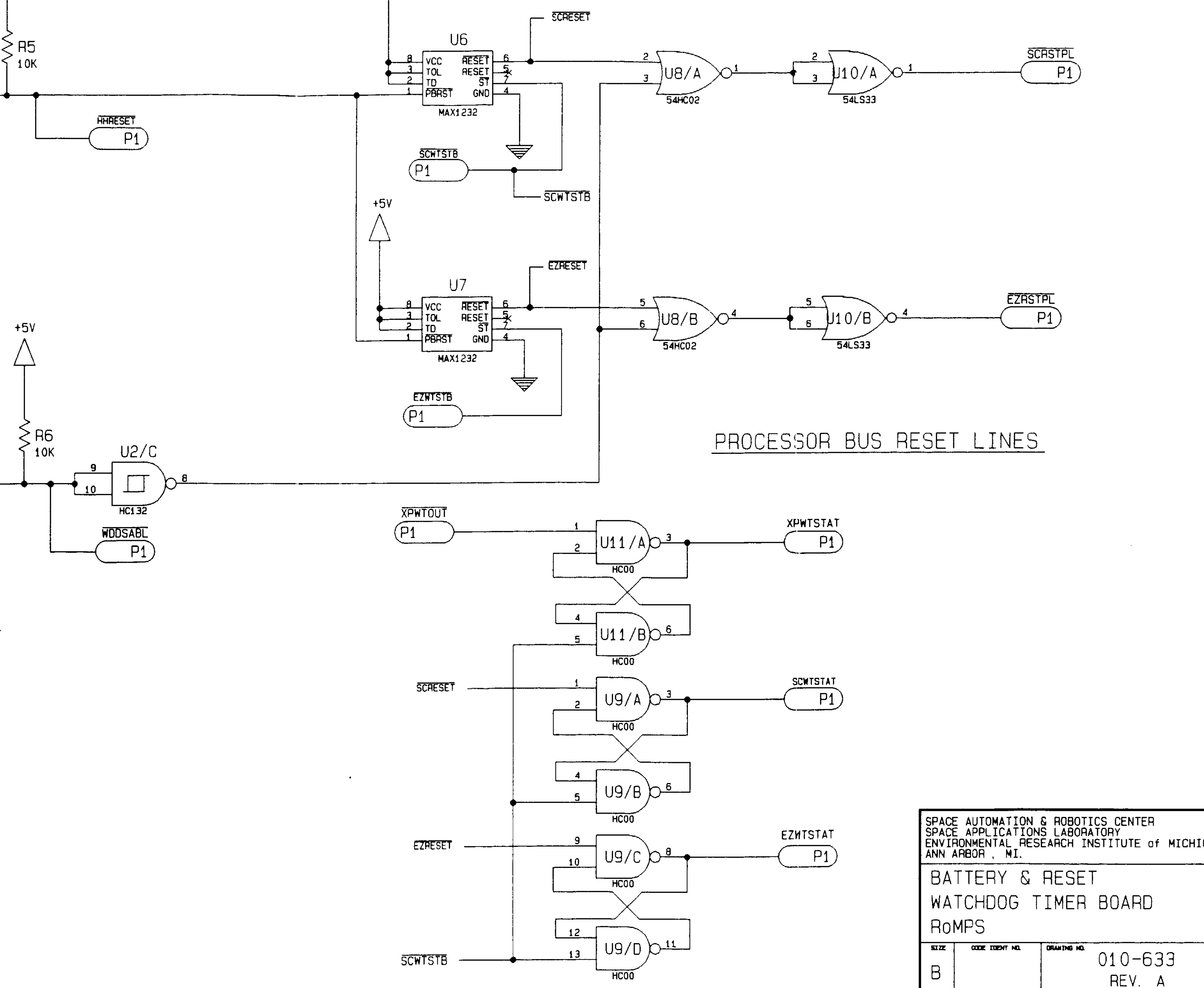
ANN ARBOR , MI.

BATTERY SWITCHING
WATCHDOG TIMER BOARD
RoMPS

SIZE	CODE IDENT NO.	DRAWING NO.
B		010-632 REV. A
DATE 12/3/92	G. W.	SHEET 1 OF 2

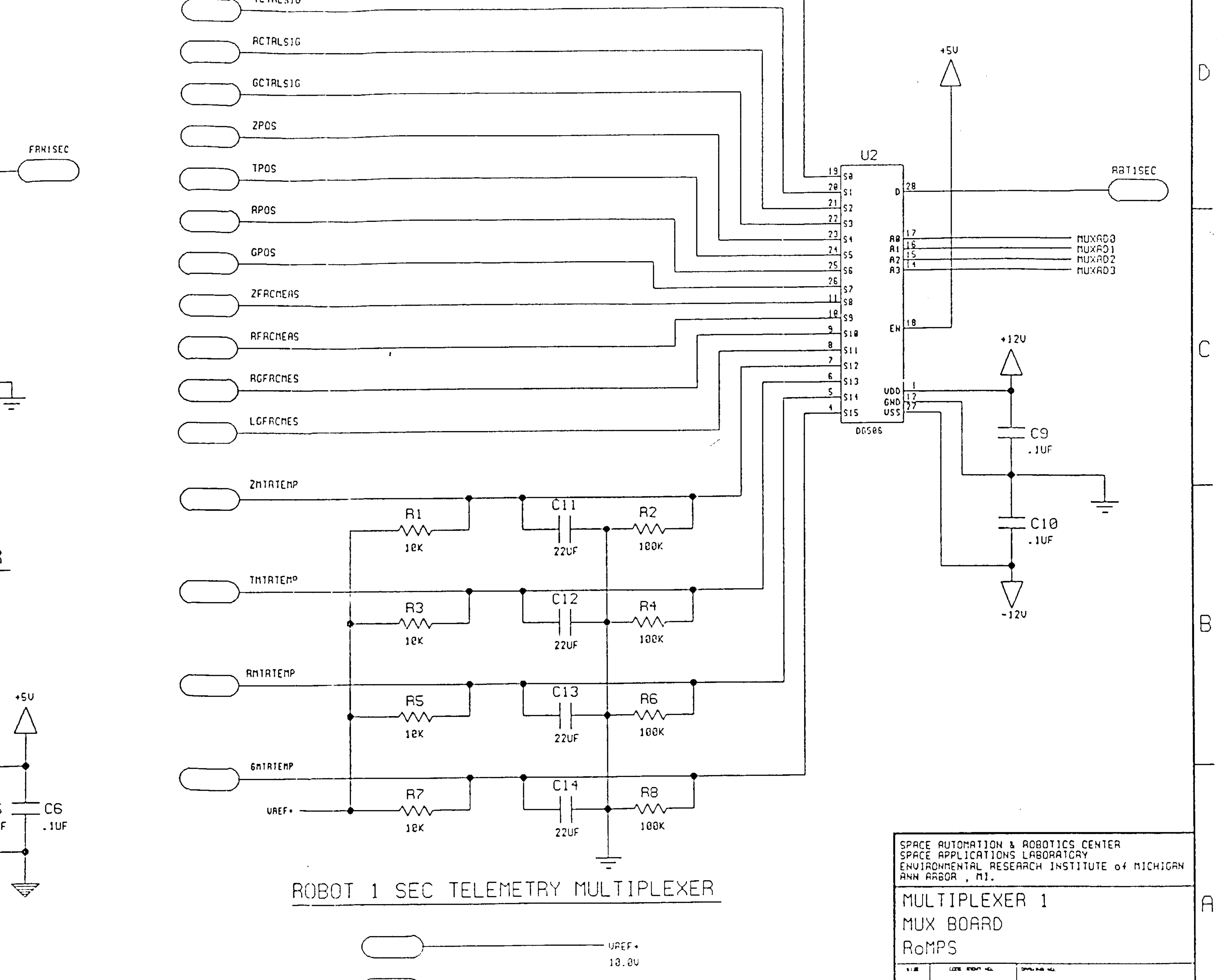


PROCESSOR BUS RESET LINES

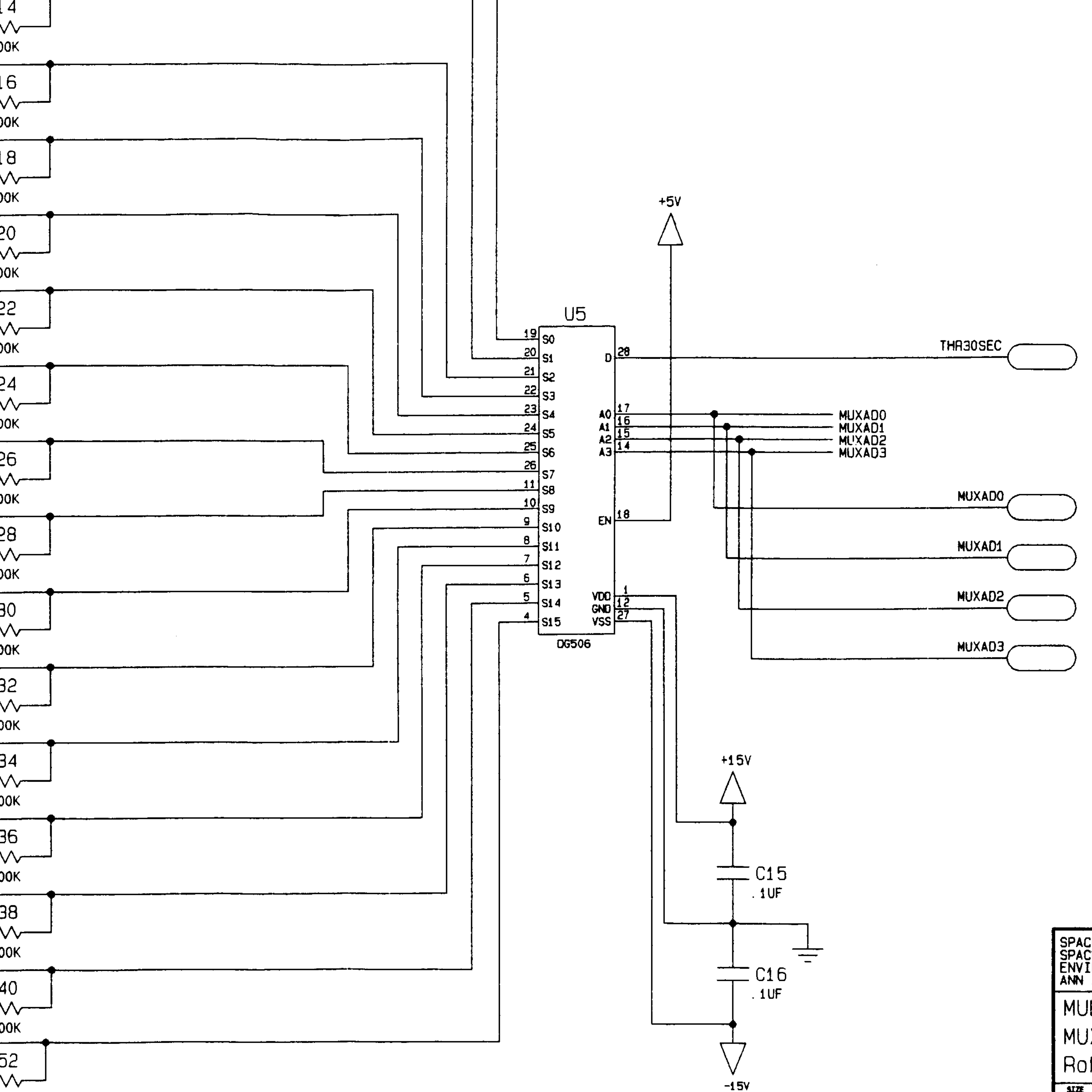
SPACE AUTOMATION & ROBOTICS CENTER
SPACE APPLICATIONS LABORATORY
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR , MI.

BATTERY & RESET
WATCHDOG TIMER BOARD
RoMPS

SIZE	CODE IDENT NO.	DRAWING NO.
B		010-633 REV. A



FRNISEC
RCTRLSIG
GCTRLSIG
ZPOS
TPOS
RPOS
GPOS
ZFRCMEAS
RFRCMEAS
RGFRCMES
LGFRCMES
ZMTRTEMP
TMTRTEMP
RMTRTEMP
GMTRTEMP
VREF+
U2
DG506
S0 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15
D
A0 A1 A2 A3
EN
VDD GND VSS
+5V
RBT1SEC
MUXAD0
MUXAD1
MUXAD2
MUXAD3
+12V
-12V
C9 .1UF
C10 .1UF
C6 .1UF
R1 10K
R3 10K
R5 10K
R7 10K
R2 100K
R4 100K
R6 100K
R8 100K
C11 22UF
C12 22UF
C13 22UF
C14 22UF
ROBOT 1 SEC TELEMETRY MULTIPLEXER
VREF+ 10.0V
SPACE AUTOMATION & ROBOTICS CENTER
SPACE APPLICATIONS LABORATORY
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR , MI.
MULTIPLEXER 1
MUX BOARD
RoMPS
D
C
B
A

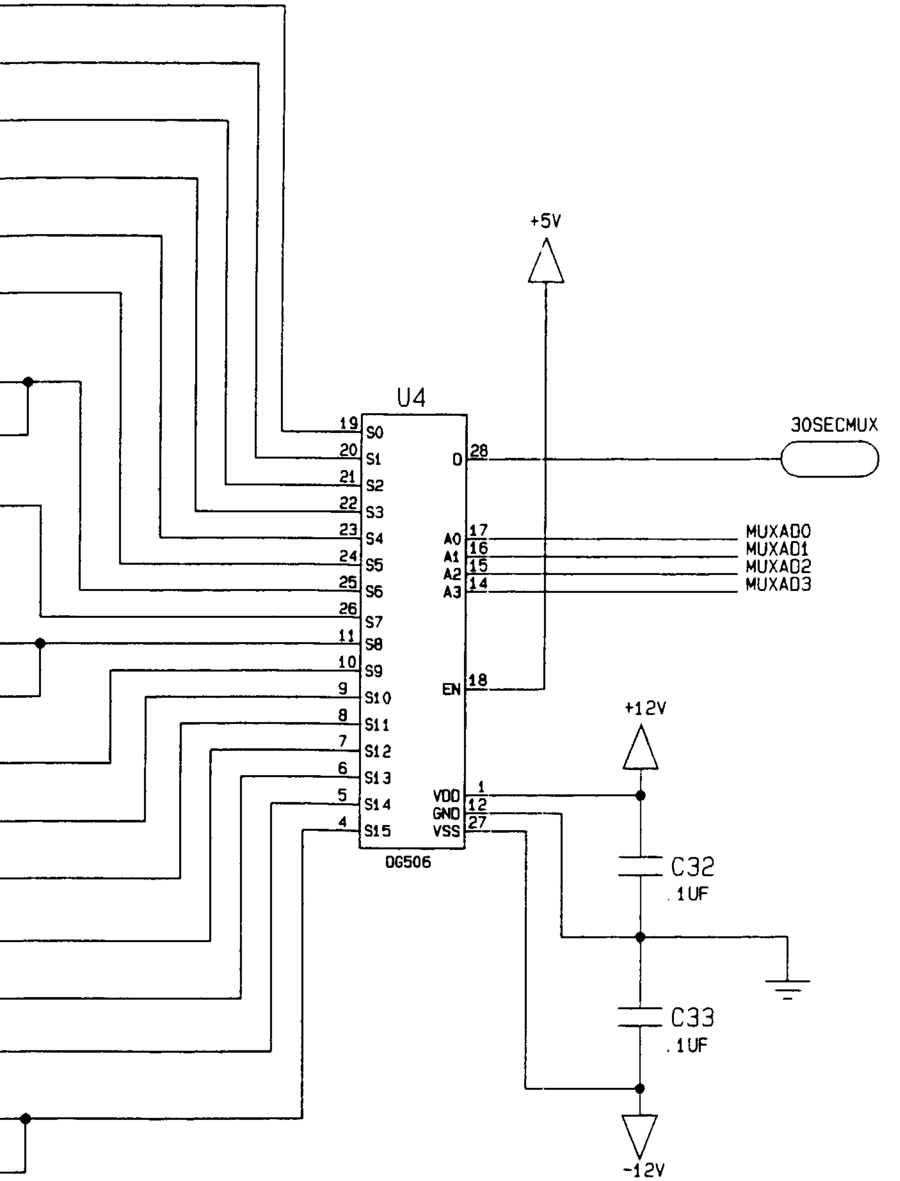


30 SEC TELEMETRY MULTIPLEXER #2

SPACE AUTOMATION & ROBOTICS CENTER
SPACE APPLICATIONS LABORATORY
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR , MI.

MULTIPLEXER 2
MUX BOARD
RoMPS

SIZE	CODE IDENT NO.	DRAWING NO.
		010-636 REV. A



SEC TELEMETRY MULTIPLEXER #1

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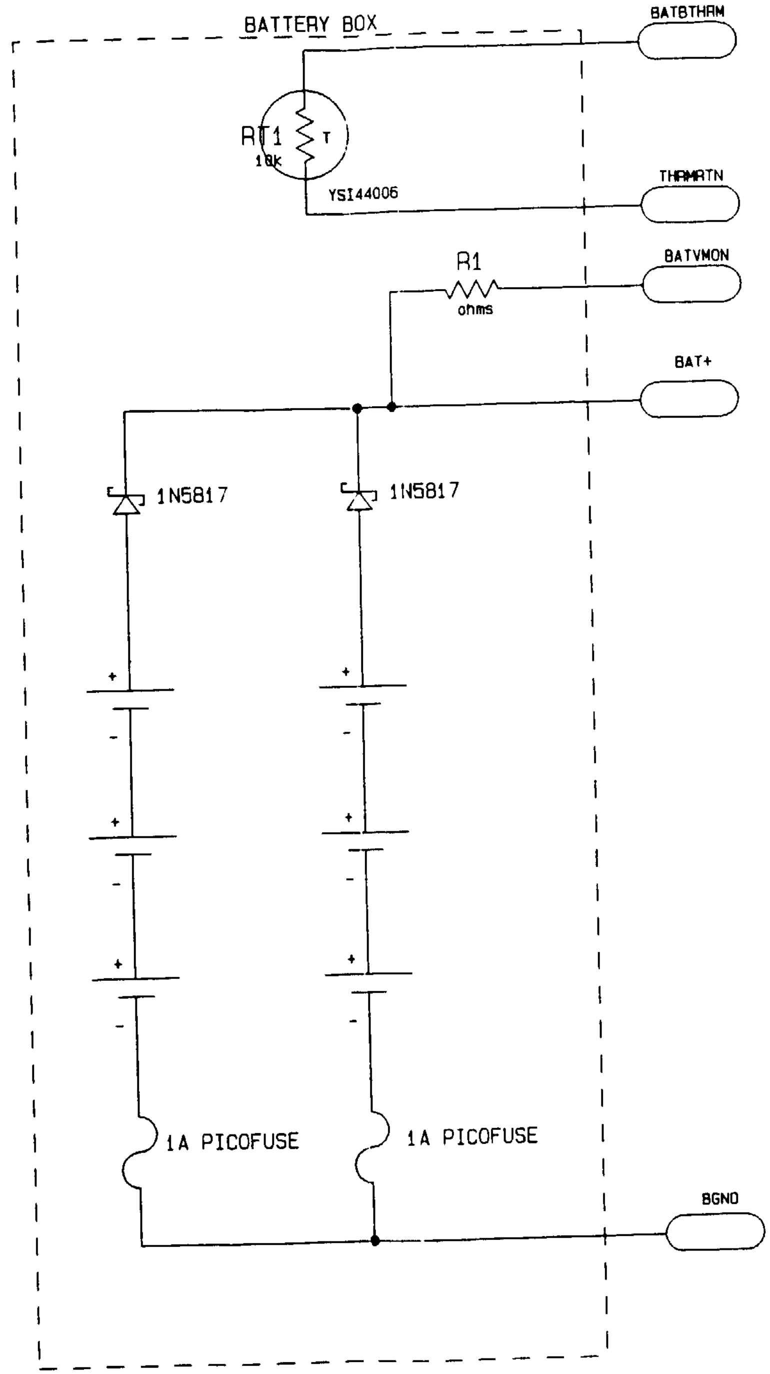
SPACE APPLICATIONS LABORATORY
ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN
ANN ARBOR , MI.

MULTIPLEXER 3
MUX BOARD
RoMPS

SIZE	CODE IDENT NO.	DRAWING NO.
		010-637 REV. A



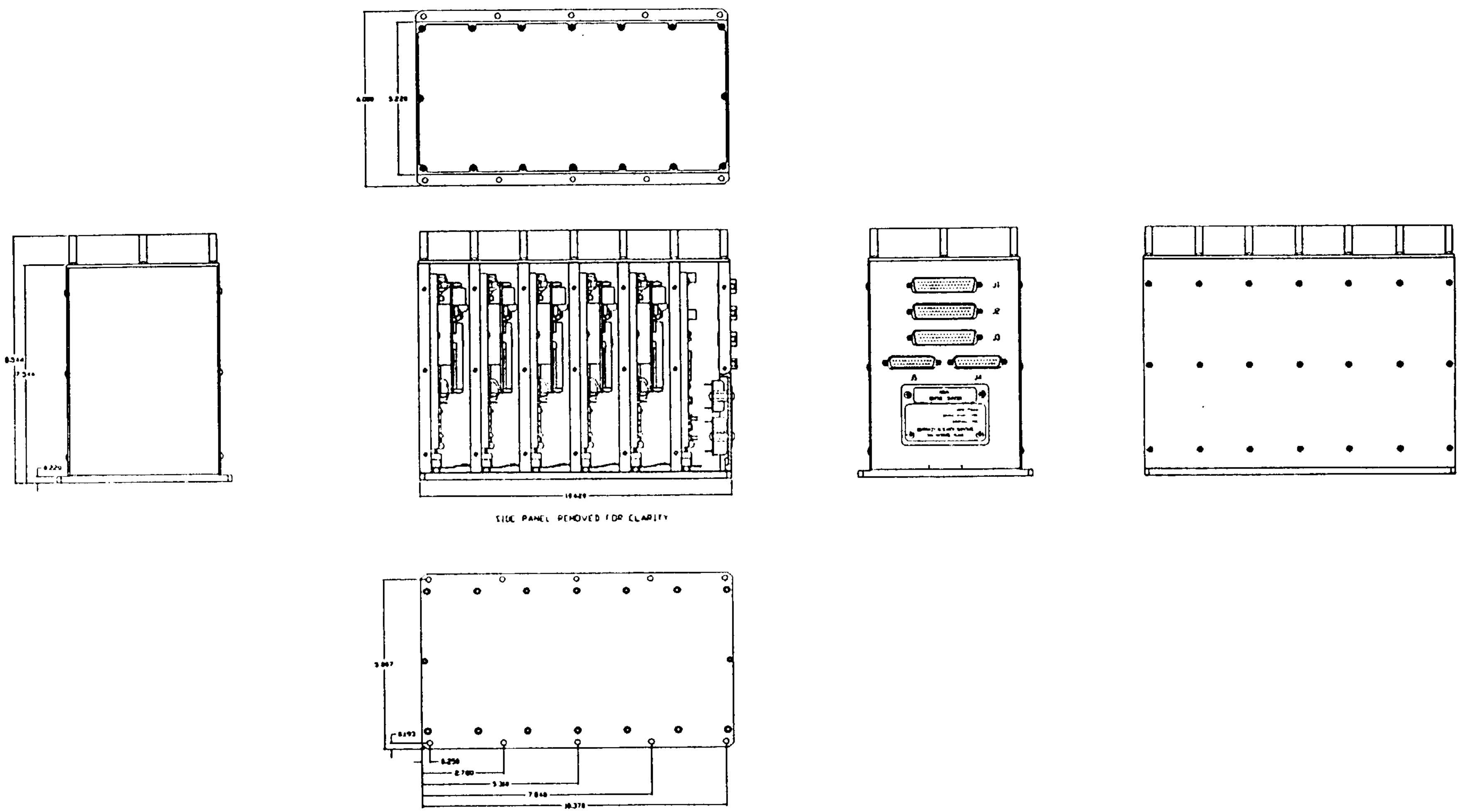
CELL:

MFGR: DURACELL
MODEL: SIZE D
SPEC: ANSI: 13A
NOM VOLT: 1.5V
RATED CAP: 14,250 mAH @ 4.7 ohm to 0.8V @ 21 c
est @ 11,000 mAH @ 4.7 ohm to 0.8V @ 0 c
OPER TEMP: -20c to +54c
STOR TEMP: -20c to +54c
SHELF LIFE: 4% Loss per Year
INT RES: 0.1 Ohm
SHORT CKT: est @ 15A w/o Protection
PRESCREENED FOR LEAKAGE

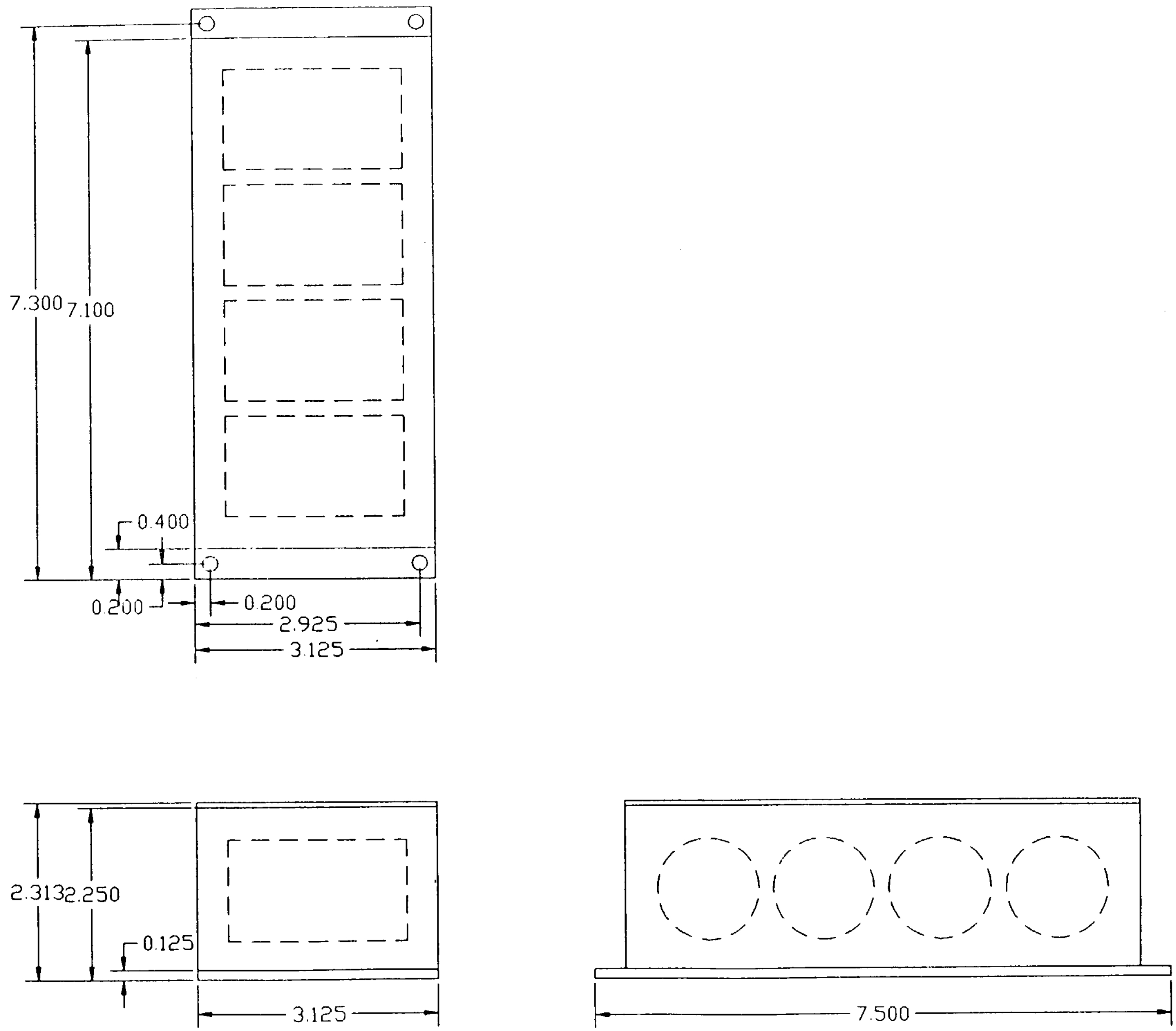
SPACE AUTOMATION & ROBOTICS CENTER SPACE APPLICATIONS LABORATORY ENVIRONMENTAL RESEARCH INSTITUTE of MICHIGAN ANN ARBOR, MI.	
BATTERY SOURCE BATTERY BOX RoMPS	
SIZE / CODE IDENT NO.	DRAWING NO. 010-638 REV. B

Control System Mechanical Design

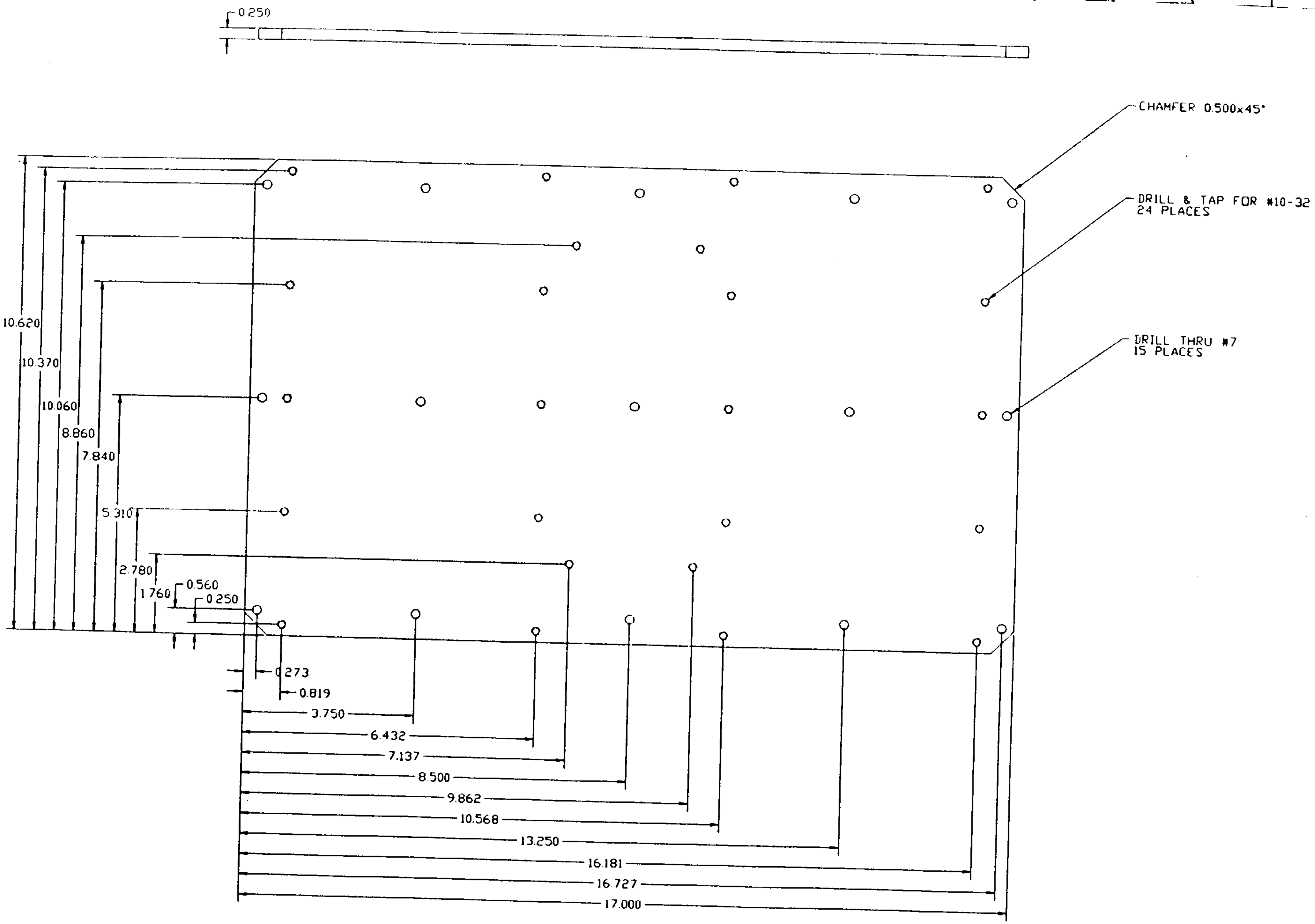
- Payload contoller housings made of 6061-T6 aluminum
- Battery box made of 6061-T6 aluminum
- Adapter plate made of 6061-T6 aluminum
- Payload controller and battery box spacers made of G-10
- 160 ksi stainless steel fasteners used for mounting payload controllers and battery box



ENGINEER R.E. QUADA	DRAFTPERSON N.J. THOMAS	UNITS: INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	PAYLOAD CONTROLLER ROMPS 010-257	TOLERANCES UNLESS SPECIFIED: ± 0.005" ± 30 MINUTES	10/30/92 DATE

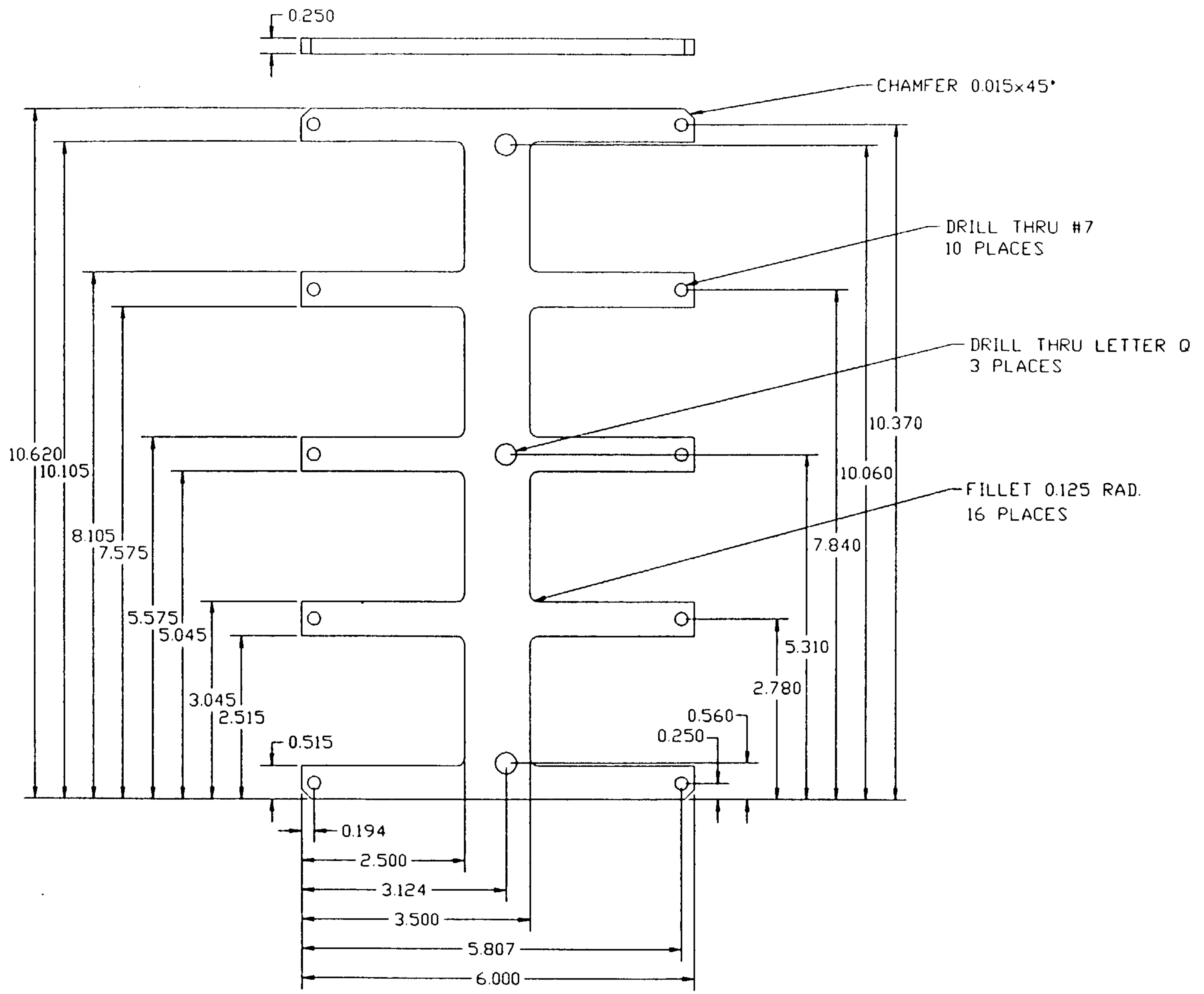


ENGINEER R.E. QUADA	DRAFTPERSON N.J. THOMAS	UNITS: INCHES	
	BATTERY BOX	TOLERANCES	
SPACE AUTOMATION & ROBOTICS CENTER	ASSEMBLY	UNLESS SPECIFIED:	
ENVIRONMENTAL RESEARCH INSTITUTE of MI	ROMPS	±0.005"	10/29/92
ANN ARBOR, MI	010-251	±30 MINUTES	DATE

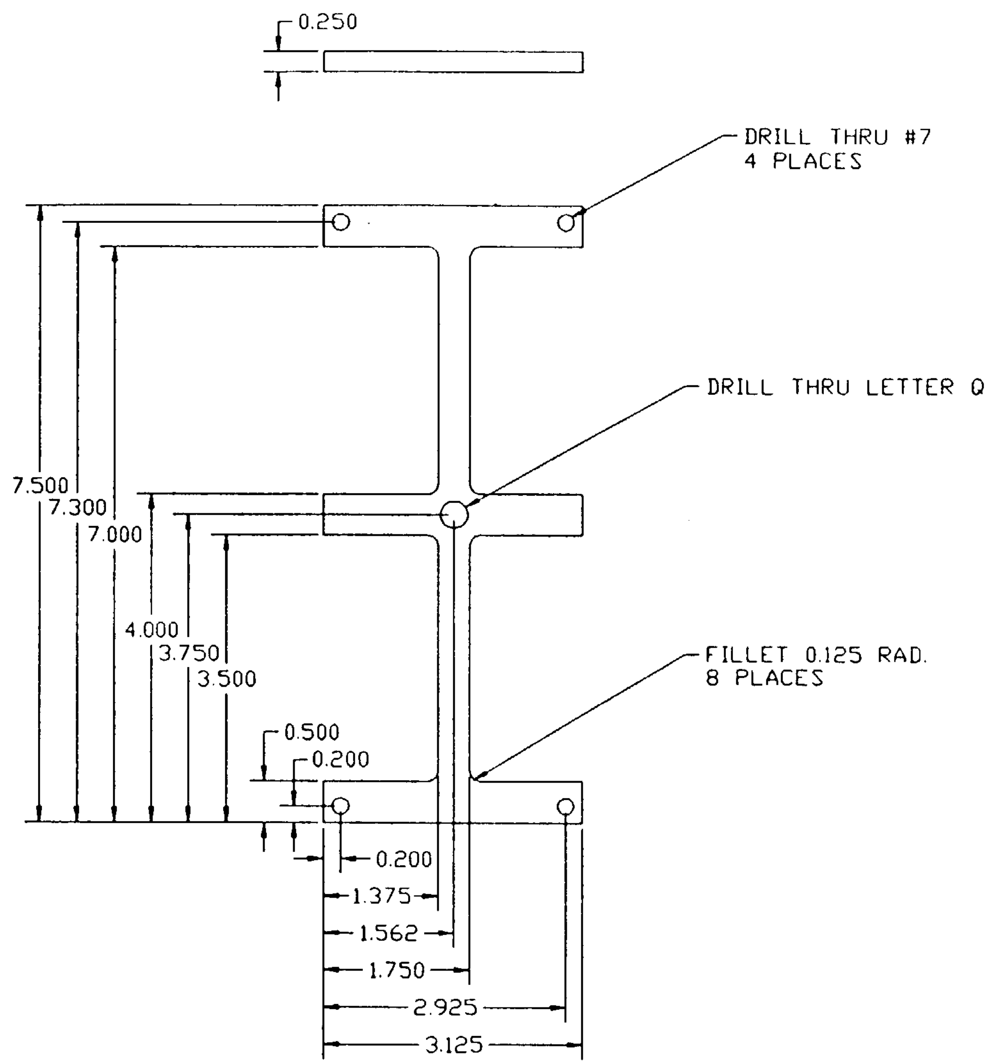


NOTES: Iridite MIL-5541, Class 1A

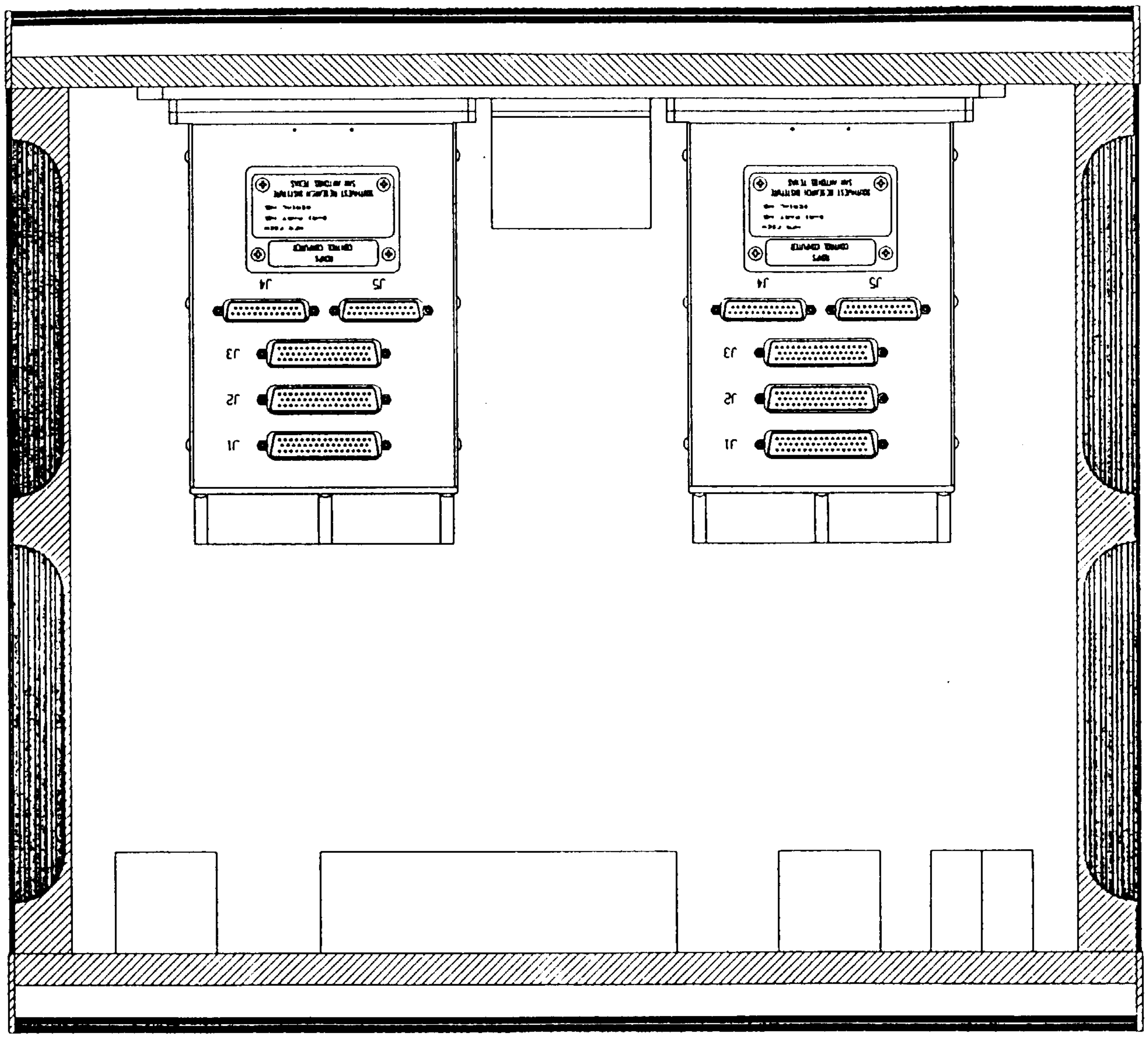
1		PART NO.			PLATE	6061-T6
L.H.	R.H.		L.H.	R.H.	PART NAME	SIZE / DESCRIPTION
NO.	REQ'D		DASH NO.			MATERIAL
ENGINEER	R.E. QUADA				DRAFTPERSON N.J. THOMAS	UNITS: INCHES
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI					ADAPTER PLATE ROMPS 010-254	TOLERANCES UNLESS SPECIFIED: ±0.005" ±30 MINUTES
						11/02/92 DATE



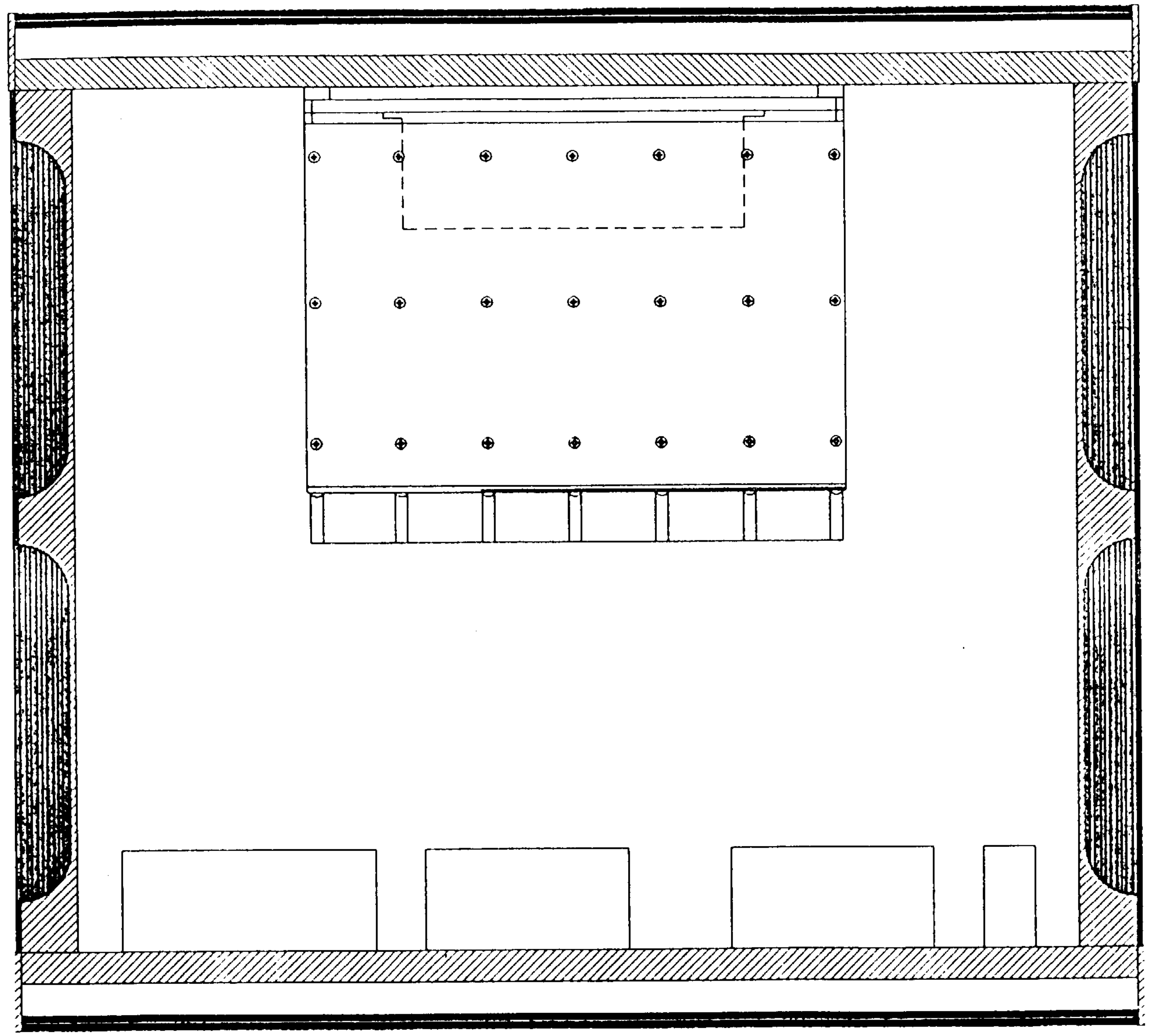
2						G-10
L.H. / R.H. NO. REQ'D.	PART NO.	L.H. / R.H. DASH NO.	PART NAME		SIZE	DESCRIPTION
					MATERIAL	
ENGINEER N.J. THOMAS			DRAFTPERSON N.J. THOMAS		UNITS: INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI			COMPUTER P.C. SPACER ROMPS 010-256		TOLERANCES UNLESS SPECIFIED: ± 0.005" ± 30 MINUTES	11/11/92 DATE



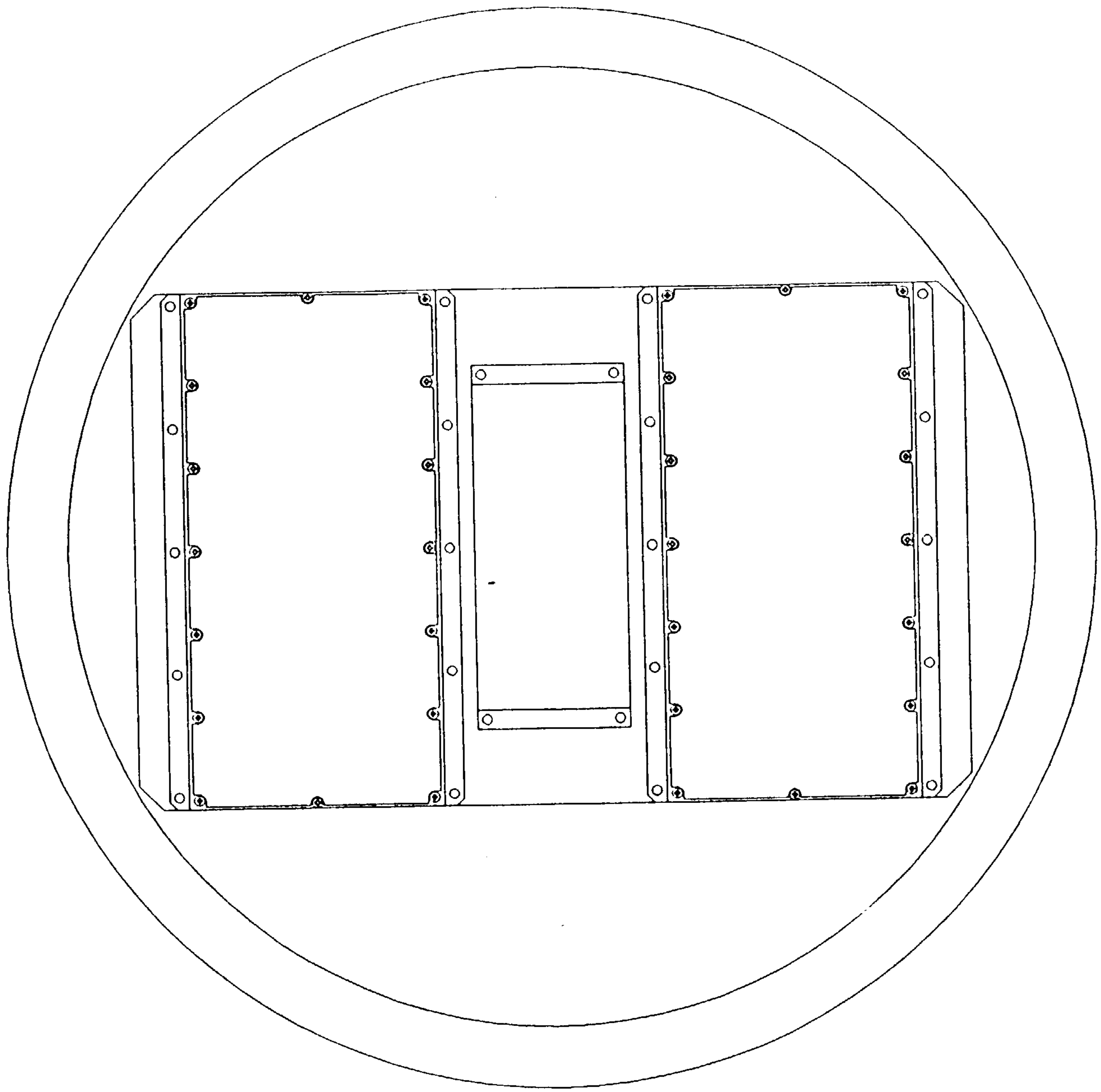
1							G-10
L.H.	R.H.	PART NO.	L.H.	R.H.	PART NAME	SIZE	DESCRIPTION
NO. REQ'D.			DASH NO.			MATERIAL	
ENGINEER N.J. THOMAS					DRAFTPERSON N.J THOMAS	UNITS: INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI					BATTERY BOX SPACER ROMPS 010-255	TOLERANCES UNLESS SPECIFIED: ± 0.005" ± 30 MINUTES	11/11/92 DATE



ENGINEER R.E. QUADA	DRAFTPERSON N.J. THOMAS	UNITS. INCHES	
		TOLERANCES	
SPACE AUTOMATION & ROBOTICS CENTER	ELECTRONICS LAYOUT	UNLESS SPECIFIED.	
ENVIRONMENTAL RESEARCH INSTITUTE of MI	ROMPS	±0.005"	11/02/92
ANN ARBOR, MI	010-250 PAGE 2 OF 3	±30 MINUTES	DATE



ENGINEER R E QUADA	DRAFTPERSON N J THOMAS	UNITS: INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	ELECTRONICS LAYOUT ROMPS	TOLERANCES UNLESS SPECIFIED: ± 0.005" ± 30 MINUTES	11/02/92
	010-250 PAGE 3 OF 3		DATE



ENGINEER R.E. QUADA	DRAFTPERSON N.J. THOMAS	UNITS: INCHES	
SPACE AUTOMATION & ROBOTICS CENTER ENVIRONMENTAL RESEARCH INSTITUTE of MI ANN ARBOR, MI	ELECTRONICS LAYOUT ROMPS	TOLERANCES UNLESS SPECIFIED: ± 0.005" ± 30 MINUTES	11/02/92
	010-250 PAGE 1 OF 3		DATE

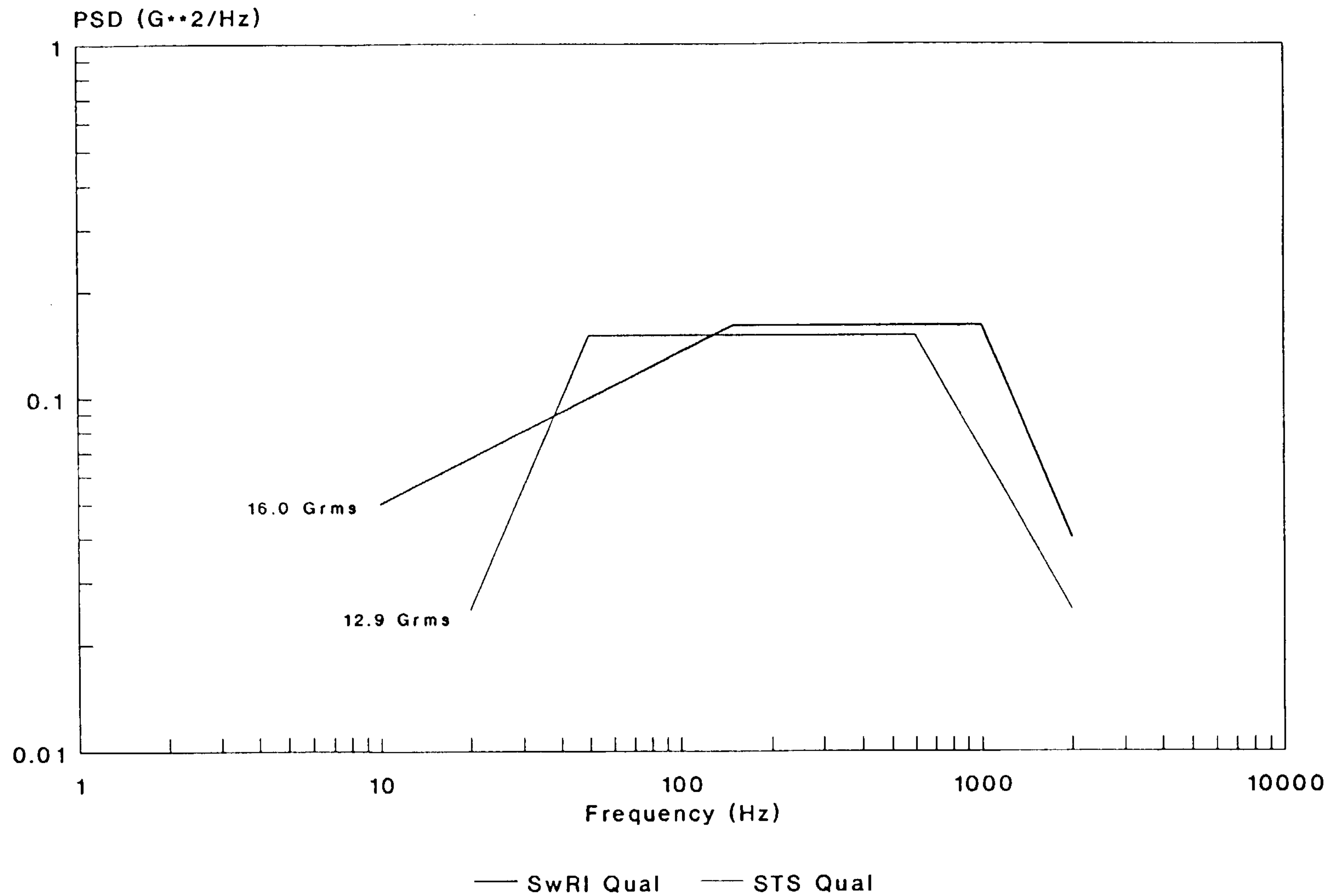
Control System Structural Analysis

- Hitchhiker CARS Table 3.3 load factors: 11 G, 85 rad/sec**2
- Factors of safety of 2.0 for yield and 2.6 for ultimate for qualification by analysis
- Allowable stresses from MIL-HDBK-5F
- Natural frequency expected to be >100 Hz
- Natural frequency of similar payload controller was 350 Hz

Control System Stress Analysis

Assembly	Item	Condition	Allowable Stress	F.S.	MOS
Payload Controller	Mounting flanges	Bearing	50000 psi	2.0	>10
			67000	2.6	>10
		Shear	27000	2.6	>10
		Tension	35000	2.0	>10
			42000	2.6	>10
	10-32 screws	Combined	160000	2.6	0.5
Battery Box	Mounting flanges	Bearing	50000	2.0	>10
			67000	2.6	>10
		Shear	27000	2.6	>10
		Tension	35000	2.0	>10
			42000	2.6	9.4
	10-32 screws	Combined	160000	2.6	0.5
Adapter Plate	Mounting holes	Bearing	50000	2.0	>10
			67000	2.6	>10
		Shear	27000	2.6	>10
	10-32 screws	Combined	160000	2.6	0.5

Payload Controller Random Vibration



Both one minute per axis, three axes

SpARC
Space Automation
& Robotics Center

RoMPS

Memos and Miscellaneous Summary Sheets

Space Engineering and Material Science Department
&
Space Automation and Robotics Center

21 October 1992

File battery 102192
Memo To: team & Del Jenstrom/GSFC
From: Michael E. Dobbs
Subject: battery update

I talked to B.J. Bragg/EP5, at JSC 713-483-9060. We discussed use of alkaline battery for encoder backup and lithium for computer memory backup. He will review material prior to CDR if we request.

Encoder Backup
Suggested both EverReady and Duracell are acceptable vendors. We need to re-read the JSC memos. Alkalines have not vented under short circuit, but 2 fault tolerant isolation is required to prevent charging. Suggested diode & fuse. Flight cells should be pretested at low pressure 0.1 psi for 6 hours with a visual inspection for leakage. With our current draw of around 300 ma, a 1000 ma fuse would be acceptable. More than 3x is undesireable. Fuse should be smaller than charging current if diode shorted.

Icharge = (Vsource-Vdiode-Vcell) / R cell >>> Ifuse.

AI call duracell, need C & D datasheets, need weld tabs
call everready, etc.

Processor Backup
The lithium backup cells also need diode and fuse protection or analysis of existing circuit that does switchover to determine level of fault tolerance.

AI call Maxim, failure modes
AI design modification to boards to add diode&fuse

XP Servo LED Control

ROMPS Notes
text modified 10/23/92 3:38 PM

What turns LEDs on and off:

		OFF	ON
THISERR	0	(pia cleared on reset) checkcomm() -- usart status checkcomm() -- comm msg ok	checkcomm() -- comm error
BASE	1	(pia cleared on reset) checkcomm() -- usart status checkcomm() -- arm done	checkcomm() -- status pending
WRIST	2	(pia cleared on reset) checkcomm() -- usart status checkcomm() -- hand done	checkcomm() -- status pending
COMMERR	3	(pia cleared on reset) checkcomm() -- usart status	checkcomm() -- comm error
VERHALF	4	(pia cleared on reset) do_servos() -- position > midpoint	do_servos() -- position < midpoint
REAHALF	5	(pia cleared on reset) do_servos() -- position > midpoint	do_servos() -- position < midpoint
ROT180	6	(pia cleared on reset) do_servos() -- position > midpoint	do_servos() -- position < midpoint
CALGONE	7	(pia cleared on reset)	main() -- ram not good
VERERR	8	(pia cleared on reset)	accutrak() -- bad
RCHERR	9	(pia cleared on reset)	accutrak() -- bad
ROTERR	10	(pia cleared on reset)	accutrak() -- bad